Deliverable 1.1 – FMM descriptions (in report form)

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Summary

This report maps Forest Management Models (FMMs) that are applied on 10 Case Study Areas (CSAs) within 9 countries of the ALTERFOR consortium, namely: Germany (2 CSAs), Ireland, Italy, Lithuania, the Netherlands, Portugal, Slovakia, Sweden and Turkey. Besides the description of their main silvicultural features, FMMs are ranked according to their capacity to provide different ecosystem services. In addition, available technology and knowhow and restrictions set by legislation were described in a so called “Technological landscape” analysis. The report serves two primary aims. Internally, it serves the ALTERFOR partners by establishing an overview of prevailing silvicultural practices that will serve as the benchmark descriptions when examining the alternative FMMs at the later stages of the project. Externally, the thorough and systematic mapping of current FMMs and their effect on ecosystem services might serve any reader interested in approaches to forest management as currently applied under a variety of ecological, technological and socio-economic conditions on the European continent.

The FMM descriptions, effects on ecosystem services and technological landscapes were elaborated by multidisciplinary research teams in the case countries. FMM descriptions were based on a structured questionnaire consisting of two main parts: (i) a background description of the historical milestones that lead to the currently dominant FMMs in respective countries and CSAs; (ii) the detailed descriptions of the FMMs, classified according to the most common silvicultural systems. Each FMMs is dissected by the most important silvicultural measures. In subsequent analysis, FMMs on each CSA were ranked for the following ecosystem services: biodiversity, carbon sequestration and substitution, water quality, flooding and water availability, cultural services and regulatory services.

The descriptions expose a large variety of FMMs applied on different CSAs which to a large extent are conditioned by different historical contexts and current socio-economic drivers. The number of the reported FMMs differ from 1 (Italy) to 12 (Lithuania) which can be explained by several factors including the area of a CSA; the actual heterogeneity of silvicultural practices; and the different degrees of aggregating the silvicultural practices within an FMM. According to our mapping, clear felling, shelterwoods and selective cutting aiming at heterogeneous forests are the most prominent silvicultural systems, together occupying around 73% of the forest area on all CSAs. Various coppice methods occupy around 10% of the area and no intervention around 5%. Around 12% of the area was either a combination of silvicultural methods or does not fit in any of the above categories. FMMs aiming at homogeneous forests account for about 39% of the area whereas FMMs aiming at heterogeneous stands made up about 33% of the area. However, the distribution of the silvicultural systems vary considerably between countries. FMMs aiming at homogeneous forests dominate in e.g. Ireland, Portugal and Sweden, contrary to e.g. Germany, Slovakia and Italy where the dominating FMMs are more favourable for heterogeneous forests.

Ecosystem services are affected by FMMs primarily via tree species, stand structure and interval of interventions and rotation length. The overall picture was that FMMs dominated by broadleaves got higher ranking for several ecosystem services than stands dominated by conifers and that the different coppice systems got lower ranking for several ecosystem services than other FMMs.

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FMMs resulting in a heterogeneous stand structure tended to have a higher overall ranking than FMMs resulting in homogeneous stands. However, the comparison between FMMs for ecosystem services is problematic since both the ranking of ecosystem services and FMMs depend on site characteristics. Another problem is that the ecosystem services may be in conflict with each other.

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I. Forest Management Models (FMMs) description

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Abbreviations used

AWF – Augsburg Western Forest (Germany)
BAU – Business as usual
CC – Clearcutting
CCF – Continuous Cover Forestry
CS – Cultural Services
CSA – Case study Area
DSS - Decision Support System
ES – Ecosystem Services
FMM – Forest Management Model
FPM – Freshwater pearl mussel
FSC – Forest Stewardship Council
FVZ – Forest Vegetation Zone (Slovakia)
IFM – Integrated Forest Management (the Neatherlands)
LCC – Local Case Coordinator
LFN - Lieberose Schaubetal Neuzelle (Germany)
MAI – Mean Annual Increment
MARA Minimum Allowable Rotation Age
NGO - Non-Governmental Organizations
NP – National Park
NWS – Native Woodland Sites
PCT – Pre-Commercial Thinning
PEFC - The Programme for the Endorsement of Forest Certification
SFE - State Forest Enterprise (Lithuania)
SFIMPI - State Forest Inventory and Management Planning Institute, (Lithuania)
WP – Work Package
ZIF Forest Intervention Zones (Zonas de Intervenção Florestal) (Portugal)

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1. Introduction

1.1. What is a forest management model (FMM)?

The concept of Forest management models (FMMs) or forest management approaches has met increasing interest in forest literature the last decades (Dunker et al 2012; Hengeveld et al 2012). Foresters have for a very long time discussed silviculture systems, e.g. (Mathews 1989). There is no clear distinction between silviculture systems and FMMs, see (Duncker et al 2012) for a discussion. What is a silviculture system? Mathews (1986, p3) defines it as "*The process by which the crops constituting a forest are tended, removed, and replaced by new crops resulting in the production of stand of distinctive form*".

Different authors discuss and describe silviculture systems using different approaches, e.g. (Daniels 1979, Fujimori 2001). One way to identify and categorize silviculture systems is based on the origin of trees, from seed or vegetative (suckers or coppice). Another way is the use of trees, if trees are harvested mainly when they reach a mature size or if small dimensions are harvested. The terms high forest and low forest are then often used. Yet another approach is based on the main methods of removing trees. Are all trees removed in one final harvest, a clearcut, or are trees harvested selective in some way? With different terminology and the possibility to combine operations, it is easy to imagine the possibilities for confusion. Classification of silviculture systems result in a large European project in itself.

One common classification contains the following categories: clear-felling, shelterwood, selective and coppice systems (Matthews, 1989, Fujimori, 2001). Each system includes different operations that can be varied and together there is a very large number of combinations.

The use and outcome of silviculture systems are dependent on the environment, the growing conditions and tree species, on economic and social situation as well as legislation. A system used in one part of Europe can in practice be different in another environment. A silviculture system can be described as a toolbox, it includes many activities or tools, used in different phases of the stand development. Such tools are for example soil preparation and thinning, but many of the tools or activities can be used in many systems.

A key concept in the ALTERFOR work is Forest Management Models. Today it is common to talk about Ecosystem Services (ESs) connected to forest. ALTERFOR will scrutinize the possibilities to increase different ESs from forestry. In a first step FMMs will be identified and described.

1.2. Data collection

During autumn 2016 the local case study coordinators described the CSA and the FMMs used. This was done by a questionnaire common for all partners. As a help examples form Lithuania and Sweden were available. The questionnaire had two parts, a general description of the CSA, areas, trees species and more, see appendix part1.

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Description of FMMs was done by using a detailed questionnaire, one for each FMM, see appendix part2. The FMMs were classified in one of the groups; Clear cutting systems, Uniform shelterwood systems, non-uniform shelterwood systems, selection systems, coppice systems, or no intervention. Information about the models and to what extent they are used, tree species and important forest management measures were collected. Many questions are divided in two parts; present situation and by LCC recommended situation.

1.3. FMMs in different countries

There is a large variation in the forestry and silviculture in the participation countries. The number of described FMMs used in the CSAs differ considerably, from 12 in Lithuania to one in Italy (Table 1 and Table 2).

Table 1 Number of reported FMMs for each partner

Country	No of FMMs	Total area CSA, ha	Forest area of CSA, ha
Germany, Bavaria	3	120 000	51 600
Germany, Brandenburg	3	60 000	22 200
Ireland	3	77 528	12 511
Italy	1	315	291
Lithuania	12	253 970	88 195
The Netherlands[1]	9	4 154 300	373 500
Portugal	4	14 850	14 474
Slovakia	10	151 768	94 855
Sweden	6	840 000	704 000
Turkey	8	81 808	40 493

[1] Encompasses the entire country.

Table 2 Name and identification, all FMMs reported

Country	FMM name	FMM ID
Germany, CSA: Augsburg, Bavaria	Beech State Forest	
	Spruce Large Private	
	Spruce State Forest	
Germany CSA Librose-Schlaubetal-Neuzelle Brandenburg	Scots Pine Private Forest-	
	Oak Stat Forest	
	Scots pine state forest	
Ireland	Clearcutting conifers	

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Country	FMM name	FMM ID
	Clearcutting lodgepole pine	
	Nature conservation and biodiversity protection	
Italy	Selective systems	
Lithuania	Aspen Greyalder Clearcuttning	SRDEC_C
	AspenGreyalder Uniform shelterwood/Clearcutting	SRDEC_CUS
	Birch BlackAlder Clearcutting	MRDEC_C
	Birch Blackalder UniformShelterwood Clearcut	MRDEC_CUS
	No intervention	NOINT
	Pine Clearcutting	LRCON_C
	Pine Uniform shelterwood	LRCON_C
	Pine Uniform ShelterwoodClearcutting	LRCON_CUS
	Special PurpouseForests	SPECP
	Spruce Clearcutting	MRCON_C
	Spruce non UniformSheltrwood	MRCON_NS
	Spruce NonUniform ShelterwoodClearCutting	MRCON_CNS
The Netherlands	NatureForest Broadleaved	
	NatureForest Oak	
	NatureForest Pine	
	NatureForest Conifers	
	ProductionForest Broadleaved	
	ProductionForest Oak	
	ProductionForest Conifers	
	ProductionForest Pine	
	Other Forest	
Portugal	MartinePineEucalyptus	
	Eucalyptus Maritime Pine	
	Chestnut	
	Eucalyptus pulpwood	
Slovakia	oak wood provision	I
	oak beech timber	II
	beech timber	III
	fir beech wood and timber	IV
	nature conservation and biodiversity protection	IX
	spruce fir beech timber	V
	spruce fir beech close to nature	VI
	spruce timber	VII
	soil protection	VIII

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Country	FMM name	FMM ID
	water purification	IX
Sweden	clearcutting intermediate final	SE1
	clearcutting long final	SE2
	clearcutting short final	SE3
	nature conservation with management	SE4
	uniform shelterwood system final	SE5
	nature conservation withoutr management	SE6
Turkey	clearcutting	
	conversion coppice	
	long shelterwood	
	Medium rotation coppice	
	nature with intervention	
	no intervention	
	short coppice	
	very long shelterwood	

The most common silviculture systems among the FMMs are the clearfelling (13) and non-uniform shelter system (12). Selective systems are not used very often, four FMMs are described as selective models. Coppice is used in 4 models, together with clearfelling system of an admixture in two other models and also one model for conversion from coppice to clerfelling model.

Clearfelling systems and uniform shelter systems both result in even-aged forest, at least for most of the rotation period. These two systems are used in 22 FMMs and an estimated area of 39% Table 6.

Selective systems and non-uniform shelterwood system both result in uneven aged forest. These two systems are used in 16 FMMs and in 4 systems combinations with selective or non-uniform shelterwood systems. Totally 20 FMMs with uneven-aged forest are estimated to cover 33% of the area. Clearfelling systems are used on 23% of the area, and selective systems on 13%, non-uniform systems on 12%, for more information see Table 3.

Table 3 FMMs classified in silviculture systems, number of FMMs and estimated proportion of area where they are used. The sum is not 100%, as all alternative FMMs are not described.

Silviculture system	Nr of FMMs	Estimated cover %, total all CSA[1]
clearfelling	13	23
uniform shelter	9	16
selective	4	13
non-uniform shelter	12	12
more than one selective[2]	4	9

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coppice	4	7
combination with coppice	2	3
transformation from coppice	1	0.3
no intervention	6	5
not defined (or combination of two or more systems[3])	4	1.5

[1] Not weighted by area of CSA instead assuming each CSA have equal size.

[2] Selective, two or more systems combined at least one selective resulting in uneven-aged forests

[3] Not selective systems

1.4. References

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2. Germany

2.1. Background and forest history

In historical time, German forests have undergone four waves of heavy devastation due to i) the invasion of the Romans (1st-3rd century), ii) rapid population growth in the middle ages (12th-13th century), iii) industrialization (18th-19th century), iv) war damages and reparation fellings during and after World War I and II.

First approaches towards sustainable forest management were designed in the 18th-19th century; they mark the start of systematic forest science in our country. Since that time until a few decades ago, the mainstream FMMs were in favour of highly productive monospecific softwood plantations. These FMMs were implemented by state forest administrations, large private forest estates, and also farmers owning small forest areas. A common concept in this context was the so-called “wake theory”, expressing the view that all required ecosystem services would be produced as a side effect (in the wake) of sustainable wood production. However, in all categories of forest ownership, there have always been individualists maintaining mixed, partly uneven-aged forests, relying on natural regeneration. Most of them deemed such forest types economically superior to monocultures on the long run.

On the background of a widening ecological consciousness, and a focus on climate impact mitigation, within state forest (30% of Germany’s forest area) and corporate forest (20%) the last decades saw a silvicultural paradigm shift towards what had been a minority’s view before.

Therefore, management in public forest stands are often promoting forest conversion and a particular focus on natural regeneration in order to establish or maintain mixed forest stands. Multifunctionality is a very important concept, i.e. a broad range of ecosystem services is intended to be provided from the same forest area.

In the private owned forest land (50%), the picture is somewhat heterogeneous. Owners of large forest estates mostly adhere to the former mainstream concept in order to generate income as their primary goal. Small private forest owners who are organized in forest owner associations increasingly adopt the public forest concept. Considerable areas are also owned by non-organized forest owners, many of them not even being aware of owning forest (e.g. urban people who inherited land). Often, such forests are managed with low intensity or not at all.

The most relevant means of public control on private forest management are financial incentives for forest owners who obligate themselves to follow certain guidelines. In general, the diversity of FMMs in Germany is high.

In Germany approx. 50% of the forest land is owned by private, 30% of state and 20 % are corporate forest.

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2.2. The case study areas

There are two case study areas in Germany. Augsburg Western Forest (AWF) in the federal state Bavaria, southern Germany and Lieberose-Schaubetal-Neuzelle (LFN), in the federal state Brandenburg in North-Eastern Germany. CSA AWF is more fertile and all land are classified as mesic, while CSA LFN have lower production and a large proportion of the land is classified as "dry" Table 4.

Table 4 A general description of forest land in the two case study areas in Germany, AWF in southern Germany and LFN in North-Eastern Germany.

Productivity/ moisture	Dry %	Mesic %	Moist %	Wet %
High		AWF 100%		
Medium		LFN 50%		
Low	LFN 50%			

2.2.1. Land area and forest cover

Table 5 Total land area, forest area, standing volumes, productivity and ownership in CSA.

	AWF	**LFN**	**Germany**
Total Area (ha)	120 000	60 000	35 737 600
Forest Area (ha)[1]	51 600	22 200	11 419 124
Forest cover (%)[1]	43 %	37 %	32 %
Average Volume (m3ha^{-1})[1]	396	288	336
Mean Yield Class (m3ha-1yr-1)1	13.7	9.6	10.85
Forest Ownership (%)[1] Public / state and other Private	 41 % 59 %	 44 % 56 %	 52 % 48 %

2.2.2. Tree species

Tree species, proportion of total forest area in the two case study areas, in the two states and in Germany are shown in Table 6.

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Table 6 Tree species, proportion of total forest area

	Case Study Area		Region		Germany
Species (Latin name)	**Proportion (% total volume)**		**Proportion (% total volume)**		**Proportion (% total vol.)**
	AWF	LSN	Bavaria1	Brand.2	
Picea abies	62.2%	2%	41.8%	≤ 5.2%	26%
Pinus sylvestris	3.4%	65%	17.1%	73.7%	22.9%
Larix decidua	2.0%	1%	2.1%	≤ 5.2%	2.9%
Pseudotsuga menziesii	0.6%	1%	0.8%	≤ 5.2%	2%
Abies alba	1.8%	≤ 6%	2.4%	≤ 5.2%	
Quercus sp.	3.5%	11%	6.8%	10%	
Fagus sylvatica	10.9%	4%	13.9%	3.2%	
other decidous	15.6%	≤ 6%	15%	8%	

2.3. FMMs in Germany and in the two CSA

While the state forest concept strives to maintain or established mixed and to a certain degree uneven-aged forests, large private forest owners mostly do not intend to reduce the area of monospecific even aged softwood (Norway Spruce *Picea abies*) stands. Different thinning concepts (selective thinning, traditional thinning from below, future tree thinning) are applied in different strengths, seeking an optimum trade-off between increment and stability. The final cut and regeneration phase is kept comparably short, often increasing the share of Douglas fir (*Pseudotsuga menziesii*) is intended. However, this is just preliminary information, research about silviculture in the private forests is still going on.

However, about private forests, we will never be as precisely informed as about the state forest, as in private forests, silvicultural guidelines seldom are documented in such detail and as openly communicated as is the case for the state forest.

The concepts are highly differentiated as is the forest status in the case study region(s). Thus, below we can give only the general state forest concepts for the main species Norway spruce, European beech (Fagus sylvatica). And we give the general concept for Norway spruce in the large private forest estates. However in reality and in our model the differentiated concepts break down into a set of several hundred silvicultural rules.

We can so far give precise answers only for the state-owned forest in the AWF case study, which however can be extended to the municipal forest and – with lower intensity – to many of the small private forest owners who are organized in forest owner associations.

2.4. Alternative FMMs

There are no substantial differences between FMMs used in the two Case study areas and the region or country. The federal State forest services and other throughout the country have similar goals. We consider the CSA AWF quite representative for forest regions in dense populated areas close to cities and in an economically welldoing context. The LSN case study represents typical rural areas in economic weak settings.

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In addition to the highly differentiated concepts mentioned above, a lot of different concepts exist in small private forests. Most important are no management at all and low intensity forestry without a real concept. However, many forms of more hobby gardening like management can be found, but not important in terms of covered area.

2.5. FMMs used in the two case study areas

Totally six Forest Management models are described, tree for each state, Table 7. Note the numbers of forest cover do not add up to 100%. However, the rest of the area is covered with a lot of different FMMs for different minor species and species mixtures. Small, unorganized private forest owners, often treat their forest with very low intensity and not with a real concept at all. Their share of the area might bring us near to 100%, together with the FMMs listed above.

Table 7 The six major forest management models (FMMs) used in the German CSA, Three in AWF/Bavaria and three in LSN/Brandenburg.

Tree-specie and forest owner	General characteristic of the FMM)	Coverage in the CSA (% forestland)	Coverage country (% forestland)
Case Study Area AWF Augsburg Western Forests, in Bavaria			
Norway spruce in large private	Shelterwood/Clear-cut/Non-uniform shelterwood	40	40
Norway spruce in state forest	selection	25	25
European beech in state forest	Selection/non-uniform shelterwood	10	10
Case study area LSN Lieberose-Schlaubetal-Neuzelle, in Brandenburg			
Scots pine state forest	Selection system / non-uniform shelterwood system without enlarging the gabs	30	30
Scots pine private	Clearcutting	25	25
Oak state forest	Selection system / Uniform / Non-uniform shelterwood system without enlarging the gabs	10	10

2.6. Ecosystem services

For private owners wood production is mentioned as the only ES but on state-land a number or services are listed. Wood production is listed first in all FMMs see Table 8.

Table 8. Ecosystem services connected to the four FMMs in the two CSA in Germany, CSA., AWF Augsburg Western Forests, in Bavaria and Case study area LSN Lieberose-Schlaubetal-Neuzelle, in Brandenbur. Ranking of important ES within each FMM. No ranking between FMM.

Forest manage model (FMM)	Ecosystem services, in order
Spruce large private forest owners (AWF Bavaria)	wood production
Spruce state forest (AWF Bavaria)	wood production, ecological stability

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Forest manage model (FMM)	Ecosystem services, in order
	biodiversity, soil and water protection forest aesthetics
Beech, state forest (AWF Bavaria)	wood production, ecological stability biodiversity, soil and water protection forest aesthetics
Pine state forest (LSN Brandenburg	wood production
Pine private (LSN Brandenburg)	wood production, ecological stability biodiversity, soil and water protection forest aesthetics
Oak State Forest (LSN Brandenburg)	wood production, ecological stability biodiversity, soil and water protection forest aesthetics

2.7. Common for the six FMMs

Many facts are true for all six FMMs in Germany. The use of introduced species, hybrids, genetic improvement, and use of chemicals and fertilizer.

Introduced species

All the six FMM described here focusses on native species. Norway spruce, the focus species of two FMM in Bavaria is native to the CS country but not native to the CS ecoregion. European larch (*Larix decidua*) which is sometimes mixed with European beech is native to the CS country (Bavaria/Germany), but not native to the CSA's ecoregion. The non-native Douglas fir will probably be-come more important as an admixture and as a stand-dominating species in the future, but its share of the CS forest area is still at about only 0.6 %.

Beech, oak (*Quercus petraea* and *Quercus robur*) and pine are all European species.

Local provenances are used. In most of the FMMs described the method for regeneration is natural regeneration which by natural reasons used very local seed sources. When underplanting is done local proveniences are used.

Genetically improved or modified seedlings

Genetically improved or modified seedlings are not used at all. The reasons are; 1) Legal restrictions, 2) Risk mitigation by maintaining genetic diversity, 3) genetically improved trees have no acceptance among most forest managers and the society.

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Herbicides and

Hybrids are not used at all. The silvicultural potential of the used species is considered high enough.

Chemicals used

Applying herbicides/pesticides is not an element of any of the FMMs. Herbicides and chemicals are very rarely used. But there are some exceptions.

In case felled/fallen trees in private owned or state spruce forests the stand or timber stored for col-lection at the edge of the stand becomes infested by the spruce bark beetle *Ips typographus* and if timber can't be removed in time, an insecticide will be applied.

In state owned forests chemicals are avoided if ever possible. Bark beetle risk mitigation compared to classic monospecific even-aged Norway spruce stands is one of the goals of the FMM.

For pine the situation is the same, if timber stored for collection at the edge of the stand becomes infested by the beetle and if it can't be removed in time, an insecticide will be applied.

In beech dominated forests in the CSA, large-area insect defoliations (which would be the most probable reason for applying pesticides) are very rare. State forest managers would apply pesticides even in such a case only if the scenario would be really catastrophic. Usual defoliations are tolerated.

No chemicals are used in oak forests.

Fertilization

Fertilization is not done in any of the six FMMs described here.

Browsing and fencing

Browsing is a problem in parts of the areas. The (theoretical) goal is to have game densities so low that fences are not required. How much fences are used in practical forestry is not clear. Regulate game with hunting is an important task for forest management and state forest invest a lot in hunt-ing to keep fencing on a low level.

Norway spruce monocultures tend to be quite robust against browsing, even with higher game densities. The highest risk connected with browsing in stands with Norway spruce is not the loss of spruce, but the loss of the other species in mixed stands.

Also for Beech the highest risk connected with browsing is not the loss of, but the loss of the other species in mixed stands.

The aim of the Brandenburg State Forest is to protect from browsing exclusively by shooting and without any fences in the two FMMs, for oak and pine. There is one exceptional case. If it is necessary seed the Oak the areas are fence because of the wild boars.

On the other hand, planted pine managed on small forest estates where clearcutting models are used, fences are used to 100%.

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2.8. FMM Spruce in large private owned forest

The management of most Norway spruce (*Picea abies*) stands in the case study region AWF (Augsburg Western Forests) is not a single FMM, but a whole family of FMM's which have a few things in common: Even-aged, mostly monospecific forests, comparably short final harvesting phases, regeneration often from planting. Thinnings in spruce stands in the CSA have to establish a compromise between stability (keeping stands not too dense) and productivity (production losses if density is too low). The choice of the optimum compromise is owner-specific.

Commercial thinnings might follow very different concepts (depending on owners' preferences). Among the possibilities are classic thinning from below, selective thinning, future-tree selection.

We are investigating more details, but we will never be as precisely informed as about the state forest, as in private forests, silvicultural guidelines seldom are documented in such detail and openly communicated as is the case for the state forest.

In this example, almost all state forest managers would probably argue, that managing spruce in the way private owners do, should not be implemented at all, but that they can understand the reasons of forest owners who do so. Private forest owners would argue either that the state should adopt their silviculture (in order to make more money), or that it is ok that the state maintains multifunctional forests while private owners have to focus on generating income.

General characterization of the FMM

Private owners manage Norway spruce not in one way (one FMM) but in many ways including clear-cutting and shelterwood systems.

Tree species used and specie composition

The most important specie and totally domination is Norway spruce, sometimes with small shares of Scots Pine, European beech and Silver fir. Norway spruce is normally 80% or more at stand level.

Rotation periods

The decision of the rotation period is completely up to the owner. The optimum rotation age strongly depends on the goals of the owners (what kind of timber do they want to produce, do they like to take risks or not, culmination of mean annual increment financial performance, sometimes including interest rate and other investments,). Typically this result in rotation periods of 70-100 years, depending on about when the production performance desired by a forest owner.

Size of clearcuts

Size of clearcuts are not regulated, but clearcuts in forest that protect neighbouring forests from storm impact is forbidden. The size of clearcuts varies from 1 to 10 ha with an average of 5 ha. Large clearcuts are avoided.

Forest regeneration

Site preparation is not used and are not regarded as necessary.

About 40% of the seedlings are natural regenerated and 60% is planted.

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Stand management

Pre-commercial thinning

If reducing over-densities (for stability reasons) is not necessary, pre-commercial thinnings are avoided. It's hard to estimate the area share requested. Assuming, 40 % of the FMM area are regen-erated naturally, at least about that area would require a pre-commercial thinning.

Commercial thinning

About four to eight times. Rough estimate. Depends on a broad range of conditions.

Pruning

Cannot be answered yet, pruning is restricted to small areas, because the production goal usually is standard quality (not top quality) timber in high amounts. Pruning Norway spruce makes only sense, when the commercial thinnings imply a future tree concept.

Harvest and logging residues

A rough estimate is that harvesters and mechanized transport of logs, forwarder is used for 95%. F the logged volume.

Logging residues, e.g. branches are not used.

Nature protection

Nothing is normally done for nature values or nature protection as it is not among the owners' goal.

2.9. FMM for Spruce in the state forest

The FMM is the current binding concept of the Bavarian state forest for silviculture in mixed and pure stands with Norway spruce (Picea abies) as the main species. The silvicultural goal is to trans-form even-aged Norway spruce pre-dominated stands into Spruce-deciduous mixed stands. This concept covers a lot of variants of how to deal with very different initial stand and site conditions, so it is actually an overall FMM with a lot of sub-FMMs. In the standard case, the FMM includes pre-commercial thinnings, two phases of commercial thinnings which go over to a target diameter harvest combined with natural regeneration of all desired species.

General characterization of the FMM

State forest (Bavaria) manage spruce with Selection system (however with preceding pre-commercial thinning, goal-tree oriented thinning phase, and a differentiated goal tree and structure thinning). It is quite consequently executed, however this FMM comprises a lot of different variants depending on the initial stand's status (mixture, age, density) and site conditions. All of these variants are coded for our DSS.

Tree species used and specie composition

All monospecific and mixed stands with Norway spruce (*Picea abies*) being the most important species. The most important additional species in mixed stands with Norway spruce are European beech (Fagus sylvatica), Scots pine (*Pinus slyvestris*), and Silver fir (*Abies alba*). Proportions of

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species in mixed stands depends on the goals of the managers. According to the guidelines (State forestry developed them in cooperation with the German partner in this project), the share of Norway spruce should not exceed 70%.

Rotation periods

Also for the state forest there are no regulations, but recommendations for when the thinning phase should be followed by the target diameter harvest phase. Individual trees are harvested at ages of 65 to 150 years depending on when the goal trees reach the desired stem diameters (in breast height) of (40) 45-50 cm.

Size of clearcuts

Size of clearcuts do not apply for a selection cutting system. Areas that are treated at one time, varies from 1 to 10 ha with an average of 5 ha.

Forest regeneration

Natural regeneration is totally dominating, 100%. Scarification are not necessary and are not performed at all.

Stand management

Pre-commercial thinning

The guidelines recommend 0-1 pre-commercial thinnings in ten years up to an age of 25. This is done in practice, thus approximately 100 % of the area this FMM applies is pre-commercially thinned at least once.

Commercial thinning

About eight times (four times in each of the two phases of commercial thinning). 100 % of the area is thinned several times. The two phases, lower H_{dom} than 25 m and higher than 25 m, differs in thinning strength.

Pruning

Cannot be answered yet, pruning is restricted to small areas, because the production goal usually is standard quality (not top quality) timber.

Harvest and logging residues

A rough estimate is that harvesters are used for 70% of the harvested volume and mechanized transport of logs, forwarder is used for 90% of the transport in the forest to the roadside.

Logging residues, e.g. branches are not extracted from the forest.

Nature protection

The goal to establish or maintain mixed and rich structured forests is seen as a nature protection feature by the managers.

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2.10. FMM for beech in state forestry

The FMM is the current binding concept of the Bavarian state forest for silviculture in mixed and pure stands with European beech (*Fagus sylvatica*) as the main species.

The silvicultural goal is to establish and maintain nature-near uneven aged mixed beech forests which provide a multitude of ecosystem services at the same time.

This concept covers a lot of variants of how to deal with very different initial stand and site conditions, so it is actually an overall FMM with a lot of sub-FMMs. In the standard case, the FMM includes pre-commercial thinnings, three phases of commercial thinnings which go over to a target diameter harvest combined with a "femel gap" approach and mostly natural regeneration of all desired species. A "femel" is a small hole as a first operation in a stand with crop trees. The small gaps are distributed across the whole area of the stand. After a few years (when there is some regeneration) the holes are enlarged more and more. Thus there won't be a climate like on a clearcut area.

General characterization of the FMM

Selection system combined with non-uniform shelterwood system (however with preceding pre-commercial thinning, an elite-tree oriented selective thinning phase, a first elite tree promotion phase (100 elite trees/ha), and a second elite tree promotion phase (50 elite trees/ha)). It is quite consequently executed, however this FMM comprises a lot of different variants depending on the initial stand's status (mixture, age, density) and site conditions. All of these variants are coded for our DSS.

Tree species used and specie composition

All monospecific and mixed stands with European beech (*Fagus sylvatica*) being the most important species. The most important additional species in mixed stands with Norway spruce are Sessile oak (*Quercus robur*), sycamore maple (*Acer pseudoplatanus*), and common ash (*Fraxinus excelsior*). The guidelines do not give exact numbers about proportion, but the concept applies to stands with European beech shares of 50 % and more.

Rotation periods

Also for the state forest there are no regulations, but recommendations for when the thinning phase should be followed by the target diameter harvest phase. Individual trees are harvested at a tree ages of 80 to 200 years depending on when the goal trees reach the desired stem diameters (at breast height) of 65 cm. Given the management goals of the Bavarian State Forest – the guidelines mirror the actual optimum that is the best compromise between production and other ecosystem services the state forest has to provide.

Size of clearcuts

Size of clearcuts is regulated and do not apply for a selection cutting system. The whole area will never be totally harvested. Coherent areas that are treated at one time, varies from 1 to 10 ha with an average of 5 ha.

Forest regeneration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The guidelines recommend 100%, although there is on option to underplant desired additional species. In practice the amount of natural regeneration very rough estimated is 90%, the rest would be under-planted additional species

Scarification are not necessary and are not performed at all.

Stand management

Pre-commercial thinning

The guidelines recommend 0-1 pre-commercial thinnings in ten years up to an age of 30. This is done in practice, thus approximately 100 % of the area the FMM applies is pre-commercially thinned at least once.

Commercial thinning

About seven times (distributed among the three phases of commercial thinning). 100 % of the area is thinned several times.

Pruning

Pruning is not a reasonable action for European beech and most other deciduous species in the CSA.

Harvest and logging residues

A rough estimate is that harvesters are used for 70% of the harvested volume and mechanized transport of logs, forwarder is used for 90% of the transport in the forest to the roadside.

Logging residues, e.g. branches are not extracted from the forest.

Nature protection

The goal to establish or maintain mixed and rich structured forests is seen as a nature protection feature by the managers. Deadwood accumulation is promoted, biotope trees (e.g. with hollows) are deliberately kept in beech stands. The state forest has given themselves a nature protection concept for beech (dominated) forests with certain goals of deadwood and biotope tree development depending on stand type and age.

2.11. FMM for Pine, private owner

The following description is about how most Scots pine (*Pinus sylvestris*) is managed in the small private forest estates in the case study region LSN (Lieberose Schlaubetal Neuzelle).

This, however, is not a single FMM, but a whole family of FMM's which have a few things in common: Even-aged, mostly monospecific forests, comparably short final harvesting phases, regeneration most of the time from planting. In most cases thinnings are done from below.

General characterization of the FMM

This FMM for pine is a clearcutting system.

Tree species used and specie composition

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Typically, the share of Scots pine is 90% and more.

Rotation periods

The rotation period is a result of the FMM and the chronology of the silviculture interventions. The period ends with a target breast height diameter. Due to the marked spatial heterogeneity of forest structure, owner type and socioeconomic conditions in Germany, the optimal rotation period is subject to large variety on the spatial scale of the stand and also on the scale level of the forest enterprise. Thus, we are not able to define an optimal rotation period, moreover, as it will again depend on the scenario of wood demand and climate to be applied.

We have to assume that the actors know best what the optimal silviculture treatment is that leads to the wanted ESs. Tree ages of 150 years depending on when the goal trees reach the desired stem diameters (in breast height) of 45-50 cm.

Size of clearcuts

There is no regulation of size of clearcuts. The size depends on the owner and the area he focus on in each activity. In most cases the area of clearcut, or other operations as thinning is 0,4-2 ha.

Forest regeneration

Regeneration is done by planting only. Number of seedlings are 8000 per ha and size around 20 cm. Site preparation is not needed and is not done.

Stand management

Pre-commercial thinning

No pre-commercial thinning is done.

Commercial thinning

Thinning is done about 4 to 8 times. Depends on a wide range of conditions.

Pruning

Pruning is not done.

Harvest and logging residues

A rough estimate is that harvesters are used for 95% of the harvested volume and mechanized transport of logs, forwarder is used for 95% of the transport in the forest to the roadside.

Logging residues, e.g. branches are not extracted from the forest.

Nature protection

Typical not, because it is not among the forest owners' goals.

2.12. FMM for Pine, state forestry

The FMM is the current binding concept of the Brandenburg state forest for silviculture in mixed and pure stands with Scots pine (*Pinus sylvestris*) as the main species. The silvicultural goal is to

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transform even-aged Scots pine pre-dominated stands into Pinus-deciduous mixed stands. This concept covers a lot of variants of how to deal with very different initial stand and site conditions, so it is actually an overall FMM with a lot of sub-FMMs. In the standard case, the FMM includes mix-ing regulation up to 7 m height of dominant trees. When height of dominant trees is higher than 7 m commercial thinnings are done to facilitate future trees. At the target breast height diameter groups of trees have to be cut to make gabs with natural regeneration.

General characterization of the FMM

This FMM for pine can be characterized as selection system combined with non-uniform shelter-wood system without enlarging the gaps. Different variants are used depending on initial stands status and site conditions.

Tree species used and specie composition

The FMM focusses on Scots pine. In general proportion of pine shall be higher than 50% and all mixing proportions together be lower than 50 % The most important additional species are beech and oak (*Quercus petrea*).

Rotation periods

The rotation period is a result of the FMM and the chronology of the silvicultural interventions. The period ends with a target breast height diameter. Due to the marked spatial heterogeneity of forest structure, owner type and socioeconomic conditions in Germany, the optimal rotation period is subject to large variety on the spatial scale of the stand and also on the scale level of the forest enterprise. Thus, we are not able to define an optimal rotation period, moreover, as it will again depend on the scenario of wood demand and climate to be applied.

We have to assume that the actors know best what the optimal silvicultural treatment is that leads to the wanted ESs. Tree ages of 150 years depending on when the goal trees reach the desired stem diameters (in breast height) of 45-50 cm.

Size of clearcuts

There is no regulation of size of clearcuts. Each size is possible, it depends on the spatial pattern of stratification. Gaps created is smaller than 0,3 ha and without further enlarging

Forest regeneration

As much as possible as natural regeneration. There is no information about the need for complementary planting. Failures depends on too much game and browsing.

Stand management

Pre-commercial thinning

Up to 7 m height of dominant trees there is just regulation of the species mixing, without harvesting, this is what normally is called pre-commercial thinning. From 7 m to 12 m there is the first harvesting intervention. If this intervention give a positive economic results is not clear.

Commercial thinning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

All area is thinned several times

Pruning

Just single trees with an extremely high probability to become quality wood get pruned.

Harvest and logging residues

A rough estimate is that harvesters are used for 70% of the harvested volume and mechanized transport of logs, forwarder is used for 90% of the transport in the forest to the roadside.

Logging residues, e.g. branches are not extracted from the forest.

Nature protection

The goal to establish or maintain mixed and rich structured forests is seen as a nature protection feature by the managers. Deadwood accumulation is promoted, biotope trees (e.g. with hollows) are deliberately kept in beech stands.

The goal to establish or maintain mixed and rich structured forests is seen as a nature protection feature by the managers.

For reasons of biotope and species protection 5 oaks per ha must be selected in pine stands older than 80 years.

2.13. FMM for Oak, state forestry

The FMM is the current binding concept of the Brandenburg state forest for silviculture in stands with oak (*Quercus petraea* and *Quercus robur*) as the main species. The silvicultural goal is to establish oak stands with a high percentage (circa 35 %). This concept covers a lot of variants of how to deal with very different initial stand and site conditions, so it is actually an overall FMM with a lot of sub-s. In the standard case, the FMM includes closed canopy until a 7-10 m stem length with-out branches is reached. Then tending by single tree selection and facilitation until a target breast height diameter of 60 cm is reached. Meanwhile a layer of mixed species cares for shading the stems. In stands with shade tolerant species the regeneration is done with nature regeneration in 0,3 – 0,5 ha gabs. In stands without shade tolerant species areas with trees that are ready for harvesting will be thinned to become a shelter for the nature regeneration. If there are no seed trees, Oaks have to be seeded or planted.

General characterization of the FMM

This FMM for oak comprises a lot of different variants depending on the initial stand's status (mixture, age, density) and site conditions. The management combines uniform shelterwood system for parts with shade tolerant species with non-uniform shelterwood system for parts with light de-manding species. There is also elements that can be characterized as selective system. Regeneration only in groups (0,3-0,5 ha without trees) without further enlarging, and tending by future tree thinning

Tree species used and specie composition

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The FMM focusses on oak, *Quercus petraea* and *Quercus robur*, accompanied by tree species *Pinus sylvestris, Fagus sylvatica, Carpinus betulus* and *Tilia cordata*.

Rotation periods

The rotation period is not regulated and is a result of the FMM and the chronology of the silvicultural interventions. The period ends with a target breast height diameter Due to the marked spatial heterogeneity of forest structure, owner type and socioeconomic conditions in Germany, the op-timal rotation period is subject to large variety on the spatial scale of the stand and also on the scale level of the forest enterprise. Thus, we are not able to define an optimal rotation period, moreover, as it will again depend on the scenario of wood demand and climate to be applied.

We have to assume that the actors know best what the optimal silvicultural treatment is that leads to the wanted ecosystem services. Rotation period is not determined as an interval of years or a target tree age. The time between regeneration up to the next regeneration of a group of trees de-pends on the time that a group of trees take to grow up to a desired breast height diameter of 60 cm. -> age is circa 200-240 years

Size of clearcuts

There is no regulation of size of clearcuts. Each size is possible. It depends on the spatial pattern of stratification. Gaps can have a typical size of 3000-5000 m^2.

Forest regeneration

More or less 100% of the seedlings are natural regenerated. Scarification are not necessary and are not performed at all.

Stand management

Pre-commercial thinning

Up to 7 m height of dominant trees there is just regulation of the species mixing, without harvest-ing, this is what normally is called pre-commercial thinning. From 7 m to 12 m there is the first harvesting intervention. It is not clear whether this intervention gives a positive economic result.

Commercial thinning

From 15 m height of dominant trees and higher every 5-8 years a commercial thinning has to be done. 100 % of the area is thinned several times.

Pruning

During the time up to a 12 m height of dominant trees the canopy should be kept closed. Then artificial pruning is not needed.

Harvest and logging residues

A rough estimate is that harvesters are used for 70% of the harvested volume and mechanized transport of logs, forwarder is used for 90% of the transport in the forest to the roadside.

Logging residues, e.g. branches are not extracted from the forest.

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Nature protection

The goal to establish or maintain mixed and rich structured forests is seen as a nature protection feature by the managers. For reasons of biotope and species protection from an age of 100 years 5 oaks per ha or mixed tree species of low quality must be left in the natural decay phase and not used.

2.14. References

Sources

The silvicultural guidelines of the Brandenburg state forest contain the interests of the Brandenburg government and society and the validated scientific knowledge of the university in Eberswalde as a forestry competence centre. Further sources include silvicultural guidelines of the Bavarian state forest, knowledge and experience from long-term collaboration with experts from the Bavarian state forest, being involved in the recent forest planning process for the state forest in the CSA, over-regional and regional experts, preliminary results of the actor analysis, available CSA data.

Bayerische Forstverwaltung, Waldflächenbilanz 2015.

Waldzustandsbericht 2012 der Länder Brandenburg und Berlin.

LWF-Wissen 49, die zweite Bundeswaldinventur 2002, numbers for Bavarian region of Swabia.

Federal State Forestry of Brandenburg, Dr. R. Hentschel, pers. comm.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

3. Ireland

3.1. Background and forest history

Following periods of heavy reforestation and deforestation from the 1600s to 1900s, forest cover in Ireland was about 1% in the early 1900s. To develop a forest industry in Ireland, the government started a large afforestation project mainly using the fast-growing exotic softwoods Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and lodgepole pine (*Pinus contorta* Douglas). The main purpose of these forests was to produce timber for domestic use. Since the early 1980s, government afforestation has declined and focus has shifted to encourage private landowners to afforest their agricultural land in exchange for economic incentives.

The total area of the Republic of Ireland is 6 975 000 ha. In 2012, about 10.5% (732 000 ha) of this was covered with forests and the goal is to bring the forest cover to 17% by 2030. The average standing volume is 140m^3ha^{-1} and the yield capacity (Sitka spruce) 20.4 $m^3ha^{-1}yr^{-1}$.

Introduced tree species dominate forestry in Ireland. The most important economically is Sitka spruce with more than 50% of the standing volume. Second is lodgepole pine, at 10% of Ireland's forest cover. There are also other tree species in Ireland. These species and their proportions are presented in Table 11.

Today, ecological and social benefits of forests are recognised in certification and legislation. This is reflected in more awareness about sensitive species habitats, increased environmental consideration during forest operations and species diversification towards more native and broadleaf forest. Since much of Irish forest area comprise fast growing softwoods, managed for a timber oriented forestry sector, spruce and pine clearcutting remain the dominant forest management models in Ireland. The long tradition of agricultural production and revenue generation through land-use management means that the exotic softwood's good production capability is a good fit for Ireland's heritage and is unlikely to change.

3.1.1. Ownership

The biggest owner of forest land in Ireland is Coillte. It is a semi-state company. Coillte own 53% of the forest area in Ireland while the remaining 47% is privately owned.

3.1.2. Nature Conservation and Biodiversity Protection non-forested land

Nature conservation and biodiversity protection in Irish forestry often incorporates areas that are not forested, this is due to Ireland historically being heavily deforested and only gaining a significant forest area in recent years. Most historically forested areas have been converted into agricultural land and much of the current forested area was historically blanket peat. Thus, a wider nature conservation approach is often taken in Irish forestry to include non-forested adjacent land that has high biodiversity values (e.g. open bog habitat, rivers and lakes).

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3.2. The case study area

The CSA is 12 511 ha forest. The forest is dominated by wet sites with a productivity between 8-14 m^3 ha^{-1} yr^{-1}. The CSA, like much of western Ireland, is dominated by blanket peat which limits the productivity of species and potential for many FMMs that could be implemented in the CSA. The eastern side of the country is more fertile and hence has more productive forests, in many cases with similar species choice. There is more interest in restoring bogs today than there was in the past and to date, some bog restoration has taken place in western Ireland.

Table 9. The forest land in the CSA expressed as forest area proportion (%) within productivity and moisture classes.

Productivity/ moisture	Productivity, yield class ($m^3ha^{-1}y^{-1}$)	Dry %	Mesic %	Moist %	Wet %
High	>14	1.3	1.8	0.2	11.0
Medium	8-14	3.0	3.3	0.1	71.8
Low	<8	0.3	0.5	0.1	6.6

Using data from the INTEGRAL project and reading Coillte forest management plans, an estimate is that ca 1,700 ha, (13.3 %) of the total 12,735 ha forest is made up of nature conservation and bio-diversity protection non-forested land. Since this area is non-forested it was not included when calculating the coverage of the actual FMM, thus the 100% Coverage of CSA forestland in question 4 is calculated from the 86.7% of the "forest estate" that is actually forested.

There are some differences in dominant soil type in the CSA compared to the rest of Ireland. CSA Connacht, like much of western Ireland, is dominated by blanket peat which could potentially limit the productivity of species and FMMs that could be implemented in the CSA. The eastern side of the country is more fertile and hence has more productive forests, in many cases with similar species choice. There is more interest in restoring bogs today than there was in the past and to date, some bog restoration has taken place in Western Ireland, see below for FMM description. Thus there could be fewer conifer clearcutting stands in the future if it is more favourable to let them develop into biodiversity habitats after clearcutting rather than planting exotic conifers again.

3.2.1. Land area and forest cover

The forest cover of the CSA is similar to Ireland, around 10%. Also in standing volume and owner-ship structure the CSA is similar to Ireland, Table 10.

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Table 10. Total land area, forest area, standing volumes, productivity and ownership in the CSA (Barony of Moycullen), County Galway and Ireland. Source: Forest Service (2013). National Forest Inventory – Republic of Ireland.

	Barony of Moycullen	**County Galway**	**Republic of Ireland**
Total Area (ha)	**77 528**	**612 430**	**6 976 110**
Forest Area (ha)[1]	12 511	59 410	731 650
Forest cover (%)[1]	16.1	9.7	10.5
Average Volume (m3ha^{-1})[1]	*No information exists at present, likely similar to County Galway*	135	140
Average Yield Class (m3ha-1yr-1)1	12	16.3	20.4
Forest Ownership (%)[1] Public (Coillte) Private (Grant aided) Private Other	 81.1 14.2 4.7	 65.1 26.2 8.7	 53.2 34 12.8

3.2.2. Tree species

Introduced tree species dominate forestry in Ireland and in the CSA. Most important is Sitka spruce which makes up more than 50% of the standing volume. Second is lodgepole pine making up 10% of forest cover in Ireland and 21 % in the CSA. There are also a number of other tree species and are presented in Table 11.

Table 11. Tree species, proportion of total forest area. Forest Service (2013). National Forest Inventory – Republic of Ireland – Results.

	Barony of Moycullen	**County Galway**	**Republic of Ireland**
Species (Latin name)	Proportion (% total area)	Proportion (% total area)	Proportion (% total area)
Sitka spruce (*Picea sitchensis*)	50.1	55.5	52.5
Pines, mainly lodgepole pine (*Pinus contorta*), excl. Scots pine (*Pinus sylvestris* L.)	37.4	20.9	9.7
Short lived broadleaves: Birch, Alder, Salix and poplar, (*Betula spp, Alnus spp, Salix spp, Populus spp* etc.)	6.1	15.7	15.5
Long lived broadleaves Oak Beech, Ash, Maple species (*Quercus* spp, *Fagus sylvatica* L., *Fraxinus excelsior* L., *Acer* spp etc.)	1.1	6.1	10.3
Norway spruce (*Picea abies*)	0.5	2.9	4.1
Larch, (*Larix* spp.)	2.7	2.2	4.4
Scots pine (*Pinus sylvestris* L.)	0.3	1.5	1.3

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Other conifers: Oregon pine (*Pseudotsuga menziesii*), English yew (*Taxus baccata*), Fir (*Abies spp) and more*	1.8	0.1	2.2

3.3. FMMs in Ireland and in the Irish CSA

Irish forestry dominates by silvicultural systems or models characterized by clear-felling. Approximately 85% of forest land is managed with CF systems. For nature conservation and biodiversity protection other management systems are used. This "FMM" won't be described below because it is not forested, but it is important to meet nature conservation and biodiversity goals in Irish forestry.

When much of Ireland's current forest area was afforested since the year 1900, the main goal was to produce timber and there was little consideration of how different species would perform on different sites and how species selection would influence non-timber benefits, i.e. biodiversity, water quality, recreation, tourism, etc.

Central and eastern Ireland has the soil to accommodate a more diverse forest, but in the CSA, the majority of all soil is blanket peat which has limitations for tree species selection. With forest knowledge increasing and policies emerging that aim to protect and enhance biodiversity features, the way forward is to establish native woodland sites, plant lodgepole pine on sites where fertilisation is restricted (Tony Clarke, pers. comm.) and restore some afforested sites back into their previous peatland habitat.

Recent changes in forest policy has resulted in a different value extraction from Irish forestry and thus timber production is no longer the only goal.

Increased emphasis on environmental and ecological factors mean that some sites are no longer considered suitable for certain species. Some of the above-mentioned sites will allow for establishment if fertiliser is applied, but new policies limit the use of fertiliser especially near freshwater pearl mussel (FPM) watersheds. In the future, it may be beneficial to establish some other forest management types on these sites, e.g. low stocking of lodgepole pine or other land-use types e.g. bog restoration.

Afforestation was initially done by the state, who bought marginal land (mainly blanket peat) for afforestation. Since the 1980s, government afforestation has declined and virtually ceased while private land owners (mainly farmers) are incentivised for afforestation grants. Much of private afforestation is carried out on marginal agricultural land which are often more productive than blanket peat.

Three FMMs are used in larger scale in the Irish CSA; 1) Clearfelling Sitka spruce and other conifers (but not lodgepole pine), 2) Clear-felling lodgepole pine 3) Nature conservation and biodiversity protection management (Table 12).

The two clear cutting models are similar. The difference is the tree species and depending on the species they are used on slightly different sites and while it is a choice to thin for other conifers, thinning is not an option for lodgepole pine.

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Table 12. The three major forest management models (FMMs) used in the Irish CSA, and in Ireland.

Forest management models (FMM) Domestic name in English	"General characteristic"	Coverage CSA (% forestland)	Coverage Ireland (% forestland)
Clearcutting system – Sitka spruce (mainly) and other conifers	Clearcutting system	55-60	63-66
Clearcutting System – lodgepole pine	Clearcutting system	25-30	20-25
Nature Conservation and Biodiversity Protection	No intervention	10-15	15
Nature Conservation and Biodiversity Protection non-forested land	No intervention	N/A	N/A

3.4. Ecosystem services

There is a large difference in the services provided with the three FMMs. Sitka spruce and lodgepole pine are used for timber or pulpwood production while areas managed with models for nature conservation and biodiversity protection are expected to result in a number of other services, see

Table 13.

Table 13. Ecosystem services connected to the four FMMs in the Irish CSA. Ranking of important ESs within each FMM. No ranking between FMM.

Forest manage model (FMM)	Clear-cutting system Sitka spruce and other coniferous	Clear-cutting system lodgepole pine	Nature conservation and Biodiversity protection
Timber production	**1**		
Timber and fibre production		**1**	
Habitat protection for invertebrates, fungi deer red squirrel, birds, plants etc.			**1**
Water quality for salmonids, freshwater pearl mussel and other aquatic species			**2**
Carbon sequestration			**3**
Recreation and tourism			**4**
Landscape amenity			**5**

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3.5. Alternative FMMs

In the CSA, three models for managing forests are dominating. But there are also other models used in Ireland, clearcutting models with broadleaves, models characterised by continuous forest cover and models for restoration of bogs. These models are described here briefly.

Continuous cover forestry. The goal is to create high forest native woodlands that can facilitate a combination of high quality wood production, biodiversity enhancement and reduce the adverse visual impact of clear-cuts in the landscape. Very few sites in the CSA have the soil to facilitate proper implementation of CCF and the current CCF area is very low. Regeneration by planting suitable conifer, broadleaves or a mix of species, full or partial natural regeneration is also acceptable.

Bog restoration. Forest land on blanket peat sites that has the potential to develop into good quality bog habitat is not replanted after harvesting. In addition, drains are blocked to facilitate the growth of Sphagnum. Between 2003 and 2020, it is expected that about 3% of the forest in the CSA will be converted into bog and most of this transformation has already occurred. Bog restoration programmes are often renewed and extended so it is possible that more forest will be converted back into bog.

Clearcutting system – Broadleaves. Similar to the two FMMs with conifer – that will be described in below - but with broadleaf tree species like oak, European beech, maple, lime and birch. Major differences to conifer clearcutting systems is generally later first thinning and longer rotation age (rarely clearcutting before the stand is 60 years of age). Since much of the CSA is blanket peat, this FMM is unsuitable as a reforestation option for most of the present day forest. Thus this FMM is more suitable for afforestation and reforestation on private land, which generally has more favourable soils for broadleaf plantations.

3.6. The two Clearcutting systems used in the Irish CSA

Today the two clear-cutting models are used on 75-85% of the forest area in the CSA, 30% of the forest area is lodgepole pine dominated stands. In the future, the total area Sitka spruce may be reduced as less fertilizer is now permitted for successful establishment, lodgepole pine will most likely be planted instead. In addition, some areas are likely to be managed as biodiversity conservation areas meaning that the total area managed under the two clear-cutting systems is likely to be reduced in the future.

Edaphic conditions

The clearcutting models can be used on more or less all sites. At present Sitka spruce is used in the CSA on all these combinations except on dry sites with low production. In the future, many suitable highly productive sites should be regenerated with native woodland species in order to reach national forest policy goals that aim to increase the area forested with native woodland species rather than exotic conifers.

Sitka spruce will produce a higher economic revenue on suitable sites (=high production sites), lodgepole pine should be used on medium and low production sites. Clearcutting (lodgepole pine) today also is used on Moist and Wet sites with higher production.

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Tree species

The main tree species managed with the two clearfelling FMMs are Sitka spruce and lodgepole pine but there are a number of other species such as larch and Scots Pine, for more details see Table 11.

The average site should be planted with either Sitka spruce, but Norway spruce, Scots pine, Douglas fir are also options.

Low productive forest sites should be regenerated with lodgepole pine or bog restored and thus no longer be included as forest land.

The stands can be described as monocultures as 90% of the volume should be the principal tree species and 10% in broadleaves (or native conifers if the site isn't suitable for broadleaves).

New planting rules require a mixture of 10-15% broadleaf or conifers other than Sitka spruce and lodgepole pine in both afforestation and reforestation stands. These rules did not exist when most of the forest stands in the CSA were established.

Tree species composition

The clearcutting systems aimed at and result in more or less pure stands (100%) of conifers including lodgepole pine. It is estimated that 80% of the stands in the CSA are monocultures, 15% have an admixture of 5-25% and the remaining 5% of the stands have an admixture of 25-50%. Afforestation and reforestation plantation rules in 2016 require that a minimum of 10% broadleaves are planted in the stand, depending on site suitability native conifers could make up these 10%. Most of the already established forest stands are homogenous as this was not a requirement previously. Most stands will therefore in the future have 5-25% admixture of other species, mainly broadleaves, DAFM (2015).

As lodgepole pine is a low nutrient demander, some Sitka spruce stands in areas where fertiliser use is restricted will be regenerated with lodgepole pine.

Rotation periods

There is no regulation of the rotation period in Ireland. Generally final felling occurs when the most profitable timber assortments can be harvested from the forest (Forest Service 2000).

Optimal rotation periods are around 35-65 years on a financial rotation, which produces the most valuable distribution of timber assortments. Other conifers have slightly longer rotation ages than Sitka spruce on the same site, Coillte (2003).

Sometimes, operational management issues change the optimal financial rotation length, this can mean longer or shorter rotations. This could be for reasons such as access, adjacent forest's suitability for harvesting, wind risk, etc.

Especially for private forest landowners, rotation ages are shorter than the optimal financial rotation as these owners prefer to see the financial values of their forests being realised earlier than the optimal financial rotation.

In addition, forests are sometimes not thinned for various reasons (e.g. wind risk, not economically viable, not informed of its benefits, etc.) which means that rotation lengths are typically shorter.

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Size of clearcuts

Harvested area is regulated in the PEFC Irish Forestry Certification Standards. No clearfell coup size larger than 25 ha and woodland clear felling area must not exceed 25% in 5-year period (Forest Service 2008a, PEFC (Ireland) 2014). The 25 ha limit also applies to all harvest operations (i.e. non-certified forests) that are 6km upstream of FPM populations.

Forest regeneration

Restocking takes place with planted stock typically. Natural regeneration is not typical for the Irish condition.

Some form of site preparation is used on 100% of the regeneration areas. Rather than using the technical definition of soil scarification where mineral soil is disturbed we refer to a wider definition called ground cultivation to include site preparation of deep blanket peat. The practical application is the same – to improve the growing site for seedlings. Mound and mound-and-drain are the most commonly used ground cultivation methods in the CSA. This number (100%) also includes regeneration sites that utilise still functioning ground cultivation method from the previous stand rotation. Replanting direct into clearfelling soil has been dried and resulted in large scale crop failure. (pers. Comm. Tony Clark).

Ground cultivation in Ireland can be divided into three systems:

Soil scarification (with mineral soil disturbance). This method is suitable only for free draining soils in eastern and southern Ireland, is done to a small extent in Ireland and not done at all in the CSA.

Mound-and-drain is the preferred ground cultivation method on wet mineral soils with a peat layer. Drains are dug in 12 m intervals to drain the peatland soils of Western Ireland. The spoils from the drain are laid out in small mounds at 2 m intervals and used as a planting medium for the seedlings.

Mounding only is done as described above but without adding drains. Mounding only is done on thick blanket peat where the old plough ribbon is no longer usable (see below).

Ploughing was the preferred ground cultivation method in the past, especially on sites with thick blanket peat, which is the dominating soil type of the CSA. The plough furrow acted as the drain and the plough ribbon as a planting medium. During reforestation, the plough ribbon from the first rotation is in many cases still present and reused as a planting medium. The impact of the first rotation crop causes the peat to be more friable and more mobile in water; since the risk of water runoff is increased, there is usually no new drainage carried out for reforestation.

Timber producing lodgepole pine is planted at 2500 seedlings/ha and the 1800 seedlings/ha stocking is used for fiber production on sites with a low yield class (Sitka spruce yield class =<12) Source: Coillte (2003). Sitka spruce is planted at a 2500 seedlings/ha stocking.

Browsing and fencing

There is little browsing threat from game and livestock on Sitka spruce in the CSA. Douglas fir and larches are the most susceptible conifers to browsing, but they only comprise up to 2% of the total forest area, so the annual regeneration area that is in need of fencing is very small.

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Introduced species

Introduced (exotic species) are used to a large extent in Ireland, approx. 85% of the seedlings. Sitka spruce, origin North America, is traditionally the most commonly used species in Irish forestry, NFI (2013). Norway spruce, is used up to 5% of the seedlings. Lodgepole pine, origin North America, is traditionally the second most used species in Irish forestry, NFI (2013).

Genetically improved or modified seedlings

Many seeds are sourced from stands all over Ireland which have been identified as having superior genetics for providing the objectives of Irish forestry, i.e. good quality timber. For this reason, it is difficult to know the extent to which non-local seed sources are used. All (100%) pf seeds/seedlings used are genetically improved (Coford, 2012). Tree breeding still has a lot of potential in increasing favourable tree features and the forest sector hasn't developed to this stage as of yet.

No genetically modified seeds/seedlings are used.

Hybrids are used very rarely in Irish forestry. A small amount of hybrid larch *(Larix x eurolepis*) is used in Ireland but not in the CSA.

Herbicides and chemicals used

Herbicides are used where vegetation competition is high; a treated plantation receives 2-3 applications in a rotation age.

Seedlings are coated in insecticides prior to planting and sometimes sprayed in the field to protect against large pine weevil (*Hylobius abietis*).

Trials are being done where a solution with entomopathogenic nematodes are been sprayed on stumps to reduce the number of emerging large pine weevil.

Fungicides are rarely used in Irish forestry, but stumps are painted with urea to prevent future dam-age from *Heterobasidium annosum* (Fr.) Bref.

A general trend in Irish forestry is that the number of available chemicals and the quantity at which they are used are being reduced. Source: Dillon & Griffin (2008).

Fertilisation

The majority of the public afforestation that took place on blanket peat is in need of fertilisation to successfully establish plantations of coniferous including lodgepole pine. One application at establishment is usually sufficient to get the stand started, but a second application might be necessary in some cases. Private afforestation is generally done on more productive sites and is not as dependent on fertilization as the public blanket peat forestry.

Nature protection/consideration

All afforestation plantations must contain a minimum 10% of broadleaves as Areas of Biodiversity Enhancement (ABE).

When an area is proposed for afforestation, it is necessary to give special regard to nature protection by identifying ABEs and rank them according to environmental sensitivity. ABE must

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comprise 15% of the afforested stand (may be reduced to 10% if the stand is smaller than 10 ha). ABEs consist of both open habitat (5-10% of the stand) and retained habitat (5-10% of the stand). Open habitats are setbacks for water (aquatic buffer zone), setbacks around roads and archaeological setbacks. Retained habitats are existing habitats like areas of scrub, non-high forest species, individual high forest species and hedgerows.

Identifying ABEs are crucial to ensuring that proper buffer zones are established around certain environmental features when afforested. However, ABEs can consist of anything from native woodland species acting as an aquatic buffer zone around a FPM watercourse to some birches and alders planted in a spruce stand, far away from any sensitive environmental feature. To some degree, ABEs can thus very similar to the Swedish FMM "Nature conservation with management" since active management is necessary to establish them and to some degree maintain them. This would justify describing them as their own FMM but it is a fairly new concept and a very broad definition.

There is a requirement to have minimum 10% broadleaves or suitable conifers (not Sitka spruce or lodgepole pine) in conifer and 10% suitable conifers (see above) in broadleaf plantations for reforestation. Special reforestation objectives exist to ensure the establishment of native woodland species in aquatic buffers for biodiversity protection, these areas are described as a different FMM.

Additionally, large parts of the CSA's forests are within or adjacent to proposed Natural Heritage Area (pNHA), Special Areas of Conservation (SAC) or a FPM watershed which restrict possible forestry prescriptions.

3.7. Clearcutting system conifers: Sitka spruce

Today the FMM clearfelling conifers/Sitka is used on 50-55% of the area but could be used on 55-60%.

Tree species

The main tree species managed with the clearfelling model conifers are: Sitka spruce, Norway spruce (*Picea abies* (L.) H. Karst.), Douglas fir, (*Pseudotsuga menziesii* (Mirb.) Franco.), Japanese larch (*Larix Kaempferi* (Lamb.) Carr.), and Scots Pine, (*Pinus sylvestris* L.)

Sitka spruce is used on approximately 90% of all stands in this model and the principal tree species account for approximately 95-100% of the stand volume. The tree species mentioned above are also used but to a lesser extent.

Stand management

Pre-commercial thinning

Pre-commercial thinning, PCT, is not used or used only in up to 5% of the established stands in this FMM. Sitka spruce has fast diameter growth in its juvenile stage and opening up the stand too early would promote the growth of undesirable juvenile wood. Due to naturally slow self-pruning it is beneficial to grow young Sitka spruce at a tight spacing.

Productivity in Ireland is generally so high that the first commercial thinning occurs before the stand starts experiencing stunted growth or heavy competition from undesired species. Due to Ire-

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lands forest estate recently being established there is little natural regeneration of broadleaf species in most conifer stands that would justify pre-commercial thinning.

Commercial thinning

Thinning is rather uncommon in this FMM, 25-35% of the stands are thinned one or more times during a rotation. Thinning should be done where appropriate, taking risk and demand factors into account. Forests dominated by blanket peat become unstable after commercial thinning which increases the risk of windthrow and there is no recommendation to increase or decrease the proportion of thinning.

Pruning

Pruning is not done, and it is not recommended.

Harvest and logging residues

Harvesting and wood extraction in this FMM is fully mechanized.

Logging residues, e.g. branches >5cm are removed only removed from fertile sites, Yield class >=18. It is financially neutral to carry out this process. The benefits of carrying it out are that there is more biomass supply and replanting is easier (where logging residue isn't extracted, it is windrowed to make planting easier) and the disadvantages are that nutrients are carried off-site and increased risk of rutting and soil compaction.

3.8. Clearcutting system: lodgepole pine

This FMM is in many aspects similar to clearcutting system (conifers). But it has been recognized as an own FMM.

Tree species

Lodgepole pine is now growing on 25-30% of the area in the CSA and all managed with the clear-felling system.

In the future the proportion of lodgepole pine will decrease to 20-25%. Recent changes in forest policy has resulted in a different value extraction from Irish forestry and thus timber production is no longer the only goal.

Despite biodiversity concerns, lodgepole pine is a suitable species on nutrient poor sites and will produce timber and pulpwood even if established with low stocking where clearcutting and reforestation of other more site demanding conifers are not an option because restricted use of fertilisers (Pers. Comm. Tony Clarke, Forest Service (2008b) Forest Service (2015).

Stand management

Pre-commercial thinning

Pre-commercial thinning is not done in FMM/lodgepole pine. Productivity in Ireland is generally so high that the first commercial thinning occurs before the stand starts experiencing stunted growth or heavy competition from undesired species. Due to Ireland's forest estate recently being

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established, there is little natural regeneration of broadleaf species in most lodgepole pine stands that would justify pre-commercial thinning.

Thinning and pruning

Thinning or pruning are not done in lodgepole pine in the CSA.

Harvest

Harvest is 100% mechanized. Logging residues, e.g. branches >5cm, are in some stands extracted. It is financially neutral to carry out this process. The benefits of carrying it out are that there is more biomass supply and replanting is easier (where logging residue isn't extracted, it is windrowed to make planting easier) and the disadvantages are that nutrients are carried off-site and increased risk of rutting and soil compaction. For this reason, logging residues are only removed from productive sites, i.e. YC(Yield Class) >= 18.

3.9. FMM for Nature conservation and biodiversity protection

This FMM don't include any active management. Today approx. 10-15% of the area in the CSA is left for no management for nature conservation and biodiversity protection. The ambition is to leave around 15% of the area. This number is an estimate based on forested area and does not include large open spaces with biodiversity protection, however small open spaces that are integrated in the stand as retained Area for Biodiversity Enhancement (ABE) are included in the number. This 15% area includes water setbacks (aquatic buffers), woody habitat, scrub forest, Native Woodland Site (NWS) Conservation and other forests with biodiversity and conservation designation.

The number is difficult to estimate properly and is based on a national goal for establishing ABEs as a way to diversify the Irish forest industry to accommodate biodiversity and social values along with timber production (which was the main reason for the national afforestation project that started in the 1920s and continues to this day). The forested portion of ABEs and other protected forest areas should comprise 15% of the total forested area in the CSA.

It is important to understand that nature conservation and biodiversity protection in Irish forestry often incorporates areas that are not forested, this is due to Ireland historically being heavily deforested and only gaining a significant forest area in recent years. Most historically forested areas have been converted into agricultural land and much of the current forested area was historically blanket peat. Thus, a wider nature conservation approach is often taken in Irish forestry to include non-forested adjacent land that has high biodiversity values (e.g. open bog habitat and lakes). Policy zones such as Special Areas of Conservation (SAC, designated according to the EU Habitats Directive), Special Protected Areas (SPA, designated according to The EU Birds Directive), National Heritage Areas (NHA, basic Irish statutory designation for wildlife habitat protection) and Proposed National Heritage Area (NHA, non-statutory designation for wildlife habitat protection) are often designated to protect non-forest land. Thus, forests that fall inside a SPA, SAC, NHA or pNHA are often subjected to regulated operation in consultation with a Forest Service official, but timber production can still be the main objective. For example: according to a management plan, large areas of the forest might be in a SAC, but if the SAC is meant to protect an adjacent bog it might only regulate forest operations adjacent to the SAC rather than restrict all forest operations

inside the policy zone. Such a forest would not be included in this FMM but would be described in the conifer FMMs, with regulation of operations done on a case by case basis. Additionally, areas such as open peat land, unplantable land, waterbodies and swamps may be included in a forest management plan as land with a biodiversity or conservation objective, but we try not to include those areas when referring to this FMM. (Forest Service (2015a) Forest Service (2015b) Forest Service (2015c) Forest Service (2016)).

The difference between ambitions of 15 % of the area and todays 10-15% depends is mainly due to nature protection policies that were not in place when the current forest was established. When an area is proposed for afforestation, it is necessary to give special regard to nature protection by identifying ABEs and rank them according to environmental sensitivity. ABE must comprise 15% of the afforested area (may be reduced to 10% if the site is smaller than 10 ha). ABEs consist of both open habitat (5-10% of the site) and retained habitat (5-10% of the site). Open habitats are setbacks for water (aquatic buffer zone), setbacks around roads, open areas for biodiversity and landscape amenity, and archaeological setbacks. Retained habitats are existing habitats like areas of scrub, non-high forest species, individual high forest species and hedgerows. Identifying ABEs are crucial to ensuring that proper buffer zones are established around certain environmental features when afforestation occurs. However, ABEs can consist of anything from native woodland species (native broadleaves and Scots pine (*Pinus sylvestris* L.)) acting as an aquatic buffer zone around a FPM watercourse to some birches and alders planted in a spruce stand, far away from any sensitive environmental feature. To some degree, ABEs can be very similar to the Swedish FMM "Nature conservation with management" since active management is necessary to establish them and to some degree maintain them. This could justify describing them as their own FMM but it is a fairly new concept and a very broad definition.

When reforestation happens, there is a requirement to have a minimum 10% broadleaf area or diverse conifers (i.e. not Sitka spruce) or lodgepole pine in conifer plantations and 10% suitable conifers (see above) in broadleaf plantations. Special reforestation objectives exist to ensure the establishment of native woodland species in aquatic buffers for biodiversity protection.

Source: Forest Service (2015a) Forest Service (2015b) Forest Service (2015c) Forest Service (2016).

Tree species

Any species could technically be used, but other species than Sitka spruce and lodgepole pine are encouraged.

Acceptable species for NWS establishment are listed below, suitable species for the site depend on the soil type.

Alnus glutinosa (L.) Gaertn., *Betula pendula* Roth., *Betula pubescens* Ehrh., *Querqus petraea* L., *Quercus robur* L., *Pinus sylvestris* L., *Populus tremula* L., *Prunus avium* L., *Salix cinerea* L., *Sorbus aucuparia* L., *Taxus baccata* L. and many, bushy small-trees. *Fraxinus excelsior* L. is a NWS species, but the planting of European ash is currently not allowed on new afforestation sites in Ireland due to risk from the ash dieback fungus (*Hymenoscyphus fraxineus*). Forest Service (2015b) Forest Service (2015d).

Ecosystem services

Wood production is not important for this FMM, see also Table 13 above. The ecosystem services are ranked;

1. Habitats protection for invertebrates, fungi, deer, red squirrel, birds, plants etc.

2. Water quality for salmonids, freshwater pearl mussel and other aquatic species

3. Carbon sequestration

4. Recreation and tourism

5. Landscape amenity

Management

There is normally no or very sparse interventions in this FMM. Planting is often necessary in order to establish the desired native species on site when New Native Woodlands Sites (NWS) are established. Subsequent management may be necessary in order to maintain the desired species composition (e.g. removing shade tolerant conifers from broadleaf plantation). On some sites, small amounts of environmentally sensitive timber extraction is allowed which would make the FMM most similar to D. Selection system.

As described above, nature protection has broad definitions that do not always focus on the protection of the forest but of the surrounding land-uses; also ABEs can vary in their make up so it is difficult to separate groups, hence this is a combined nature conservation and biodiversity protection FMM.

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4. Italy

4.1. Background and forest history

Italy has a total forest area of about 10.9 million hectares (Table 14) -i.e. 9.3 million ha forests and 1.6 million ha other wooded lands (CFS, 2015a)-, mostly located in mountainous or hilly areas (95%). Lowland forests mostly consist of industrial poplar plantations and arboriculture systems. According to the 2005 edition of the National Forest Inventory (INFC, 2005) about 66% of Italian forests are privately owned, mostly consisting of small forests owned by individuals (79%): the final result is strong forest ownership fragmentation that affects forest management practices and profitability. The remaining 34% forests are public, with a prevalent role played by local municipalities (65.5%).

Forest resources quality differs depending on their geographical position, in the Alps (North) or Apennines (Centre or South and Islands). About 42% of forests are managed as coppices (mostly as coppice with standards), whereas high forests represent 36%, and the remaining proportion is not classified or consists of very specific management types (e.g. cork oak or chestnut forests). Coppices predominate in Central-Southern Italy, whereas most of the productive high forests (mainly coniferous ones) are in the North-Eastern part of the Country.

High forest management follows different models, mostly consisting of uniform (even-aged forests) or non-uniform (uneven-aged forests) shelterwood systems. Clearcutting systems are not very common due to strong limitations in clearcut areas imposed by Law.

Forests with a higher quality (i.e. higher production potential) are more frequently covered by forest management plans (e.g. up to 94% in Autonomous Province of Bolzano, in the Alps).

As a consequence of a decentralization process started in the 70s, agriculture and forest matters are under ruling responsibilities of local governments (i.e. 19 Regions and 2 Autonomous Provinces), with poor horizontal coordination and no single/updated National Forest Programme (NFP) nor a comprehensive sectorial policy.

Despite the relatively large amount of forest cover (33% of total land), for various reasons Italian forests have been systematically underutilized over the years. Today, only 23.8% of the net annual increment is harvested, i.e. less than half of the average figure at EU level (55.6%). Over about 50 years (1950-2007) the forest cover has doubled, wood consumption tripled, while the economic value of domestic timber production has halved. The expansion of forest area is one of the most relevant land use changes currently underway in the country (+6.2% in the last 10 years, from 2005 to 2015; +0.6% in the last year), mainly associated with farmland abandonment and natural forest expansion.

The forestry and logging sector share on the national GDP has reduced considerably in the last decades (remaining negligible, i.e. accounting for about 0.05% of national GDP). The whole forest

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sec-tor share (i.e. including the contributions of wood industry and pulp and paper industry) has had similar trends. Also the employment (formal sector) and the number of enterprises in forest sector have reduced significantly. Notwithstanding a general decrease in overall wood imports in recent years, Italy remains one of the major European wood importers, accounting for 15% of the EU sawnwood imports in 2013. As for the industrial wood, the self-sufficiency rate is only 17% (with 4.7 million of cubic meters of production of raw material and sawnwood and 14.2 millions of cubic meters of consumption) (UNECE FAO, 2015). These data show the structural disconnection be-tween the use of domestic forests and the national wooden-based industrial activities (Ciccarese et al. 2014), which is associated to a lack of wood mobilization, land abandonment and very limited active management. Despite the fact that about 65% of domestic removals consist of wood for energy, Italy became the largest worldwide importer of firewood and the fourth largest importer of wood residues, particles and chips, and the first European importer of pellets for residential use.

Table 14. Total land area and forest area divided in different land uses, the Italian CSA, Veneto region and Italy.

		AFP (case study)	**Veneto**	**Italy**
Total area (ha)		315.41[a]	1 840 742	30 207 284
Forest area (ha)*		291.05	2015: 465 624 2005: 444 766	2015: 10 982 013 2005: 10 345 282
Forest cover (%)*		92.3%	2015: 25.3% 2005: 24.2%	2015: 36.3% 2005: 34.2%
Forest area per altitude classes (m asl) (%)*			2005:	2005:
	0-500	100.0%	21.2%	35.4%
	501-1000	-	27.1%	34.7%
	1001-1500	-	28.8%	17.4%
	1501-2000	-	16.9%	7.3%
	>2000	-	1.4%	1.2%
Forest area potentially suitable for harvesting (ha)[b]		291.05	2005: 369 715	2005: 8 511 098
Forest area potentially suitable for harvesting (%)[b*]		100%	2005: 83.1%	2005: 81.3%
Average volume (m^3/ha)		50.7	2005: 204.1	2005: 144.9
Natura2000 areas (%)		24%	37.4%	21.5%
Forest area under hydrogeological constraints (according to Law 326, 1923)		25%	91.2%	80.9%

Notes: Inclunding other wooded lands; [a] Referred to the total area within the scope of the forest management plan and not to the total area of municipalities hosting forests included within the case study. In this case the total area would be 68,931.97ha; [b] Taking into account legal/normative and physical factors/constraints.*

Sources:

The 2015 edition of the National Inventory has not been completed and no data are available apart from preliminary area estimations. As a consequence hereinafter reference will be made to the 2005 edition.

CFS (2015). Stime preliminari basate sui risultati della sola fotointerpretazione di INFC2015 e sui risultati di INFC2005. Corpo Forestale dello Stato. Available online, URL: www.corpoforestale.it [accessed 03.011.2016]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Ciccarese, L., Pettenella, D., Pellegrino, P. (2014). A new principle of the European Union forest policy: the cascading use of wood products. L'Italia Forestale e Montana-Italian Journal of Forest and Mountain Environments, 69 (5), 285-290, DOI: 10.4129/ifm.2014.5.01

INFC (2005). Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. Ministero delle Politiche Agricole, Alimentari e Forestali/Corpo Forestale dello Stato/Consiglio per la Ricerca e la Sperimentazione in Agricoltura. Available online, URL: www.sian.it/inventarioforestale [accessed 03.011.2016]

UNECE/FAO (2015). Forest Products Statistics. UNECE/FAO Forestry and Timber Section. Available online, URL: www.unece.org/forests/forestsfpmonlinedata/forest-products-statistics/production-and-trade-tables-2010-2014.html [accessed 03.11.2016].

The disconnection between national forests and wood&paper industry also reflects on forest certification data: while Italy ranks in the first 3 to 5 positions globally in terms of number of FSC and PEFC chain of custody certificates, certified forest areas remain limited (about 820,000 ha PEFC certified and 45,000 ha FSC certified) (FSC, 2016; PEFC, 2016).

Domestic industrial wood production (i.e. removals) is mostly concentrated in two clusters: (i) more than 70% of softwood industrial production is provided by the three North-Eastern regions (Trentino Alto-Adige, Veneto and Friuli Venezia Giulia); and (ii) about 50% of hardwood industrial production is provided by poplar plantations in the Po Valley (North).

Domestic forest removal trends have been mostly influenced by the market for wood for energy rather than by the demand for industrial timber. Industrial timber removals remained more or less stable until the end of the last Century, when a downturn started. On the other hand the absolute and relative incidence of wood for energy among total removals increased, especially in areas where coppices prevail. This has been interpreted as a general de-specialization trend within the Italian forest sector favoured by several factors, including (among others) lower complexity of firewood production (e.g. lower mechanization level), viability for smallholders, large firewood demand at local scale (especially in mountainous areas), the existence of a more informal market.

Apart from wood and wood-based products Italian forests deliver multiple services that are not (or not fully) reflected into national accounts. A major role is played by non-wood forest products (or forest wild products), such as mushrooms, truffles, resin, fruits, etc. While in many cases economic activities related to these products remain largely informal, there is an increasing number of situations where wild product production became structured and more important than wood production in terms of direct and indirect income opportunities, job creation, visibility etc.

Moreover, in the last years the number of forest management experiences aimed to the provision of cultural-recreational services increased (adventure parks, art exhibitions and concerts within forests, environmental education etc.).

4.2. Ownership

All forest land in the CSA has public owner, the province of Venetio. In Veneto 35% of forest land is owned by the province and for Italy 34%. Information about the CSA and ownership, Table 15.

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Table 15. Forest area ownership in CSA, Veneto province and in Italy, figures refer to 2005.

	AFP (case study)	Veneto	Italy
Total. Public	100%	34,6%	33,8%
State/Region	-	7,7%	7,9
Municipalities/Province	100.0%	25,9%	22,2%
Other public	-	1,1%	2,7%
Public not classified	-	-	1,0%
Tot. Private	-	65,4%	66,2%
Individuals	-	53,5%	51,9%
Companies	-	1,2%	4,1%
Other private	-	8,7%	2,8%
Private not classified	-	2,0%	7,4%

4.3. The case study area

Table 16. The forest area in the Italian CSA divided in productivity and moisture classes, %.

Productivity/ moisture	Productivity, ($m3ha^{-1}y^{-1}$)	Dry %	Mesic %	Moist %	Wet %
High	>1.5	0.0%	6.9%	6.9%	0.0%
Medium	0.75-1.5	0.0%	0.0%	16.5%	1.0%
Low	<0-0.75	0.0%	3.3%	65.4%	0.0%

4.3.1. Tree species

There is a large number of tree species in the CSA. Most common is *Pinus pinea* and *Quercus robur*, 13, 2 and 12, 6 % of standing volume respectively. Broadleaves dominate, the coniferous, *Pinus pinea*, *Pinus alepensis* and *Pinus nigra*, are together less than 20% of the standing volume, Table 20.

Table 17. Tree species, proportion of total volume in the Italian CSA, Veneto region and in Italy.

Specie	**CSA** (% total volume)	**Region Veneto** (% total volume)	**Italy** (% total volume)
Pinus pinea	13.2%	0.1%	0.7%
Quercus robur	12.6%	0.3%	0.6%
Ulmus campestris	11.4%	0.1%	0.3%
Quercus ilex	8.9%	0.3%	2.8%
Acer campestre	8.7%	0.4%	0.5%
Carpinus betulus	8.3%	[a]NA	[a]NA
Fraxinus excelsior	7.5%	1.6%	1.1%
Pinus nigra	6.6%	0.9%	2.4%

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Specie	CSA (% total volume)	Region Veneto (% total volume)	Italy (% total volume)
Fraxinus angustifolia	5.8%	[a]NA	[a]NA
Fraxinus ornus	5.5%	1.4%	1.4%
Alnus glutinosa	2.5%	0.1%	0.7%
Populus nigra	2.4%	0.5%	0.5%
Pinus alepensis	1.8%	0.0%	0.7%
Populus alba	1.5%	[a]NA	[a]NA
Populus nigra hybrids	1.1%	0.2%	0.6%
Robinia pseudoacacia	0.5%	1.3%	1.6%
Salix alba	0.5%	aNA	aNA
Acer platanoides and Acer spp.	0.2%	[b]1.1%	[b]0.7%
Ostrya carpinifolia	0.1%	6.3%	
Other broadleaves (incl. cherry, walnut, black walnut, linden, etc.)	0.8%		

[a] Not available; [b] Just referred to Acer platanoides;

Sources:

Rasera, R. (2016). Piano Sommario dei beni dell'Associazione Forestale di Pianura. Periodo di validità 2016-2025/Forest Management Plan of the Lowland Forest Association. Regione del Veneto. Available online, URL: http://static.forestedipianura.it/media/uploads/Piano_sommario_dellAssociazione_Forestale_di_Pianura_PDF.pd [accessed 03.011.2016]

INFC (2005). Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. Tabella 1.9.1.6 - Valori totali e per unità di superficie, distinti per spe-cie, del numero di alberi, dell'area basimetrica, del volume del fusto e dei rami grossi, dell'incremento corrente di volume e della fitomassa arborea epigea, per la macrocategoria inventariale Bosco in Veneto/ National Forest and Carbon Sink Inventory. Table 1.9.1.6 – Number of trees, basal area, volume, annual increment and aboveground mass for "Forest" category, total and unit (i.e. per ha) values per species in Veneto. Ministero delle Politiche Agri-cole, Alimentari e Forestali/Corpo Forestale dello Stato/Consiglio per la Ricerca e la Sperimentazione in Agricoltu-ra. Available online, URL: www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp [accessed 03.011.2016]

INFC (2005). Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. Tabella 1.9.1.22 - Valori totali e per unità di superficie, distinti per specie, del numero di alberi, dell'area basimetrica, del volume del fusto e dei rami grossi, dell'incremento corrente di volume e della fitomassa arborea epigea, per la macrocategoria inven-tariale Bosco in Italia/National Forest and Carbon Sink Inventory. Table 1.9.1.22 – Number of trees, basal area, volume, annual increment and aboveground mass for "Forest" category, total and unit (i.e. per ha) values per species in Italy. Ministero delle Politiche Agricole, Alimentari e Forestali/Corpo Forestale dello Stato/Consiglio per la Ricerca e la Sperimentazione in Agricoltura. Available online, URL: www.sian.it/inventarioforestale/jsp/dati_carquant_tab.jsp [accessed 03.011.2016].

4.4. FMMs in the Italian CSA

A number of FMMs are used in Italy while in the CSA only one model, selective cuttings, is used on almost all forest area, Table 21. A marginal part of the case study – one stand consisting of a walnut and black walnut forest plantation and corresponding to less than 0.5% of the overall case study area- is to be first removed through uniform shelterwood system and then replanted to be managed through selective systems.

Since there are no national-wide data available on FMMs, the figures in Table 18 have been estimated building assumptions based on available data from the National Inventory of Forest and

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Carbon Sinks (INFC, 2005) (see notes below). Experts' opinion has also been sought, by interviewing Prof. Dr. Emanuele Lingua (Associate Professor in Forest Ecology and Silviculture at TESAF Dept., University of Padova) who however confirmed the lack of specific statistics and the difficulties in providing fully reliable data and estimations especially for high forests.

Data only refer to Forests and do not take into account Other Wooded Lands. While the Inventory clearly distinguishes between coppice systems and high forests, it does not include detailed information regarding FMM applied within the latter. In addition to this there are no official data regarding the proportion of managed and unmanaged (i.e. abandoned) forests, nonetheless there is empirical evidence that in many cases –especially in marginal areas- forests are not managed and they are left to natural evolution. This however can hardly qualify as a real management choice, rather de-pends on several factors, including, lack of awareness/interest/skills by owners as well as low profit-ability due to fragmentation, slope, poor assortments, etc. According to some sources, unmanaged forests would account up to 50% (Fedagri, 2011): this would lower all figures.

Finally it has to be considered that FMM implemented in the field are not always black or white, i.e. clearly identifiable and classifiable within strict and highly standardized silvicultural models. While this might possible for productive forests, it remains very difficult for newly formed forests growing on marginal lands and for forests having not wood production as the main management objective. Finally, even when wood production remains the main objective, close to nature silviculture and even single-tree silviculture are becoming more common and popular.

Table 18. The major FMMs used in the Italy and in the CSA. The total sum for Italy is larger than 100% depending on the uncertainness in the estimation.

FMMs	Coverage **CSA** (% forestland)	Coverage **Italy** (% forestland)
Clearcutting	0.0%	(1.4%[a])
Uniform shelterwood systems	0.0%	(17.2%[b])
Non-uniform shelterwood systems	0.0%	(13.2%[c])
Selective cutting	**100%**	**(5.6%[d])**
Coppice	0.0%	10.0%[e]
Compound coppice	0.0%	4.4%[e]
Coppice with standards	0.0%	27.5%[e]
Natural evolution	0.0%	?
Other specific FMM (e.g. cork oak forests, chestnut forests for chestnut production…)	0.0%	1.2%[e]
Not defined	0.0%	10.1%[e]
Not classified		10.7%[e]

a Forest plantations are managed through clearcutting systems at the end of the rotation period (clearcut in natural and semi-natural forests is limited by Law)

b Even-aged high forests and high forests originated from coppice forests are managed through uniform shelter-wood systems

c Uneven-aged forests are managed through non-uniform shelterwood systems

d Irregular high forests are managed through selective systems (or not managed at all)

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e Data for coppices are provided by the National Inventory of Forest and Carbon Sinks (INFC, 2005).

There is a large difference between the CSA and Italy in the use of FMMs. This is mostly due to the fact that the case study area consists of lowland forests, including newly/recently planted forests (afforestation and reforestation areas, max 20 years old), 60-70 years old planted forests (mostly planted pine forests) and semi-natural lowland forest remnants.

As reported by the newly developed and approved forest management plan for the case study area, sivilcultural models for these forest types are not yet consolidated. Planned forest management operations are not primarily aimed to wood production, rather to improve forest areas according to their features and purposes (environmental protection and/or tourism), trying to support their development towards more close-to-nature conditions. More in detail management objectives include:

1. Improvement of ecologic and environmental functions/features;

2. Improvement of tourism, recreational and social/cultural functions;

3. Valuing ecosystem services provided by the forest area.

While the area has limited wood production capacity (low-value assortments, mostly firewood, chip-wood and very limited wood for packaging) it plays a relevant role with reference to:

- tourism and recreation activities, and

- wild product production (mostly truffles and pine nuts).

Moreover about 24% of the forest area is part of the regional Natura 2000 network (with a lower percentage being also part of the Sile River Regional Park). Although the belonging to such a net-work per se does not exclude active forest management it affects the intensity of management regimes.

Last but not least the area is under preparation for forest certification according to FSC standards. It will likely be the first FSC forest management certification in Veneto and - consistently with both forest features and FSC Principles & Criteria (version 5-0) - management operation will aim to ensure an adequate ecosystem service flow while dealing with some limiting factors like forest frag-mentation and discontinuity, as well as human pressure by both locals and tourists.

4.5. Ecosystem services

The most important ecosystem services in the Italian CSA is Biodiversity and nature conservation. Also a number or forest products are also important, such as pine nuts and truffles are of interest, while wood products are ranked as number five, The proportion of the total volume refers to all tree species in the compartment (forest stand), however the proportion of area refers to the main tree species in the compartment (the last option is important in defining the FMM). Only compartments covered by forest stands in forestland are included. Non-forestland being grown with the forest was not included. The country level statistics were obtained from Forestry statistical yearbook 2015, published by State Forest Service.

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The proportion of Norway spruce is larger in the CSA than in the country, contrary, the Scots pine seems to be under-represented in the CSA, which is primarily due to relatively rich forest soils, prevalent on the CSA. Also we can note relatively larger shares of Grey alder and Pedunculated oak and a smaller share of Black alder in the CSA than in the country.

Table 22.

Table 19. Ecosystem services in the Italian CSA. Ranking of important ES

Ecosystem services connected to the FMM/CSA
Biodiversity and nature conservation
Cultural services, in particular tourism and recreation
Wild forest products (non-wood forest products, in particular truffles and pine nuts)
Protection against marine aerosol and hydrogeological protection
Wood (mostly firewood)
Landscape and scenic beauty

4.6. The selection system used in the Italian CSA

The FMM used all over the CSA is classified as Selective system. Given the specificity of forests within the case study area and the lack of consolidated FMM and silvicultural approaches for them, the forest management plan defines specific management directions and objectives, but at the same time remains flexible, leaving to the manager the possibility to choose the best solution case-by-case. In line with this approach, criteria for selecting trees to be harvested are not only based on age distribution, but again take into account multiple issues, including health status, present and future potential forest structure, presence of deadwood, presence and status of natural regeneration, accessibility and risk for visitors, etc.

The selection system/model aims to protect and enhance biodiversity and nature conservation in lowland and coastal forest areas, thus favouring progress towards more natural conditions. It also aims to create appropriate conditions for tourism and recreation activities within (part of) the area, and (to some extent) to support wild product production (pine nuts and truffles). In addition to the point above, in some areas the FMM is also aimed to ensure appropriate protection against wind, marine aerosol and against hydrogeological risks (e.g. floods). The management model is not primarily intended to produce wood assortments, nonetheless forest operations can also generate marketable wood products (firewood, chip-wood).

Based on previous considerations, the FMM consists of selective cutting inspired by close-to-nature silviculture principles and to be largely defined case-by case (intensity, target trees, etc.). As a consequence, within a common framework in terms of orientation, management practices and goals defined by the forest management plan and existing regulations, the FMM gives the manager(s) room and flexibility to make and implement management choices. This is also due to additional

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issues including the fact that lowland forests mostly consist of forest patches (rather than large, continuous forest areas) and that silvicultural practices for lowland forests are not well consolidated as they are in traditional productive forests in mountainous (e.g. alpine) areas.

In general terms forest management practices can be broadly distinguished according to the three main forest types that can be identified in the case-study area:

- coastal forests (pine and mixed pine-holm oak stands)

- lowland oak-hornbeam forests

- riparian forests (dominant role of poplar and willow).

Besides environmental issues connected with the FMM and the management/conservation of relevant and rare forest remnants and/or newly established forests, the social dimension should not be forgot: the case study area is highly populated (about 140,000 inhabitants just in the municipalities within the case study area) and it directly/indirectly attracts a huge number of tourists and visitors.

In relation to this it worthwhile remembering that the case study represents a unique case in Italy, being an association of public owners (mostly Municipalities) active in managing lowland forests and working in strict connection with private actors (forest technicians, forest enterprises, farmers, not-for profit organizations, a university spin-off etc.).

Edaphic conditions

The FMM should be (and actually is) adopted under different edaphic conditions. From high production to low production, from dry to wet sites. However specific measures and management intensity/frequency vary depending on specific situations. Management on very dry (e.g. close to sand dunes and arid meadows) and wet areas should normally be performed at lower intensity compared to the intensity level that is normally defined under mesic and moist conditions.

Tree species used

A number of tree species are growing and then managed with selection systems, see Table 17.

Tree species composition

The case study areas is characterized by the presence of multiple species or in other words; mixed stands. While some of them tend to prevail, none is supposed to have a dominant position within the whole area. This is due to several issues, including the coexistence of multiple forest types - each characterized by different species and species-blends- variability of site conditions, the fact that some stands are still at early development stages, the dynamicity of forest development and the forest management activities that do not aim to maximize wood production, favouring the most productive species, rather to support evolution towards more natural forest ecosystems and multiple functions/services.

Nonetheless, percentage shares of prevalent species might increase (up to 25-49% or even more) if the main forest types are considered separately:

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- coastal forests: today prevalence of holm-oak and pines. It is recommended that forest management orientation should tend to favour the combination with holm-oak whenever possible, maintaining pure (or almost pure) pine forest areas in those areas where they play a relevant role as windbreaks and/or aerosol interceptors, and where they support recreation and tourism activities (camping, shadow for visitors, etc.). Native pine species (i.e. black pine in the Tagliamento river area) should also be favoured when they occur.

- oak-hornbeam forests: today prevalence of oak and European hornbeam (the former to be supported through appropriate forest management choices aiming to facilitate natural regeneration and growth). It is recommended to keep the prevalence of oak and European hornbeam (in a wide range: 20 to 100%). The later normally tends to prevail and oak regeneration shall normally be supported through appropriate forest management (e.g. clearings to support regeneration, thinning, etc.). Oak tends to prevail (or even dominate) in areas that are periodically submersed by water. Depending on water availability and, more in general, on edaphic conditions additional broadleaf species include elm, ash, maple, alder, linden, cherry, etc.

- riparian forests: prevalence of poplar and willow. Poplar and willow with presence of huge single trees. In terms of stand volume poplar and willow represent 50% or more of the total volume.

Only one stand makes exception because at the moment the stand is dominated by walnut and black walnut trees.

Although there are no specific data available, it can be observed that forest resources within the case study area are undergoing development processes (both natural and driven by forest management operations) towards conditions described above.

Rotation periods

There are no regulations about rotation period. The definition of rotation period in selection cutting systems/models are not as clear as for other forest models. Selecting trees to be harvested are not only based on age distribution, but take into account multiple issues, including health status, present and future potential forest structure, presence of deadwood, presence and status of natural regeneration, accessibility and risk for visitors, etc.

Size of clearcuts and gaps

In the case selective cutting consists in creating forest gaps or clearings (e.g. in the case of pine forests planted on/just behind coastal sandy dunes) the recommended minimum size of clearings in order to maximize naturalization effects should be 1,000 to 1,500 m2. If trees have some control function over marine aerosol then smaller (300 to 400 m2 or even less) but more frequent (i.e. higher number per ha) clearings are allowed. Mean size of openings are around 1000m2. Maximum size depends on each situation and are deicide from case to casa.

Forest management and goals for forestry

The selection of appropriate forest management operations and the identification of target trees/groups of trees for harvesting operations depend on multiple issues (see also question 12 above) including desired output in terms of ES delivery:

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Biodiversity and nature conservation

Planted Oak-hornbeam forests: harvesting operations should remove wilting trees and facilitate natural oak regeneration.

Riparian forests: harvesting operations should remove trees and residues that might obstruct water flow and increase hydrogeological risks (thus also maintaining regulatory services), while favouring the development of the forest structure and composition. Isolated big trees should be released to favour saproxylic invertebrates (e.g. *Osmoderma eremita*, *Lucanus cervus*, *Cerambyx cerdo* and *Morimus funereus*).

Coastal forests: harvesting operations should remove wilting/unstable (pine) trees and facilitate natural holm-oak regeneration. In the case of pine forests on xeric soils and pine forests planted on/just behind sandy dunes this can be achieved through the creation of small-medium clearings.

Tourism and recreation

Forest management operations (harvesting, pruning) shall focus on ensuring safe conditions for visitors and/or infrastructures (e.g. access roads, parking areas, etc.) and create appropriate access conditions (e.g. by allowing/not allowing access to certain areas, or by “forcing” the staying on paths). Target trees shall be identified accordingly.

Wild forest products

Truffles (*Tuber borchii* Vittadini or *Tuber albidum* Pico): low forest density favours higher yields, therefore forest management operations in areas where favourable conditions from truffle-growing exist (coastal pine forests, holm-oak forests and oak-hornbeam forests) should be oriented to keep density appropriately low (according to some studies basal area should be around 18-25 m2/ha and canopy cover around 45-60%) as long as this is compatible with other forest features and management objectives.

Pine nuts: existing pine (*Pinus pinea*) forests are normally too dense for achieving optimal pine nut yields. Density reduction through thinning and the creation of clearings can improve nut production in the short-medium term (5-8 years) and, at the same time, favour progress towards more natural forest conditions (by supporting the spreading of holm-oak trees). Where compatible with naturalization aims, inoculated-pine trees can be planted to support nut production while creating favourable conditions for truffle growing. Low forest density conditions can also favour the growth of other wild products, in particular wild asparagus (*Asparagus officinalis*).

Forest regeneration

Site preparation. Site preparation is normally not done unless totally new areas are planted. This is unlikely to occur in the short run -next 7 years- because no funds for reforestation/afforestation in lowland areas are made available through the current Regional Rural Development Program).

New seedlings. About 60% of existing stands have been originally established through artificial re-generation but are currently managed through natural regeneration (Brotto, 2011). Artificial re-

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generation (planting) mostly regards shrubs to be established within artificial/natural clearings established in coastal pine forests, however tree seedlings can be planted as well.

Also in the future it is suggest that between 90 and 100% of the new seedlings are natural regenerated. Artificial regeneration (planting) should just be performed to support natural regeneration within existing forests in cases where this is not enough or it is not possible. This is for example the case of forest parcels with a prevalent tourism-recreational aim that are subject to regular mowing operations: artificial regeneration is then needed to replace trees when this is needed.

Artificial regeneration should also be performed in the case new forest areas are established, for example through compensation mechanisms (green-funds) or sponsorship initiatives (e.g. local retailers).

Fences are not used.

Introduced species

No non-European species are used because the rationale behind forest management in the case-study area is to facilitate re-naturalization of local forest areas: the use of non-native tree species would be in contrast with this idea as well as with current normative requirements at least in the case of Natura 2000 and other protected sites. Moreover since the area is approaching FSC certification the use of native species is very much encouraged and to be preferred. Forest management plan requires that seedlings consist of ecologically coherent species and are locally sourced so they can better adapt to local conditions. Hybridization however can occur naturally, for example in the case of poplars.

There is no need to use genetically improved trees or hybrids as long as local species are used.

Use of GM trees is not allowed by Law (with exceptions for authorized experimental trials). Moreover the area is undergoing preparation for FSC certification that does not allow the use of GM trees in certified forests.

Herbicides and chemicals used

Mechanical control of invasive species is done instead of chemical one (cutting, weed control fabric in the case of newly established plantations/planted forests,

Fertilization

Fertilization is normally not done. Fertilizers might be used in the early stages of newly established plantations. At present no new plantation/planted forest are forecasted within the CSA.

Harvest

Harvest is normally done manually with chain-saw. Wood extraction is normally performed with tractors and trailers and about 10% with forwarder. Loading operations can be either manual or mechanized, depending on the size and nature of different assortments.

After logging is normally 80 to 100% of logging residues as braches and tops (>5cm in diameter). According to the forest management plan, logging residues shall be completely removed or, as an

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alternative, partly left in ad-hoc identified areas within the forest. If residues are left, attention shall be paid to the prevention of phytosanitary (pests) and fire risks. The management of residues, however, is to be defined case-by-case through specific harvesting plans/projects.

Stand management

Pre-commercial and commercial thinning

About 15-20% of the area is today pre-commercial or commercial thinned during a rotation period. Very often this is removal of invasive and not wanted species. It is recommended that this is doubled, another 15-20% managed with thinnings or pre-commercial thinnings, invasive shrubs not accounted. It shall be considered that the real performing of thinning operations is sometimes influenced by availability of rural development funds (e.g. young forest stands).

The FMM adopted within the case study area has not the primary aim to produce wood, therefore the distinction between pre-commercial and commercial thinning might not be always appropriate. Even when wood is extracted, assortments consist of firewood and chip-wood that allow taking advantage also of small trees and, sometimes, even shrubs.

Pruning

Based on the existing forest management plan it is estimated that trees on 5% of the area is pruned during a rotation period.

Pruning is a costly operation and so far it is performed just to ensure safety for users/visitors, while in the next future, once forest stands will be more mature, their structure better defined and potentialities more evident, it could become relevant to use pruning for producing valuable assortments from the best broadleaf trees (single tree-silviculture). Suggested that pruning increase to 8-10%

Nature protection/consideration

Nature protection is one of the main objectives of the forest management implemented in the case study-area. Silvicultural operations planned and put in practice are intended to facilitate (whenever possible) the development of forest stands towards more natural conditions (species composition, structure etc.) rather than maximize wood extraction.

In particular the forest management plan defines best practices to minimize negative impacts on natural resources during harvesting operations, as well as those deriving by the use of the areas by visitors. Among measures defined by the plan, the release of deadwood (on average 5m3/ha) is included.

High Conservation Values have been identified according to requirements laid down by FSC Principle 9 (including stakeholder consultation) and specific measures have been defined for their conservation and, whenever possible, enhancement. These include, among other, areas belonging to the regional Natura 2000 network and the Sile River Regional Park.

It is also worthwhile remembering that nature protection measures are laid down within FSC Principle 6, including, for example, the identification and protection of representative sample areas of native ecosystems, the protection of rare and threatened species as well as their habitats, etc.

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5. Lithuania

5.1. Background and forest history

The Lithuanian forestry is young by the European standard, the national forest administration only emerged after establishing the Republic of Lithuania in 1918. The new country inherited forests that were quite severely depleted by noble landlords during the rule of the Tsar Russia 1795–1915. The Lithuanian forestry of the interwar period (1918–1940) was primarily shaped by: (i) development of forestry institutions (organizations, practices, etc.) by returnee nationals educated in Russia and Germany and accordingly influenced by respective forestry schools; (ii) land reform during which most forests were nationalized, resulting in domination of State forests and (iii) the economic necessities of the poor agrarian country, where forests were an important natural resource both for needs of rural population (fuel, timber of building) and for the national economy through in-comes from timber exports. Essentially, the interwar forestry was struggling to hit a reasonable balance between establishing ordered silvicultural practices (adequate regeneration, tending, etc.) and maintaining rather intensive utilization (Brukas 2015).

During Soviet occupation (1940, 1944-1990) Lithuania was one of 15 Soviet republics under Muscovite command economy with all its particularities including a complete ban of private forest property. Planned economy relied on strict managerial hierarchies as generally as in forestry. Planners had a heavy say on what should be done by state forestry enterprises in terms of cutting norms and silvicultural measures. As elsewhere in Eastern Europe, forest management system in Lithuania had its ideological base in the classical theory of normal forests. The silvicultural ideal to strive after was productive stands that by the end of the (sufficiently long) rotation can deliver the highest possible amount of timber of sawlog dimensions. In addition, forest management should aim at achieving an even forest age class distribution to ensure the evenness of timber flow. Forest management planning was set up accordingly with strict rotation ages and area control of age classes. Important additional features were the introduction of forestland zoning by forest functions (practices applied in the whole USSR) and the attempt by the Lithuanian authorities to save the (previously depleted) domestic resources due to the possibilities of timber shipments from the Russian Federation (Brukas 2015).

The restoration of independence in 1990 brought radical economic, ideological, and institutional changes at multiple levels inevitably challenging the forestry subsystem. Among the most salient examples, the transition to market economy exposed forestry to market pricing of timber as well as production inputs; forest ownership restitution to pre-war landowners and their heirs was commenced in 1994, leading to the current ownership structure: 50% state forests; 40% private forests and 10% reserve for restitution. These developments did not lead to relaxation of forest regulation and planning. Rather on the contrary, the regulatory clout was enlarged due to substantial increase of environmental consideration. The latter was caused by changing public

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preferences, international influences (Rio 1992, signing international agreements, joining the EU in 2004) and powerful national patrons of environmental cause (Brukas 2015). This lead to considerable expansion and refinement of forestland zoning resulting in 4 so-called forest groups:

I – strict reserves (1% of the total forest land);

II - special purpose forest with primary function of either environmental conservation or recreation (12%);

III – protective forests for protection of soils, water, etc. (15%);

IV – commercial forests with primary function of timber production (71%).

Also in commercial forests additional environmental stipulations were introduced, e.g. concerning biodiversity trees, seasonal harvesting restrictions, etc. Further restrictions of different degrees apply in groups I-III (Brukas et al. 2013).

Measured by the total forest area the extent of private forests came close to state forestry. However, the forest policy arena is strongly dominated by state forestry institutions, especially by the policy-formulating Forest Department under the Ministry of Environment and the state forestry coordinating Directorate General of State Forests. State forests (1 million ha) are managed by 42 state forest enterprises with average forest area of 25,000 ha. Private forests (0.83 million ha) are managed by 250.000 owners, a private forest estate averaging 3.3 ha. Voluminous forest-related legislation treats state forest enterprises and private forest owners largely identically despite the huge differences in respective aims and management conditions. On average managing 25,000 ha, state forest enterprises have by far superior prerequisites for following the legislated forest management paradigm. Facing stringent control, private forest owners largely comply with overarching legislative requirements (such as minimum allowable rotation ages), however, the actual approaches to forest management are highly diverse, reflecting the diversity of ownership objectives (Stanislovaitis et al. 2015). Following the traditional forest management paradigm, majority of forests are under even-aged management system with long rotations and rather small-sized clear cuts (averaging about 2 ha in size). Silviculturaly preferred species are conifers (Scots pine and Norway spruce) and noble broadleaves (Oak and Ash). In reality, the management intensity (in terms of planting and thinning regimes) is much lesser than prescribed, especially in private forests.

5.2. General description of CSA

The main features of the CSA is that diversity of Lithuanian forest management conditions are represented here, even they are not proportionally distributed:

Table 20. Data about Lithuania and the Lithuanian CSA

Preconditions for managing forests*	CSA	Lithuania
Total area	253 971 ha	6 528 600 ha
Forest land area	88 195 ha	2 179 895 ha
Proportion of forest land area	34.7 %	33.4 %
Forests under state ownership	33 799 ha 38.3 %	1 084 517 ha 49.8 %
Private, reserved for restitution and other forests	54 396 ha	1 095 378 ha

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Preconditions for managing forests*	CSA	Lithuania
	61.7 %	50.2 %
Private forest land area	43 812 ha	832 104 ha
Number of private forest owners	10 372	247 825
Number of private land parcels	14 279	290 094
Forest land area per private land parcel	3.1	2.9
Forest groups: Reserves forests (I) Forests for protection of ecosystems (IIA) Recreational forests (IIB) Protective forests (III) Commercial forests (IV)	 2.1 % 14.3% 0.9% 25.1% 57.6%	 1.6 % 9.7% 3.0% 14.6% 71.1%
Gross annual increment State forests managed by state forest enterprises and national park other forests	6.4 m3/ha 6.6 m3/ha	7.0 m3/ha 7.4 m3/ha
Average stand age (all forests) State forests managed by state forest enterprises and national park other forests Average stand age (mature forests) State forests managed by state forest enterprises and national park other forests	54 years 52 years 85 years 64 years	56 years 52 years 87 years 67 years
Average site class index State forests managed by state forest enterprises and national park other forests	II.2 I.8	I.6 I.4
Average stocking level State forests managed by state forest enterprises and national park other forests	0.69 0.68	0.74 0.73
Growing stock volume (all forests) State forests managed by state forest enterprises and national park other forests Growing stock volume (mature forests) State forests managed by state forest enterprises and national park other forests	193 m^3/ha 204 m^3/ha 271 m^3/ha 232 m^3/ha	229 m^3/ha 230 m^3/ha 312 m^3/ha 257 m^3/ha

Notes:

The area and cover of forestland is based on the international definition of forest, while productive forestland have a production potential of > $1m^3ha^{-1}year^{-1}$. This distinction is of high practical importance because forest management is not allowed in unproductive forests

(<1m3ha-1year-1). The coverage of the different FMMs described in this questionnaire are therefore expressed as their coverage on productive forestland.

The annual increment values in m3 ha-1 yr-1 are provided below by tree species (they were estimated based on actual data from stand-wise forest inventory; all forests of the CSA. Should be noted, that area weighted average values were calculated for all soil type x main tree species combinations not accounting for other stand characteristics, like actual tree species combination,

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basal area and other stand attributes. Calculations done using standard functionality of State Forest Cadaster IS):

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Table 21. Site productivity m^{3}ha^{-1}y^{-1} different sites, calculated on actual data from stand inventory in Lithuanian CSA

	Productivity/soil moisture	Dry	Mesic	Moist	Wet
High productivity:	Norway spruce	8.26	6.68	5.8	7.39
	Scots pine	9.63	7.11	-	-
	Birch spp.	6.89	7.17	6.02	6.08
	Grey alder	6.89	7.03	7.07	6.09
	Black alder	5.51	6.36	6.96	7.01
	European aspen	7.38	7.9	4.84	6.54
	Pedunculate oak	5.41	5.29	-	-
	Ash	4.47	4.26	4.79	-
Medium productivity	Norway spruce	9.16	7.93	7.38	6.56
	Scots pine	9.04	7.88	6.64	5.64
	Birch spp.	7.51	7.61	6.06	5.16
	Grey alder	6.9	7.55	6.83	5.95
	Black alder	6.41	4.84	6.93	6.08
	European aspen	6.46	7.87	6.35	5.88
	Pedunculate oak	5.72	5.06	-	-
	Ash	5.07	4.64	-	-
	Norway spruce	8.88	8	7.01	5.92
Low productivity	Scots pine	7.87	7.55	5.68	3.65
	Birch spp.	6.6	6.13	4.59	3.3
	Grey alder	-	-	-	-
	Black alder	-	-	7.91	3.56
	European aspen	-	8.49	5.39	-
	Pedunculate oak	-	-	-	-
	Ash	-	-	-	-

5.3. Tree species in Lithuania and in the CSA

The proportion of the total volume refers to all tree species in the compartment (forest stand), however the proportion of area refers to the main tree species in the compartment (the last option is important in defining the FMM). Only compartments covered by forest stands in forestland are included. Non-forestland being grown with the forest was not included. The country level statistics were obtained from Forestry statistical yearbook 2015, published by State Forest Service.

The proportion of Norway spruce is larger in the CSA than in the country, contrary, the Scots pine seems to be under-represented in the CSA, which is primarily due to relatively rich forest soils, prevalent on the CSA. Also we can note relatively larger shares of Grey alder and Pedunculated oak and a smaller share of Black alder in the CSA than in the country.

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*Table 22. Tree species, % of standing volume and % of forest area in CSA and Lithuania, *http://www.amvmt.lt/images/veikla/stat/miskustatistika/2015/01%20Misku%20ukio%20statistika%202015_m.pdf*

Species (Latin name)	Proportion (% total volume)		Proportion (% of area as main species)	
	CSA	**Lithuania***	**CSA**	**Lithuania***
Norway spruce (*Picea abies*)	36.7	21.2	33.8	20.9
Scots pine (*Pinus sylvestris*)	20.6	36.6	18.5	35.0
Birch spp. (*Betula - Betula pendula* or *Betula pubescens*)	20.3	16.3	24.7	22.3
Grey alder (*Alnus incana*)	6.5	4.2	8.4	6.1
Black alder (*Alnus glutinosa*)	4.5	8.6	4.8	7.3
European aspen (*Populus tremula*)	5.7	6.3	4.6	4.1
Pedunculate oak (*Quercus robur*)	4.0	2.8	3.8	2.1
Ash (*Fraxinus excelsior*)	0.5	1.0	0.5	1.2
Small-leaved lime (*Tilia cordata*)	0.3		0.2	
Norway maple (*Acer platanoides*)	0.4		0.4	
Elm (*Ulmus glabra*)	0.1		0.1	
Goat willow (*Salix caprea*)	0.3		0.1	
Other (Larix, *Carpinus betulus*, *Salix*, *Populus*, *Quercus rubra* etc.)	0.1		0.1	

5.4. Generally about FMMs used in CSA and in Lithuania

Currently, there are 12 FMMs in the list covering 93.7% of the CSA. Long rotation uniform shelter-wood cutting in pine forests on dry low productivity soils (Labanauskas felling) will not be investigated in more details due to small share and low experience of local foresters to utilize it. There were some attempts to apply it by forest company Telsiai SFE, however they did not manage to reach natural regeneration sufficient for re-establishment of pine stands.

Majority of FMMs applied in Lithuania are represented in CSA. As the Scots pine is the most common tree species in Lithuania, which is represented in much less proportions in CSA, the long rotation forestry in coniferous forests is under-represented. Clear cutting in pine forests can be easily discussed, unfortunately there is not good material for so called Labanauskas felling. This type of felling is applied on dry low productivity near pure pine stands removing part of the main layer and leaving the stand for natural regeneration. In some areas this FMM results satisfactory results in mixed pine-spruce stands, however it has never succeeded in Telsiai SFE. Nevertheless, there are numerous studies conducted or on-the-way in Lithuania, thus we may expect to use materials out-side CSA to define this FMM. Next, Norway spruce dominated stands are present in larger proportions in the CSA than may be expected in the whole country.

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Table 23. The FMM used in CSA and in Lithuania, and % of area in CSA, in state forest in CSA and in Lithuania

Forest Management Model (FMM)	Corresponding silviculture system	Coverage CSA (% forest-land)	Share of state forests %	Coverage country (% forest-land*)	Main tree species
Medium rotation clear cuttings in coniferous forests (*spruce*) MRCON_C	Clear-felling system	14.6	51	10	spruce
Medium rotation non-uniform shelter-wood / clear cuttings in coniferous forests (*spruce*) MRCON_CUS	Non uniform shelterwood system/clear-felling system	9.9	40	5	spruce
Long rotation clear cutting in coniferous forests (*pine*)	Clearfelling system	7.4	41	8	pine
Long rotation uniform shelter-wood / clear cutting in coniferous forests (*pine*) LRCON_CUS	Uniform shelterwood system/clear-felling system	5.0	51	6	pine
Medium rotation non-uniform shelter-wood in coniferous forests (*spruce*) MRCON_US	Non uniform shelterwood system	3.7	47	2.5	spruce
Long rotation uniform shelter-wood in coniferous forests (Labanauskas felling) *(pine)* LRCON_US	Uniform shelterwood system	2.9	47	15	pine
Medium rotation uniform shelter-wood / clear cutting in deciduous forests (*birch & black alder*) MRDEC_CUS	Uniform shelterwood system/clear-felling system	12.7	23	13	birch & black alder
Medium rotation clear cutting in deciduous forests (*birch & black alder*) MRDEC_C	Clear-felling system	10.2	31	10	birch & black alder
Short rotation uniform shelter-wood / clear cutting in deciduous forests (*aspen & grey alder*) SRDEC_CUS	Uniform shelterwood system/clear-felling system	7.5	10	6	aspen and grey alder
Short rotation clear cutting in deciduous forests (*aspen & grey alderl)* SRDEC_C	Clearfelling system	3.2	11	3	aspen and grey alder
Management in special purpose forests	Non uniform shelterwood system	13.4	62	12.2	
No intervention	No intervention	3.2	95	2	

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Total:		93.7	38.3	92.7	

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Table 24. Ecosystem services for FMMs in Lithuanian CSA.

Forest Management Model (FMM)	Most common/ important ES	Second most important	Notes ("also")
Medium rotation clear cuttings in coniferous forests (*spruce*) MRCON_C	Timber production		Secure biodiversity protection and provision of environmental protection and recreational and carbon sequestration services
Medium rotation non-uniform shelter-wood / clear cuttings in coniferous forests (*spruce*) MRCON_CUS	Timber production	Fuel wood supply	Ibid. (cf. MRCON_C)
Long rotation clear cutting in coniferous forests (*pine*)	Timber production		Ibid.
Long rotation uniform shelter-wood / clear cutting in coniferous forests (*pine*) LRCON_CUS	Timber production.		Ibid.
Medium rotation non-uniform shelter-wood in coniferous forests (*spruce*) MRCON_US	Timber production		Ibid. The importance of other ESs is higher than in other Spruce dominated stands of CSA. Fuel wood supply.
Long rotation uniform shelter-wood in coniferous forests (Labanauskas felling) (*pine)* LRCON_US	Timber production		Ibid
Medium rotation uniform shelter-wood / clear cutting in deciduous forests (*birch & black alder*) MRDEC_CUS	Timber production	Fuelwood supply	Ibid.
Medium rotation clear cutting in deciduous forests (*birch & black alder*) MRDEC_C	Timber production	Fuel wood supply	Ibid.
Short rotation uniform shelter-wood / clear cutting in deciduous forests (*aspen & grey alder*) SRDEC_CUS	Fuelwood production		Ibid. Timber supply in some cases.
Short rotation clear cutting in deciduous forests (*aspen & grey alderl)* SRDEC_C	Fuelwood production		Ibid. Timber supply may be considered to be important in European aspen stands, not damaged yet by the stem rot and under conditions of sufficient demand for the wood for packaging.
Management in special purpose forests	Sustaining and recovering of forest ecosystems or their specific components	Recreation on ~5% of the FMM area.	
No intervention (Reserves)	Biodiversity protection and biosphere monitoring		

5.5. Other FMMs used in Lithuania

Long rotation clear cuttings in deciduous forests, mainly dominated by noble deciduous tree species, like pedunculated oak and ash, covering ~1.6% of the CSA. Very long rotations are applied there – MARA for oak is 121 and 141 years in group IV and III, respectively and the methodology for estimating the allowable cutting amount requires that all mature oak forests are cut no less than in

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30 years (for ash – 20 years). This requirement is applied for state forests and extends the rotation period significantly. Around 1.4% of the area is covered by oak and ash dominating stands, which may be cut both using clear or shelter-wood systems, as well as there are 0.7% of noble deciduous stands with clear final felling prohibited due to location of the stand (e.g. inside the Zemaitija National park, along the main roads or surrounding some reserves). Going beyond the CSA – oak and ash dominated stands in group III-IV forests cover around 3% of the country's forest area.

There are 1.9% of birch and black alder and 0.8% of aspen and grey alder stands, for which the uniform shelter-wood systems is mandatory due to the location of the stand (see above). Otherwise, these stands are managed similarly to respective uniform shelter-wood – clear cuttings systems, except that clear felling is not allowed.

Additionally, even not present currently, plantation forestry is expected to play an important role in CSA. Plantations are expected to be established in the areas outside the current forest land.

5.6. General information for all FMMs in the Lithuanian CSA

Origin of tree species and tree breeding

No non – native European species are used in the CSA today. There have been very limited tests of lodgepole pine, (*Pinus contorta*) but not anymore.

Species used are native to Lithuania. But there is a discussion whether European larch (*Larix decidua* subsp. *polonica*, which is the most common larch in Lithuania) should be considered native or non-native to Lithuania. Some larch trees were planted during last decade both in state and private forests. Otherwise, only local tree species are used.

The general approach is to use locally collected seeds. Birch seeds mostly are collected more than 100 km from the CSA aiming to get higher selection values stands than present locally.

Seeds are sometimes purchased from neighbouring SFEs, sometimes more than 100 km distance, due to insufficient amounts collected locally and following the requirement to have a reserve of seeds for up to 7 years. Birch seeds were purchased because of aiming to use seeds collected in higher se-lection values stands than present locally. Seeds are stored in a special seed storage place near Kaunas for all SFEs. Birch seeds are not collected locally.

Genetically improved

Seeds used in artificial regeneration, in absolutely most cases planting, are collected in stands be-longing to the 1st selection group, which are identified be officers of State Forest Service. Seeds may not be collected in other stands. The national forest sector development program requires by 2020 more than 50% of seeds (for coniferous) for planting material to be collected in seed plantations.

Hybrids and genetically modified trees

No hybrids are used so far, but there is an interest to use hybrid aspen (*Populus tremula* x *tremuloides*) in models for short rotation clearcutting in deciduous trees.

No genetically modified regeneration material is used in the Lithuanian CSA.

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Use of herbicides/pesticides and fertilizers

Herbicides (Roundup FL) are used to prepare the clear-cut areas, relevant only for some managing models, for artificial regeneration, on high and medium productivity soils (total area on ALL FMM, state forests managed by Telsiai SFE) – 2013 – 59.6 ha; 2014 – 17.8 ha; 2015 – 23.7 ha.

Repellents (3 different brands) to protect regeneration are used in areas with spruce and pine planted (1-4 years from planting annually) in the areas with denser game population soils (total area on ALL FMM – 2013 – 600 ha; 2014 – 577 ha; 2015 – 502 ha). Also, seedlings are treated in nurseries as is treated timber in storage places.

No information is available from private forests about use of herbicides and pesticides, however, herbicides (Roundup FL) are usually used in private forests if regeneration of clear cut areas is carried out by contractor (i.e. not by the owner himself). Most likely for preparation of clear-cut areas for artificial regeneration.

No fertilizers are used in the Lithuanian CSA.

Fencing

Regeneration areas are only fenced in case of planted Scots pine, oak and larch no matter what forest management method. This is about 10% of the artificially regenerated areas, in total small areas are fenced, 2016 2ha of Scots pine plantation.

Size of stand and clearfelled areas

Many of the forest management models used in Lithuania are clearcutting systems. Forest cutting rules in Lithuania require the maximum clear-cut area not to exceed 8 ha (commercial forests, i.e. group IV) or 5 ha (protective forests, group III).

The width of clear-cutting area shall not exceed 150 m (100 m in group III forests) on dry soils and 100 m (75 m in group III forests) on other soils. This limit may be expanded by 1.5 times if attempting to match the borders of clear-cut area with the borders of forest compartments, nevertheless the clear-cut area limit shall not be violated. The width of clear-cut area may not be followed in low density stands or if the clear-cut area is under 3 ha (5 ha in over-mature stands). Also, the clear-cut width limitation does not apply in stands, located in restricted areas, state parks and biosphere reserves if whole forest compartment is to be harvested and the total area limit is not violated. The width of clear-cut area on steep slopes (15°-45°) shall not exceed 75 m. The longer edge of clear-cut area shall follow North-South orientation. If there is a need to follow the direction of forest block network, the clockwise deviation from the North-South orientation shall not exceed 25° and anti-clockwise deviation - 45°. Clear-cut areas shall be allocated moving against prevailing wind directions, i.e. from the East to the West, and adjacent area needs to be cut not earlier than 5 years and it needs to be reforested and the height of targeted tree species shall be not less than 0.5 m. Maximal length of clear-cut area is 1 km. The width of uncut forest belt between clear-cut areas planned to be cut the same year shall at least twice (one time in over-

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mature stands or in forest tracts under 20 ha) exceed the width of the clear-cut area. There is also requirement that clear-cutting area shall not exceed 20% of the land parcel size in isolated forest tracts, smaller than 15 ha in protected areas.

If no clearcutting occasional cuttings is applied, there are no limitations for this FMM regarding the area to be harvested at one-time point.

Influences on rotation period

For private owners there are no regulations about length of rotation periods. For State forest the rotation period is defined in the Forest Cutting Rules, approved by Minister of Environment by the minimum final cutting age (https://www.e-tar.lt/portal/lt/legalAct/TAR.4A966C7D30EB/myILxRuchG)

The minimum final cutting age in spruce stands was 60 years in Lithuania before the WWII.

There were several studies conducted a decade ago suggesting differentiation of maturity age based on soil and site productivity properties. According to (Brukas et al. 2001), minimum allowable rotation age (MARA) for spruce on typical sites and using different estimation approaches is:

Forest rent: 75 years

SEV with 2 or 3% discount rate: 65 years
SEV with 4%: 60 years
SEV with 5%: 55 years
For Scots pine on typical sites and using different estimation approaches is:
Forest rent: 80 years
SEV with 2 discount rate: 65 years
SEV with 3%: 60 years
SEV with 4%: 55 years
SEV with 5%: 50 years

Deltuvas et al., 2003 suggested the economic maturity age for pine stands to be dependent on the site index: 70-80 years for IA-I sites (making 51% of the FMM area) and 80-90 for II-III sites (31% of the FMM area) and 110-120 years for IV-V sites (remaining 18%). They also suggested technical maturity ages based for sawn logs – 70-80 and 90-100 years for site types IA-I and II-III, respectively, as well as financial maturity ages based on present net value (80-90 (IA-III), 110-120 (IV-V)) and soil expectation value – 70-80 (IA-I), 80-90 (II-III) and 110-120 (IV-V).

The same considerations were also provided for clear cutting based FMM on Norway spruce dominated stands.

In principle, the rotation periods suggested by some experts are slightly shorter than the ones applied in practice. Especially, it should be noted, that due to specifics in establishment the allowable cutting amount, even longer rotation periods are applied in state forests than one could guess based on the minimum final cutting age – in spruce stands by 15 years. This leads to accumulation of mature forest stands, losing the timber quality (significant amount of over 70 years

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old spruce stems contain some rot) and permanent harvesting priorities on over-maturing forest. This could be explained by the forestry approaches which have developed during the Soviet period and have not been changed yet - the aspiration to preserve domestic forest resources and shipping significant amounts of timber from the Russian Federation. Up to some extent reduction of rotation period is avoided due to political reasons and willingness to look more environment friendly in the eyes of society. Discussion on alternative rotation periods is considered to be taken into consideration while elaborating alternative FMMs in ALTERFOR.

5.7. Medium rotation clearcutting in coniferous forest (spruce) MRCON_C

The most common forest management model in the Lithuanian CSA is clearfelling models for coniferous, mainly spruce. Today is used on 14.6% (only the area of forest stands is taken into account), 51% of this area belongs to state.

This FMM could be considered as the most attractive for the CSA. Dry and mesic medium fertility soils suitable for spruce stands and outside the areas with additional environmental restrictions and without high potential for natural regeneration cover around 21% of the forest land. Currently, this FMM model is “competing” with models involving clear cutting in medium rotation deciduous forests on similar soil conditions.

Even though the artificial regeneration aiming for spruce stands is costlier than the natural regeneration, the yield is around 1.7-2 times larger in spruce than in birch. Some mixed birch stands, currently assigned to FMM with non-clear or clear cutting at the maturity age, could be in fact clear felled and artificially regenerated to become spruce stands (as the establishment of spruce stands via non-clear cutting is rather difficult).

Current share of this FMM is lower than it could be expected, basically due to the fact that Norway spruce is often replaced by trivial (i.e. not noble) deciduous tree species and thus assigned different FMMs with different rotations. The share of Norway spruce has decreased notably during last two decades first of all due to bark beetle and wind damages. Open gaps in the former spruce stands were filled by softwood deciduous trees, sometimes also by younger spruce trees making the 2nd spruce layer. The common practice is to prioritize planting Norway spruce stands to be harvested later by clear cutting. The exception is the areas with root rot (*Heterobasidion annosum*) in a stand of previous generation – then deciduous species may replace spruce. Also, this FMM is the most attractive for natural conditions of the CSA – there are some planted Norway spruce stands under 20 years with volume more than 200 m^3/ha.

Edaphic conditions

This model is mainly used on medium productive sites on dry and mesic soils.

Ecosystem services

The main ecosystem services from this model is timber production. Forest management shall also secure biodiversity protection and provision of environmental protection and recreation and carbon sequestration services.

Tree species and mixtures

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

The model is mainly used for Norway spruce stands. Previously the mono-cultures were prioritized without taking into consideration that mixed spruce stands is more resistant to unfavourable factors. Today pure stands of spruce can only be accepted in stands smaller than 1ha. Instead the aspiration should be to avoid spruce monocultures. The ideal spruce stands to be clear cut should have 75-94% of spruce volume with some share of more mixed stands (focusing on the main ecosystem service, which is timber production). Actual stands are more mixed than the ideal, i.e. the majority of stands have 50-74% spruce. This is much explained by increased share of trivial tree species especially in younger age. Proper management (i.e. thinning cuttings) should move the actual condition towards the ideal one, especially increasing the share of spruce from 50-74% to 75-90%.

The tree species to be used in addition to the Norway spruce are provided below according to the edaphic condition type for commercial forests, group IVA (based on Re-forestation and afforestation rules):

Dry - medium: Scots pine, larch spp., Pedunculated oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp.

Mesic – medium: Scots pine, birch spp., Norway maple, small-leaved lime, pedunculated oak, European aspen, black alder

Mesic – high: Birch spp., European ash, Pedunculated oak, Sessile oak (*Quercus petraea*), Black alder, Norway maple, Small-leaved lime, European aspen.

The Re-forestation and afforestation rules suggest tree species which are not present currently in stands managed by current FMM (European beech, Sessile oak). The list of tree species includes some low commercial value trees, like Goat willow, Salix, grey alder, which are in very small amounts and make the tree species diversity richer.

In the Norway spruce prevailing stands other tree species share the volumes (%):

Norway spruce (*Picea abies*)	80.0
Birch (*Betula - B. pendula* or *B.pubescens*)	9.2
Scots pine (*Pinus sylvestris*)	4.8
European aspen (*Populus tremula*)	1.9
Pedunculate oak (*Quercus robur*)	1.8
Grey alder (*Alnus incana*)	0.7
Black alder (*Alnus glutinosa*)	0.7
Ash (*Fraxinus excelsior*)	0.1
Goat willow (*Salix caprea*)	0.1
Small-leaved lime (*Tilia cordata*)	0.1
Norway maple (*Acer platanoides*)	0.1

Also present are larch (*Larix*), hornbeam (*Carpinus betulus*), *Salix, Populus, Ulmus laevis*, other hard-wood deciduous

Regeneration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Regeneration is normally done by planting, approx. 2/3. During the last decade in spruce stands natural regeneration share in state forests was 25%, while in private forests 70%. Should be noted, that in private forests were numerous clear cut areas recorded as non-reforested. Also, local forest nursery did not sell at all Norway spruce plantings to private forest owners during last year. Also should be noted, that the volume harvested in private spruce forests exceeded the volume harvested in state owned spruce forests.

For the future planting is suggested to 65-75%. The different figures depend on the type of forest ownership – state owned forests are managed following current silvicultural requirements and prioritize artificial regeneration. Private forest owners seem to be attempting to save on the forest regeneration.

Natural regeneration in this FMM in state forests is much dependent on the competence and professionalism of local forest district manager. However, opinion of Telsiai SFE is that within this FMM clear cutting and artificial regeneration need to be prioritized assuming the targeted ES which is timber production.

Site preparation

Site preparation is done on 100% if artificial regeneration is applied in state forests. No information available on soil preparation in private forests. Most likely, some private forest owners, especially if using services of third parties, apply the soil preparation.

Soil scarification shall be done always if artificial regeneration is applied. Planting Norway spruce has always been associated with soil preparation. No need for scarification if natural regeneration is applied

Stand management

Pre-commercial thinning

According to the data from stand-wise forest inventory, 50 % of stand 11-20 years old in state forests have been pre-commercially thinned (PCT) in the period 2006-2015). In private forests, only approximately one stand of ten have been PCT. Also should be noted, that the same stand could be thinned before 2006 and planned to thin during coming decade. Thus, the area where pre-commercial thinning is applied at least once during the rotation period is much below 100% in private forests, how-ever each state owned stand is thinned more than once.

Pre-commercial thinning should be carried-out on average ~2.5 times in artificially regenerated stand and ~1.5 time in every naturally regenerated stand in order to develop spruce dominated stand (opinion of forest management planning expert from SFIMPI, they follow this requirement when planning the pre-commercial thinning during the process of elaborating internal forest management plan for the state forest enterprise). On this FMM, the first PCT takes place usually at the age of ~7 years. In ~5 years the aspen and birch are back. Thus, share of the area where stands are pre-commercially thinned at least once during a rotation period should be 100% in this FMM.

Commercial thinning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

According to the data from stand-wise forest inventory, the commercial thinning was applied and recorded during the period 2006-2015 on 57% of the area and having age 25-44 years in state owned forests (16% in private forests). The commercial thinning in state owned stands over 44 years old was applied and recorded during the last decade on 26% of the area (16% in private forests). The area where commercial thinning is applied at least once during the rotation period is below 100% in private forests, however each state owned stand is thinned more than once.

There are 2 types of commercial thinning applied in Lithuania, which are later referred to as "1st commercial thinning" ("retinimai" in Lithuanian) and "2nd commercial thinning" ("einamieji kirtimai" in Lithuanian). Commercial thinning in this FMM is carried-out in 21-60 years old stands and must be done at least 2 times.

Private forest owners tend to avoid even the commercial thinning, most likely due to short-term economic consideration (i.e. avoiding the costs for thinning and limited incomes from the timber harvested). The ratio between the 1st commercial and 2nd commercial thinning conducted during the last decade and recorded by the stand-wise forest inventory in state owned forests is 1:0.2, while in the private forests it is 1:1.35. Even accepting the potential omission error in inventory data, there is a clear tendency that private forest owner tends to avoid less the 2nd commercial thinning, most likely due to increased amounts of commercial timber to be harvested.

Pruning

Pruning is not relevant

Harvest

Around 70% of harvesting is done using harvesters in state owned forests. Harvesters are used in private forests less than 50% of cases. In state forests – Telsiai SFE has its own harvester and the chain saws are used basically by harvesting contractors in areas with more unfavourable conditions for harvester. However, according to the experts from Telsiai SFE, sometimes the use of harvester may result in loses of 7-8 m3/ha of timber due to mistreating the stump part of the log. Also, the use of harvester is associated with more soil damages, however it is more cost efficient and nowadays the harvesting contractors are lacking

Wood extraction to 100% mechanized, using forwarders. However, some private forest owners for own timber utilization may not use fully mechanized wood extraction. Telsiai SFE extracts using own equipment 85-90% (all FMMS).

Use of logging residues

At present there is no demand for logging residues, Telsiai SFE has not sold anything in the market for biofuels. The extraction of logging residues becomes unprofitable if the extraction distance starts to exceed 300 m and the amount of residues collected in one spot is under 25 m3. However, the expert from Telsiai SFE suggest using the same chassis for chipping and chip transportation equipment as for the forwarders. However, the biofuel produces and buyers prefer not to go off the road.

Nature protection

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

At least 7 live trees (among them at least 3 trees need to be older or having DBH larger than the aver-age value for the whole stand) per 1 ha and 3 dead trees (DBH > 20 cm) per 1 ha shall be left in clear-cut areas over 1 ha. For clear-cut areas 0.5-1 ha, the figures are, respectively, 3 (2) and 2. Biodiversity trees are left in clear-cut areas for natural decay. Also stand level restrictions are introduced due to woodland key habitats, presence of nests of some birds.

5.8. Medium rotation shelter-wood/clear cuttings in coniferous forests MRCON_CUS

The shelter-wood management model with group-occasional and group-selective final cutting could be considered as the most optimal in terms of silvicultural considerations. This model includes use of uniform and non-uniform shelter-wood and also clearcutting of smaller areas.

Nearly 10% of the CSA area is managed by this FMM aiming for mixed Norway spruce dominated stands to be cut by non-clear or clear cutting at maturity age.

Timber production is the primary ecosystem service.

Private forest ownership dominates (60%) in this FMM. Practically all edaphic conditions are represented. The main criteria to assign a Norway spruce dominating stand to this FMM was a significant presence of other tree species, such as birch, Scots pine, pedunculated oak, European aspen, grey and black alders in tree species composition; and availability of lower canopy layers.

Non-clear final cutting usually implies limited restrictions, while clear cutting, if applied, involves rather strong regulations regarding the size, dimensions and allocation of areas harvested at one time-point. The MARA for this FMM (71-81 years) is defined by legal acts.

In principle, natural regeneration should dominate in this FMM as both occasional and selective cuttings are aimed to facilitate natural regeneration and development of undergrowth. However, natural regeneration slightly dominates in private forests, while state forest managers' predominantly use artificial regeneration, including the non-clear cutting areas. Soil scarification is always done regenerating forests artificially, more, soil is also scarified to support the natural regeneration (~10% of cases). Even though forestry principles suggest intensive thinning; they are at the recommended levels only in state forests.

The nature protection integrated in the stand-level management is associated mostly with leaving some large and old trees when harvesting.

Ecosystem services

The most important ES is Timber production followed by fuel wood supply. Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Cutting Rules) and carbon sequestration services.

Tree species and mixtures

Norway spruce is the dominant tree species but many other do occur; (share % of volume)

Norway spruce (*Picea abies*)	69.0
Birch (*Betula pendula* or *B. pubescens*)	12.6
Scots pine (*Pinus sylvestris*)	8.9
Pedunculate oak (*Quercus robur*)	3.6

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European aspen (*Populus tremula*)	3.5
Grey alder (*Alnus incana*)	1.2
Black alder (*Alnus glutinosa*)	0.8
Ash (*Fraxinus excelsior*)	0.1
Goat willow (*Salix caprea*)	0.1
Small-leaved lime (*Tilia cordata*)	0.1
Norway maple (*Acer platanoides*)	0.1

Also present larch (*Larix*), hornbeam (*Carpinus betulus*), *Salix*, *Ulmus minor*, other softwood deciduous species.

Tree species recommended to be used in addition to the Norway spruce are provided below according to the edaphic condition type for commercial forests, group IVA (based on Reforestation and afforestation rules):

Dry - medium: Scots pine, larch spp., Pedunculated oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp.

Mesic – medium: Scots pine, birch spp., Norway maple, Small-leaved lime, Pedunculated oak, European aspen, Black alder

Mesic – high: Birch spp., European ash, Pedunculated oak, Sessile oak (*Quercus petraea*), Black alder, Norway maple, Small-leaved lime, European aspen

On dry high productivity soils the following tree species should be targeted: Pedunculated oak, ash, Small-leaved lime, Norway maple, elm, Norway spruce, Sessile oak, birch, European aspen, Black alder.

Regeneration

Artificial regeneration dominates in state forests (~90%) on the soils associated with this FMM, however, natural regeneration slightly dominates in private forests (54%).

Large diversity of cutting options could be applied in this FMM resulting also in diversity of regeneration options. Natural regeneration should dominate in this FMM. Both group-occasional and group-selective cuttings are aimed to facilitate natural regeneration and development of under-growth. The first type of non-uniform shelter-wood system aims for facilitating the natural regeneration in the whole stand, while the second one – only in the gaps. However, if the resulting natural regeneration is not sufficient, artificial regeneration is applied, e.g. the Forest Cutting Rules require artificial regeneration in gaps without sufficient amount of natural regeneration. If the clear cutting is used, then the regeneration should be artificial.

Following the algorithms of forest management planning incorporated into the Integrated IS of Forest Cadaster, natural regeneration is planned on 72% of state forests, previously dominated by Norway spruce and cut using non-clear cutting. ~50% of private forests harvested using the non-clear cutting were suggested for natural regeneration only.

Site preparation

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

In state forests: soil scarification is always used for artificial regeneration. If natural regeneration is used, then soil is scarified on ~10% of the area. However, if there is a seed-rich year, soil scarification is used on ~30% of the area for natural regeneration. No confirmed facts about private forests, but most likely no soil scarification is used to facilitate the natural regeneration.

Stand management

State forests are thinned practically following the thinning standards, while private forests are significantly under-thinned, most likely due to avoiding extra costs and undervaluing the importance of pre-commercial thinning on the structure and growth of future stand.

The share of thinned stands in private forests tends to increase with the stand age – e.g. the relatively largest share of thinned stands belongs later part of the rotation period, when the output of commercially more valuable timber is higher.

Pre-commercial thinning

Stand-wise forest inventory records indicate, that pre-commercial thinning was done on 1376 ha in state forests, making 49 % of the pre-commercial thinning age area and on 206 ha in private forests, making just 5% of the pre-commercial thinning age area.

All stands with Norway spruce and deciduous tree species shall be pre-commercially thinned at least once. The aim of pre-commercial thinning is to have a fully established mixed spruce stand with deciduous trees at an age of 20 years.

No matter the density, Norway spruce stands with 30-50% of deciduous trees, need to be thinned first at age ~7-10 years removing the deciduous trees which directly competing with spruce trees. Quite often the deciduous trees may come back and the pre-commercial thinning may need to be repeated for the 2nd time. However, if the natural regeneration is in tree-species groups, the pre-commercial thinning should aim to expand spruce groups. On mesic medium productivity soils groups of deciduous forests may be maintained on relatively lower and more wet places, without the spruce or where the wind damage risk is relatively higher.

Commercial thinning

Stand-wise forest inventory records indicate, that the 1st commercial thinning was done on 937 ha in state forests, making 37% of the 1st commercial thinning age area and on 249 ha in private forests, making just 6% of the 1st commercial thinning age area. The 2nd commercial thinning was done on 445 ha in state forests, making 20% of the 2nd commercial thinning age area and on 599 ha in private forests, making 9% of the 2nd commercial thinning age area.

The 1st commercial thinning should reduce the amount of deciduous trees in the stand. However, the deciduous trees which are located in groups and do not disturb the spruce, do not need to be removed. Usually weak or so called "wolf" trees are removed; noble deciduous and pine, if present, need to be preserved. Groups of spruce are thinned to reach required number of stems per ha. The 2nd commercial thinning follow the same principles as the 1st commercial thinning, however, the thinning intensity should be less. Usually, the commercial thinning in spruce dominated stands should be repeated ~2 times.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Pruning

Not relevant

Harvest and logging residues

There were some attempts to use harvesters for non-clear cutting, however, chain saws are preferred under shelter-wood cutting systems. If clear cutting in state forests is applied, then the harvester may be used.

Extraction of wood/timber is almost always (100%) done by forwarders, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction. Telsiai SFE extracts using own equipment 85-90% (all FMMS).

Use of logging residues are not used (extracted).

Nature protection

This model for forest management aims for continuous cover forestry (up to some extent). The Forest felling rules also requires leaving not less than 3 trees per ha with the age over MARA and the diameter over the average value for the compartment.

5.9. Long rotation clearcutting in coniferous forest (pine) LRCON_C

Over 7% of the CSA area is managed by this FMM aiming for mainly Scots pine (over 80% of volume) dominated stands to be cut by clear cutting at maturity age. Around 40% of forests under this FMM belong to state.

This FMM includes the stands on wet soils, stands having relatively low density at pre-mature and mature age as well as pure pine stands.

The clear cutting is the harvesting method suggested by both economic and silvicultural reasoning, there are numerous restrictions regarding the size, dimensions and locating of cutting areas, see above. Timber production is the main ecosystem service. The stands are dominated by Scots pine, but there are often an admixture of Norway spruce and birch. The rotation period for this FMM (110-120 years) is defined by legal acts and is considered to be too long by forestry experts who analysed forest rotations during last 2 decades.

Artificial regeneration is prioritized no matter the ownership in this FMM with just ~10% of natural regeneration on wet soils. Soil scarification is done always if artificial regeneration is applied. The pre-commercial thinning should be applied at least once and the commercial thinnings – 2-3 times during the rotation. State forest managers are doing pre-commercial thinnings.

Nature protection integrated in the stand-level management is associated mostly with leaving some live and dead trees in clear-cut areas.

Edaphic conditions

The management model is used mainly on sites with lower production than average, from dry to wet sites, but it is also used on dry sites with medium production.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Ecosystem services

The main ecosystem services from this model is timber production. Forest management shall also secure biodiversity protection and provision of environmental protection and recreation and carbon sequestration services.

Tree species and mixtures

On sites managed with this model Scots pine mixed with some Norway spruce, birch, and larch should dominate. Only Scots pine and birch should be grown on wet low productivity soils. Dry medium productivity soils should be shared by Norway spruce, Scots pine, larch spp., Pedunculate oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp. On dry sites with low productivity Scots pine should grow in pure stands. Scots pine, Norway spruce and birch should be found on mesic low productivity soils.

Today many stands have an admixture of more than 25%, but it is suggested that majority of the area shall be managed as pure stands of Scots pine.

Tree species on all sites managed with clearcutting model with long rotation period for coniferous, % of volumes (no matter the main species):

Scots pine (*Pinus sylvestris*)	80.4
Norway spruce (*Picea abies*)	12.4
Birch (*Betula pendula* or *B. pubescens*)	6.1
Larch (*Larix*)	0.3
European aspen (*Populus tremula*)	0.3
Pedunculate oak (*Quercus robur*)	0.2
Black alder (*Alnus glutinosa*)	0.1
Grey alder (*Alnus incana*)	0.1

Regeneration

Artificial regeneration, planting is most common, on approx. 10% of the area natural regeneration is done.

Site preparation

Depends on the type of seedlings used. Usually soil is prepared, however, if planting material with closed root system is used and then the soil scarification is not applied.

Stand management

Pre-commercial thinning

The thinning objective in pine dominated forests is to develop productive pine dominating forests. The pre-commercial thinning in pure pine stands should be started at age 15-20 years, thus, sometimes going beyond the pre-commercial thinning age. Of course, denser stands can be thinned at younger age. During the pre-commercial thinning special care shall be on minimizing snow damage

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risks. Mixed pine-birch stands should be pre-commercially thinned already at age 5-8 years and thinning needs to be repeated if birch starts covering pine trees. European aspen needs to be always removed from pine stand. Large gaps in thinned mixed stands should be avoided. No thinning is applied in pine stands on wet low productivity soils.

Majority of pine stands need to be pre-commercially thinned 1-2 times. According to the records of stand-wise forest inventory, during the period 2006-2015 the pre-commercial thinning was done on 37% of the area, covered by stands of pre-commercial thinning age in state forests. The figure in private forests is 4%.

Based on data from stand-wise forest inventory the following pre-commercial thinning shares are proposed for 2016-2025: in state forests pre-commercial thinning is suggested on the area making 34% of the pre-commercial thinning age stand area. The figure for private forests is 38%.

Pre-commercial thinning in state forests seems to be done at the level corresponding to current silvicultural concepts. Private forests are under-thinned; the pre-commercial thinning seems to be avoided.

Commercial thinning

The aim of commercial thinning in Lithuania is declared to be the development of optimal growing conditions for the most productive trees, removing damaged, low productivity trees. Mixed stands are maintained, however, reducing the share of deciduous trees. As the period for the 2nd commercial thinning is rather long (21-90 years), experts from SFIMPI suggest the 1st commercial thinning to be carried-out 1 time during the rotation and the 2nd commercial thinning – 1-2 times during the rotation (i.e. the commercial thinning should be carried-out 2 to 3 times during the rotation).

Based on data from stand-wise forest inventory the following commercial thinning shares are proposed for 2016-2025: in state forests the 1st commercial thinning is suggested on the area making 52% of the 1st commercial thinning age stand area (in private forests - 52%). The 2nd commercial thinning is suggested on the area making 21% of the 2nd commercial thinning age stand area (in private forests – 24%).

Pruning

No pruning shall be done. However, there are some recommendations to have 2nd layer and under-growth under main Scots pine layer to facilitate natural removing low branches.

Harvest

Near all state forests in this FMM are cut using harvesters. Chain saws dominate in private forests - harvesters are used in private forests less than 50% of cases.

Extraction of wood is fully mechanized as forwarders are used to almost 100%, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction. Telsiai SFE extracts using own equipment 85-90% (all FMMS).

Logging residues are not extracted and used.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Nature protection

At least 7 live trees (among them at least 3 trees need to be older or having DBH larger than the aver-age value for the whole stand) per 1 ha and 3 dead trees (DBH > 20 cm) per 1 ha shall be left in clear-cut areas over 1 ha. For clear-cut areas 0.5-1 ha, the figures are, respectively, 3 (2) and 2. Biodiversity trees are left in clear-cut areas for natural decay. Also stand level restrictions are introduced due to woodland key habitats, presence of nests of some birds.

5.10. Long rotation uniform shelterwood or clearcutting in coniferous forest LRCON_CUS

The model is focused on forestry in mixed Scots pine dominated stands, sometimes with the 2nd layer or undergrowth, where the non-clear felling is prioritized at maturity age due to silvicultural reasoning. Clear cutting is also possible.

Around 5.0% (only the area of forest stands is taken into account). 51% of the FMM area belongs to state. The area under this FMM should remain stable or decrease due to replacement with shorter rotation Norway spruce stands.

Timber production is the main ecosystem service.

The FMM is applied on dry-to-moist and medium and low productivity soils. There are practically 2 extra tree species in addition to Scots pine growing in this FMM – Norway spruce and birch, however in relatively larger shares than in other Scots pine stands.

When the non-clear cutting is applied there are no limitations regarding the area to be harvested at one-time point.

Natural regeneration should be prioritized where this is possible and should approach 100%. How-ever, this is followed on private forests and most likely not due to silvicultural consideration. The share of naturally regenerated stands at pre-commercial thinning age was 69% in state forests. Soil scarification if natural regeneration is applied is used on ~10% of the area in state forests.

The pre-commercial thinning should be applied at least once and the commercial thinning – more than twice during the rotation. State forest managers are doing pre-commercial and the 1st commercial thinning following the silvicultural requirements, however private forests are significantly under-thinned.

Up to some extent this FMM aims for continuous cover forestry and the nature protection integrated in the stand-level management is associated mostly with leaving some large and old trees when harvesting.

Edaphic conditions

This model is mainly used on low productive sites and some sites of medium productivity on dry and mesic soils.

Ecosystem services

Timber production.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Cutting Rules) and carbon sequestration services.

Tree species and mixtures

Scots pine with some Norway spruce, birch, larch should dominate. Dry medium productivity soils should be shared by Norway spruce, Scots pine, larch spp., Pedunculated oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp. Scots pine, Norway spruce and birch should be found on mesic low productivity soils.

Tree species share of volume volumes%

Scots pine (*Pinus sylvestris*)	66.7
Norway spruce (*Picea abies*)	24.4
Birch (*Betula pendula* or *B. pubescens*)	7.8
European aspen (*Populus tremula*)	0.7
Pedunculate oak (*Quercus robur*)	0.3
Grey alder (*Alnus incana*)	0.1
Black alder (*Alnus glutinosa*)	0.1

Also present Goat willow (*Salix caprea*), Norway maple (*Acer platanoides*)

Regeneration

Natural regeneration should be prioritized where this is possible and should approach 100%.

State forestry still use rather significant part of artificial regeneration, while near all private forest stands under 20 years are naturally regenerated in this FMM.

Site preparation

Depends on the regeneration type. Soil should be prepared for artificial regeneration. However, if natural regeneration is applied, then soil scarification should be used in some area to facilitate the regeneration. In state forests soil scarification is always used for artificial regeneration. If natural regeneration is used, then soil is scarified on ~10% of the area. No confirmed facts about private forests, but most likely no soil scarification is used to facilitate the natural regeneration.

Stand management

The thinning objective in pine dominated forests is to develop productive pine dominating forests.

Pre-commercial thinning

During the pre-commercial thinning special care shall be on minimizing snow damage risks. Mixed pine-birch stands should be pre-commercially thinned already at age 5-8 years and thinning needs to be repeated if birch starts covering pine trees. European aspen needs always to be removed from pine stand. Large gaps in thinned mixed stands should be avoided. No thinning is applied in pine stands on wet low productivity soils. Majority of pine stands need to be pre-commercially thinned at least 1 time.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Pre-commercial thinning in state forests seems to be done at the level corresponding to current silvicultural concepts. Private forests are under-thinned; the pre-commercial thinning seems to be avoided. Reasons are cost, not caring, not considering pre-commercial thinning as important.

Commercial thinning

The aim of commercial thinning in Lithuania is declared to be the development of optimal growing conditions for the most productive trees, removing damaged, low productivity trees with bad stem form.

Mixed stands are maintained, however, reducing the share of deciduous trees. As the period for the 2nd commercial thinning is rather long (21-90 years), experts from SFIMPI suggest the 1st commercial thing to be carried out 1 time during the rotation and another 1-2 thinnings during the rotation (i.e. the commercial thinning should be carried-out 2 to 3 times during the rotation).

Pruning

No pruning is done.

Harvest

There were some attempts to use harvesters for non-clear cutting, however, chain saws are preferred under shelter-wood cutting systems. If clear cutting in state forests is applied, then the harvester may be used.

Almost all extraction of timber/wood is done by forwarder, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction. Telsiai SFE extracts using own equipment 85-90% (all FMMS).

Logging residues are not extracted or used.

Nature protection

FMM aims for continuous cover forestry (up to some extent). The Forest felling rules also requires leaving not less than 3 trees per ha with the age over MARA and the diameter over the average value for the compartment.

5.11. Medium rotation non-uniform shelter-wood in coniferous forests MRCON_NUS

This FMM is associated with using non-clear cutting in pure and mixed Norway spruce dominated forests due legal requirements (i.e. no clear cutting requirement in National Parks, along major roads and around reserves). Forestry professionals consider that such requirements sometimes contradict professional forestry concepts, even leading to degradation of Norway spruce stands.

Nearly 4% of the CSA area is managed by this FMM, the shares of state and private forests are nearly equal. The area should remain at the same level as covered today if there are no changes in forestry legislation and the system of protected areas.

Timber production is the primary ecosystem service.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Practically all edaphic conditions are represented here, except some wet soil types. The non-uniform shelter-wood FM system with group-occasional and group-selective final cutting could be considered as the most optimal in terms of silvicultural considerations here. Non-clear final cutting usually implies limited restrictions, regarding the size, dimensions and allocation of areas harvested at one time-point. The lowest age for final felling (71-91 years) is defined by legal acts and is considered to be too long by some forestry experts. The rotation period in state forests is even longer due to the principles of estimation of annual cutting norm, which are not applied for private forests.

Around 1/3 of stands in this FMM are naturally regenerated both in state and private forests. Notably, this is practically the only FMM in the CSA with near equal shares of artificial regeneration in state and private forests. In state forests, soil scarification is always done if regenerating forests artificially. Soil is also scarified to support the natural regeneration (~10 to 30% of the area to be regenerated, depending on seed-productivity).

Pre-commercial and commercial thinning in state forests are at appropriate level, while the private forests are practically neither pre-commercially nor commercially thinned.

The nature protection integrated in the stand-level management is associated mostly with leaving some large and old trees when harvesting. The non-clear cutting requirement is an important measure itself, too.

The forest management principles in this model are predefined by the location of forests – i.e. they involve clear cutting restrictions in National parks, around the reserves and along major roads, sometimes contradicting with the forestry practice in Lithuania. The common opinion of professional foresters is that the Norway spruce stands are best re-established using clear cut system followed by artificial regeneration. According to current legal acts there should be no changes in the share of current FMM. However, alternative FMM could involve combining this FMM with clear-cut or shelter-wood FMM in medium rotation coniferous forests.

Edaphic conditions

This management model is mainly found on medium productive sites on dry soil. The model should be avoided on wet soils due to silvicultural considerations. 0.5% of the area was found basically around the reserves.

Ecosystem services

Timber production and second Fuel wood supply. However, the importance of other ESs is higher than in other Norway spruce dominated stands of the CSA. Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Cutting Rules) and carbon sequestration services.

Tree species and mixtures

Norway spruce shall dominate, with birch, Scots pine, pedunculated oak, European aspen, and black alder making slightly larger share. The tree species to be used in addition to the Norway spruce are provided below according to the edaphic condition type for commercial forests.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Dry – medium fertility: Scots pine, larch spp., Pedunculated oak (*Quercus robur*), Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp.

Mesic – medium fertility: Scots pine, birch spp., Norway maple, small-leaved lime, pedunculated oak, European aspen, black alder.

Mesic – high fertility: Birch spp., European ash, Pedunculated oak, Sessile oak (*Quercus petraea*), Black alder, Norway maple, Small-leaved lime, European aspen.

On dry high productivity soils the following tree species should be targeted: Pedunculated oak, ash, Small-leaved lime, Norway maple, elm, Norway spruce, Sessile oak, birch, European aspen, Black alder.

In the Norway spruce prevailing stands other tree species share the following volumes:

Norway spruce (*Picea abies*)	0.4
Scots pine (*Pinus sylvestris*)	7.9
Birch (*Betula – B. pendula* or *B. pubescens*)	5.8
Pedunculate oak (*Quercus robur*)	3.7
European aspen (*Populus tremula*)	1.2
Grey alder (*Alnus incana*)	0.4
Black alder (*Alnus glutinosa*)	0.2
Ash (*Fraxinus excelsior*)	0.1
Goat willow (*Salix caprea*)	0.1
Small-leaved lime (*Tilia cordata*)	0.1
Norway maple (*Acer platanoides*)	0.1

Also present larch (*Larix*), hornbeam (*Carpinus betulus*)

Regeneration

According to the records from stand-wise forest inventory, the share of natural regeneration was during the last decade 33% in state forests and 28% in private forests.

The non-clear cutting requirement is usually associated with the increased importance of natural regeneration. However, in this FMM, the non-clear cutting requirement is due to the requirements of legal acts and the geographic location of forests. So, due to natural conditions, special purpose of the forests and importance of recreational and aesthetic values, the natural regeneration should not dominate.

According to the data of stand-wise forest inventory, natural regeneration is suggested for 31% of state forests (18% in private forests).

Site preparation

Depends on the regeneration type. Soil should be prepared for artificial regeneration. However, if natural regeneration is applied, then soil scarification should be used in some area to facilitate the regeneration, including the scarification in gaps.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Soil scarification is always used for artificial regeneration in State forest. If natural regeneration is used, then soil is scarified on ~10% of the area. However, if there is a seed-rich year, soil scarification is used on ~30% of the area for natural regeneration. No confirmed facts about private forests, but most likely no soil scarification is used to facilitate the natural regeneration.

Stand management

Pre-commercial thinning

The pre-commercial thinning (based on data from stand-wise forest inventory from 2015 and using the functionality of integrated forest cadaster IS) should be carried-out on 52% of the area covered by forests of pre-commercial thinning age in state forests during 2016-2025. The share of planned pre-commercial thinning during the coming decade in private forests is 50%.

Thus, the share of the area where this FMM is applied should be pre-commercially thinned at least once during a rotation period is 100%.

Stand-wise forest inventory records indicate, that pre-commercial thinning was done during 2006-2015 on 135 ha in state forests, making 50 % of the pre-commercial thinning age area and on 3,4 ha in private forests, making just 3% of the pre-commercial thinning age area. Note: some omission errors may be present in the database.

Commercial thinning

The 1st commercial thinning (based on data from stand-wise forest inventory from 2015 and using the functionality of integrated forest cadaster IS) should be carried-out on 29% of the area covered by forests of the 1st commercial thinning age in state forests during 2016-2025. The share of planned 1st commercial thinning during the coming decade in private forests is 75%. The figures for the 2nd commercial thinning are, respectively, 22% and 55%. The relatively larger share of stands requiring the commercial thinning in private forests is likely resulted by larger stand densities due to under-thinning.

Stand-wise forest inventory records indicate, that the 1st commercial thinning was done during 2006-2015 on 100 ha in state forests, making 33% of the 1st commercial thinning age area and on 7 ha in private forests, making just 2% of the 1st thinning age area. The 2nd commercial thinning was done on 29 ha in state forests, making 15% of the 2nd commercial thinning age area and on 39 ha in private forests, making 11% of the 2nd commercial thinning age area.

Pruning

No pruning is done in this FMM

Harvest

Chain saws are preferred under shelter-wood cutting systems.

Extraction of wood are mostly mechanized, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction.

Logging residues are not extracted and used.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Nature protection

This model for managing forest aims for continuous cover forestry (up to some extent). The Forest cutting rules also require leaving not less than 3 trees per ha with the age over MARA and the diameter over the average value for the compartment. The non-clear cutting requirement is an important measure itself, too.

5.12. Long rotation uniform shelter-wood in coniferous forests LRCON_US

This FMM is associated with using non-clear cutting in pure and mixed Scots pine dominated forests due legal requirements (i.e. no clear cutting in National Parks, along major roads and around reserves) and political will of forestry administration to increase the share of non-clear cutting (here – applying so called Labanauskas cutting, when the stand is cut in two occasions, leaving ~80-100 pine trees per ha after the first cutting intervention and expecting for natural regeneration). Timber production is the main ecosystem service.

Around 3% of the CSA area is managed by this FMM, the shares of state and private forests are near equal. This model for managing forest is very important at the country level, thus it was included even though the share at CSA level is relatively low. The shares of state and private forests in this FMM are practically equal (47:53%).

The FMM is applied practically on all edaphic conditions where the Scots pine may be met. There are practically 2 extra tree species in addition to Scots pine growing in this FMM. The rotation period for this FMM (110-120 years) is defined by legal acts and is considered to be too long by some forestry experts. The rotation period in state forests is even longer due to the principles of estimation of annual cutting norm, which are not applied for private forests, yielding in relatively large areas of over-mature forests and high average age.

There are no limitations regarding the area to be harvested at one-time point, except the Labanauskas cutting, where the simplified clear-cutting limitations for the cutting area dimensions, allocation and cutting repetition frequencies apply.

Even the natural regeneration should be prioritized under this FMM, local conditions require artificial regeneration to dominate, especially in state forests. Soil scarification if natural regeneration is applied is used on near 100% of the area in state forests.

The pre-commercial thinning should be applied at least once and the commercial thinning – more than twice during the rotation. State forest managers are doing pre-commercial and the 1st commercial thinning following the silvicultural requirements, however private forests are significantly under-thinned.

Up to some extent this FMM aims for continuous cover forestry and the nature protection integrated in the stand-level management is associated mostly with leaving some large and old trees when harvesting.

Edaphic conditions

This FMM is mainly used on dry sites with medium and low production. It should be avoided on wet soils due to silvicultural considerations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Ecosystem services

Timber production is the main ES with this FMM.

Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Cutting Rules) and carbon sequestration services.

Tree species and mixtures

The main tree species are Scots pine (*Pinus sylvestris*) but also some larch stands can be found.

Tree species share the following volumes (%):

Scots pine (*Pinus sylvestris*)	84.6
Norway spruce (*Picea abies*)	11.7
Birch (*B. pendula* or *B. pubescens*)	3.1
Pedunculate oak (*Quercus robur*)	0.3
European aspen (*Populus tremula*)	0.1
Grey alder (*Alnus incana*)	0.1

Also present Small-leaved lime (*Tilia cordata*), Black alder (*Alnus glutinosa*), Goat willow (*Salix caprea*), Norway maple (*Acer platanoides*), *Populus*, larch (*Larix*), hornbeam (*Carpinus betulus*).

Regeneration

In principle, the objective should be to have natural regeneration on 100% of the FMM area. However, based on regeneration proposals of integrated forest cadaster IS, around 50% of areas with clear cutting restrictions in state forests (basically in Zemaitija NP) should be naturally regenerated. The figure for private forests is 46%. Artificial regeneration is prioritized (~90%) on dry low productivity soils.

But in reality, the share of naturally regenerated stands at pre-commercial thinning age was 10% in state and 38% in private forests.

State forest managers prefer artificial regeneration. The share of naturally regenerated forest in state forests could be larger. It seems, that the state forest managers prefer having higher regeneration quality using artificial regeneration. Natural regeneration, especially if Labanauskas cutting method is used, is very poor in the CSA. For that reason, they plant artificially a lot.

Site preparation

With Labanauskas cutting method scarification is always done. The scarification should be less intensive with decreasing soil productivity. Soil scarification should be combined with the seed yield years. Soil scarification sometimes is not welcome in Zemaitija National Park.

Stand management

The thinning objective in pine-dominated forests is to develop productive pine-dominated forests.

Pre-commercial thinning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

During the pre-commercial thinning special care shall be taken to minimize snow damage risks. Mixed pine-birch stands should be pre-commercially thinned already at age 5-8 years and thinning needs to be repeated if birch starts covering pine trees. European aspen needs to be always removed from pine stand. Large gaps in thinned mixed stands should be avoided. No thinning is applied in pine stands on wet low productivity soils. So, majority of pine stands need to be pre-commercially thinned at least one time.

Based on data from stand-wise forest inventory the following pre-commercial thinning shares are proposed for 2016-2025: in state forests pre-commercial thinning is suggested on the area making 47% of the pre-commercial thinning age stand area. The figure for private forests is 48%.

According to the records of stand-wise forest inventory, during the period 2006-2015 the pre-commercial thinning was done on 42% of the area, covered by stands of pre-commercial thinning age in state forests. The figure in private forests is 2%.

Pre-commercial thinning in state forests seems to be done at the level corresponding to current silviculture concepts. Private forests are under-thinned; the pre-commercial thinning seems to be avoided. Reasons: cost saving, not caring, not considering pre-commercial thinning as important under this FMM, avoiding additional forestry activities in protected areas.

Commercial thinning

The aim of commercial thinning in Lithuania is declared to be the development of optimal growing conditions for the most productive trees, removing damaged, low productivity trees. Mixed stands are maintained, however, reducing the share of deciduous trees. As the period for the 2nd commercial thinning is rather long (21-90 years), experts from SFIMPI suggest the 1st commercial thing to be carried-out 1 time during the rotation and the 2nd thinning – 1-2 times during the rotation (i.e. the commercial thinning should be carried-out 2 to 3 times during the rotation).

The 2nd commercial thinning seems to be under assumed optimal level both in state and private forests. It should be noted, that the share of the 2nd commercial thinning in private forests is larger than for thinning in younger stands, possible due to the availability of more valuable timber assortments. The 1st commercial thinning is approximately at the expected level in state forests and under that level in private forests.

Pruning

No pruning.

Harvest

There were some attempts to use harvesters for non-clear cutting, however, chain saws are preferred under shelterwood cutting systems. If clear cutting in state forests is applied, then the harvester may be used. Extraction of wood/timber is 100% mechanized.

The logging residues are usually not extracted in state forests.

Nature protection

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The management model aims for continuous cover forestry (up to some extent). The Forest felling rules also requires leaving not less than 3 trees per ha with the age over MARA and the diameter over the average value for the compartment. The non-clear cutting requirement is an important measure itself, too.

5.13. Medium rotation uniform shelterwood clearcutting in deciduous forest MRDEC_US

This FMM is applied on birch (much less Black alder and Small-leaved lime) dominated mixed stands with the diversity of other tree species on dry to moist medium productivity soils.

The FMM belongs to the uniform shelter-wood management system, however, group selection cutting of non-uniform shelter-wood system may also be applied. Clear felling and artificial regeneration may be applied here; however, they are rare

Nearly 13% of the CSA area is managed by this FMM and the private forest ownership dominates here (77%).

As the timber production is the main ecosystem service, the FMM is focused on converting trivial deciduous dominating stands into more profitable mixed Norway spruce and deciduous stands. The rotation length is the same as for clear felling and is considered to be too long.

There are practically no limitations for the characteristics of area to be harvested at one-time point. The distinctive feature is that this FMM is dealing with mixed forests with the most abundant tree species on the stand being around 50-74% and this diversity should be maintained, however, trying to care for Norway spruce and remove low value species like Grey alder and Goat willow.

According to silvicultural recommendations, the pre-commercial and commercial should be applied at least several times during a rotation, especially where is the need to take care for Norway spruce. The pre-commercial and the 1st commercial thinning are done in practice in nearly required amount in state owned forest. The 2nd commercial thinning seems to be rare in all forests no matter the ownership.

Nature protection integrated in the stand-level management is associated mostly with leaving some old and large trees when harvesting.

Edaphic conditions

This FMM will be continued on medium productivity soils. It is very unlikely the non-clear felling to be effective on highly productive soils, unless there are groups of coniferous trees to apply group-selective cutting. Low productivity soils should be associated with other FMMs.

Ecosystem services

Timber production.

Fuel wood supply.

Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Felling Rules) and carbon sequestration services.

Tree species and mixtures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

This FMM is associated first of all with mixed birch and Norway spruce stands and aiming to get mixed Norway spruce – birch stands. So, the most abundant tree species on the stand will always be around 50-74%.

Tree species share the following volumes (no matter the main species):

Birch (B. pendula or B. pubescens)	58.2
Norway spruce (Picea abies)	11.4
European aspen (Populus tremula)	9.9
Black alder (Alnus glutinosa)	7.6
Grey alder (Alnus incana)	6.2
Scots pine (Pinus sylvestris)	2.8
Pedunculate oak (Quercus robur)	2.0
Goat willow (Salix caprea)	0.7
Small-leaved lime (Tilia cordata)	0.6
Ash (Fraxinus excelsior)	0.3
Norway maple (Acer platanoides)	0.2
Hornbeam (Carpinus betulus)	0.1

Also present willow (Salix), elm (*Ulmus glabra*), European white-elm (*Ulmus laevis*), Field elm (*Ulmus minor*), other deciduous tree species.

Regeneration

This method is associated with natural regeneration, only if clear felling is applied artificial regeneration shall be used. Artificial regeneration during the last decade was ~ 2% in forests which could be associated with this FMM according to the characteristics of previous stand.

Site preparation

No scarification should be needed or used.

Stand management

Pre-commercial thinning

There should be no pre-commercial thinning applied if the pure deciduous stands are under focus. However, if the aim is to develop Norway spruce dominating stand, then the pre-commercial thinning should be applied at least once. The internal forest management plan for Telsiai SFE suggests pre-commercial thinning on 40% of birch dominated stands (this partly overlaps with the FMM involving clear final felling on medium rotation deciduous forests).

All pole stage birch dominated stands (under 20 years) were thinned during the last decade on 40% of the area in state forests and only on 2.5% in private forests (data from stand-wise forest inventory, private forest data may contain some omission errors). As some of alder stands could be thinned more than a decade ago, the share of the area where this FMM is applied is pre-commercially thinned at least once during a rotation period could be guessed to be 60-80% in the state forests and much under 10% in private forests.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Pre-commercial thinning seems to be applied following the required amounts in state forests but is practically abandoned in private forests, most likely due to considering naturally regenerated deciduous stands as not requiring additional care and no interest for developing spruce stands.

Commercial thinning

According to the opinion of forest management planning experts from FIFMPI, there should be the 1st and the 2nd pre-commercial thinning applied at least once each, i.e. yielding in 2 commercial thinnings for medium rotation deciduous forests. However, the state forest managers do not support this approach suggesting less commercial thinning. So, our expert judgement is that on average medium rotation deciduous forests should be commercially thinned on average 1.5 times.

Based on the data from stand-wise forest inventory, the 1st commercial thinning is suggested on 43% of the area in birch dominated stands in state forests (40% in private forests), the 2nd commercial thinning is suggested on 57% of the area in birch dominated stands in state forests (59% in private forests).

Commercial thinning in birch dominated stands assumed to be cut at maturity age using non-clear cutting seem to be under suggested level. Especially the 2nd commercial thinning seems to be avoid-ed. This is also much to the fact, that the 2nd thinning is applied when stands are of 41-50 years of age, i.e. just one decade younger than the MARA.

No pruning is done in this FMM.

Harvest

No harvesters are applied in non-clearcutting. Extraction is fully mechanized. Logging residues are not extracted

Nature protection

FMM aims for continuous cover forestry (up to some extent). The Forest felling rules also requires leaving not less than 3 trees per ha with the age over MARA and the diameter over the average value for the compartment.

5.14. Medium rotation clear cutting in deciduous (birch and black alder) forests MRDEC_C

Today 10,2 % of the area is managed with this model for clearcutting mainly birch but also black alder. This FMM is the main competitor to medium rotation clear cutting in coniferous (Norway spruce) forests on dry and mesic medium productivity edaphic conditions. Spruce dominated stands yield which 1.7-2 time more than birch (or alder). However, potential market for birch timber should be taken into account as well as lower costs for afforestation (due to larger share of natural regeneration) and thinning (due to less thinning). In any case, this model should keep its importance on wet edaphic conditions making ~50% of the area managed by this FMM. So, the share of the forest area should be 5-10%. The share of the forest area in the CSA covered by this FMM could be less but no lower than 5%, because this is a FMM competing with medium rotation management approach ending with clear cutting in Norway spruce stands. After being cut, current forests on wet soils (basically black alder stands) should be left for natural regeneration resulting in continuation of this FMM.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Notably, >2/3 of the area under this FMM are privately owned, thus silvicultural treatments requiring professionalism or costs, would be rather doubtful

The rotation periods and the sizes and distribution of final cutting areas are strongly regulated by the Forest cutting rules. The rotation periods are suggested to be shorted by many experts. Although the rotation period is the same for all main tree species under this FMM (Black alder and birch spp.), regeneration principles and implementation of thinnings are somewhat different for birch (72% of FMM area) and alder (27%) dominated stands.

On mesic and dry medium productivity soils this FMM “competes” with growing Norway spruce dominated stands, however there are no “competitors” for Black alder stands on wet and some moist soils. Although this FMM is dealing with mixed forests with the most abundant tree species on the stand being around 50-94% of standing volume and this diversity should be maintained, some pure stands may also be naturally regenerated, especially on wet soils. High diversity of tree species is suggested for artificial regeneration, however the share of Black alder should be increased. Most of current Black alder stands should be recovered using natural regeneration (except the stands on drained soils). Around 50% of birch stands, belonging to the 1st selection group should also be naturally regenerated. However, artificial regeneration is more commonly used than it should be in state forests, while private forest owners prioritize natural regeneration even in the areas where it should not be used.

Usually more thinnings are required in birch dominated than in Black alder dominated stands. Pre-commercial thinning is usually not suggested only in pure stands, however, it is practically completely avoided by private forest owners. State foresters apply pre-commercial thinning in optimal amounts. Although interviewed experts recommend that stands should be commercially thinned on average 1.5 time, the actual implementation is less than 1 time. One of the reasons why the 2nd commercial thinning is much under suggested amounts is the unwillingness to interrupt with in-termediate cutting not long before the final cutting is done.

Nature protection integrated in the stand-level management is associated mostly with leaving some live and dead trees in clear-cut areas.

Edaphic conditions

This FMM should be continued on moist and wet soils, however forestry on dry and mesic soils should aim to replace birch and black alder with spruce. However, medium rotation deciduous forests may hardly be fully replaced by spruce-dominated stands on dry and mesic medium productivity soils, thus we assume there will always be some birch and black alder-dominated stands pre-sent there. High productivity dry and mesic soils should be reserved for more valuable tree species.

Ecosystem services

Timber production and second fuel wood supply.

Forest management shall also secure biodiversity protection and provision of environment protection and recreational services (Forest Cutting Rules) and carbon sequestration.

Tree species and mixtures

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

The tree species to be used are provided below according to the edaphic condition type for commercial forests. Pure stands usually are birch stands (sometimes with Norway spruce in the 2nd layer). Pure black alder stands dominate on wet and moist soils.

Wet and highly productive – Black alder, ash, birch spp., Norway spruce.

Wet and medium productivity – Black alder, birch spp., Scots pine, Norway spruce.

Mesic and medium productivity – Norway spruce, Scots pine, birch spp., Norway maple, Small-leaved lime, pedunculated oak, European aspen and Black alder.

Dry and medium productivity – Norway spruce, Scots pine, larch spp., Pedunculated oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp.

Dry and mesic highly productive sites currently under this FMM, should be reforested by pedunculated oak, ash, Small-leaved lime, Norway maple, Elm, Norway spruce, Sessile oak, birch spp., European aspen and Black alder

In general, the share of Black alder should increase (Telsiai SFE).

Today the tree species share (%) of standing volumes (no matter the main species):

Birch (Betula pendula or B pubescens)	61.0
Black alder (Alnus glutinosa)	23.8
Norway spruce (Picea abies)	6.1
European aspen (Populus tremula)	2.8
Grey alder (Alnus incana)	2.7
Scots pine (Pinus sylvestris)	1.8
Pedunculate oak (Quercus robur)	0.7
Ash (Fraxinus excelsior)	0.3
Small-leaved lime (Tilia cordata)	0.3
Goat willow (Salix caprea)	0.1
Norway maple (Acer platanoides)	0.1

Also present willow (*Salix*), hornbeam (*Carpinus betulus*), larch (*Larix*), elm (*Ulmus glabra*), European white-elm (*Ulmus laevis*), poplar (*Populus*).

The share of Black alder should increase, as should increase the share of Norway spruce. The share of birch should go down as this FMM should be replaced with medium rotation coniferous forest management ending with clear cut where it is possible.

Regeneration

During last decade the clear-cut areas were re-established using natural regeneration as follows:

Former birch stands – 31% in state forests and 70% in private forests, and former Black alder stands – 65% in state forests and 98% in private forests

Around 10% of clear cut areas in private forests were not regenerated more than 4 years after being cut.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Natural regeneration is used in birch stands belonging to the 1st selection group – currently ~50% of birch stands belong to this group. Thus, assuming the shares of birch and Black alder – around 60% of the trees reaching the pole stage should be established through natural regeneration. 70-80% of current Black alder stands should be left for natural regeneration. The exception is Black alder stands on drained soils with lowered water-table – there is practically no natural Black alder regeneration in the CSA on dry turf.

Natural regeneration is under the expected level in state forests, even though the opinion of reforestation experts from Telsiai SFE supports larger shares of natural regeneration, they seem to be preferring artificial regeneration. Vice-versa, natural regeneration exceeds the optimal level in private forests (the share of 1st selection group birch stands in private forests is 54% as well as the share of drained Black alder stands is 27%), most likely due to avoidance of costs for artificial regeneration.

Site preparation

Soil scarification shall be done if artificial regeneration is applied. No need for scarification if natural regeneration is applied. However, sometimes soil conditions may not be improved by scarification in this FMM... Planting has always been associated with soil preparation in advance. If container seedlings are used, the soil preparation may not be mandatory needed.

With artificial regeneration soil preparation is always done on state forests land. No information available on soil preparation in private forests. Most likely, some private forest owners, especially if using services of third parties, apply the soil preparation.

Stand management

Pre-commercial thinning

According to the data from stand-wise forest inventory, 11-20 years old stands in state forests have record of pre-commercial thinning on 30% of the area (i.e. they have been thinned in the period 2006-2015). In private forests, only 3% of the area have thinning record. Thus, the area where pre-commercial thinning is applied at least once during the rotation period is much below 100% in private forests and around 100% or below in state forests.

There should be no pre-commercial thinning applied if the pure deciduous stands are under focus (there are over 7% of such stands in this FMM which have reached the pole stage). However, if the aim is to develop Norway spruce dominating stand, then the pre-commercial thinning should be applied at least once. The internal forest management plan for Telsiai SFE suggests pre-commercial thinning on 40% of birch-dominated stands and on 20% of Black alder-dominated stands (this partly overlaps with the FMM involving non-clear final cutting on medium rotation deciduous forests).

Pre-commercial thinning seems to be used applied following current silvicultural concepts in state forests. However, pre-commercial thinning in private forests is practically avoided. This could be explained, in addition to saving costs, that private forest owners, majority of which are “house-hold” or “ad-hoc” foresters in the CSA (Stanislovaitis et al., 2015), are lacking professional forestry knowledge and skills, or sharing concept that “there is no intervention need in young deciduous dominated forests at all”.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

Commercial thinning

According to the data from stand-wise forest inventory, the commercial thinning was done and is recorded during the period 2006-2015 on 25% of the area managed by this FMM and having age 25-44 years in state owned forests (2% in private forests). The commercial thinning in state owned stands over 44 years old but below the thinning age limit was applied and recorded during the last decade on 9% of the area (3% in private forests). Thus, the area where commercial thinning is applied at least once during the rotation period is below 100%.

It is often recommended that there should be the two commercial thinnings a yielding in medium rotation deciduous forests. However, the state forest managers do not support this approach suggesting less commercial thinning. So, our expert judgement in that on average medium rotation deciduous forests should be commercially thinned on average 1.5 times.

Based on the data from stand-wise forest inventory, the 1st commercial thinning is suggested on 43% of the area in birch dominated stands in state forests (40% in private forests), the 2nd commercial thinning is suggested on 57% of the area in birch dominated stands in state forests (59% in private forests).

In Black alder dominated stands: state forests, the 1st commercial thinning – 17% and the 2nd commercial thinning – 78%; private forests, the 1st commercial thinning – 3% and the 2nd commercial thinning – 53%.

Pruning

Pruning in not done in this FMM.

Harvest

Around 70% of harvesting is done using harvesters in state owned forests. Harvesters are used in private forests less than 50% of cases. Chain saws are used basically by harvesting contractors in areas with more unfavourable conditions for harvester or in private forests.

Extraction of wood and timber is fully mechanized on state forest, but some private forest owners for own timber utilization may not use fully mechanized wood extraction. Logging residues are not extracted and used.

Nature protection

At least 7 live trees (among them at least 3 trees need to be older or having DBH larger than the aver-age value for the whole stand) per 1 ha and 3 dead trees (DBH > 20 cm) per 1 ha shall be left in clear-cut areas over 1 ha. For clear-cut areas 0.5-1 ha, the figures are, respectively, 3 (2) and 2. Biodiversity-ty trees are left in clear-cut areas for natural decay. Also stand level restrictions are introduced due to woodland key habitats, presence of nests of some birds.

5.15. Short rotation uniform shelter-wood/clear cutting in deciduous forests SRDEC_CUS

About ~7.5% of the CSA area is managed by this FMM. This is one of few FMMs with clear dominance of private forest owners (90%). Following the Lithuanian forestry concepts, the area

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under this FMM could be related to the cases of “unsuccessful” forestry, as mixed Grey alder and European aspen stands occupy the most productive soils here.

Although the main ES is assumed to be fuelwood supply, there is some potential for timber supply, especially focusing on specific assortments, too.

The FMM resembles most the uniform shelter-wood management system due to silvicultural considerations, however clear cutting and non-uniform shelter-wood systems may also apply. If non-clear occasional cutting is applied, there are no limitations for this FMM regarding the area to be harvested at one-time point.

The rotation period for private forest owners is not regulated. The final cutting methods chosen for this FMM are focused on taking care for more commercially valuable tree species, which are expected to replace grey alder or European aspen or decrease their abundance. However, the management that is applied does not indicate any chances for reaching formal forestry objectives.

Only natural regeneration is used in this FMM. Even some pre-commercial and 1st commercial thinning is proposed following silvicultural recommendations, the thinning in fact is done only on several compartments.

Nature protection integrated in the stand-level management is associated mostly with leaving some old and large trees when harvesting.

Edaphic conditions

This model is mainly used on high productive sites. Following the Lithuanian forestry principles, the high productivity soils should not be used for low commercial value tree species as grey alder and should be transferred to other FMMs. Mixed forests belong to this FMM, usually containing more commercially valuable tree species in tree species composition and significant amount of under-growth, i.e. the reason for separating such forests from the FMM with short rotation deciduous clear cutting has been the expectations for better use of soil potential (in commercial terms).

Ecosystem services

Fuelwood production.

Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Cutting Rules) and carbon sequestration services. Timber supply in some cases.

Tree species and m*i*xtures

Mixed stands on productive soils are managed in this FMM. Usually there is significant amount of undergrowth or 2nd layer, which is distributed evenly in the area, suggesting simplified occasional cutting. However, if the undergrowth is distributed in groups or there is relatively significant share of Norway spruce (>30%) in tree species composition, group-occasional cuttings (system C) may also be applied. Clear cutting is also possible.

Based on Re-forestation and afforestation rules, the following tree species should be present on soils, occupied by forests belonging to current FMM:

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- On dry sites with high productivity soils the following tree species should be targeted: Pedunculated oak, ash, Norway spruce, Small-leaved lime, Norway maple, elm, Norway spruce, Sessile oak, birch, European aspen and black alder.

- Dry sites with medium productivity: Norway spruce, Scots pine, larch spp., Pedunculated oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp.

- Mesic with high productivity: Norway spruce, birch spp., European ash, Pedunculated oak, Sessile oak (*Quercus petraea*), Black alder, Norway maple, Small-leaved lime, European aspen

Mesic with medium productivity: Norway spruce, Scots pine, birch spp., Norway maple, Small-leaved lime, pedunculated oak, European aspen, Black alder

Tree species share the following volumes (no matter the main species):

Grey alder (*Alnus incana*)	41.6%
European aspen (*Populus tremula*)	28.3%
Birch (Betula B. pendula or B. pubescens)	15.1%
Norway spruce (*Picea abies*)	4.8%
Pedunculate oak (*Quercus robur*)	3.5%
Goat willow (*Salix caprea*)	1.4%
Black alder (*Alnus glutinosa*)	1.4%
Norway maple (*Acer platanoides*)	1.2%
Ash (*Fraxinus excelsior*)	1.2%
Willow (*Salix*)	0.6%
Scots pine (*Pinus sylvestris*)	0.3%
Small-leaved lime (*Tilia cordata*)	0.3%
Elm (*Ulmus glabra*)	0.1%

Also present: poplar (*Populus*), other trivial deciduous, European white-elm (*Ulmus laevis*), other hardwood deciduous, Field elm (*Ulmus minor*), hornbeam (*Carpinus betulus*) and larch (*Larix*).

Regeneration

Sometimes regeneration is done in gaps. In group-occasional system the maximum size of gap is 0.3 ha and total area of gaps shall not exceed 30% of the compartment's area. If group-selective cutting, the group (gap) size shall not exceed 0.1 ha. Repetition period shall not be less than 5 years.

Only natural regeneration is used.

Site preparation

No site preparation is used.

Stand management

Pre-commercial thinning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Stand-wise forest inventory records indicate that pre-commercial thinning was done on less than on 4% of the pre-commercial thinning age area during 2006-2015.

Silvicultural concepts shaping Lithuanian forestry principles in this FMM are primarily focused on development of fast growing, productive stands providing timber suitable for specific industries. The pre-commercial thinning in European aspen dominated stands is recommended to be started at age 10-14 when the tree differentiation into development classes is taking place. Green-bark form of aspen should be focused as it is more resistant to stem rot. Grey alder and Goat willow trees are recommended to be removed from the stand.

The pre-commercial thinning (based on data from stand-wise forest inventory from 2015 and using the functionality of integrated forest cadaster IS) should be carried-out on 44% of the area covered by forests of pre-commercial thinning age during 2016-2025. Assuming that the pre-commercial thinning in this FMM usually start when the stand age is >10 years, this means that in principle the share of the area where this FMM is applied should be pre-commercially thinned at least once during a rotation period does also equal 44%.

Formally, the stands under this FMM are under-thinned, i.e. the pre-commercial thinning is recorded just for few compartments. This may be explained both by low motivation of private forest owners to spend resources on pre-commercial thinning and specifics of the FMM, i.e. potential focus on timber use for fuel and unwillingness to invest in growing more commercially valuable forests.

Commercial thinning

Stand-wise forest inventory records indicate, that the 1st commercial thinning was done on ~1% of the 1st commercial thinning age area during 2006-2015.

Only the 1st commercial thinning is possible due to low rotation period. The objective is to facilitate the increment, also aiming to develop the undergrowth and 2nd layer of relatively more valuable tree species.

The 1st commercial thinning (based on data from stand-wise forest inventory from 2015 and using the functionality of integrated forest cadaster IS) should be carried-out on 43% of the area covered by forests of the 1st commercial thinning age during 2016-2025.

We have to state significant under-thinning or even avoiding the 1st commercial thinning. In fact, there is rather limited commercial value of the timber harvested here and, assuming domination of private forests in this FMM, the reasons of being below formal silvicultural objectives, could be explained by lacking thinning motivation and, probably, discrepancies of current silvicultural concepts and the real life.

Pruning

Pruning is not done in this FMM.

Harvest

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

No harvesters are applied in non-clear cutting. Harvesting is basically done using chain-saws. Almost all extraction of timber is done by forwarders, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction.

Use of logging residues are not utilized.

Nature protection

FMM aims for continuous cover forestry (up to some extent). The Forest felling rules also requires leaving not less than 3 trees per ha with the age over MARA and the diameter over the average value for the compartment.

5.16. Short rotation clear cutting in deciduous forests (aspen, grey alder) SRDEC_C

Clearcutting with deciduous trees are used on 3.2% of the CSA area. This is one of few FMMs with clear dominance of private forest owners (near 90%).

Three types of short rotation deciduous trees dominated stands were assigned to this FMM – over-mature low density European aspen dominated stands, stands on moist and wet soils and naturally regenerated pure grey alder and other low commercial value stands on usually productive soils.

Fuelwood supply is considered as the main ES, however, timber supply may also be considered to be important in European aspen stands, not damaged yet by the stem rot and under conditions of sufficient demand of wood for packaging.

This FMM is best illustrating the disagreement between Lithuanian forestry concepts, suggesting replacing low commercial value deciduous tree species on fertile soils by more valuable ones and the real life, involving different forestry objectives of private forest owners and non-industrial usage of the resources.

The rotation period for these tree species is not regulated in private forests.

Following the Lithuanian forestry principles, natural regeneration should dominate only in stands on moist and wet soils, while artificial regeneration should prevail (66-75%) in the remaining areas. In fact, natural regeneration dominates. Notably, some private owners follow the recommendations for artificial regeneration in a line with Lithuanian forestry principles.

Pre-commercial and commercial thinning are practically avoided.

Nature protection integrated in the stand-level management is associated mostly with leaving some live and dead trees in clear-cut areas.

Edaphic conditions

Mainly used on high production sites, 75% of the clearcutting model in decides stands are found on such sites.

Ecosystem services

Fuelwood production is the main ecosystem service related to this FMM.

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Forest management shall also secure biodiversity protection and provision of environmental protection and recreational (Forest Cutting Rules) and carbon sequestration services.

Timber supply may be considered to be important in European aspen stands, not damaged yet by the stem rot and under conditions of sufficient demand for the wood for packaging.

Tree species and mixtures

Pure or near pure stands should dominate stands managed with this FMM.

Based on Re-forestation and afforestation rules, the following tree species should be present on soils, occupied by forests belonging to current FMM:

- On dry sites with high productivity soils the following tree species should be targeted: Pedunculated oak, ash, Norway spruce, Small-leaved lime, Norway maple, elm, Norway spruce, Sessile oak, birch, European aspen and black alder.

- Dry with medium productivity: Norway spruce, Scots pine, larch spp., Pedunculated oak, Norway maple, Small-leaved lime, European beech, Sessile oak (*Quercus petraea*), birch spp.

- Mesic with high productivity: Norway spruce, birch spp., European ash, Pedunculated oak, Sessile oak (Quercus petraea), Black alder, Norway maple, Small-leaved lime, European aspen

Mesic medium productivity: Norway spruce, Scots pine, birch spp., Norway maple, Small-leaved lime, pedunculated oak, European aspen, Black alder

Tree species share the following volumes (no matter the main species):

Grey alder (*Alnus incana*)	55.8%
European aspen (*Populus tremula*)	29.3%
Birch (*Betula -B. pendula or B. pubescens*)	6.6%
Pedunculate oak (*Quercus robur*)	2.4%
Norway spruce (*Picea abies*)	2.1%
Black alder (*Alnus glutinosa*)	1.0%
Ash (*Fraxinus excelsior*)	0.8%
Goat willow (*Salix caprea*)	0.6%
Norway maple (*Acer platanoides*)	0.4%
Willow (*Salix*)	0.3%
Small-leaved lime (*Tilia cordata*)	0.3%
Scots pine (*Pinus sylvestris*)	0.2%
Elm (*Ulmus glabra*)	0.1%
Poplar (*Populus*)	0.1%

Also present: European white-elm (*Ulmus laevis*), hornbeam (*Carpinus betulus*) and larch (*Larix*), other trivial deciduous

Regeneration

There are 3 different types of short rotation deciduous stands associated with this FMM:

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- Stands on moist and wet soils – such stands need to be naturally regenerated. E.g. stand-wise forest inventory data suggests natural regeneration during the period 2016-2025 on 99% of such area.

- Over-mature low density European aspen dominated stands. Stand-wise forest inventory data suggests natural regeneration during the period 2016-2025 on 25% of such area.

- Naturally regenerated pure grey alder and other low commercial value stands on usually productive soils. Stand-wise forest inventory data suggests natural regeneration during the period 2016-2025 on 33% of such area.

Establishment of stands on sites previously grown with aspen or grey alder is rather difficult and costly task. However, majority of areas under this FMM are privately owned and the major ES is considered to be fuel timber supply. Thus, hardly the objective to regenerate aiming for oak, ash, spruce forest should be applied in private forests, especially if the forest owner belongs to the household PFO type (cf. Stanislovaitis et al. 2015 for forest owner types). Thus, our expert judgement is that natural regeneration should dominate in this FMM. The share of naturally regenerated stands at pre-commercial thinning age is 76%.

Site preparation

Site preparation is normally and most often not done.

Stand management

Silvicultural concepts shaping forestry principles in this FMM are primarily focused on development of fast growing, productive stands providing timber suitable for specific industries.

Pre-commercial thinning

The pre-commercial thinning in European aspen dominated stands is recommended to be started at age 10-14 when the tree differentiation into development classes is taking place. Green-bark form of aspen should be focused as it is more resistant to stem rot. Grey alder and Goat willow trees are recommended to be removed from the stand. As the majority of forests under this FMM are privately owned and the assumed main ES is fuelwood supply, no thinning could also be suggested as well.

The pre-commercial thinning (based on data from stand-wise forest inventory from 2015 and using the functionality of integrated forest cadaster IS) should be carried-out on 30% of the area covered by forests of pre-commercial thinning age on wet soils during 2016-2025. Naturally regenerated pure grey alder and other low commercial value stands are suggested to be pre-commercially thinned on 9% of the area covered by forests of pre-commercial thinning age.

Commercial thinning

Stand-wise forest inventory records indicate, that the 1st commercial thinning was done on less than on 1% of the 1st commercial thinning age area during 2006-2015.

We have to note under-thinning or even avoiding the commercial thinning, no matter very low requirements for the areas to be thinned. In fact, there is rather limited commercial value of the

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timber harvested here and, assuming domination of private forests in this FMM, the likely reasons could be lacking thinning motivation by private forest owners and discrepancies of current silvicultural concepts and the real life.

Pruning

No pruning is done in this FMM.

Harvest

Harvesting is basically done using chain-saws. Almost all extraction of timber is done by forwarders, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction. Logging residues are not collected, extracted and used.

Nature protection

At least 7 live trees (among them at least 3 trees need to be older or having DBH larger than the aver-age value for the whole stand) per 1 ha and 3 dead trees (DBH > 20 cm) per 1 ha shall be left in clear-cut areas over 1 ha. For clear-cut areas 0.5-1 ha, the figures are, respectively, 3 (2) and 2. Biodiversity trees are left in clear-cut areas for natural decay. Also stand level restrictions are introduced due to woodland key habitats, presence of nests of some birds.

5.17. Management in special purpose forests

The main ecosystem services associated with this FMM are sustaining and recovering of forest eco-systems or specific components of ecosystems and recreation and all forests belong to Group II (Special purpose forests). Key forest management principles in special purpose forests are regulated by the Forests Law and other supporting legal acts, leaving limited flexibility for forest manager. Non-uniform shelter-wood management system mostly resembles the group-selective cutting sys-tem that dominates in this FMM.

13.4% of forests in the CSA belongs to this FMM and near two-thirds of them are state owned. The area under this FMM should remain stable, as it is much predetermined by forest groups. Majority (~95%) of forests under this FMM belong to Ecosystem protection forests whose area may be changed only involving revision of forest groups or grouping principles.

Rotation periods are based on natural maturity age that is approx. 60% higher than the MARA in commercial forests. As non-clear harvesting is carried-out during a long period throughout the whole stand, there are no limitations regarding the area harvested at one time-point, however the gaps cut are very small, not exceeding 0.1 ha.

All soil conditions present in the CSA are represented in this FMM as the diversity of tree species present is very high. Species, making more than 5% of standing volume, are Norway spruce, birch spp., Scots pine, Black alder, Grey alder, Pedunculated oak, and European aspen.

Artificial regeneration dominates in state forests, while the natural regeneration dominates in private forests. There are numerous cases where natural regeneration is not possible, e.g. due to low regeneration capacity at natural maturity age.

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The objective for stand management in this FMM is to improve the ecological, aesthetic, recreational and other forest functions and to develop conditions for sustaining the objects under protection, recovering and maintaining biological diversity in the forests, thus, very diverse treatment solutions may be used. The pre-commercial thinning is practically at the level required by silvicultural requirements in state forests, however, practically no pre-commercial thinning is done in private forests. The commercial thinning in state forests is slightly under optimal amounts, however, only very few private forest owners do pre-commercial thinning in special purpose forests.

Edaphic conditions

The management model is used on all site, fertile and unfertile from wet to dry.

Ecosystem services

The main aim with this management system is sustaining and recovering of forest ecosystems or specific components of ecosystems. Also recreation is an aim with this model, recreation is important on ~5% of the FMM area.

Tree species and mixtures

Tree species share (%) the following volumes (no matter the main species):

Norway spruce (*Picea abies*)	37.4
Birch (Betula -B. pendula or B. pubescens)	18.9
Scots pine (Pinus sylvestris)	15.8
Black alder (Alnus glutinosa)	9.0
Grey alder (Alnus incana)	6.0
Pedunculated oak (Quercus robur)	5.7
European aspen (Populus tremula)	4.4
Norway maple (Acer platanoides)	0.8
Small-leaved lime (Tilia cordata)	0.7
Ash (Fraxinus excelsior)	0.5
Elm (Ulmus glabra)	0.3
Hornbeam (Carpinus betulus)	0.2
Goat willow (Salix caprea)	0.2
Willow (Salix)	0.1
Larch (Larix)	0.1

Also present: European white-elm (*Ulmus laevis*), other softwood and hardwood deciduous, Jack pine (*Pinus banksiana*), Field elm (*Ulmus minor*) and poplar (*Populus*).

Rotation period

The Forest cutting rules allow also non-clear occasional cutting in the type of stands where this model is used. There are no regulations nor experience on implementation. Free-selective cuttings,

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which resemble best the B – uniform shelter-wood system is also applied in recreational forests, which are in minority in this FMM.

Regeneration

Artificial regeneration in state forests dominates. However, even if the target is to maximize natural regeneration, there are numerous cases where it is not possible. MARA in this FMM is usually associated with natural maturity age and trees at maturity age sometimes have already lost the regenerating capacity. Thus, the only option is to use artificial regeneration.

The area of artificial regeneration during last decade in state forests was 72.2 ha, in private forests – 9 ha. Natural regeneration during last decade in state forests was 44.7 ha, in private forests – 51 ha. Thus, the share of natural regeneration is ~38% in state forests and 85 % in private forests.

Site preparation

Soil scarification could be applied to facilitate the regeneration in some minor locations. Currently no soil scarification is applied. Telsiai SFE has scarified soil previously soil to facilitate the regeneration in Zemaitija National Park, however, the response from the park was strongly negative

Stand management

The main objective of thinning under this FMM is to improve the ecological, aesthetic, recreational and other forest functions and to develop conditions for sustaining the objects under protection, recovering and maintaining biological diversity in the forests. This FMM includes rather large diversity of forest conditions

Pre-commercial thinning

It is rather difficult to suggest the required extents of pre-commercial thinning.

The pre-commercial thinning is practically at the level required by silvicultural requirements in state forests, however, practically no pre-commercial thinning is carried-out in private forests. Assuming that the FMM covers special purpose forests, private forest owners hardly are motivated to seek the thinning objectives - improve the ecological, aesthetic, recreational and other forest functions, etc.

Based on data of stand-wise forest inventory from 2015, the pre-commercial thinning is suggested for the next decade to be implemented on 220.8 ha (47% of the area covered by stands of pre-commercial thinning age) in state forests and 66.3 ha (47%) in private forests.

The forest management project for Telsiai SFE for the period 2006-2015 suggested the pre-commercial thinning on 313 ha (46% of the area covered by stands of pre-commercial thinning age).

Commercial thinning

Based on data of stand-wise forest inventory from 2015, the 1st commercial thinning is suggested for the next decade (2016-2025) to be implemented on 196.5 ha (31% of the area covered by stands of the 1st commercial thinning age) and the 2nd commercial thinning is suggested for the

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next decade to be implemented on 391.5 ha (22 % of the area covered by stands of the 2nd commercial thinning age) in state forests. The figures for private forests are, respectively, 192.2 ha (52 %) and 408.2 ha (26 %).

According to the forest management plan for Telsiai SFE for the period 2006-2015, the 1st commercial thinning was suggested on 265 ha out of 604 ha (44%), the 2nd commercial thinning – on 132 ha out of 1432 ha (9%). The suggested area for thinning is estimated based on silvicultural requirements valid in Lithuania.

According to the records from stand-wise forest inventory, the 1st commercial thinning in state forests was done on 187 ha (31% of the area covered by stands of the 1st commercial thinning age). The 1st commercial thinning in private forests was done on 10.1 ha only. The 2nd commercial thinning in state forests was done on 130.7 ha (9% of the area covered by stands of the 2nd commercial thinning age). The 2nd commercial thinning in private forests was done on 23.4 ha.

The commercial thinning in state forests seems to be slightly under suggested amounts and only very few private forest owners do pre-commercial thinning in special purpose forests. Assuming the specifics of thinning under this FMM, private forest owners hardly are motivated to seek the thinning objectives - improve the ecological, aesthetic, recreational and other forest functions, etc.

Pruning

No Pruning is done in stands managed with this model.

Harvest

Chain saws dominate. Almost all extraction of timber is done by forwarders, however, some private forest owners for own timber utilization may not use fully mechanized wood extraction.

Use of logging residues are collected and extracted.

Nature protection

The main purpose with this management model is sustaining and recovering of forest ecosystems or specific components of ecosystems, thus all forestry is focusing on nature protection. No clear-cutting, final cutting at natural maturity age, regeneration and thinning approaches, harvesting technologies – all they are aimed for nature protection first. Additionally, the Forest cutting rules require leaving not less than 3 trees per ha with the age over MARA and the diameter over the aver-age value for the compartment.

5.18. Stands with no intervention

This is not really a model for management as no intervention are done. 3.2% of the CSA area is as-signed to “no intervention” or no management. It assumes leaving forest ecosystems for natural succession in their natural state, thus no human intervention is allowed. Majority of forests with no intervention belong to the state and are managed by Telsiai SFE. The ecosystem service is biodiversity protection and biosphere monitoring. All edaphic conditions as well as all tree species found in CSA are represented in this FMM. Most common tree species are Norway spruce, Scots pine and birch spp.

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NEPCon Interim Standard for Assessing Forest Management in Lithuania (2014) requires that the forest management enterprise shall leave representative samples of existing rare and/or endangered ecosystems for natural succession in their natural state covering at least 5 % of the total forest area. As only 40% of the CSA is belongs to state and is managed by Telsiai SFE, the area with no intervention meets the certification requirement. Less than 1% of private forests (~160 ha) belongs to this FMM.

As the areas assigned for this FMM were identified using data from recent stand-wise forest inventory (year 2015), it is accepted that all values requiring no intervention status were considered during the inventory and the share of this FMM is at its proper level.

Edaphic conditions

The reserves should be represented by all site type, fertility and soul moisture, what opens the possibility for the conservation of maximal species amount (Margules and Nicholls 1988, Possingham, Ball and Andelman 2000). Though we see a slightly irregular distribution of the reserves areas within the CSA. The reserve network is state-wide and is distributed within the whole country, so the sites, which are poorly represented within the CSA, can be more widely represented in other reserves in Lithuania. A low percent of highly-productive moist sites under this FMM can be explained by the fact that such sites usually form after artificial draining of the wet sites, which is followed by plantation forestry.

Ecosystem services

Biodiversity protection and biosphere monitoring.

Tree species and mixtures

The species admixture level will form itself depending on the site conditions, original tree composition and other similar factors.

In the stands (reserves) tree species distributions (%) and volume (th - thousand m^3) are:

Norway spruce (*Picea abies*) –	42.7%,	280th. m^3
Scots pine (*Pinus sylvestris*) – 3	3.2%,	217th. m^3
Birch (*Betula - B pendula or B pubescens*)	9.3%,	61th. m^3
Black alder (*Alnus glutinosa*) –	7.4%,	49th. m^3
Pedunculate oak (*Quercus robur*) –	4.1%,	27th. m^3
Grey alder (*Alnus incana*) –	1.3%,	8th. m^3
European aspen (*Populus tremula*) –	1.1%,	8th. m^3
Small-leaved lime (*Tilia cordata*) –	0.4%,	2th. m^3
Ash (*Fraxinus excelsior*) –	0.3%,	2th. m^3
Elm (*Ulmus glabra*) –	0.1%,	1th. m^3

Norway maple (*Acer platanoides*) and hornbeam (*Carpinus betulus*) – under 0.1%

Rotation period

Harvesting is prohibited. No intervention allowed due to Forest Law requirements.

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Regeneration

As long as no intervention is allowed, the regeneration in modern reserves is only natural. However, these reserves could be founded in the areas where previously were managed/planted forests.

Stand management

No intervention is allowed

Harvest

No harvest

Nature protection

The whole idea is dedicated mainly to nature protection. The forest is left to grow naturally, without any human intervention and sometimes with visiting limitations.

5.19. References

Personal communication:

Forest management planning experts from State Forest Inventory and Management Planning Institute (SFIMPI) were interviewed (M.Lynikas, V.Beržanskis). The experts are right now working with the elaboration of forest management plan for the CSA.

2 experts from Telsiai SFE were interviewed – deputy director (A.Jokužys), who is in charge of forestry issues and forest regeneration engineer (L.Servienė).

Information collected within the frames of conventional stand-wise forest inventory, conducted in 2015 and describing also the forestry activities during 2006-2015.

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6. The Netherlands

6.1. Historical background of Dutch forest management

1945 – 1960s: Rationalized timber production

In the Netherlands, the period after WWII can be described as a time in which the country had to recover from WWII. This also was the case for the Dutch forest sector. Main objective was the production of wood as supply of timber was low (Buis and Verkaik, 1999; Verbij, 2008). As stated by the chairman of the Dutch Royal Forestry Association (cited in: Buis and Verkaik, 1999, p. 99): “the in-crease of the timber production is not only a duty imposed by accepting the Marshall Plan” but is of “enormous societal importance”, especially in times “when the economic position of our country is as precarious as it is right now”. As there was a large shortage of labour, including the forest sector (Buis and Verkaik, 1999), rationalization and mechanization processes were introduced.

1960s – 1970s Dutch forestry in crisis

In the 1960s, due to an increase of management costs and decreasing timber prices, the financial position of forest owners worsened (Buis and Verkaik, 1999). As forest became more important for recreation, the Dutch government decided to set up two subsidy schemes (one for public and one for private owners) to support forest owners under the condition that they opened up their forests for society (Buis and Verkaik, 1999). This resulted in an opening of the forests, but it did not change the focus of forest management on timber production. The schemes also did not solve all the financial problems (Buis and Verkaik, 1999). Because of the precarious financial situation and the fear of imminent wood shortages (Verbij, 2008), a “Report on Forestry and Forestry Policy in the Nether-lands” was developed. On the basis of this document, the Dutch government decided in 1970 to grant private forest owners further subsidies: these subsidies covered at maximum half of the planting cost for afforestation and for replanting after harvesting (Verbij, 2008).

1970s – 1986: multifunctionality

The 1970’s reflect two important societal trends that impacted Dutch forestry:

1. More free time – resulting in increased popularity of recreation in forest areas, to the extent that Dutch society felt that forests were common property (Buis and Verkaik, 1999).

2. Increased societal attention for environmental issues (e.g. due to the Club of Rome, and the establishment of a separate department for nature conservation and recreation at the Dutch Ministry for Culture, Recreation and Social Work) (Zevenbergen, 2003).

Recreation and nature conservation therefore became more important than in the period before. Timber production remained important as several studies (such as that of the FAO) forecasted shortages in timber (Zevenbergen, 2003). Especially in the Netherlands, highly dependent on imported timber, domestic timber production remained an important issue. All these thoughts

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were politically anchored in the first official policy document, the Long-term Policy for Forestry of 1986(Verbij, 2008). This policy plan intended "create such conditions for the forest area in the Netherlands that they would fulfil societal wishes towards forests, for now and in the future" (in Verbij, 2008, p. 120). Underlying idea is multifunctional forests (80% of Dutch forests), the other forests having "accent on nature" (Verbij, 2008). Forest management was practiced in the mean time in a more nature oriented manner. Severe storms in 1972 and 1973 had resulted in large damages to Dutch forests. Especially from the nature conservation side, it was discussed how forest management had reinforced the damages due to the silvicultural practices oriented on timber production (even aged production forests). Inspired by German and Swiss insights, foresters started to experiment with more nature oriented forest management.

1986 – 2000: marginalization of timber production

Despite the focus on multifunctional forests in the forest policy plan of 1986, at the end of the 1990's attention for timber production decreased, due to among other the following (Zevenbergen, 2003; Hoogstra and Willems, 2005):

- No expected wood shortages and a further internationalization of the wood processing industry
- Timber prices declined which made timber production financially less interesting for forest owners
- Nature conservation gained a more important place among others, in Dutch policy
- Dutch society, confronted with images of the destruction of tropical forests for timber production, found timber harvesting difficult to accept in "their" forests

Forest management still combined the three functions, practicing forest management in a more nature oriented way by using concepts like "integrated forest management" and "pro Silva" (Verbij, 1999), however the amount of Dutch timber harvested decreased largely.

2000 – 2010: forests as part of nature

In 2000, an integrated policy plan (combining forest and nature policy in one document) came out. Only one sentence in this plan refers to the multifunctional character of forests, basically "allowing" wood production in 70% of the forests designated as multifunctional forests (Verbij, 1999). Attempts to increase the focus on timber production of Dutch forests (among others by the wood processing industry) did not succeed, timber remained one of the functions of Dutch forest management, but became secondary.

2010 – present: economization of ecology

In October 2010, a new government coalition was installed. Because of the financial crises, this (right wing) coalition implemented drastic changes in policy and policy finances, which struck the nature sector dramatically. The implementation of several key-policies for nature were halted and budget cuts up to 70% were set for the nature sector (Buijs et al., 2014). Some people saw this as the end of Dutch forest and nature. One of the national newspapers, for example, talked about the "downfall of Dutch nature" (Trouw, 15-04-2011). Others see opportunities in the spending cuts. By finding new sources of income by marketing forest and nature in new (or renewed) ways, forest

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and nature owners can improve their financial situation, while becoming less dependent from the government (InnovationNetwork, 2013; Kamerbeek, 2012). Markets, entrepreneurship and innovation are the keywords. Forest owners start to search or intensify their search for economic outputs of forests and try to become more independent from the government. Next to new economic outputs (e.g. related to recreational and environmental services), timber production is on the agenda of forest owners again (even of the nature conservation organizations managing forest areas).

6.2. Forest management approaches in the Netherlands

The following two sections are copied and adapted from the report INTEGRAL WP3.1 The Netherlands

Most of the Dutch forests are second-generation forests that were the result of large afforestation projects at the end of the 19th and beginning of the 20th century. Until the 1970's, the prevailing silvicultural systems were clear cutting with replanting, and coppice system. Traditionally, silvicultural systems using natural regeneration did not receive much attention, mainly because of a widely held belief that most Dutch forests were too young and had not enough soil development for natural regeneration instead of planting after clear cutting. However, after 1970, more emphasis was placed on the role of forests in the protection of nature, and natural processes received more attention (Mohren and Vodde, 2005).

The main events, which drove Dutch forest management towards an integrated forest management focused on natural processes, were the storms at the end of 1972 and in the spring of 1973. These storms resulted in a wind throw of many hectares of forest (Mohren and Vodde, 2005). Overall, for the Netherlands, the events were of such scale, that not all of the forest could be replanted in a short time. This resulted in large-scale regeneration on most forest sites. This was unexpected to most foresters and local forest experts. Since these events, natural regeneration is common sense for most foresters, especially since naturalness, biodiversity and recreation became more important than timber production (Mohren and Vodde, 2005). Interviews with experts in the INTEGRAL project also showed that these events are considered as one of the most influential events for Dutch forest management since 1945, causing a shift of focus to naturalness and natural processes.

Over the last decades, in forest management, two concepts seem to prevail: (1) multifunctional forests and (2) Integrated Forest Management. Despite the popularity of the concepts, no uniform definition or shared understanding of the two concepts exists. In the majority of the Dutch literature, multi-functional forest management is seen as the integration of different functions, while IFM is considered not only to incorporate the integration of different functions, but also the way man-agement is carried out, i.e. making use of natural processes as much as possible. In other words, IFM can be a way of "managing multi-functional forests" (Verbij, 2008, p. 129). Or, as stated by Van Raffe et al. (2005), IFM is a management approach that can realize multi-functional management.

As regards the way management is carried out in IFM, IFM is related to concepts such as "nature oriented" and "pro silva" management (Province of Gelderland, s.a.), and the basic underlying conditions that are often considered, are (Province of Gelderland, s.a.):

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- Small-scale felling where possible (not more than 30 acres);
- Natural regeneration where possible;
- More horizontal and vertical structure;
- Mixing with indigenous species;
- Large proportion of standing or fallen dead trees;
- Old forests with substantial old trees.

However, this is where the shared understanding ends. Subject of debate are especially which functions should be integrated, how these functions should be realized, and on what level these functions should be combined.

No agreement exists about which functions should be integrated. In the descriptions of Van der Jagt et al. (2000) and Van Raffe et al. (2005), for example, of IFM, it is specifically mentioned that IFM focuses on the three most important functions: nature, recreation, and wood production. Klingen (2005) disagrees with this view. He states that IFM is about the integration of timber production and nature: these two functions are the two that conflict most and IFM solves this conflict success-fully. The recreational value of a forest has nothing to do with the management of the forest itself, but with the provision of recreational facilities, "such as the size of the parking place, and the condition of the walking tracks" (Klingen, 2005). In Klingen's view, therefore, recreation is not part of IFM. Other views include the combination of nature, and recreation (Van Blitterswijk et al., 2001), or add education as one of the functions of forest (PHN and Ministry of LNV, 2005).

Next to a debate on which functions should be integrated, there is also a discussion on how these functions should be realized. Forests fulfilling multiple functions at the same time is for some al-ready enough to be classified under multi-functional management or IFM (AVIH, 2016). However, several authors state that, because forests always fulfil different functions to a certain extent, an integration also implies that forest managers have concrete objectives for these three functions (Van Raffe et al., 2006; Van der Jagt et al., 2000). "It cannot be that a manager has only timber production objectives, with recreation and nature conservation only 'as a by-product'" (Van Raffe et al., 2006, p. 6).

Discussion also exists about the level on which the integration should take place. Some authors state that the three functions cannot be realized equally everywhere and therefore, main objectives per forest stand have to be set (in other words, integration on landscape level). Van Raffe et al. (2006) distinguish between IFM (integration of functions on stand level) and multi-functional management (integration of functions on landscape level). This means that IFM is always multifunction-al-management.

The following two sections are copied and adapted from the article of Hoogstra-Klein, Brukas and Wallin, currently under review with Ecology and Society:

Despite all the discussions on what the concept entails, most forest managers, when asked, would indicate to follow the ideas of Integrated Forest Management (IFM, Geïntegreerd Bosbeheer). In a survey of Blitterswijk et al. (2001) among 413 Dutch forest owners and managers (with areas > 5 ha), 75% of the respondents indicated to apply IFM. The survey, however, showed that in practice "integrated forest management is used in such a broad way that it means different things to every-

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one" (Van Blitterswijk et al., 2001, p. 53), with, a.o., differences in functions integrated, the balance between the functions, and the level of integration.

The results of the study of Van Blitterswijk et al. (2001) are confirmed by the interviews with the forest managers in the INTEGRAL project. The practices of Dutch forest managers can all classified as multiple-use in the sense that different functions are combined, but the practices are diversified: in the functions combined (varying between two and six functions per owner), the focus on these functions (from almost equal focus on functions to almost single use when one function is favoured), and the spatial strategies (from land zoning to integration on stand level, and the combination of these strategies within management units).

6.3. Dutch Forest management approaches for the ALTERFOR project

As the forest management practices in the Netherlands are manifold and not classified according to forest management models, we base our insights on actual forest management practices on:

1) the data gathered in the Sixth Netherlands Forestry Inventory (NBI6), which has been conducted by Alterra, Probos, Silve and Bureau Daamen, commissioned by the Ministry of Economic Affairs (Schelhaas et al., 2014),

2) the Dutch Subsidy Scheme Nature and Landscape (SNL Subsidy Natuur en Landschap),

3) the insights the EFISCEN SPACE model (our DSS) provides.

6.4. Sixth Netherlands Forestry Inventory, NBI6

The Netherlands Forestry Inventory is held every ten years and provides information on the state of forests in the Netherlands and the developments since previous inventories. One of the topics of inventarization is the "management approach" as found at the different sample plots that were part of the inventory. Based on these approaches and the description of these approaches, we selected the ten approaches that a) rank highest as regards the cover and b) cover together 90% of the total forest area. These are listed in Table 28.

Table 25. Management approaches distinguished for the Netherlands, based on data from the 6th Nether-lands Forestry Inventory (Schelhaas et al., 2014).

Dutch name	English translation	Description	%
Grootschalig vlaktegewijze opstand, gelijkjarig	Large-scale management, with regeneration felling, in even-aged forests	Average dbh > 5cm; even-aged on scale > 0,5 ha; cover of understory/2nd canopy layer (dbh > 5 cm) < 50% or basal area understory/2nd canopy layer < 20%	59%
Grootschalig vlaktegewijze opstand, ongelijkjarig	Large-scale management, with regeneration felling, in uneven-aged forests	Average dbh > 5cm; even-aged on scale > 0,5 ha; cover of understory/2nd canopy layer (dbh > 5 cm) > 50% or basal area understory/2nd canopy layer > 20%; age difference with main canopy layer at least 20 years.	14%
Kleinschalig vlaktegewijze	Small-scale management, with	Average dbh > 5cm; even-aged on scale < 0,5 ha; cover of understory/2nd canopy layer	3.2%

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Dutch name	English translation	Description	%
opstand, gelijkjarig	regeneration felling, in even-aged forests	(dbh > 5 cm) < 50% or basal area understory/2nd canopy layer < 20%	
Kleinschalig vlaktegewijze opstand, ongelijkjarig	Small-scale management, with regeneration felling, in uneven-aged forest	Average dbh > 5cm; even-aged on scale < 0,5 ha; cover of understory/2nd canopy layer (dbh > 5 cm) > 50% or basal area understory/2nd canopy layer > 20%; age difference with main canopy layer at least 20 years	1.6%
Kleinschalig ongelijkjarig bos (uitkap)	Single-tree selection system	Average dbh > 5 cm; un-even aged; mixture of age classes on scale < 0,1 ha	1%
Korte omloophout	Short rotation system	Short rotation forest of willow or poplar; mechanically harvested; rotation < 5 years	1.8%
Hakhout/griend	Coppice system	Coppice of hardwoods; on dry soils; rotation > 5 years willow or poplar; mostly on wet soils, rotation < 5 year	
Park-landgoedbos	Parks and recreation	Open forests; architectural design	2.5%
Recreatiebos			
Spontaan bos	Spontaneous forests	-	6.6%
Overig	Other	-	10%
TOTAL			100%

6.5. Subsidy Scheme Nature and Landscape SNL

The Subsidy Scheme Nature and Landscape (SNL) is based on a nature and landscape index. This is a classification system that "aims to unite all management and policy systems in a single system" (CBS, PBL, Wageningen UR (2014)). As described by the CBS, PBL, Wageningen UR (2015):

"Index NL is a typology of natural areas, describing their nature in terms of management types. These management types can be used to regulate the management of natural areas, and constitute a basis for agreements between the provincial authorities and the area managers about tar-gets and resources. A management type is therefore not a specific form of management, such as integrated forest management, but a type of natural area which requires a particular form of management."

For the purpose of management, natural areas in the Netherlands have been categorised into 17 so-called 'nature types', which are based on a combination of abiotic conditions (water balance, trophic status, and environment) and the management carried out. The 17 nature types are subdivided into 47 management types, comprising a description of a specific type of natural habitat, an average package of management measures, with a standardised cost price (CBS et al., 2015).

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Four nature types with 13 management types relate to the forests in the Netherlands (Portaal Natu-ur en Landschap, 2015 – own translation):

N14. Wet forest
- N14.01 Riverine forest
- N14.02 Bog forest
- N14.03 Horbeam- and ash forest

N15. Dry forest
- N15.01 Dune forest
- N15.02 Pine-, oak-, and beech forest

N16. Forest with timber production
- N16.01 Dry forest with timber production
- N16.02 Wet forest with timber production

N17. Forest with high cultural value
- N17.01 Wet coppice and middle forest
- N17.02 Dry coppice
- N17.03 Park and stinze forest
- N17.04 Duck decoy forest
- N17.05 Osier
- N17.06 Coppice on slopes

For all these types, descriptions exist of what the type entails (including historic background, species, soil type, allowed level of harvesting, etc.). The management obligations are in all cases limited to the following (Portaal Natuur en Landschap, 2015 – own translation): "The manager needs to maintain the type. How to do this, is up to the manager."

6.6. European Forest Information SCENario model SPACE (EFISCEN SPACE)

The European Forest Information SCENario model SPACE (EFISCEN SPACE) is a large-scale forest scenario model that projects forest resource development on regional to European scale. For the Netherlands a version is available, which makes use of the national forest inventory data (NBI). The model is able to simulate forest development and management for different scenarios at the scale of 1km^2 (Verkerk et al., 2016).

6.7. FMMs defined for the Dutch forest sector

Based on the three sources described above, we defined 9 FMMs for the Dutch forest sector (Table 29).

Table 26: FMMs defined for the Dutch forest sector in the frame of the ALTERFOR project

FMM	Description	Percentage of area
FMM1	NatureForest Broadleaved	10.4%
FMM2	NatureForest Oak	4.6%
FMM3	NatureForest Pine	7.4%
FMM4	NatureForest Conifers	12.1%
FMM5	Production Forest Broadleaved	11.0%

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FMM6	Production Forest Oak	14.1%
FMM7	Production Forest Conifers	18.3%
FMM8	Production Forest Pine	7.9%
FMM9	Other Forest	14.2%
Total		100%

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7. Portugal

7.1. Background and forest history

After centuries of an intensive forest wood consumption (fuelwood, building of merchant ships and warships) it is well recognized that mainland Portugal reached in the XVIII century the highest level of deforestation. However, in the second half of the XIX century Portugal was the European country that most rapidly reversed the destruction of the forest cover, mainly through plantation programs (adapted from Reboredo and Pais, 2015; Reboredo and Pais 2014; Fernow, 1907; Ribeiro and Delgado, 1868).

Radich and Baptista (2005) showed that the forested area in mainland Portugal increased from 7 % to approximately one third of the territory between 1875 and 2005. It is believed that between 1875 and 1938 the area grew 1.8 million ha mainly through the action of private owners - in the Central and Northern areas with the expansion of Pinus while in the South with the increase of the area of ''montado'' i.e., *Quercus suber* and Q*uercus rotundifolia*.

In the last three decades of the XIX century the area occupied by forests increased from 14 to 22.1 %, while the increase in cultivated land was more pronounced - from 21.3 to 35.1 %. This increase was accomplished through the conversion of uncultivated areas to arable lands (Lains, 1995). These facts were closely related with the demography - between 1864 and 1900, the population increased by approximately 1.2 million inhabitants (Reboredo and Pais, 2015).

During the 1950s and the 1960s, the emergence of the pulp and paper industry was an important factor contributing to the appearance of a new ownership type in Portugal. By then, the demand for pulp from eucalypt was too high for it to be met by family forest businesses and/or by areas with incipient management. Therefore, the pulp and paper industries developed vertically and engaged in eucalypt forest management by both renting and buying forestland. In Northern Portugal, eucalypt often replaced maritime pine deemed as more vulnerable to forest fires (Fernandes, 2008; Feliciano et al., 2015).

In 2010, forests were the main land use in the Portuguese mainland accounting for 35 % of total land area (Figure 1), around 3.15 million ha, according to the last National Forest Inventory (IFN6) (ICNF, 2013). The forest area decreased during the period 1995-2010 at a net loss rate of -0.3% per year. This decrease is related to frequent and intense wildfires. The abandonment of agriculture land (24% of total area) and the increase of shrubland and pasture land (32% of total) are also reported.

There are three major forest tree species in Portugal (Figure 1): eucalypt (Eucalyptus spp.) is the first tree species in mainland Portugal (26% of the total forest area), cork oak (Quercus suber L.) is the second (23%), followed by maritime pine (*Pinus pinaster* Aiton) (23%) (ICNF, 2013). The remaining area is occupied by holm oak (*Quercus ilex* L.) (11%), stone pine (*Pinus pinea* L.) (6%) and other broadleaf and conifer species (17%). A considerable increase in wooded areas (forest stands) with stone pine (+54%) and chestnut (+48%) has been recorded.

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The decrease of maritime pine (*Pinus pinaster* Aiton) and the expansion of eucalypt plantations were the most significant trends in the last decades. The total area of maritime pine decreased 263,000 ha between 1995 and 2010 (-13%). Most of this area changed to “shrub/grassland” (165,000 ha), 70,000 ha changed to eucalypt stands, 13,000 ha changed to urban areas and 13,700 ha were planted with other tree species.

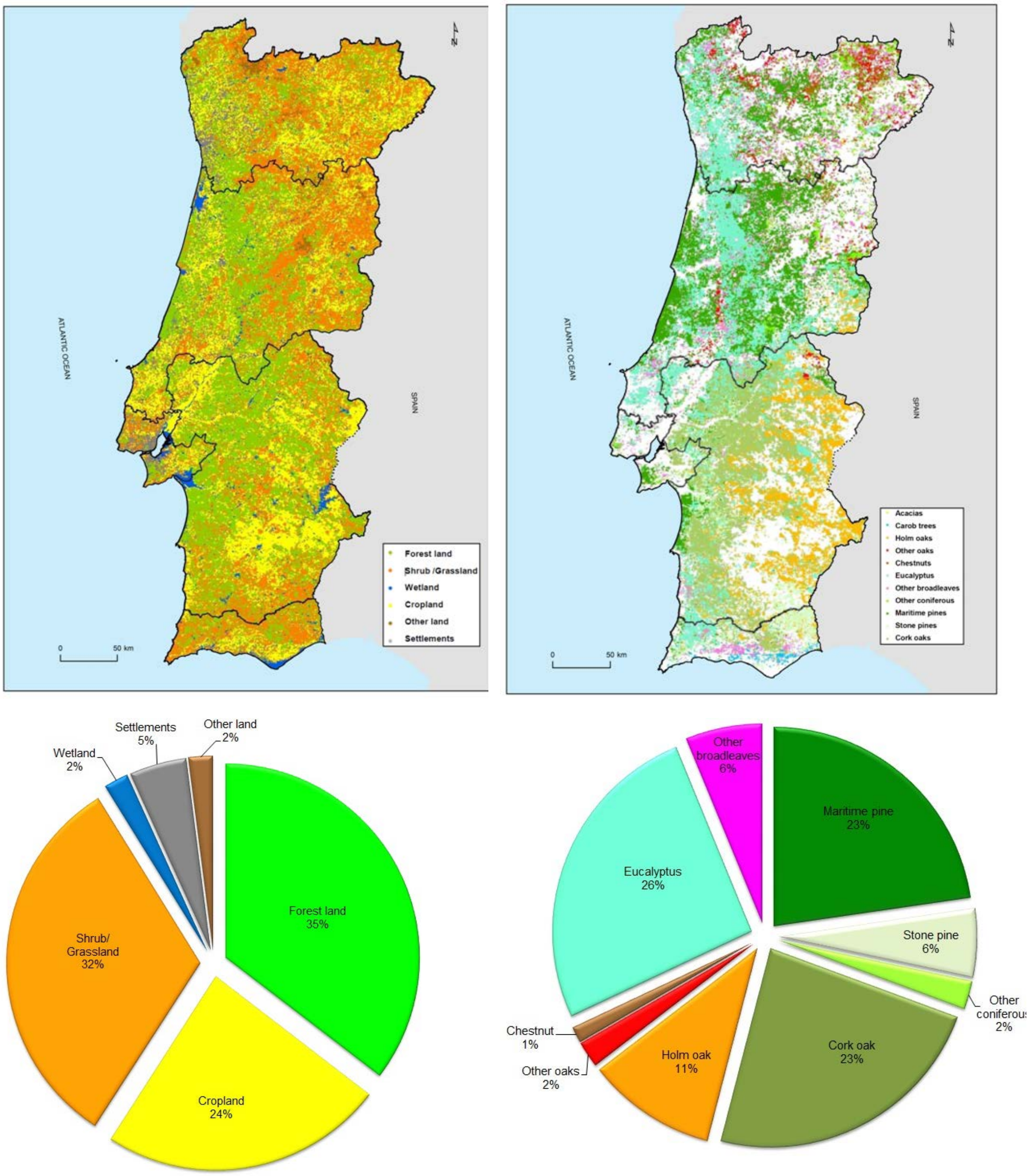

Figure 1. Land use and forest land of mainland Portugal. Source: adapted from ICNF, 2013 and Uva, 2014

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The species composition of Portuguese forests varies across regions. In the South, forest areas consist mostly of montado agroforestry systems, combining cork oak and holm oak with agriculture and grazing activities. In the North and Central regions, forests consist mostly of conifer stands (Pinus pinaster Aiton) and eucalypt stands (Eucalyptus spp.) (pure or mixed). Most Portuguese forests are primarily intended for production functions, not only for roundwood but also for pulpwood, cork and other non-wood forest products. This means that the dominant paradigm associated to forest management is the one giving priority to wood production. However multifunctional management situations can be found, especially in the montado systems, where the dominant production is based on cork extraction, also a valuable non-wood forest product.

In the North and Central regions of mainland Portugal, forest has often low profitability and tenure is highly fragmented. The proximity of forest holdings favours family engagement in forest work, which in turn influences forest management. About 47% of the non-industrial forest owners (small properties) are 70 years old or more and only undertake few types of silviculture practices. They outsource harvesting practices, particularly in the case of eucalypt stands. The forest management models where internalization of silviculture practices depends on family labour are at risk since family labour is decreasing in Portugal, and forest owners are old (Novais and Canadas, 2010). Larger private owners usually live in the city and lease out their lands to tenants or leave them under-used (Feliciano et al., 2015). Forest management is thus often incipient.

Eucalypt (*Eucalyptus globulus* Labill)

Cork oak (*Quercus suber L.*)

Maritime pine (*Pinus pinaster* Aiton)

Holm oak (*Quercus ilex* L.)

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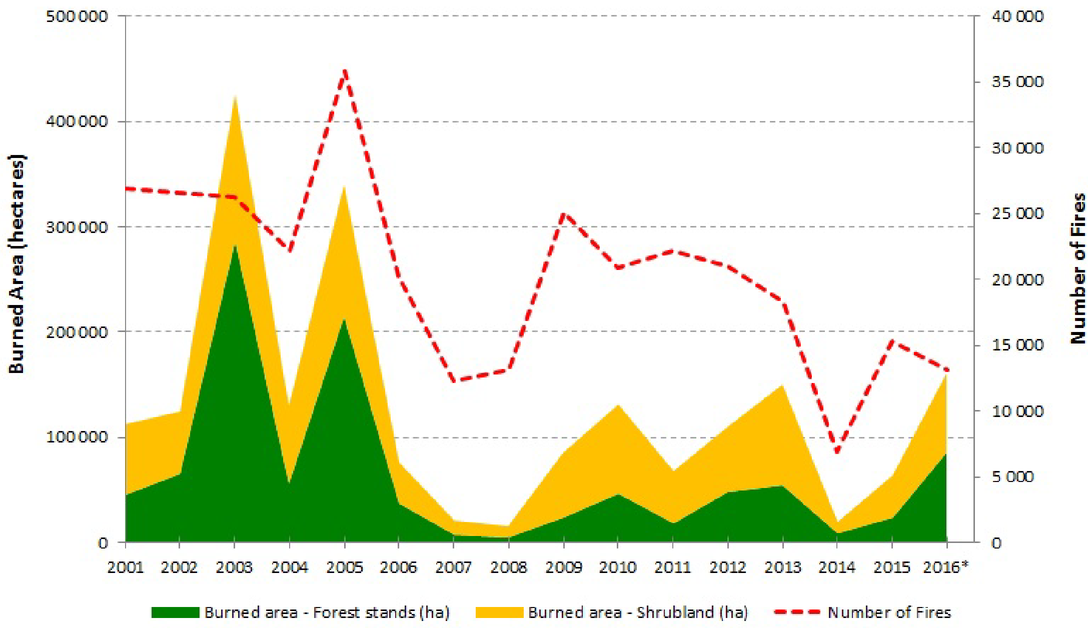
Figure 2.Main tree species in Portugal. Photo: Maria Marques.

In Portugal, wildfires have been common events, with an increasing intensity, since the 1950s. The years of 2003 and 2005 were particularly catastrophic and, since then, fires have been at the top of the agenda of public concern in Portugal. The total burned area exceeded 400,000 ha in 2003 and almost 350,000ha in 2005 (Figure 3). These events have been very important in influencing the forest policy agenda and decision-making process.



*Provisional data

Figure 3. Burned area and number of fires in mainland Portugal (2001-2016). Source: AFN, 2011 and ICFN, 2016.

The Forest Intervention Zones (Zonas de Intervenção Florestal - ZIFs) are joint management areas that must encompass at least 1,000 ha and 50 forest owners and that promote the integration of multiple owners' forest management plans to address wildfire prevention goals (Martins and Borges, 2007; Pinho, 2015). In February 2017, there were 183 ZIF in mainland Portugal, representing more than 21,000 forest owners, responsible for joint management of areas extending over 940,432 ha (ICNF, 2017b) and corresponding to 30% of the country's forest area and about 11% of the country's mainland area. The ZIFs typical tenure heterogeneity derives from the number of ownership types involved e.g., nonindustrial private forests, industry and community/municipalities. ZIFs have a management board that may consist of a forest owners association. This management board is responsible for developing the ZIFs forest management plans. Typically, the management board holds meetings with representatives from each ownership type as well as with representatives from other stakeholders e. g., other non-governmental organizations (NGOs), forest service, to engage them in the development of the plan (Borges et al. 2017). The forest owners with forest stands with-in the perimeter of a ZIF are compelled to follow the forest management plan after its approval by the general assembly of the ZIF and by the National Forest Authority (Fernandes, 2008; Marques, 2011; Valente, 2013; Feliciano et al., 2015).

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Table 27. Data about mainland Portugal and the Vale do Sousa CSA.

	Vale do Sousa CSA4	North Region (NUTS II)5	Mainland Portugal6
Total area (ha)	14,840	2,128,629	8,908,893
Forestland (ha)	14,474	680,659	3,154,800
Forestland cover (%)	97	32	35
Productive forestland (ha)1	14 474	-	-
Productive forestland cover (%)	97	-	-
Average volume (m3ha-1)2	-	-	-
Site productivity (m3ha-1year-1)2	-	-	-
MAI 2011-2015 (m3ha-1year-1)2	-	-	-
Ownership forestland (%) Companies Private Communal and Public	 20 75 5	 - 86 14	 7 78 16
Protected areas (%)2,3	3	24	22

[1] >1m3ha-1year-1

[2] On productive forestland,

[3] Formal and voluntary protection,

[4] The data is reference to 2012,

[5] The data is reference to 2005.

[6] The data is reference to 2010.

7.1.1. Ownership

State ownership represents only 2% of the Portuguese forest land and communal land 14% of the total forest area. Private ownership accounts for 85% of forest land and 70% of it has less than 4 ha, while only 1% of it has 100 ha or more (ICNF, 2017a; Louro, 2015), Table 27 and Figure 4.

In North-ern and Central Portugal most forest holdings are less than 0.5 ha and are occupied by maritime pine and eucalypt. Land tenure is heterogeneous and highly fragmented. The Vale do Sousa Case Study Area (CSA) reflects this situation. Forest estates in the CSA are frequently scaled with dimensions of 1.5 ha and scattered over multiple blocks. The CSA area extends over 14,840 ha distributed over 360 private owners, who are members of the ZIF.

Under these tenure conditions, effective intervention to protect forests and increase its profitability is made possible through cooperation within forest owners associations and through the establishment of partnerships (e.g. ZIFs). This is a precondition for the effectiveness of landscape-level management planning and the sustainability of the provision of ecosystem services. Those institutions support active management and protection of private and communal forests. The Portuguese CSA is characterized by such an institutional framework - an active and representative forest owner association the Vale do Sousa Forest Owners' Association (AFVS, Associação Florestal do Vale do Sousa) and a ZIF.

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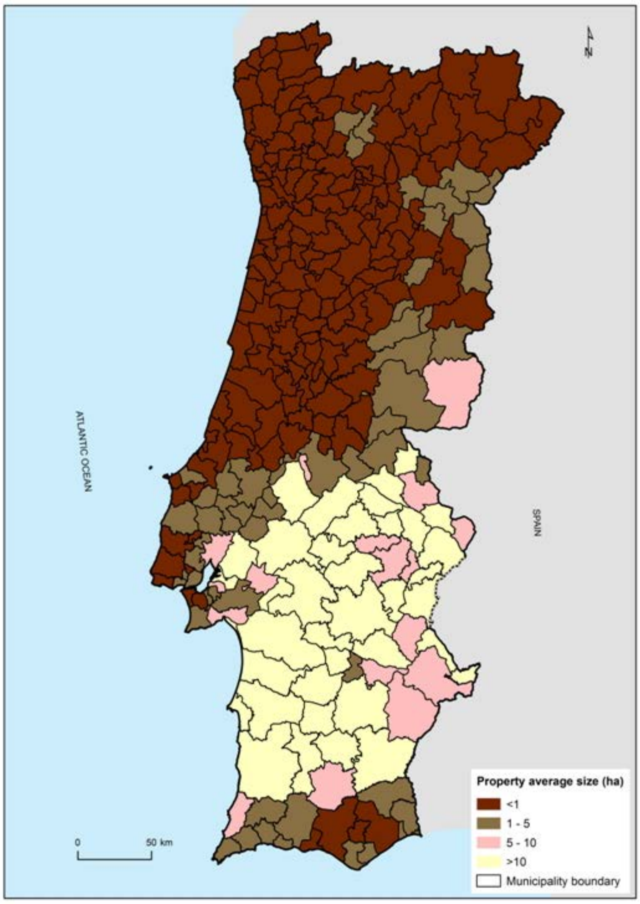

Figure 4. Forest ownership in Portugal. Source: adopted from DGCI, 2006 in EFN, 2015.

7.1.2. Nature conservation

The geographical position of mainland Portugal, covering two biogeographic regions - Atlantic and Mediterranean – leads do ecological diversity. Biodiversity levels are high in 22% of the country's territory. The national protected areas network has the following typologies: National Park (1), Natural Park (13), Natural Reserve (9) and Protected Landscape (2). This network represents 7.5% of the country's territory. All protected areas at the national level have a management plan. The Natura 2000 European network represents 62 sites, of which 60 have already been recognized as Sites of Community Importance (SCIs), and 42 Special Protection Zones (SPAs) (ICNF, 2017a).

7.2. The case study area

The Vale do Sousa CSA covers the southern part of the Sousa Valley, and extends over an area of 14,840 ha corresponding to the following ZIF separated by the Douro river: Entre-Douro-e-Sousa (north of the Douro river) and Paiva (south of the Douro river). The total number of forest owners who are members of these ZIF is 360, but the area mentioned above includes other forest owners who have land inside the ZIF, but are not members yet.

The Vale do Sousa CSA is representative of Portuguese conditions in terms of ownership type and structure as well as of species composition: over 85% of the forest area in Portugal is privately

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owned (mostly by small non industrial private forest owners) and eucalypt and maritime pine are two of the main forest species. Its ecological endowment does not favour the plantation of species dominant in Southern Portugal; cork oak (Quercus suber) and holm oak (Quercus ilex). The difference between the CSA and the entire country regarding the coverage of FMM is thus explained first by its location in Northern Portugal. In this region eucalypt productivity is higher. Further, in a ZIF (joint management area) management is prone to be more active. Nevertheless, since the 80s a clear trend exists of declining pine and mixed pine and eucalypt areas, and of increasing eucalypt areas. Other areas and sub regions are going through earlier stages of the same trend. Moreover, as ZIFs are being actively promoted by public policy the representativeness of the CSA will tend further to in-crease. The CSA sets a model that might be followed by other forest areas and ZIFs in the region.

The Vale do Sousa Forest Owners' Association (AFVS) is the only forest owners' association in the case study area. Therefore, it is the only voice representing the forest owners in the dialogue with public authorities and other stakeholders. It is, also the most important organization providing technical support to forest owners, and the only one having forest sapper brigades to carry on preventive silvicultural works for reducing the risk of forest fires.

The CSA socio-demographical environment is heterogeneous, since it includes two contrasting are-as on both river Douro banks. Municipalities to the North (Paredes and Penafiel), at a short driving distance from the major urban area of Porto are inhabited by many urban commuting residents, while the municipality to the South (Castelo de Paiva) contrast to these as a typical North-Western Portugal rural and lowly populated area with less commuting residents. Also the latter is still losing population while the population in the former is increasing. Nevertheless, as the municipalities to the North of Douro demographically outnumber Castelo de Paiva, the region as a whole is still in-creasing its population numbers.

The Vale do Sousa CSA is managed by the ALTERFOR local stakeholder, AFVS, (Borges et al. 2017) and it encompasses 360 landowners. Community (local parish) property accounts for 35% of the Vale do Sousa CSA. Medium and large private properties (area greater than 5 ha) extend over 60% of the Vale do Sousa area. The remaining 5% is owned by small or very small forest owners. Eucalypt pulp-wood and maritime pine saw logs rank very high in the list of ecosystem services provided by Vale do Sousa CSA. This list also includes hardwood (chestnut) saw logs and carbon storage (INTEGRAL, 2015). The landscape-level FMM results thus from the spatial distribution of stand-level FMM agreed by the ZIF's forest owners. Of concern and being a focus of the research within ALTERFOR is the impact of landscape and stand-level FMMs on the provision of biodiversity and regulatory services (wildfire).

7.2.1. Land Area/ forest area proportions

The Vale do Sousa CSA was chosen for its representativeness of forest management practices and forest ownership structure of the North-Western Portugal forest, were the topography is typically very irregular, the forest estates typically very small scale and scattered over multiple blocs, and are privately owned. The average rainfall is high (last 30 years averaged 1240 mm yearly), but unevenly distributed round the year, with three very dry months (June, July and August) with average rainfall of 31.1 mm, and three very wet months (October, November and December) with average rainfall of 170.4 mm. Soils are mostly poor, well drained and thin. The average

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temperature varies annually between 9.5ºC in January and 20.8ºC in August. The predominant forestry species are Pinus pinaster Aiton and Eucalyptus globulus Labill in pure and mixed stands.

Tree species

In the Vale do Sousa CSA, forestry is the main land use. The CSA has a high productive potential for species with country-wide importance: blue gum/ eucalypt (Eucalyptus globulus Labill) and maritime pine (Pinus pinaster Aiton). Its forests are thus mainly dominated by eucalypt (pure and mixed), followed by maritime pine. The proportion of eucalypt is larger in the CSA than in the country and in the north-west region (Table 31) but is still representative of the sub-region reflecting its high productivity and the decrease of the maritime pine area.

Eucalypt pulpwood and maritime pine saw logs rank very high in the list of ecosystem services provided by the Vale do Sousa CSA. On this, the CSA diverges from other forested areas in North-Western Portugal, where the importance of the eucalypt area is not as important, and maritime pine is more important, but this situation has been changing towards a pattern closer to the situation existing in Vale do Sousa. Gonipterus platensis disease constitutes a major problem for the eucalypt forest in the CSA.

Table 28. Tree Species important in Portugal and the Vale do Sousa CSA.

Species (Latin name)	Proportion (% total volume)			Proportion (% of species area)		
	CSA[1] (Vale do Sousa)	North Region (NUTS II)[2, 3]	Country[3] (Mainland Portugal)	CSA[4] (Vale do Sousa)	North Region (NUTS II)[2, 3]	Country[3] (Mainland Portugal)
Eucalyptus globulus Labill	90.46	16.15	17.27	66.00	13.70	16.38
Eucalyptus globulus Labill **x** Pinus pinaster Aiton	6.22	N/A	N/A	17.00	N/A	N/A
Pinus pinaster Aiton **x** Eucalyptus globulus Labill	3.29	N/A	N/A	16.00	N/A	N/A
Castanea sativa Mill	0.04	2.39	0.65	1.00	3.13	0.70

[1] The data is referenced to 2012. No meaningful changes have been reported by AFVS.
[2] NUTS II.
[3] The data is reference to 2005.
[4] The data is reference to 2010.
N/A: not applicable (there isn't available the information about the dominated species).

7.2.2. Site productivity and tree species

There is a large difference in growth and yield of tree species. On the best sites eucalypt reaches 22-25 meters dominant height in 10 years (Table 30) while chestnut needs 45 years to reach approx. the same height (Table 31) and maritime pine reaches 30 m in 50 years (Table 29).

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Chestnut is mainly growing on the best sites, while maritime pine and especially eucalypt have a more even distribution over all sites.

Table 29. Maritime pine site productivity.

Maritime pine (*Pinus pinaster* Aiton)		
Index value	Height (of dominant trees) at **50 years** (m)	% of area with maritime pine
1 (inferior)	14	5
2 (low)	18	6
3 (medium)	22	28
4 (high)	26	33
5 (superior)	30	29

Table 30. Eucalyptus site productivity.

Eucalyptus (Eucalyptus globulus Labill)		
Index value	Height (of dominant trees) at **10 years** (m)	% of area with eucalyptus
1 (inferior)	13	12
2 (low)	16	24
3 (medium)	19	30
4 (high)	22	24
5 (superior)	25	8

Table 31. Chestnut site productivity.

Chestnut (*Castanea sativa* Mill)		
Index value	Height (of dominant trees) at **45 years** (m)	% of area with chestnut
1 (inferior)	14	0
2 (low)	16	0
3 (medium)	18	23
4 (high)	22	29
5 (superior)	24	49

7.2.3. Forest fires

Wildfires have been very frequent in the three municipalities over which the Vale do Sousa CSA is distributed (Figure 5). There were years with particularly high incidence, such as 2003, 2005, 2010 and 2013, each of these years with more than two thousand hectares of burnt forest area. The year of 2005 was particularly catastrophic. The total burned area in the municipalities of Paredes,

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Penafiel and Castelo de Paiva, exceeded 9,000 ha in 2005 (Figure 6), 57% of this burned area was in the CSA. These were years where the same high incidence of fires also existed all over the country and not only in Vale do Sousa. On the whole, over the period 2001/ 2015 the total forest burnt area amounted to 26,395 ha. Further, there has been a recurrence of one large fire (fire with more than 1000 ha of burnt area) in the CSA almost every two years. These events have had a great influence on management decisions taken by forest owners. They prefer eucalypt stands, because of their shorter rotation and because the income loss is smaller in the case of wildfire occurrence. Other forest species with longer rotations, e.g. maritime pine, chestnut, rank lower in forest owners' preferences.

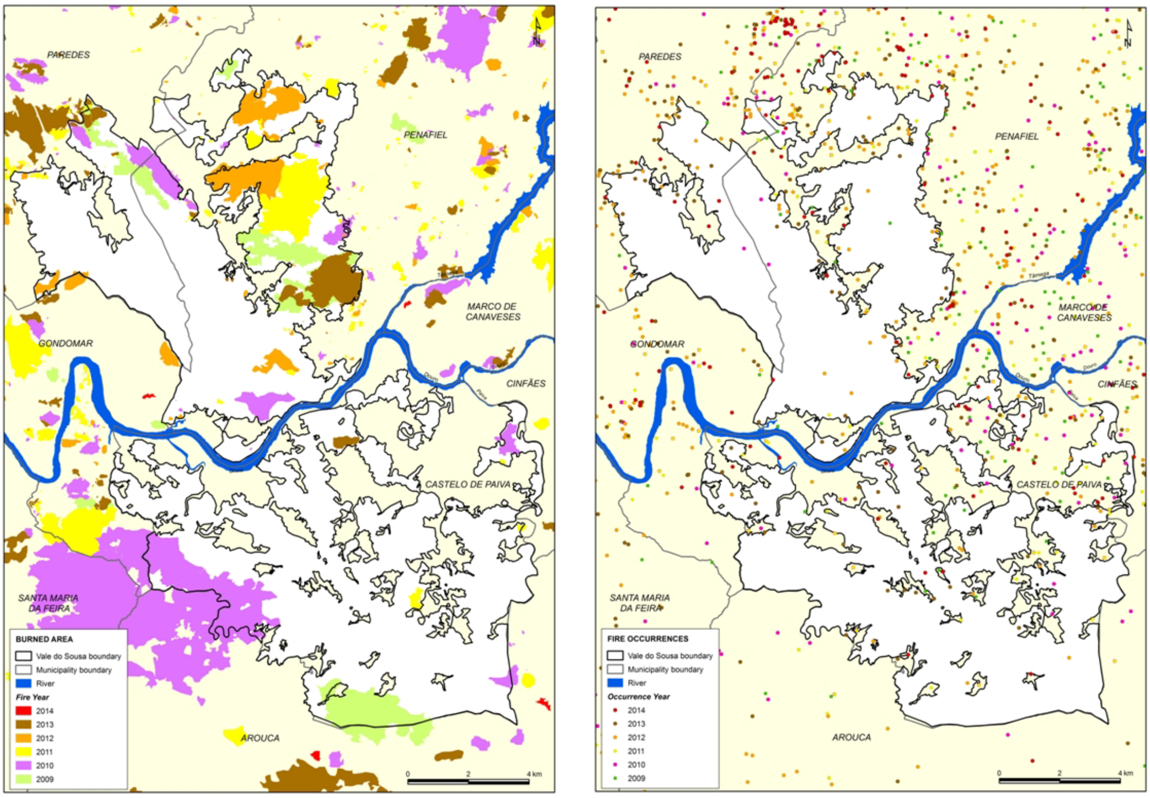

Figure 5. Distribution of burned are and fire occurrences in the Vale do Sousa CSA (2009-2014). Source: ICNF, 2016b.

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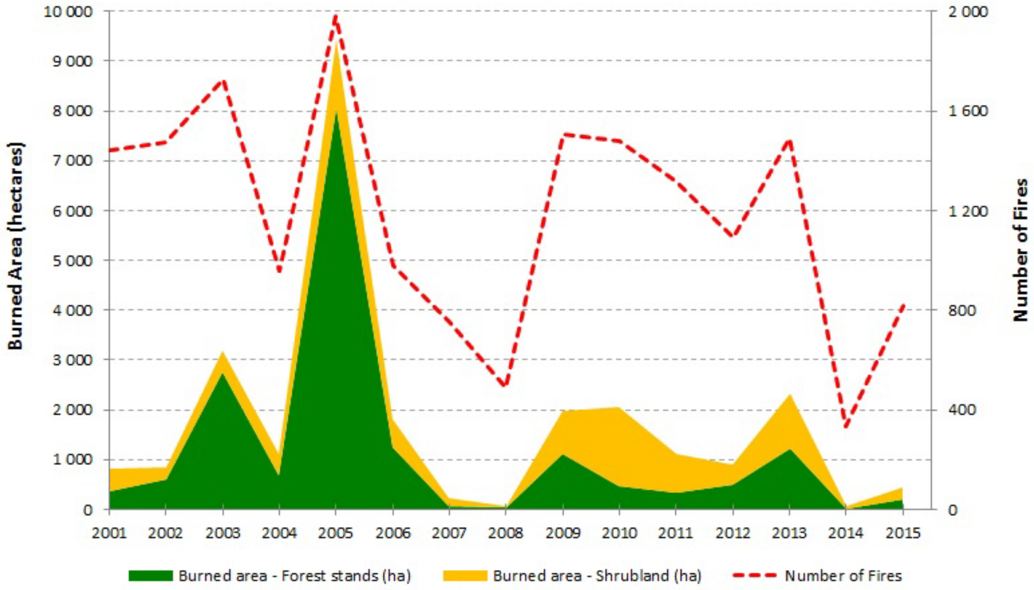

Figure 6. Burned area and number of fires in the municipalities of Paredes, Penafiel and Castelo de Pavia (2001-2015). Source: ICNF, 2016b.

7.2.4. FMMs used in Portugal and in the CSA

Eucalypt is the most important species in terms of distribution area both in Portugal and in the CSA. In pure stands, it covers 2/3 of the area. In a mixture with maritime pine it grows on another 1/3. Chestnut grows on a limited area, approx. 1% Table 32. In terms of volume, the dominance of eucalypt is even more striking, approx. 90% of the volume in the CSA. Of the four FMMs in the Vale do Sousa CSA three encompass eucalyptus. The fourth with chestnut. These four FMMs cover the entire CSA. There are no additional FMMs as other species present are residual.

Table 32. FMMs used in the Vale do Sousa CSA, Portugal.

Domestic name in English (FMM, Forest Management Model)	Corresponding FMM	Coverage CSA (% forestland)	Suggested coverage in CSA (%)	Coverage country (% forestland)
1. Mixed maritime pine and eucalyptus forest system, dominance of maritime pine	Clear cutting systems/ Coppice systems	16.0	3.2	4 - 7
2. Mixed maritime pine and eucalyptus forest system, dominance of eucalypt	Coppice systems/ Clear cutting systems	17.0	5.3	3 - 6
3. Chestnut forest systems for production of chestnut saw logs	Clear cutting systems	1.0	8.9	0.7
4. Eucalyptus forest system for pulpwood production	Coppice systems	66.0	82.5	16.4

Ecosystem services

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The ecosystem services (ES) provided from the four FMMs are mainly wood products, e.g., eucalypt pulpwood and pine and chestnut sawlogs (Table 33).

Table 33. Ecosystem services connected to the four FMMs in the Vale do Sousa CSA. Ranking of important ES within each FMM. No ranking between FMMs.

Forest management model (FMM)	Eucalypt pulpwood	Pine sawn timber	Standing Volume (wood)	Carbon stock storage	Chestnut sawlogs
1. Mixed maritime pine and eucalyptus forest system, dominance of maritime pine	1	1	4	3	
2. Mixed maritime pine and eucalyptus forest system, dominance of eucalypt	1	1	4	3	
3. Chestnut forest systems for production of chestnut saw logs			3	2	1
4. Eucalyptus forest system for pulpwood production	1		3	2	

Size of clearcuts in the CSA

The Tâmega Regional Forest Plan (PROF-T), approved in 2007 by Minister of Agriculture (www.icnf.pt/portal/florestas/profs/tameg), has a recommendation stating that in areas without a Forest Management Plan (PGF) contiguous clearcut areas should not exceed 10 ha. Typically, in the CSA, harvest areas in properties with Forest Management Plans do not exceed 50 contiguous hectares.

For the different FMMs, data about clearcut areas shows that there is a large variation between smallest and largest clear-felled areas (Table 34). In average the largest clear-felled areas are found in the eucalypt FMM.

Table 34. Size of clear-felled area at one-time in the Vale do Sousa CSA.

Forest management model (FMM)	Minimum area (ha)	Maximum area (ha)	Mean area (ha)
1. Mixed maritime pine and eucalyptus forest system. dominance of maritime pine	0.2	47.5	2.8
2. Mixed maritime pine and eucalyptus forest system. dominance of eucalypt	0.1	35.2	2.7
3. Chestnut forest systems for production of chestnut saw logs	0.5	14.8	2.2
4. Eucalyptus forest system for pulpwood production	0.5	100.2	8.2

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Rotation for different FMMs

The minimum rotation period is defined in the Tâmega Regional Forest Plan (PROF-T). Besides that, there is a stipulation stating that an authorization is needed from the National Forest Authority (ICNF) for premature cuts in maritime pine in areas greater than 2 ha and in eucalypt in areas greater than 1 ha (Decree-Law No. 173/88 of 17 May).

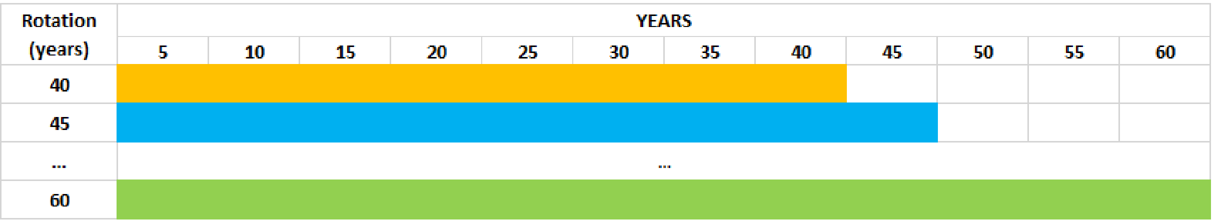

Figure 7. Maritime pine rotation (40 to 60 years).

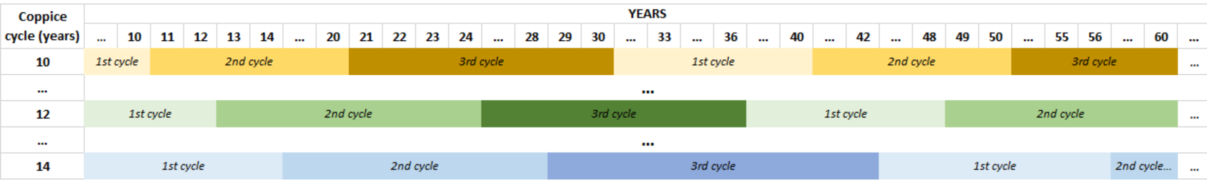

Figure 8. Eucalypt rotation (40 to 70 years).

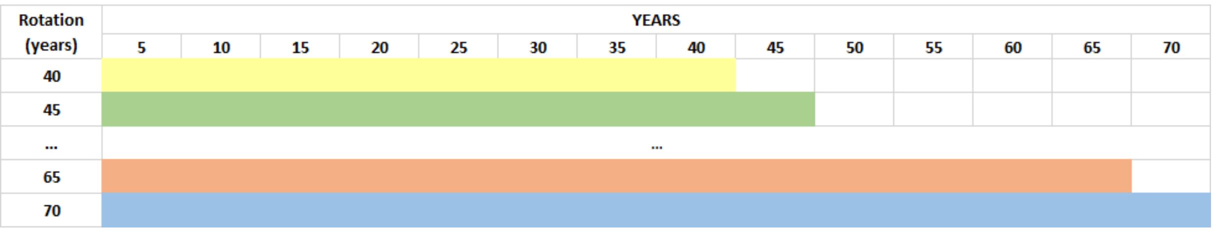

Figure 9. Chestnut rotation (40 to 70 years).

7.3. Mixed eucalypt and maritime pine (FMM1 and FMM2)

Two different models are identified both including a mixture between maritime pine and eucalypt. Maritime pine is dominant, approx. 73% of the standing volume, in the case of FMM1 while eucalypt is dominant, approx. 67% of the standing volume, in the case of FMM2. In many aspects these two systems are similar and are described together below.

Short description

Eucalypt grows fast and typically it is harvested three or more times during one rotation of maritime pine. Therefore, these mixed stands are uneven-aged over most of the planning horizon:

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only after plantation and during the first rotation of eucalypt do the stands have equal age. Stakeholders suggested the conversion to other FMMs (pure even aged stands) to promote active management and enhance productivity.

The area under the two FMMs is thus expected to decrease with conversions to pure stands (even-aged). The system today covers 16% and 17% respectively of the CSA but the recommendation is to decrease the area to about 3% and 5% respectively.

The schedule of forest operations in these FMMs may be summarized as follows:

Maritime pine: Plantation with spacing of 2200 trees per ha (2.25 m between rows and 2 m between plants). The seedlings are in a container with clod. Harvest ages: 40, 45, 50, 55 or 60 years, fuel treatments may take place every 5 years in its share of area, pre-commercial thinning at 10 years of age, commercial thinning occurring every five years in the period from 20 to 50 years of age (up to 5 years before the clearcut) based on a spacing factor (Wilson) of 0.27. Rotation ranging from 40 to 60 years.

Eucalypt: Plantation with spacing of 1400 trees per ha (3.5 m between rows and 2 m between plants). The seedlings are in a container with clod. Fuel treatments may take place every 5 years in its share of area. Rotation including three coppice cycles with 10 to 14 years. Stool thinning leaving an average of two shoots per stool at year 3 of each cycle.

In FMM1 the main species is maritime pine, approx. 8180 m3 (73%) and eucalyptus 3065 m3 (27%). In FMM2 eucalypt is the main specie approx. 14150 m3 (67%) and eucalyptus 7100 m3 (33%).

Size of clearcuts

See Table 34, page 136.

Rotation

There are regulations about rotation length. In practice the optimal stand-level rotation depends on the site index and on financial considerations. In the case of maritime pine, the target tree age ranges from 40 to 60 years, for eucalypt the target tree age ranges from 10 to 14 years, with three coppice cycles. The optimal harvest ages depend on the stand, on the ecosystem service target levels and on the management planning spatial scale (stand versus whole CSA). In practice the variation in rotation lengths is shorter, 45 to 55 years for maritime pine and 30 to 36 years for eucalypt. In the mixed forest the harvests of eucalypt and maritime pine are performed independently, when the species reach the harvest age.

Distribution over edaphic conditions, and performance

There is no information about soil moisture in the CSA. But the two systems may be found in all sites, from sites with low to high productivity.

There is a large difference in performance of the species in this mixture (maritime pine: Table 29, eucalypt: Table 30, page 133).

Mixtures Tree Species and tree species composition

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Mixture of maritime pine and eucalyptus characterize this FMM. The current distribution of standing volume per species in each FMM over the whole CSA was reported above. In individual stands the relations differ somewhat and also over time as eucalypt is harvested thrice, during one rotation of maritime pine.

Forest regeneration

The maritime pine is planted, but some natural regeneration occurs (approximately 10% of the total maritime pine area, according to expert knowledge of Sandra Pinto from AFVS). Maritime pine seeds stored in the canopy are the main source of natural regeneration, particularly in post-fire situations, as the seed bank in the soil is scarce and not very durable. Frequently there is abundant post-fire regeneration from seed in burned adult stands. Adult trees are often killed by fire, depending on the degree of crown and cambium damage, and there is no re-sprouting in the species. So, the typical postfire management is salvage logging of burned trees and either active (plantation or seeding) or passive (natural regeneration from seeds) restoration (Moreira et al, 2017). However, due to the frequency of forest fires in the CSA, Figure 6, the natural regeneration of the maritime pine is becoming scarce in the area, forest owners choose to plant this species.

No site preparation or fencing is done or recommended.

Genetically improved and genetically modified and use of hybrids

Eucalyptus is non-native and the maritime pine is native to Europe and the Vale do Sousa CSA.

Maritime pine and eucalypt seedlings are produced from Portuguese origins that have been selected based on desired traits (e.g. quality); overall they are mostly from sources more than 100 km away from the planting spot. The main sources of seedlings for forest species are defined by National Forest Authority (ICNF): www.icnf.pt/portal/florestas/gf/ps/resource/doc/reg-prov/reg-prov12 (AFN, 2012).

The eucalypt is genetically improved and/ or clone hybrid but not genetically modified. The eucalypts that is genetically improved shows greater adaptability to different soil and climate conditions and higher wood volume and pulp yield. According to CELPA (2017), these plants show a higher growth compared to the unimproved plants (of at least 20 %), besides that improved plants have better straightness of the logs. Hybrid eucalypt results from a rootstock of eucalypt from a variety more adapted to different soils, climate conditions and resistance to diseases, such as Gonipterus platensis, and Eucalyptus globulus Labill as grafts due to its good wood qualities for pulp industry.

Pesticides and fertilizer

Pesticides are applied mainly in the eucalypt trees because of eucalypt weevil or eucalypt snout beetle pest (Gonipterus platensis). The application of herbicides is more unusual, some forest owners apply it for spontaneous plants control and wildfire risk prevention, when the stands are four/five years old.

Fertilizers are applied in all CSA FMMs at the time of planting the trees (eucalypt and maritime pine), in the first two years. In the case eucalypt trees fertilizers are also applied in the second and third cycle when the trees are two/five years old.

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Stand management

Pre-commercial thinning

In practice Pre-commercial thinning (PCT) is done in about 35-45% of the area of maritime pine in this FMMs (local knowledge from Sandra Pinto, forest engineer of AFVS). The eucalypt trees are planted at final density, so thinning and pruning are not usual during the first cutting cycle. In second and third cutting cycle there is a shoot selection on the first three years to get two shoot per stool from eucalypt.

PCT is recommended to be done in 100% of the maritime pine share of the FMM area. Maritime pine pre-commercial thinning should take place at age 10, when the tree differentiation into development classes is taking place to remove dead trees, diseased and poorly shaped trees and in order to reduce stand density. In the case of the eucalypt share of the FMM area, a shoot selection should be done rather than a pre-commercial thinning. This should take place at age 3 of the second and third rotations.

The difference results from incipient forest management by the owners, who often don't make the recommended pre-commercial thinning in the maritime pine area share.

Thinning

Maritime pine thinning occurs every five years between age of 20 up to 50 years and the last thinning takes place 5 years before clear cut.

In practice thinning is done in about 50 % of the share of area of maritime pine in this FMM (local knowledge from Sandra Pinto, forest engineer of AFVS). It is done in 0% of the eucalypt share of this FMM.

Commercial thinning of maritime pine is recommended to be done in 100% of the stands. Maritime pine thinning should take place between 20 and 50 years of age, up to 5 years before the clear-cut, typically with a 5-years interval. Commercial thinning should not be done in the eucalypt share of this FMM area.

The difference results from incipient forest management by the owners, who often don't make the recommended commercial thinning in the maritime pine area share.

Pruning

Pruning is not done.

Harvest

The maritime pine trees are typically harvested using chain saws. A harvester is used only in the case of the eucalypt share of area that is managed by the industry.

Extraction is fully mechanized (100%): skidder in areas managed by the industry and tractor with winch in the remaining areas.

Nature protection

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The maximum contiguous harvesting area is less than 50 ha (see Table 34, page 136) to address environmental concerns with impacts of harvests.

7.4. Chestnut (FMM3)

Short description

This FMM targets the supply of chestnut timber. It provides further carbon stock storage and may also contribute to standing volume at the end of planning horizon. Its contribution to the supply of other ecosystem services (biodiversity and regulatory services) is currently being investigated. The schedule of forest operations in this FMM may be summarized as follows:

Chestnut: Plantation with spacing of 1250 trees per ha. Rotation age at 40, 45, 50, 55, 60, 65 or 70 years, thinning occurring every five or 10 years in the period from 20 to 55 years of age, based on the diameter of the trees. Fuel treatments may take place every 5 years.

At present chestnut management model cover approx. 1 % of the area. The area of mixed eucalyptus – maritime pine stands (mostly uneven-aged) and shrublands may be converted to pure (even-aged) chestnut stands to increase the supply of hardwood saw logs and the potential of the forest to pro-vide recreational opportunities.

Size of clearcuts

General information common for the CSA is given above (see Table 34, page 136). For chestnut the average clearcut area is 2.2 ha with a variation from 0.5 ha up to 14.8 ha.

Rotation

The optimal stand-level rotation age depends on the site productivity. In the case of chestnut it may range from 40 to 70 years. This complies with silviculture rules in the Tâmega Regional Forest Plan (PROF-T) that sets the minimum rotation at 40 years. The optimal harvest ages depend on the stand, on the ecosystem service target levels and on the management planning spatial scale (stand versus whole CSA). There are no mature stands of chestnut yet in CSA, so we don’t know in practice what is the rotation period for chestnut.

Distribution over edaphic conditions, and performance

There is no information about soil moisture in the CSA. Chestnut is assumed to be evenly distributed over Mesic and moist conditions, on high, medium and low productive sites. There is a large difference in performance of chestnut (Table 31).

Mixtures Tree Species and tree species composition

Chestnut is growing in pure stands. In the CSA the standing volume today is 124 m3.

Forest regeneration

No site preparation or fencing is done or recommended. Chestnut trees are typically planted at final spacing, approx. 1250 trees per ha (4 m between rows and 2 m between plants). The planting should be done on deeply mobilized soil or in pits 40 cm deep. The seedlings should have an average height of 40-60 cm and bare root (Correia and Oliveira, 2003).

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

Genetically improved and genetically modified and use of hybrids

Chestnut seedlings are produced from Portuguese origins that have been selected based on desired traits (e.g. quality); overall they are mostly from sources more than 100 km away from the planting spot. The main sources of seedlings for forest species are defined National Forest Authority (ICNF): www.icnf.pt/portal/florestas/gf/ps/resource/doc/reg-prov/reg-prov12

All seedlings are genetically improved but no genetically modification is done.

Pesticides and fertilizer

Application of herbicides is unusual, some forest owners apply it for spontaneous plants control and wildfire risk prevention, when the stands are four/five years old. Pesticides are not applied in the chestnut stands.

Fertilizers are applied in all CSA FMMs, also chestnut stands, at the time of planting the trees and in the first two years.

Stand management

Pre-commercial thinning

Chestnut trees are typically planted at final spacing. Thus, there is no need for pre-commercial thinning.

Thinning

It is recommended that thinning is done in all chestnut stands between age 20 and 55 years, up to 5 years before the clearcut, typically with a 5-years interval.

It has not been possible to carry out thinning's in 100% of the area (local knowledge from Sandra Pinto, forest engineer of AFVS).

The reasons why stand are not thinned are: a) the high mortality of trees in mature stands, caused by Phytophthora cinnamomi, responsible for the ink disease, and by Endothia parasitica., responsible for the chestnut cancer and b) incipient forest management by forest owners.

Pruning

Pruning is not currently practiced.

Harvest

Chestnut stands are typical harvested with chainsaw. Extraction is done with tractor equipped with winch.

Nature protection

The maximum contiguous harvesting area is less than 50 ha (see Table 34) to address environmental concerns with impacts of harvests.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

7.5. Pure eucalyptus stands (FMM4)

Short description

Eucalyptus (Eucalyptus globulus Labill) grows in a coppice system. This FMM targets the supply of eucalypt pulpwood. It provides further carbon stock storage and may also contribute to standing volume at the end of planning horizon. Its contribution to the supply of other ecosystem services (biodiversity and regulatory services) is currently being investigated. The schedule of forest operations in this FMM may be summarized as follows:

Eucalypt: Plantation with spacing of 1400 trees per ha (3.5 m between rows and 2 m between plants). The seedlings are in a container with clod. Fuel treatments may take place every 5 years. Rotation including 3 coppice cycles with 10 to 14 years. Stool thinning leaving an average of two shoots per stool at year 3 of each cycle.

This FMM provides eucalyptus pulpwood but is also carbon stock storage and may also contribute to standing volume at the end of planning horizon.

At present pure eucalyptus cover approx. 66% of the area. It may increase as suggested recently by stakeholders. The actual percentage depends on the balancing of ecosystem services supply targets. he area of mixed stands, mostly uneven-aged, reflecting incipient management, under other FMMs (e.g. FMM1 and FMM2) and shrublands may be converted in part to pure (even-aged) eucalyptus stands (this FMM), to increase the supply of pulpwood.

The estimated volume of eucalyptus is 309160 m3 in the CSA.

Size of clearcuts

General information common for the CSA is given above (Table 34, page 136). For eucalyptus the average clearcut area is 8.2 ha with a variation from 0.5 ha up to 100.2 ha.

Rotation

The optimal stand-level rotation (coppice cycle) age depends on the site index. In the case of eucalypt coppice cycles the optimal rotation range from 10 to 14 years, with three coppice cycles, total-ly 30-42 years. This complies with silviculture rules in the Tâmega Regional Forest Plan (PROF-T) that prescribes coppice cycles ranging from 9 to 14 years. In practice rotation is slightly lower, 10 to 12 years. The optimal coppice cycle as well as the number of cycles depend on the stand, on the ecosystem service target levels and on the management planning spatial scale (stand versus whole CSA).

Distribution over edaphic conditions, and performance

There is no information about soil moisture in the CSA. Eucalyptus is assumed to be evenly distributed over Mesic and moist conditions, on high, medium and low productive sites. Eucalyptus grows fast compared to other species growing in the CSA. Dominant height after 10 year are in the same magnitude as after 45-50 years for maritime pine and chestnut (Table 29 and Table 31, page 133).

Mixtures Tree Species and tree species composition

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

In this FMM eucalyptus is growing in pure stands.

Forest regeneration

No site preparation or fencing is done or recommended. Eucalypt is typically planted at final spacing approx. 1400 trees per ha (3.5 m between rows and 2 m between plants). Seedlings must have between three and five pairs of well-formed leaves, with a height between 10 and 50 cm and a diameter greater than 2 mm.

Genetically improved and genetically modified and use of hybrids

Eucalypt seedlings are produced from Portuguese origins that have been selected based on desired traits (e.g. quality); overall they mainly originate more than 100 km away from the planting spot. The main sources of seedlings for forest species are defined by National Forest Authority (ICNF): http://www.icnf.pt/portal/florestas/gf/ps/resource/doc/reg-prov/reg-prov12

All seedlings are genetically improved and/ or hybrid but no genetically modification is done (see above).

Pesticides and fertilizer

Pesticides are applied mainly in the eucalypt trees because of eucalypt weevil or eucalypt snout beetle pest (Gonipterus platensis). The application of herbicides is more unusual, some forest owners apply it for spontaneous plants control and wildfire risk prevention, when the stands are four/five years old.

Fertilizers are applied in all CSA FMMs at the time of planting the trees and in the first two years. In eucalyptus stands fertilizers are also applied in the second and third coppice cycle when the trees are two/five years old.

Stand management

Pre-commercial thinning

A shoot selection, rather than a pre-commercial thinning, should be done in 100% of the FMM share of area. This should take place at age 3 of the second and third cycles.

Thinning

No thinning is either recommended or done in pure eucalyptus stands.

Pruning

No pruning is done or recommended.

Harvest

Harvester is used only in the case of the eucalypt area that is managed by the industry (about 20% of the total forest area). Extraction is fully mechanized (100%): skidder in areas managed by the industry and tractor with winch in the remaining areas.

Nature protection

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The maximum contiguous harvesting area is less than 50 ha (see above, page 121) to address environmental concerns with impacts of harvests.

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8. Slovakia

8.1. Background and forest history

The history of intentional forest management in Slovakia is very long and extends to 15th century. During the Hungarian Kingdom and Austro-Hungarian Empire very intensive mining activity, over-harvesting, strong agriculture and pasture pressure caused a severe deficiency of wood on Slovak territory.

Due to this, several kings and emperors declared several regulations related to forest protection and utilization. The forest management according to forest management programs (FMPs) for imperial forests was established already at the end of 19th century, mainly due to the existence of Mining and Forestry Academy in Banska Stiavnica which is considered as a first technical university in the Europe.

During the first Czechoslovak republic, the duty to manage the forest was obligatory introduced for all forest owners above 50 hectares. Such important intervention to owner´s rights was mainly motivated by bad state of private forests and emerging concerns about wood availability in the country. The concerns arose from the unregulated utilization of forest sources and increasing demands on wood at international markets and uncontrollable wood trading. The measure lead to more effective forest management, enlargement of forest areas (28 % in 1929 compared to 41 % in 2015, Bavlšík et al. 2010, Green report of Ministry of Agriculture and Rural Development of Slovak republic 2015), steady improvements in health status and quality of forests and steady increase of available stock volumes (171 m3ha-1 in 1970 to 246 m3ha-1 in 2014, Green report of Ministry of Agriculture and Rural Development of Slovak republic 2015).

After 1945, the Czech and Slovak forest management was completely changed in line with the com-plete change of political system resulting to transition from a market economy based on private ownership to centrally planned socialist economy based on nationalization of all private estates. The management style, ideological paradigms, and applied approaches were very similar to Lithuania.

Key features of forest management in socialist era

• No private owners – all forests were owned by the state and were managed by State Forest Enter-prise.

• Planned economy and strict top-down management hierarchy- economic targets for forestry were prescribed by the national planning committee in 5-year cycles and subsequently, forest planning specialists transferred the national targets into forest management plans. The normal age class forest concept was considered as ideal for planned economy. The general economic goal based on normal forest idea was maximized and even-flow production of high-quality timber (furniture, veneer, sports equipment, sawlogs, pulpwood etc). Especially even-flow target was

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important and age class distribution was regulated for each forest management unit (4000-6000 ha) to approach even normal state guaranteeing the evenness of wood harvests. Prevailing silvicultural system was strip or gap clear-cutting system with subsequent artificial regeneration of forest stand by site suitable species compositions. Natural deciduous species compositions were very often “enriched” by more economic profitable conifer tree species.

• Strictly regulated operational management at stand level - forest management plans strictly pre-scribed and controlled silvicultural actions and cutting rules and volumes at stand level. Main forestry paradigm at stand level was idea that environmental conditions, site fertility, current species composition and ecological stability predefine possible actions and economic outputs independent of individual human opinion. The needs of human society were completely prioritized. Based on various environmental surveys, the full utilization of site given potential to produce the wood and other benefits (ecosystem services) strived from forester´s point of view, once again independent of individual needs of any particular person. As the main tool for wood production and quality maximization, sufficiently long rotation periods were used.

• The fulfillment of other ecosystem services except for the wood production (especially these ones that were important for society) were assured through forestland spatial zoning according to the preferred forest functions/ecosystem services. The concept was named functionally-integrative forest management, but the integration of fulfillment of different ecosystem services was achieved at forest management unit level through spatially segregating management.

Forestry in Slovakia after 1990

Although the economic environment was completely changed after 1990, the management of forests through forest management plans, FMP (that elaboration is financed by state) remains an obligatory duty of each forest owner subject. Also, main paradigms at stand levels (environment and state of forests prescribe possible actions) and at ownership unit level (forestland zoning) remain intact. FMP are considered as a main political tool of the state for regulation and control of forest management in order to assure the correct fulfillments of requirements of society. At the same time, the FMP through strict rotation ages states the cutting limits preventing to overharvesting of forest estates (limits determined according to old forestry paradigms).

Three categories/management zones of forests were distinguished according to prevailing ecosystem services: commercial, protection, and special-purpose forests. The protection forests oriented to regulative ecosystem services (water, air, nutrient, natural hazards regulation) and environment protection are given by site and environment properties and are determined by planning authority. Similarly, some special-purpose forests are stated independent to owner opinion, especially if their management orientation is stated by some other acts (e.g. military forests, forests for the protection of water reservoirs, forests for nature conservation etc.). All other forests where regulative or social services are not at risks are primarily considered as commercial unless the owner changes their orientation for some preferred cultural service (eg. recreation, hunting ...).

Thus the FMP sets the amount of allowable cuts and profits to forest owners through three mechanisms: forestland zoning, thinning volume determination and prescription of rotation and regeneration period length. Moreover, sustainability of forest is assured by obligatory duty to

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restore the forest stand on cleared areas up to 2 years by Act on Forests. On the other hand, the many regulations and prescribed actions in FMP had lost their obligatory nature i.e. now they are more recommendations than prescriptions.

Although production-oriented paradigm still prevails in contemporary forest management in Slovakia, the important trend of so-called ecologization of forestry has emerged. Whereas the wood and biomass is the primary source of financial benefits for forest owners, today forest management still primarily oriented to sustainable environmentally admissible economic yield based on timber wood production, but the need to fulfil a broader, more balanced variety of ecosystem services already at stand level has been emphasized in recent years. This trend is clearly related to growing demands of broader public and environmental agencies on forest biodiversity and ecological stability in changing climate.

As a consequence, due to some incompatibilities of Act on Forests and Act on Protection of Nature and Landscape and due to different views on forests from environmental professionals and activists' frequent conflicts and disputes arising about FM. Increased public opinion pressure leads to accepting the certification of forests from many owners in Slovakia. Moreover, milder (mostly shelterwood) silviculture systems linked to natural regeneration of stands are applied as standard (the clearcuts almost excluded from planning and practice). Also, close-to-nature approaches based on selection systems are tested now.

8.1.1. Ownership

After 1990, the restoration of private ownership and transition to market economy and parliament democracy profoundly changed the Slovak forestry paradigms and legislation and affected the Slovak forestry practice. Now, half of the forests are owned by the state and another half belongs to different private or communal owners (municipal, communal, church, cooperative, private, etc.) orientation for some preferred cultural service (e.g. recreation, hunting, etc.).

The ownership structure in Slovakia showed some regional differences, but state and non-state ownership is almost fully balanced. The state owns app. 54 % of forests, non-stated subjects 46 %. Within non-state owners, the communal entities dominate (app. 29 %) followed by municipal (10 %) and private owners (8 %).

As it was already mentioned, the forests are managed irrespective the ownership category by the same forestry legislation demanding the management under state-financed FMP elaborated by authorized planning specialists according to the exact rules following the traditional forests paradigms. Therefore, all owners subjects managed their forests by much unified way – even-aged long-rotation non-uniform shelterwood systems associated with natural regeneration are preferred. At the same time, the realization of pre-commercial thinnings, the volume of commercial thinnings and final cuttings are strictly controlled. The economic profits are environmentally predetermined. Generally, forest management is still primarily oriented to sustainable environmentally admissible economic yield based on timber and biomass production, but nature conservation and biodiversity promotion are taken into account to a greater extent than in the past.

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8.2. Case study area

8.2.1. General about the CSA

The case study area corresponds very well to the average country situation in terms of forest production and environmental/natural conditions (6 out 8th forest vegetation zones occurring at the western Carpathians are covered), but substantial differences exist in ownership structure, species composition and also partly in shares of forest management categories. The relatively favourable terrain and site conditions and long-term human utilization of landscape located relatively close to mining cities contributed to the preference of commercial forests dominated by spruce (especially at pre-mountain and low-altitude locations). At the same time, the forests more distant from human settlements at higher altitudes have a very well preserved species compositions and high bio-diversity that make them an interesting from nature conservation point of view. The ownership structure is a markedly biased toward state ownership, probably due to historical development, when the forests in CSA were an estate of kings or several noble families during the Austro-Hungarian empire for hunting purposes and were nationalized after 1948.

Table 35. General information about forestry in Slovakia and the Slovakian CSA.

	CSA	Slovakia
Total area (ha)	151 768	4 903 397
Forest land area (ha)	94 855	2 014 259
Forestland cover (%)	62.5	41.1
Average volume (m3ha^{-1})	249	246
Site productivity 2014 (m3ha^{-1}year^{-1})	6.5	6.33
MAI 2014 (m^{3}ha-1year^{-1})	3.77	3.72

8.2.2. Ownership, Slovakia and CSA

Table 36. Ownership of forest land in Slovakia and in the Slovakia CSA.

Ownership	CSA, %	Slovakia, %
State	75	40
Communal	18	20.9
Church	0	2.6
Municipal	0.2	8.7
Cooperative	0	0.3
Private	6.8	10.6
Unknown	0	10.6
Protected areas %	1.6	2.5 (57%)[1]

[1]the number in parenthesis represent the ratio of the forest area restricted in some way by nature protection

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Table 37. Forest management categories in Slovakia and in the Slovakian CSA.

Forest management categories	CSA	Slovakia
Commercial forest %	82	71.
Protection forests %	9.6	17.2
Special purpose forests %	8.4	11.2

8.2.3. Tree species in Slovakia and CSA

In Slovakia beech is the most common specie, about 1/3 of the standing volume and spruce the second most important. These two species dominate forest in Slovakia and in the CSA, other species have all less than 10% of the standing volume in the CSA. In the CSA, spruce is the most common, 41% and beech the second most common, 27%.

Table 38. Tree species distribution in Slovakia and in Slovakian CSA (proportion (%) of total volume).

Slovakia	CSA	Region	Country
Species (Latin name)	Proportion (% total volume)	Proportion (% total volume)	Proportion (% total volume)
Picea abies	40.57	20.02	23.73
Fagus sylvatica	27.21	32.11	32.99
Quercus spp.	8.68	19.67	13.16
Carpinus betulus	5.85	9.38	5.86
Acer spp.	3.89	3.05	2.37
Fraxinus excelsior	2.96	1.58	1.59
Abies alba	2.17	3.63	4.02
Larix decidua	1.94	1.41	2.49
Pinus sylvestris	1.67	2.76	6.81
Robinia pseudoacacia	0.74	3.02	1.73
Tilia cordata	0.28	0.44	0.41
Ulmus glabra	0.03	0.03	0.03
Other broadleaves	4.0	2.30	3.70

8.2.4. Growing conditions in the Slovakian CSA

Table 39. Production potential for different tree species and site index.

Species	CAI for growing stock at age 100 years		
	Site index under 24	24-30	over 30
Picea abies	<4,5	4.7-5.5	5.7-6.9

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Abies alba	<4,9	5.1-5.8	6.1-7.0
Fagus sylvatica	<3,9	4.0-4.6	4.8-5.4
Quercus	<2,5	2.6-2.9	3.0-3.2
Pinus sylvestris	<3,0	3.2-3.8	4.0-4.2

Table 40. Production potential for different tree species MAI.

	CAI for total volume production at age 100 years		
Species	under 24	24-30	over 30
Picea abies	<7.7	8.3-10.2	10.7-13.8
Abies alba	<8.6	9.1-11.1	11.8-14.4
Fagus sylvatica	<7.3	7.6-8.9	9.3-10.6
Quercus	<5.2	5.5-6.0	6.2-6.7
Pinus sylvestris	<5.6	6.0-7.3	7.5-8.1

8.3. General about FMMs in Slovakia

In Slovakia Non-uniform shelterwood systems dominated forestry. Clearfelling systems are not used at all. A small proportion is managed with selection systems. There are also some forests with no management/intervention.

Table 41. Summary of FMMs in the Slovakian CSA, corresponding silviculture system, Coverage, % in CSA and Slovakia.

Domestic name in English	Corresponding silviculture system	Coverage CSA, (% forestland)	Coverage Slovakia (% forestland)
1 Mixed beech-oak	Non-uniform shelterwood system	4 %	10 %
2 Mixed oak-beech stands oriented to timber and biomass production	Non-uniform shelterwood system	6 %	17 %
3 Beech stands oriented to high-quality timber production	Non-uniform shelterwood system	4 %	15 %
4 Mixed fir-beech stands oriented to timber and biomass production	Non-uniform shelterwood system	1 %	15 %
5 Mixed spruce-fir-beech stands oriented to timber and biomass production	Non-uniform shelterwood system	1 %	7 %
6 Close-to-nature management in spruce-fir-beech stands oriented to continuous wood and timber production	Selection system	1 %	5 %
7 Spruce dominated stands oriented to timber production	Non-uniform shelterwood system	65 %	23.5 %
8 Specialized management for soil protection	No intervention and/or selection system	9.6 %	13.5 %

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Domestic name in English	Corresponding silviculture system	Coverage CSA, (% forestland)	Coverage Slovakia (% forestland)
9 Nature conservation management without intervention	No intervention	1.6 %	2.5 %
10 Specialized management for water purification	Non-uniform shelterwood system/selection system	6.8 %	1 %

There is a difference in use of FMM between the country and the CSA. The largest difference is the use of spruce. Management of spruce dominated stands oriented to timber production "Non-uniform shelterwood system with spruce", in the case study area this FMM is used on 65% of the forest land and 23 % in entire Slovakia. The main reason for this substantial difference in use of FMM between Slovakia and the CSA is a changed current species compositions in favour of spruce. Many stands on the CSA are spruce dominated. The changes occurred across the different sites, forest vegetation zones and altitudes. Artificial regeneration of spruce and its silviculture promotion (frequently out-side the natural distribution area) enlarged the share of spruce well above the natural level. The main reason is high-volume productivity, better economic profitability and simpler silviculture (lower stem and crown form variability) in comparison to broadleaved trees. In the past, the spruce showed also considerable vitality and regeneration ability on various sites, even outside its natural range, but now the spruce is under strong pressure of the changing climate and natural hazards (drought, windstorms, bark beetle, fungi infestation, browsing).

8.4. Other FMMs in Slovakia

In Slovakia minor additional FMMs are applied for stands with considerable changed tree species compositions, for example, black locust or hornbeam monocultures. Here, non-uniform shelter-wood systems linked to shorter rotation ages (70-90 years) are applied reflecting the faster growth of species, and effort to convert the site-not-suitable and low-profitable (frequently coppice) forests.

Also, selection, permanently uneven-aged forests and other forms of CCF have an application potential, but their actual utilization is a very marginal.

Comments: The information about areas of individual categories and subcategories (management classification into commercial, regulative and socio-cultural forests) were combined with information about areas of forest vegetation zones (environmental /site classifications) in Slovakia in order to estimate the share of potential FMM application at the country level. Source: National Forest Centre, www.forestportal.sk + Green report 2015, Ministry of Agriculture and Rural Development.

8.5. FMMs in Slovakian CSA

8.5.1. Overview

Most of the forest management is classified as non-uniform shelterwood systems. Four (no 1 - 4) are used are used with broadleaves such as oak, beech and two FMMs are used in spruce dominated stands (no 5 and 7). Selection systems are used on small areas with spruce-fir-beech. As

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spruce is the most common tree species in the CSA the most common FMM is non-uniform shelterwood with spruce (FMM 7) that is used on 65% -70% of the area. On 18% of the area managed is focused on soil protection, nature conservation or water shed management. Then no invention is combined with selection cuttings or non-uniform shelterwoods, see Table 41 above.

8.5.2. Common for all models

Origin of trees and seed sources

There is no non-European tree species used, only local species. Approx. 1% of the seedlings are not local, from sources more than 100km distance. For the species *Picea abies, Abies alba, Fagus sylvatica* and *Quercus petraea* there are the forest seeds regions defined in a seed law (Act No. 138/2010) and it is not allowed to transport seeds between forest seeds regions. It is only possible to use seeds from the same seed region and the same altitudinal vegetation zone.

Genetically improved and genetically modified and use of hybrids

No genetically improved or modified seedlings are used. There is priority to conserve the local tree species and original ecosystems.

Herbicides/Pesticides and fertilizers

There are pesticides applied on a small scale usually for application on trap trees (individual trees used to attract bark beetles).

There is no need and use of fertilizer.

8.6. Non-uniform shelterwood systems with broadleaves (FMM no:1-5)

Non shelterwood systems with broadleaves are used in 5 FMMs. Tree species and the vegetation zone are important in choice of FMM, Table 43. FMM1-5 together cover 15% of the area of the CSA at present but it is recommended to increase this area to 63,8% by increasing the amount of broadleaves and reduce the amount of Norway spruce. The main tree species in these FMMs are oak (*Q. petreae*) and beech (*F.sylvatica*).

The five FMMs (1-5) used differs mainly in the conditions where it is used. They are used in beech-fir vegetation zone 2 to 5 respectively. The important difference between the zones is height above sea level, Table 42.

Table 42. Forest management models (FMMs) for broadleaves, some characteristics and ES

FMM	Proportion of CSA, present and recommended	Where, edaphic conditions	Species
1 mixed oak-beech stands wood and biomass production	4% today Recommended 16%	Mesotrophic, lower-to-average quality sites, relatively warmer 2nd beech-oak vegetation zone, sufficiently supplied by water, pre-mountain or low-mountain locations on regular slopes, (200-550 m a.s.l.)	*Quercus petraea Fagus sylvatica Carpinus betulus Acer platanoides Tilia cordata*
2 mixed oak-beech	6%	Mesotrophic, lower-to-average quality	*Quercus petraea*

FMM	Proportion of CSA, present and recommended	Where, edaphic conditions	Species
timber production	recommended 18.6%	sites, 3rd beech-oak vegetation zone, drier or heavy moisture soils, lower-mountain locations not extreme slopes, (250-700 m a.s.l.)	*Fagus sylvatica* *Acer platanoides* *Tilia cordata*
3 beech dominated stands (oriented to high-quality timber provision)	4% Recommende d 29.2%	Mesotrophic, average and good quality sites , 4th beech vegetation zone, soils with normal or slightly above normal water content, mid-mountain locations on regular slopes, (300 - 800 a.s.l.)	*Fagus sylvatica* *Abies alba* *Acer presudoplatanus* *Acer platanoides* *Tilia coradata*
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	1% Recommende d 16.4%	Mesotrophic, medium and high quality sites , 5th fir-beech vegetation zone, soils with optimal water content medium-mountain locations, (650-1150 m a.s.l.)	*Fagus sylvatica* *Abies alba* *Acer pseudoplatanus* *Ulmus glabra Fraxinus excelsior*
5 non uniform shelter wood system in shade – tolerant spruce fir-beech mixed stands	1% recommended 7%	Mesotrophic average-to-higher quality sites in cool 6th spruce-fir-beech vegetation zone on mesic or moisture, water well supplied deeper soils in mid- and higher mountain locations, (850-1200 m a.s.l.)	*Fagus sylvatica, Abies alba, Picea abies, acer pseudoplatanus Ulmus glabra*

The four shelterwood systems used with broadleaves are recommended to be used on much larger areas than present use, an increase from 15 % to 80%, Table 42. The majority of forest stands potentially managed by these FMMs were under negative human pressure for several millennia. The massive harvests, cattle grazing, litter extraction, destruction by fire, conversion of forest to pasture and arable land were present. Today these areas are dominated by spruce, and managed with a shelterwood model described below.

The severe species composition changes in existing stands are clearly evident. Today, original beech-oak species composition exists only at 25 % of the area. Four characteristic deviations from original species composition exist: On better sites, approx. 15 % of the area dominated by beech, 50-60 % and common hornbeam; 30-40%. The largest areas, about 50 %, is transformed to stands dominated by coniferous. Of this 70 % are Norway spruce, Scots pine and European larch and 30 % beech and hornbeam. Common hornbeam 70-75 %, oak (20-25 %) and beech, 0-5 % is growing on not so fertile sites and on the sites with lowest average, about 7 % of the area, black locust and hornbeam are dominating.

The stand structure was changed mostly by incorrect management (shortened rotation length), some areas were converted into coppices in the past and then re-converted to the normal high for-est. Oakwood and biomass were extensively used by local human population for a wide array of needs: from building construction, furniture, heating, mining, charcoal and transformed to agriculture utilization. Many species compositions were “enriched” by coniferous species to improve wood volume production (“economic admixture”), some stands were converted into

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spruce monocultures. In relation to climate change, non-native Black locust (*Robinia pseudoacacia*) is aggressively spreading over the lowest altitudes from Pannonia.

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Ecosystem services

The ecosystem services provided by FMM 1-5 are described in Table 43.

Table 43. Ecosystem services for FMM 1-5, ranking by forest managers.

FMMs for broadleaves in the Slovakian CSA	ES, ranking/priority by forest manager
1 mixed oak-beech stands wood and biomass production	wood production, hunting and game management, landscape protection, recreation, soil erosion control
2 mixed oak-beech timber production	wood and timber production, game management and hunting, landscape protection and planning, recreation, soil erosion control
3 beech dominated stands (oriented to high-quality timber provision)	wood provision, soil erosion control, landscape protection, recreation, tourism
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	wood production, water regulation, soil protection, landscape protection, recreation, biodiversity
5 non-uniform shelter system in shade –tolerant spruce fir-beech mixed stands	wood production, water regulation, soil protection, landscape protection, recreation, biodiversity

Size of stand and management units

In general, the size of harvested area at one time isn`t regulated. The harvested area is indirectly regulated through the volume of allowable cut, fixed to working plan area then, the cutting is recalculated on each management unit (e.g. forest stand). The average harvested area is 1.5 ha, with a minimum of 0,5ha or for sub-compartments 0,3ha, and a maximum of 3ha. Cutting is typical done in strips with a width of strips and distance between them maximum two tree heights. In a large-scale forestry in parts of the CSA the largest harvest area is 5 ha, or in some cases 7,5ha if a complete area of compartments is regenerated. This is done with shelterwood systems and rarely with clearcutting systems.

In these four systems, the size of gaps are maximum 2000m^2 or 0,2 ha.

Rotation period

Rotation age in Slovakia is used to limit annual cuts in the forest. It is a tool for the state to ensure sustainable and balanced annual allowable cuts in the long-term perspective. It was defined based

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on the rotation age of individual species. The rotation age was defined as the age in which the mean annual volume/value increment culminates (Halaj et al. 1990).

The rotation periods are defined for the group of forest site types (i.e. forests with the same species composition growing on similar site conditions). However, recent research showed the high variability of forest production (expressed by site index) inside the individual forest site types (Kulla et al. 2012). The authors suggested defining the rotation period according to site index categories instead of forest site types. The rotation period should also take into account the potential and current status of natural regeneration.

Table 44. Rotation periods for FMM 1-5, "optimal" and in practical used periods.

FMM	"Optimal" rotation age	In practice used rotation
1: mixed oak-beech, wood & biomass production	150+ years	120 years (in case of mono-specific oak forests)
2: mixed oak-beech, timber production	90-150	100-110 for beech and 120 for oak
3: beech dominated stands (oriented to high-quality timber provision)	90-150. The rotation should be more differentiated taking into account the variability in site production potential. It should also better reflect the needs of individual forest owners.	100-110 for beech and 90-100 years for spruce, 100-110 for fir. In mixed forest a weighted mean rotation period is calculated for species-specific ages
4: non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	90-150. The rotation period should be more differentiated into account the larger variability in site production potential. It should also better reflect the needs of individual forest owners.	100–110 for beech, 100–110 for spruce, and 100–110 for fir. For mixed forests, a weighted mean rotation period is calculated from species-specific rotation ages.
5: non uniform shelter system in shade –tolerant spruce fir-beech mixed stands	As for FMM4.	100–110. The rotation for mixed forest stands is calculated as for FMM4.

The currently used rotation periods follow from the work of Halaj et al. (1990) and are prescribed in forest management plans – so there is no legal possibility to deviate from the prescribed rotation periods. There are some exceptions in cases when the health status or current species composition require using lower or higher rotation periods.

The forest in the case study area have been certified under the FSC and PEFC certification systems. Based on this, they keep 3-5 large trees on each harvested area.

Tree species and species composition

FMM 1-5 are all characterize of mixed stands. The species mixture differs and have changed over time. Thousands of years of exploitation by man especially on lower altitudes in the vicinity of human settlements or near agriculture arable land have influenced species and species mixture. Hu-man pressure significantly changed natural species composition, especially due to overharvesting of wood, grazing, and litter extraction.

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Coniferous species were preferred in planting before and after WWII due to their economic profitability. The preference of spruce monocultures instead of mixed stands during 19th and the first half of 20th century is known across Europe. Artificial addition of conifers into broadleaves stands was also characteristic during socialist era and it was justified as “economic admixture”.

Also climate change have most probably effected some species and forest communities, – the pressure of invasive Black locust has been increased in recent years. Some expert discussions about validity of forest site phytocoenological classifications exist – some experts argue that changes in tree species distribution and mixture is rather a result of classification of vegetation zones, e.g. a part of the area classified as 2nd vegetation zone now belongs to 3th zone where beech dominance is characteristic.

The original oak share was significantly reduced in favour of spruce, pine, beech and hornbeam and partly due to black locust invasion. The oak has a higher representation only in mixtures with conifers on better-than-average quality sites.

Areas suitable for FMM1 where originally dominated by oak but the oak presence was reduced by long-term human pressure on the forests in the vicinity of human settlements, preference of spruce and other conifers within artificial regeneration due to economic reasons, high game browsing pressure in naturally regenerated stands and by climate change impacts causing the black locust invasion.

Beech is the most abundant tree species in natural species composition on sites where FMM2 is suitable. The natural species composition is diverse and rather even, so the beech dominance is not very pronounced. The presence of beech in original stands of 3rd vegetation zone on mesotrophic soils varied between 40-50-55 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

The beech share on original species compositions in stands suitable for FMM3 was significantly reduced in the past. Now only small portion of stands is fully beech dominated in accordance to site potential. Large portion of originally beech stands was transformed into spruce dominated stands or even spruce monocultures. The spruce was artificially introduced into many beech stands frequently regenerated by small-area clear cuttings in the past. The higher wood volume production and lower silviculture costs were strived, even at expense of spreading the spruce outside its natural distribution area.

Although some portion of stands suitable for FMM4 has a well preserved natural species composition, majority of stands were converted into spruce dominated ones from economic reasons. The conversions had a greater extent than it was in beech vegetation zone due to great vitality and re-generation ability of spruce. Moreover, some wrong silviculture actions led to conversion to valuable broadleaved composition (elm, ash, maple). The reasons are the same as it was in lower vegetation zones (FMMs1-3): better economic profitability of spruce monocultures, simpler schematic silviculture, more effective mechanized harvests and past preference of small-area clear cuts linked to artificial regeneration – main forestry framework for a planned economy.

All FMMs used in broadleaves are characterized by mixtures with oak and beech as important and dominating species.

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The FMM1 assume prevalence of oak in the species composition. More than 70 years of phytoceonological research in Slovakia revealed and existing old-growth remnants showed that presence of oak in original stands of 2nd vegetation zone on mesotrophic soils varied between 50-65 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009). Today the admixture is larger and the oak component smaller, in more than half of the area oak is less than 50% of the standing volume.

The oak presence in original stands was reduced by long-term human pressure on the forests in the vicinity of human settlements, preference of spruce and other conifers within artificial regeneration due to economic reasons, high game browsing pressure in naturally regenerated stands and by climate change impacts causing the black locust invasion.

FMM2: the most abundant tree species expected in natural species composition is beech. The natural species composition is diverse and rather even, so the beech dominance is not very pronounced. The presence of beech in original stands of 3rd vegetation zone on mesotrophic soils varied between 40-50-55 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009). The presence of beech on higher quality sites is frequently increased above natural level because oak was not intentionally supported by tending. Moreover, oaks as low-productive species was replaced within planting (following the clearcuts applied in the past) by more effective spruce to increase the economic profitability of stands.

FMM3: the most abundant tree species expected in natural species composition is beech. The beech dominance is rather pronounced. The presence of beech in original stands of 4th vegetation zone on mesotrophic soils varied between 50-75 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009). According the survey of actual species compositions of stands growing at 4th vegetation zone, the presence of beech was frequently lowered in favour of spruce (even spruce monocultures exists).

FMM4: the most abundant tree species expected in natural species composition is beech. The beech dominance is not very pronounced due to participation of higher number of tree species on natural composition. The presence of beech in original stands of 5th vegetation zone on mesotrophic, well moist soils varied between 45-55 % (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

FMM 5: the ratio of beech in stands is partly reduced in favour of fir and spruce as more economic profitable tree species. Today mixtures only marginally deviate from natural composition.

Information about actual beech proportions in stands growing on sites suitable for FMM applications was obtained from FMP databases. The dominance of beech in the current stands was lowered by its substitution by spruce.

Why differences? The beech share on original species compositions was significantly reduced in the past. Now only small portion of stands is fully beech dominated in accordance to site potential. Large portion of originally beech stands was transformed into spruce dominated stands or even spruce monocultures. The spruce was artificially introduced into many beech stands frequently regenerated by small-area clear cuttings in the past. The higher wood volume production and lower silviculture costs were strived, even at expense of spreading the spruce outside its natural distribution area.

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Table 45. Tree species distribution in FMM1-5 today and recommended.

FMM	Tree species distribution today	recommended
1 mixed oak-beech stands wood and biomass production	Four types of changed species composition can be found on sites suitable for FMM1 Beech 50-60 %, hornbeam 30-40 % Norway spruce-scots pine-larch 70 % vs. sessile oak-beech-hornbeam 30 % (40 % of the area mainly on better than average quality sites, hornbeam 70-75 %, sessile oak 20-25 %, beech 0-5 % *Robinia sp*. 75-85 %, hornbeam 15-25 % on worse than average sites.	sessile oak 50-60 % beech 20-35 % hornbeam 0-5 % Norway maple 5-15 % linden 5-10 %
2 mixed oak-beech timber production	Today: 66 % of FMM potential area is covered by stands with changed species composition. Four types of changed species composition can be found on sites suitable for FMM beech 95 %- hornbeam 5% (on -13 %of the area) Norway spruce 50, beech 30, hornbeam 10, other 10 (40 % of the area) beech 50 hornbeam 40 sessile oak 10 (6 %of the area) Robina sp. 40% beech 40% Norway spruce 20 (7 %of the area, mainly on poorer sites.	sessile oak 30-40% beech 40-50% Norway spruce 5-10% linden 5-10%
3 beech dominated stands (oriented to high-quality timber provision)	Today the tree species mixture is typical 85 % of FMM potential area is covered by stands with changed species composition. Two types of changed species composition can be found: beech 80-90% Norway spruce 5, maple 5-20 (8.5 % of the area) ii) Norway spruce 50-55% beech 30-40% Norway Maple 10% and Ash 5% (76.5 % of the area)	beech 55-70% , Silver Fir 15-20%,, Sycamore and Norway maple 5-10%, linden/lime 5-10% (Large leaved lime)
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	Today 93 % of FMM potential area is covered by stands with changed species composition. Three types of changed species composition can be found: beech 60-70%, Silver fir 5-20% Maple 10-20% Norway spruce 5% (4 % of FMM area) Norway spruce 70% beech 25% maple 5% (72 % of FMM area) beech 50% Norway spruce 40% Maple 5% Silver Fir 5% (17 % of FMM area)	beech 45-50%, Silver fir 35-40% Norway Maple 5-10%, elm 5-10%,
5 non uniform shelter system in shade –tolerant	Fagus sylvatica 50% maple 30% ash 20%	Fagus sylvatica 40-55, Abies alba 20, Picea abies 10-20, Maple 5-

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spruce fir-beech mixed stands		15, *Ulmus glabra* 5

Although some portion of stands has a well preserved natural species composition, majority of stands were converted into spruce dominated ones from economic reasons. The conversions had a greater extent than it was in beech vegetation zone due to great vitality and regeneration ability of spruce. Moreover, some wrong silviculture actions led to conversion to valuable broadleaved composition (elm, ash, maple). The reasons are the same as it was in lower vegetation zones (FMM): better economic profitability of spruce monocultures, simpler schematic silviculture, more effective mechanized harvests and past preference of small-area clear cuts linked to artificial regeneration – main forestry framework for a planned economy.

Regeneration

Natural regeneration is dominating, % of the area are natural regenerated, but could be even more

Table 46. Natural regeneration in FMM1-5.

	Proportion of natural regeneration today	Recommended proportion of natural regeneration
1 mixed oak-beech stands wood and biomass production	60%	80%
2 mixed oak-beech timber production	60%	80%
3 beech dominated stands (oriented to high-quality timber provision)	70%	90%
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	70%	90%
5 non-uniform shelter system in shade – tolerant spruce fir-beech mixed stands	80%	95%

The main reason of differences between todays proportion of natural regeneration and recommended depends on the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

The soil scarification is done only on area of the harvested strips before seed production. Generally, it is mostly applied in the broadleaves stands and the current proportion in CSA is only 1% of the area, and where the conditions for spring and growth of seedlings are worse. It depends on slope, soil type and stand exposure. Wild boars and their recently increased numbers indirectly help preparing the forest soils for potential natural regeneration.

Browsing and fencing

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It is especially on the south`s exposures near fields with higher

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frequency of game. It should be up to 1% for full-area fencing and for individual protection up to 10 % of the CSA. On the base of available data, the individual tree protection is applied on the 5% of the CSA.

Stand management

Pre-commercial thinning

The pre-commercial thinnings are applied on 90% of area and usually should be done three or four times (each three till five years). All tending operations are done on the base of Forest management plan. For cutting to 50 years of age can be applied by the adjusting of forest manager. This cutting is classified as priority cutting. The pre-commercial thinnings are applied on 70% of area and usually should be done two or three times (generally each five years, with beginning in tenth year of the stand establishment). In two-layer forest stands, the pre-commercial thinning is usually not done in the bottom layer, although they should be.

Commercial thinning

The commercial thinnings are applied on 90% of the area and usually should be done every five to ten years. The volume percentage of thinning is descending with stand age and it ranges between two and seven percent when before the final harvesting.

The volume of thinnings in stands older than 50 years must be specified in Forest management plan and the total volume of the thinning in the stand can be increased by 15 percent at maximum. (in the act No. 326/2005)

Pruning

Pruning might be an alternative on spruce, then approx. 400 spruces per ha is pruned. For other species and models pruning has no meaning and is not done.

Harvest and transport

Harvester technology is used only on 2.5% of the CSA. It is only used in commercial thinning in the coniferous (spruce-dominated) stands and not in broadleaves stands. Fully mechanized by forwarder is 10 % of the area. The forwarder is used for minimizing skidding damages. Forest wheeled tractors and horses are used on 80 % of the area.

As much as 10% of the logging residues are extracted from the forest stands. This is mainly used for wood chips and firewood.

Nature protection

Nature protection is integrated in the forest management plan (description of stands) through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.7. Close to nature management FMM6

Close to nature management is applicable to 2.5 % of case study area. Today the actual share is 1 % (it`s 40 percent of potential area). The model should be applied in beech as dominant tree species

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for 45 to 50 percent, then fir for 35-40% and in minority maple and elm. This forest management model is applied in stands with natural tree species composition at higher quality sites and usually with proportion of spruce 5-10%. Close-to-nature management is preferred management system in the forest management model. Provisioning services and regulating services are the main services, but cultural services as recreation and aesthetic are expected as well. An average rotation period in the range of 120-150 years is prescribed in spruce-fir-beech stands. Natural regeneration can be achieved on 90 % of the area, there is a tendency to continuous regeneration. The soil scarification is done in the forest management model very rarely (up to 1%). The pre-commercial thinnings have been obligatory done each 5 years (usually two or three times). Commercial thinnings should be done every 5 or 10 year (in practice every 10 years), their volumes are prescribed by forest management plan and actual thinning volume after 50 years of stands can exceed the planned volume up to 15 % limit. The utilization of harvesters and forwarders for wood harvests and extraction is marginal (up to 2,5 %)usually use in coniferous. As much as 10% of the logging residues are extracted from the forest stands. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

This FMM is suitable for mesotrophic average-to-higher quality sites in cool 5th fir-beech and 6th spruce-fir-beech vegetation zone on mesic or moisture, water well supplied deeper soils at mid- and higher mountain locations (650-1200 m a.s.l.). Such sites are naturally dominated by shade-tolerant beech and fir mixed with spruce. The main tree species grow in ecological optimum. The FMM can be applied in stands with natural or near to natural species compositions. The management is balanced – continuous wood and timber production is aimed together with maximization of regulation services provision in combination with biodiversity and natural heritage promotion.

Ecosystem services

The ecosystem services are wood production, biodiversity, wood production, biodiversity, nature conservation, carbon sequestration, water, air and nutrition cycle regulation, soil protection, recreation, landscape protection.

Size of management unit and rotation period

This is in individual selection system and the size of harvested area at one time, management unit, are not regulated. The harvested area is indirectly regulated through the volume of allowable cut, fixed to working plan area. Then, the cutting is recalculated on each management unit (e.g. forest stand). (in the act No. 326/2005). The average size of stands where this system is used is 9ha.

For selection silvicultural system is the size of maximal harvested area depend on forest stand are. The cutting is planned for a stand especially thinnings and regeneration cutting together. The allowable cut can be exceeded by 30 percent of total current increment. If gap-like type of the selection system is used, the size of gap depends on mean height of stand with maximum width of two mean heights. Maximum size of gap is 2 000 m2. Total area of gaps together in the compartment is up to 3 ha. (in the act No. 326/2005). The average width of gap in case study area is between one and two mean height of forest stand. (expert judgement).

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No rotation period is used in practice if selection system defined for the forest stand. Harvesting then follows the principles of the selection system. However, there are cases when the forest structure allows applying selection system. Harvesting is based on "rotation age" of individual trees. However, tree level models should be developed and used to define individual tree rotation age. There is an ongoing research aiming to define it, but there are no clear results yet released

Tree species and mixture

The most abundant tree species expected in natural species composition should be beech. The beech dominance is not very pronounced due to participation of higher number of tree species on natural composition. The presence of beech in original stands of 6th vegetation zone on mesotrophic, well moist soils should be around 45-55 % (Zlatník, 1959, Vološčuk, 2000, Rizman et al. 2009). Recommended tree species mixture is; Beech 45-50%, Silver fir 35-40%, Elm 5-10% and Maple 5-10%. The model application is possible only for stands with original compositions and natural structure, therefore no major differences against natural composition is expected

Forest regeneration

Around 95% of the forest area should be established by natural regeneration but is today approx. 90%. Calamities increase the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favorable conditions to establish forest stand and the planting is used instead.

Scarification are not used in this FMM.

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It is especially on the south`s exposures near fields with higher frequency of game. It should be up to 1% for full-area fencing and for individual protection up to 10 % of the CSA. On the base of available data, the individual tree protection is applied on the 5% of the CSA. In practice the protection of stands is done along with commercial thinning, generally by chemical application to individual trees. Only a small part of the protection is done by fencing.

Stand management

The pre-commercial thinnings are applied on 20% of the cutting area and usually should be done two or three times (generally each five years, with beginning in tenth year of the stand establishment).). It is recommended to increase the area of PCT to 50%.

Commercial thinnings are applied on 90% of area and usually should be done every five to ten years. The commercial thinning is the part of selection cutting. The volume percentage of thinning is descending with stand age and it ranges between two and seven percent when before the final harvesting.

Pruning is not used in the CSA. Usually the branches on the coniferous trees are kept till commercial thinning to prevent from debarking by deer species.

Harvesting

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Harvester is not used in this FMM. Fully mechanized by forwarder is 10 percent of the area. The forwarder is used for minimizing skidding damages. Forest wheeled tractors and horses are used on 80 percent of the area. As much as 10% of the logging residues are extracted from the forest stands.

Nature protection

Nature protection is integrated in the forest management plan (description of stands) through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.8. Non-uniform shelterwood systems with spruce FMM7

Spruce should be growing and managed on approx. 0.5 % of case study area, the actual share today is applicable to 65 %. The model should be applied in spruce as dominated tree species for 80 to 90 %, then acer and rowanberry in minority. This forest management model is applied in stands especially with changed tree species composition and minority in original species composition. Non-uniform shelterwood system is preferred management system in the forest management mod-el. In lower extent can be used individual selection system, especially on sites with high degree of nature regeneration. From ecosystem services are made mainly provisioning services and regulating services. The average rotation period is prescribed in Slovak conditions 110 - 150 years (generally lower in the shelterwood system and higher in the individual selection). Natural regeneration can be achieved on 50-90 % of the area (lower in changed stands), there can be tendency to continuous regeneration for a natural stand. The soil scarification isn`t done in the forest management model. The pre-commercial thinnings have been obligatory done each 5 years (usually two or three times). Commercial thinnings should be done every 5 or 10 year (in practice every 10 years), their volumes are prescribed by forest management plan and actual thinning volume after 50 years of stands can exceed the planned volume up to 15 % limit. The utilization of harvesters and forwarders for extraction of wood are mainly in spruce but marginal (up to 2,5 %). Logging residues utilized for a chip wood production and fire wood are extracted from the app. 20 % of stands with final cut-tings and from 100 % of thinned stands. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

Based on environmental survey and management categorization, the FMM area corresponding to a specific site, forest type and selected management orientation is known from current FMP data-bases.

The FMM is suitable for mesotrophic medium and lower-to-average quality sites in cool 7th spruce dominated vegetation zone where trees are growing in harsh mountain climate typical for low temperatures, high humidity, short vegetation period and high annual snowfall on shallow soils in high-mountain locations (1050-1500 m a.s.l.). Such sites are naturally dominated by spruce with small admixture of fir and sycamore. Broadleaved species are severely limited in their growth and are therefore present only sporadically in forests around the bottom range limit. The management is focused on wood and timber production on not extreme slopes and/or soil protection, water regulation and carbon sequestration on more extreme sites.

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The secondary artificial spruce monocultures or spruce prevailing/dominated stands occupying an extensive area outside the spruce natural distribution. Each forest vegetation zone has a significantly changed species composition, the spruce presence was very often favoured instead of original species from economic reasons. The spruce was used as a main tree species within artificial regeneration of stands in the past, but it also shows excellent competition abilities and good natural regeneration potential on many sites outside of its natural distribution today. Moreover, spruce dominance was highly demanded in areas primarily oriented to water purification and protection

Ecosystem services

This FMM produce wood and timber, water regulation, water purification, soil erosion control, carbon sequestration, recreation, tourism.

Tree species

This FMM are used for management of especially spruce but in such stands also Sycamore maple, *Acer pseudoplatanus, Sorbus aucuparia*, and Silver fir *Abies alba* occur.

Size of stand

In general the size of harvested area at one time-point isn`t regulated. The harvested area is indirectly regulated through the volume of allowable cut, fixed to working plan area. Then, the cutting is recalculated on each management unit (e.g. forest stand). (in the act No. 326/2005)

In the CSA the mean area of harvest is 1,5ha. The minimum is 5 ha if it is a compartment and 0,3ha for sub compartment for this FMM.

In the system for spruce, the harvested area is maximum is 3ha. Cuttings are done in strips and the maximal with of a strip is two tree heights and the distance between the two harvested strips is one strip width.

Rotation period

The rotation age is regulated. The rotation period is used to limit annual cuts in the forests. It is a tool for the state to ensure sustainable and balanced annual allowable cuts in the long-term perspective. It was defined based on the rotation age of individual species. The rotation age was defined as the age in which the mean annual volume/value increment culminates (Halaj et al. 1990). An optimal rotation period is 100-150 years (Kulla et al. 2012). The rotation period should be more differentiated taking into account the large variability in site production potential (Kulla et al. 2012). It should also better reflect the needs of individual forest owners. In the CSA it is around 110-120 years. The currently used rotation periods follow from the work of Halaj et al. (1990) and are prescribed in forest management plans – so there is no legal possibility to deviate from the pre-scribed rotation periods. There are some exceptions in cases when the health status or current species composition require using lower or higher rotation periods.

The forests in the study area have been certified under the FSC and PEFC certification systems. Based on this, they keep 3-5 large trees on each harvested area.

Tree Species and tree species composition

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Spruce strongly dominates in this FMM. The dominance of spruce is expected in original species composition. The presence of beech in original stands of 7th vegetation zone on oligotrophic and mesotrophic, well moist soils varied between 90-95 % (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

Today in many stands spruce grow in mixture with other species. The mixtures vary a lot, from spruce dominated to stand where spruce proportion is less than ¼. Experts recommend spruce to dominate (75-95%) and grow in mixture with beech.

The dominance of spruce is expected in original species composition. The presence of beech in original stands of 7th vegetation zone on oligotrophic and mesotrophic, well moist soils varied between 90-95 % (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

Many stands from 2nd-to 6th vegetation zones have species compositions changed in favour of spruce. Due to this high diversity of spruce presence can be found on CSA.

The main reason of differences is the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

Forest regeneration

Around 90% of the forest area should be established by natural regeneration. Currently, around 80% of the area of FMM is established through natural regeneration (available data). The main reason of differences is the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

There is no need to use soil scarification in this FMM.

Browsing and fencing

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It is especially on the south`s exposures near fields with higher frequency of game. It should be up to 1% of the CSA for individual protection. (expert judgement) On the base of available data, the individual tree protection is applied on the 1% of the CSA.

In practice the protection of stands is done along with the commercial thinning, generally by mechanical protection of individual trees.

Stand management

Pre-commercial thinning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The pre-commercial thinnings should be applied on 50% of area and these are a part of selection cutting, (each ten years). All tending opearations are done on the base of Forest management plan. For cutting to 50 years of age can be applied by the adjusting of forest manager. This cuttings are classified as priority cutting. The pre-commercial thinnings are applied on 20% of selection cutting area and usually should be done once. (expert judgement).

The main reason of divergence is usually in smaller number of even age stands. In practice, the pre-commercial thinning is not done in the understory. (expert judgement).

Thinning

The commercial thinnings are applied on 80% of area and usually should be done every ten years. In practice they are done every ten to fifteen years. The volume percentage of thinning near the time of regeneration is increased and it ranges between twenty and twenty 5 %.

Pruning

No pruning is not done and shall not be done in this FMM.

Harvest and logging residues

Harvester is used only on 2,5% of the area of the CSA. It is only used in commercial thinning in the coniferous (spruce-dominated) stands.

For extraction Forwarder is used on 10% pf the area, Forwarder is used to minimize skidding damages. Forest wheel tractors and horses are used on 80% of the area

As much as 70% of the logging residues are extracted in this FMM.

Nature protection

Nature protection is integrated in the forest management plan (description of stands) through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.9. Three FMMs for soil protection, nature conservation and water purification

In Slovakia CSA three forest managing models are used where management goals are other than wood production, for soil protection, for nature conservation and for water purification.

Soil and soil protection, FMM8. App. 9.6 % of CSA should be managed under a special model, FMM8. The forest management model should be applied in beech, oak, fir and spruce stands. There are grown also hornbeam and pine as minority species. These stands are mainly grown on extreme sites with low production mainly with stabile natural tree species composition. The preferred ecosystem service is a regulating service at first (soil protection, landscape protection, water regulation, biodiversity. Selection system is prescribed with average rotation period 150-250 years. The rotation period is generally continuous in this management model. Natural regeneration can be achieved on 90 % of the area. The soil scarification isn`t done (it`s protected in this FMM). The pre-commercial thinnings are done obligatory 10 years (if it`s necessary in better conditions). Commercial should be done every 10 years (in practice every 10-15 years), their volumes are prescribed by the forest management plan and actual thinning volume after 50 years of stands can

exceed the planned volume up to 15 % limit. The utilization of harvesters and forwarders aren`t done in the FMM. Logging residues are extracted for a chip wood and firewood production up to 5 %. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP

Nature conservation and cultural heritages are the main goals for this management model, FMM9, covering 1.6 % of CSA. The model should be applied in beech stands, maple-silver fir -beech stands (for CSA 50 %), spruce-silver fir-beech and spruce stands (25% for CSA). These stands are located in natural protected areas with no intervention management allowed and with the original tree species composition. The preferred ecosystem service is a cultural service at first. The rotation period is not defined and is not relevant. The soil scarification is strictly inhibited in this FMM. No forest management and other interventions are allowed in the FMM. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

Based on environmental survey and management categorization, the FMM area corresponding to a specific site, forest type and selected management orientation is known from current FMP data-bases.

FMM 9 is applied in stable old growth/virgin forests with very-well preserved species composition, uneven-aged structure with diverse horizontal and vertical distribution of trees. The stands do not show any signs of past human activities, have a great biodiversity and presents the natural benchmark for regularly managed even-aged forests. The forests are under 5th degree of nature protection (i.e. national natural reservation), that means they are fully left to self-regulation. Such stands exist in 5^{th}-7^{th} vegetation zone (fir-beech, spruce-fir-beech and spruce zones) at localities more distant from human settlement. The management is focused on nature conservation, natural heritage protection and tourism. The utilization of provisioning services is fully excluded.

Water and water purification, FMM10. On 6.7 % of CSA management is focused on water management. The forest management model should be applied by fir-spruce stands (coniferous) near the water reservoirs, acer-fir-beech stands and acer-fir-beech stands in buffer zone. These stands are mainly grown on sites near drink water reservoirs with different production and tree species com-position. That must be changed to coniferous dominance for better quality of water. The preferred ecosystem service is a regulating service at first (water regulation, soil protection, landscape protection). Non-uniform shelterwood system is prescribed with average rotation period 80-120 years. Natural regeneration can be achieved on 90 % of the area (for stands near reservoir usually planting regeneration). The soil scarification isn`t done (it`s protected in the areas where FMM19 is used). The pre-commercial thinnings are done obligatory 10 years. Commercial thinnings should be done every 10 years (in practice every 10-15 years), their volumes are prescribed by the forest management plan and actual thinning volume after 50 years of stands can exceed the planned volume up to 15 % limit (it is necessary to keep horizontal canopy). The utilization of harvesters and forwarders aren`t done in FMM10 (mainly by horses). Logging residues are extracted for a chipwood and firewood production up to 5 %. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

Ecosystem services

ES are, different from the FMMs described above oriented to other values than wood production, see Table 47

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Table 47. Ecosystem services for FMM 8-10 for soil protection, nature protection and water management.

FMM	Ecosystem services
8. Soil protection	soil protection, natural hazard protection, landscape protection, water regulation, carbon sequestration, biodiversity and natural heritage protection, tourism
9. Nature protection	natural heritage, biodiversity, water and air, nutrient regulation, soil protection, natural hazards protection, recreation and tourism
10. Water management	water purification and quality, soil erosion control, nutrient regulation, carbon sequestration, wood provision

The three management models for soil and nature protection and water management include many different silviculture systems, see Table 48.

Table 48. Characteristics for the three FMM for nature, soil protection and water management.

FMM	Characteristic of Forest management system
8 Soil protection	Selection system
9 Nature protection	No intervention
10 Water management	Non-uniform shelterwood system, also some elements of individual selection system can be applied, especially in close vicinity of reservoirs where very specialized management have to be applied.

Tree species and composition

All three models are characterized by many species in mixture and structure of mixtures depending on Forest vegetation zone. There are some differences between today's tree species mixture and recommended mixture, Table 49.

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Table 49. Tree species in the three models focusing on non-wood products.

FMM	Species Mixture Today Present Situation:	Recommended Specie Mixture on Different FOREST VEGETATION ZONE
8 Soil protection	Forest Vegetation Zone 2, beech (23 % Of FMM Area)	
	1) Oak 40-50% Beech 25-30% Hornbeam 10%-15% Beech 5% (5 % Of FMM Area) 2) *Robina* 35% Hornbeam 30%% Norway Spruce 15% Beech 15% Oak 5% (18 % Of FMM Area)	Oak 50%-55%, Beech 15-20%, Maple 5%, Lime 5%. Hornbeam 5%, *Sorbus torminalis* 5%, Scots pine 10%
	Vegetation Zone 3 and 4 beech and beech-fir (52% of FMM area)	
	Beech 50% Hornbeam 40% Oak 10% (7 % Of FMM Area) 2) Hornbeam 50% Beech 40% Oak 5% Norway Spruce 5% (18 % Of FMM Area) 3) Beech 75% Silver Fir 20% Norway Spruce 5% (3 % Of FMM Area) 4) Beech 50% Norway Spruce 45% Oak 5% (24 % Of FMM Area)	Vegetation zone 3 beech (25% of FMM) Oak 15-40%, Beech 40%-75%, Lime 5%, Maple 5% Vegetation zone 4 fir-beech (27% of FMM) Beech 55-65%, Silver Fir 10%-15%, Maple 5%, Lime 5%
	Forest Vegetation Zone 5 spruce-fir-beech (24% of FMM)	
	1) Beech 70% Silver Fir 15% Maple 10% Norway Spruce 5% (1 % of FMM Area) 2) Norway Spruce 45% Beech 40% Silver Fir 15% (21 % of FMM Area) 3) Beech 55% Norway Spruce 25% Silver Fir 20% (2 % of FMM Area)	Beech 40%-45%, Silver Fir 15-35%, Maple 15-30%, Elm 5%
9 Nature protection Present situation and recommended, no difference	Forest Vegetation Zone 4, Beech-Fir (10 of FMM area) Beech 70%, Silver Fir 20%, Maple 10% Forest Vegetation Zone 5, (50% of FMM area) Beech 40% Silver Fir 30% Maple 20% Elm 10% Forest Vegetation Zone 6, (15 % Of FMM Area) Beech 35% Silver Fir 25% Norway Spruce 20% Maple 10% Elm 10% 7th Forest Vegetation Zone (25 % Of FMM Area) Norway Spruce 80% Maple 15% Sorbus 5%	
10 Water management	In vicinity of reservoirs : (1 % of FMM Area) Norway Spruce 100% In Buffer Zone (4th And 5th Forest Vegetation Zone,) 99 % Of FMM Area) 1) Beech 95% Norway Spruce 5% (8 % Of FMM Area) 2) Norway Spruce 60% Beech 30% Maple 5% Ash 5% (91 % Of FMM Area) 3) Beech 65% Norway Spruce 10% Maple 10% Ash 15% (2 % Of FMM Area)	In vicinity of water reservoirs: Norway Spruce 80%-90%, Silver Fir 10%-20% Forest vegetation zone 4 (70% of FMM area): Beech 55-70%, Silver Fir 15-20%, Maple (Sycamore and Norway) 5-10% Lime 5-10% Forest vegetation zone 5 (29% of the area): Beech 45-50%, Silver Fir 35-40%, Maple 5-10%, Elm 5-10%

Although degree of changes in species composition is lower than in commercial forests, same tendency of increased shares of coniferous species above natural levels is evident. At the same time, the black locust invasion and artificially enlarged shares of hornbeam at low altitudes in beech- oak zone is also obvious. Black locust invasion can be regarded as early sign of climate

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change, increased presence of conifers is probably caused by their spreading on extreme sites from surrounding commercial forests through natural regeneration.

The optimal species compositions are differenced according to distance from water reservoirs and forest vegetation zones (FVZ) existing in buffer zone (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

In the water purification model the share of beech in buffer zone is lowered in comparison to expectations. The reason is intentional promotion of spruce dominance due to better ability to preserve the quality of water. The quickly decomposing broadleaved litter may infiltrate the water by nitro-gen, therefore the beech and other deciduous species are not considered as convenient.

8.9.1. Soil protection model

Compared to other FMM with the wood production as the priority function, the rotation periods in this FMM are much longer with a long regeneration periods. The aim of this FMM is to ensure continuous forest cover and required forest structure to fulfilling non-wood special-purpose forest functions (soil protection – protection against soil erosion, etc.).

The rotation period larger than 150 years is used, depending on species composition and the purpose for which the forest is managed. Although the rotation period is defined, the principles of selection system are applied in this FMM.

The optimal rotation period depends on species composition and site productivity. However, the rotation period has only informative character and is based on the expected life span of species. The main criterion is to ensure continuous forest cover, rather than rotation age or target diameter.

8.9.2. Nature protection model

No cutting is done and rotation period is not relevant.

8.9.3. Water purification model

In this FMM, the aim of the management is to protect water sources from contamination. There are two zones of water protection with different requirements on forest management. The first zone (a) is a narrow belt surrounding the water source. Here the selection cutting with the principles of se-lection system is preferably used. In the zone (b) the normal forest management is mostly applied, so the normal rotation periods are used but taking into account water protection (e.g. gap-size re-generation).

In the study area, the rotation period of 80 – 110 years is used, depending on the health status of the forest stands (especially the spruce stands). In the zone (a), the rotation period should be based on the potential species life span (so should be large) and forest management should ensure continuous forest cover. In the zone (b), the rotation periods should reflect the variability in site production potential. Selection system with target tree diameter should be preferred.

8.9.4. Regeneration

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Only natural regeneration is used in the nature protection where the non-invention model is used. It is recommended that 90% of the new seedlings should be natural regenerated in the models used for soil protection and water purification natural regeneration. Today it is 90%. New forest is established with natural regeneration.

The main reason of differences is the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

Site preparation is not used in any of the three Models, it is not needed and in the nature conservation areas it is forbidden.

Browsing and fencing

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It should be up to 1% for full-area fencing and for individual protection up to 5% of case study area. (expert judgement).

In areas for nature protection no fences are used.

Stand management

Pre-commercial thinning

The pre-commercial thinnings are applied on 30% of area and usually should be done once (generally each ten years). (expert judgement). The pre-commercial thinnings are recommended to be applied on 50%% of area and these are a part of selection cutting each ten years in the model for soil protection. The main reason of divergence is usually in smaller number of even age stands. In practice, the pre-commercial thinning is not done in the understory).

In the areas for water purification the pre-commercial thinnings are currently applied on 70% of area and usually should be done two or three times (generally each five years, with beginning in tenth year). It is recommended to increase the area to 90% of area and usually should be done three or four times (each three till five years). The main reason of divergence is usually in smaller number of even age stands. In practice, the pre-commercial thinning is not done in the understory.

In areas for nature protection no pre-commercial thinning done.

Commercial thinning

The commercial thinnings are applied on 90% of area and usually should be done every ten to fifteen years. The commercial thinning is usually the part of selection cutting. The beginning of regeneration is earlier than in production forest and restoration is longer. The volume of thinning in stands older than 50% years must be specified in Forest management plan and the total volume of the thinning in the stand can be increased by 15 % at maximum.

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The commercial thinnings are recommended to be applied on 90% of the area and usually should be done each ten years till the age of 70 years. Before the time of regeneration cutting (increment thinning) the commercial thinnings are usually not done in practice. The divergences are only at the beginning of commercial thinnings, where the trees with non-commercial parameters are avoided. In some cases, near before the regeneration cutting and when the planned thinning volume is low, thinnings are not done.

No thinning is done in areas for nature protection

Pruning

Pruning is not done in any of the three models. Usually the branches on the coniferous trees are kept until commercial thinning to prevent from debarking by deer species.

Harvest

In the nature protection areas no harvester are used.

In areas for soil protection extraction of timber is done by forest wheel tractor and horses and in areas for water purification some forwarders are used and horses (80%).

Logging residues are extracted up to 70% in soil protection areas and 10% in water purification areas.

Nature protection

Nature protection is integrated in the forest management plans through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.9.5. References

The information collected from the available data of Forest management plans and interviewed of practice experts (P. Kral, M. Rejko, I. Nevolná) from Forests, state estate. Forest management model description was elaborated by R. Sedmak PhD., M. Bosela PhD., J. Bahyl PhD. and R. Smrecek PhD.

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9. Sweden

9.1. Background and forest history

Due to an increase in foreign demand associated with the industrial revolution, the export of wood became an economically lucrative business in Sweden during the 19th century. This resulted in repeated unregulated exploitative cuttings throughout the country. Diminishing timber dimension requirements combined with little care for regeneration meant that the forest state was poor in many parts of the country in the beginning of the 20th century. Emerging concerns over the forest state as well as a future wood-shortage stimulated the establishment of forest regulations and the principle of sustained yield were gradually institutionalized. Improved forest management methods, afforestation of former agricultural-land and transformation of broadleaved forests into productive conifer monocultures in southern Sweden all contributed to a steady increase in the standing stock as well as annual harvest during the 20th century. Forestry in Sweden is today highly mechanized and cost-effective, placing the country among the world leaders on the global wood-market despite its relatively small forest area, low forest productivity and high labour costs. In line with overall production-orientation, the very dominant FMM since the 1950s is the clear-cutting sys-tem, primarily of conifer monocultures. Scots pine are more common in northern Sweden while Norway spruce dominates in the south. Due to the long-lasting stability of current dominant practices, the level of scientific knowledge and practical “know-how” are much more advanced for clearcutting compared with alternative forest management approaches.

The production-oriented paradigm aiming for increased supply of timber for industrial use remained intact into the 1990s. However in 1993, stimulated by the conference in Rio and domestic tension with environmental interests the prevailing forest policy was put into place, stipulating that production goals and environmental goals are equally important. In addition to a steadily in-creasing share of protected areas, this policy shift has resulted in the integration of conservation measures into the management of production stands over the last decades, but in practice the production-orientation remains strong. Today much of the nature conservation activities in forestry are governed by the voluntary market based certification standards (PEFC, FSC), and more than half of the productive forestland is controlled by certified owners. Beyond integrative conservation measures, certified owners need to engage in forestland zoning at estate level to meet set-aside requirements.

9.2. Ownership

For all Sweden 50% of the forest land is owned by private, 25% by a few large limited companies as SCA, Stora Enso and BergvikAB, and 25% by public owners including church, communities and the state own limited company Sveaskog, Table 50. The ownership structure in Sweden shows distinct regional differences, a high proportion of the forest in the north are owned by big companies in-cluding state owned Sveaskog, whereas small-scale private forest ownership dominates in the

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south. Private forest owners in Sweden constitute a strong stakeholder group since a high proportion of them (around 50%) are organized in forest owner associations with their own wood-processing industries. This is especially valid in southern Sweden, where the members of the forest owner association Södra in addition to organizing more than half of the forest area have substantial industrial resources, including large pulp-mills.

9.3. The case study area

9.3.1. General description CSA Kronoberg

The Swedish Case study area is one region, Kronoberg. This is one of the 24(?) regions. The total land area is 840 000ha and 84% is forestland. Kronoberg County has a higher cover of productive forest relative to Sweden. The higher share of productive forest in the CSA express regional differences between southern and northern Sweden. With harsher climate and lower evapotranspiration, the share of unproductive forests increase with increasing latitude e.g. sparsely forested mires, and mountain forest. The forest yield capacity of $9m^3ha^{-1}y^{-1}$ is low compared to European conditions but higher than average for Sweden. For more information about the forest situation see Table 50.

Table 50. Data about Sweden and CSA. Götaland is one of the three "large" regions in Sweden, covering the very southern part. Sources: SLU. 2016. Skogsdata 2016 (Forest data 2016).

	CSA Kronoberg	Götaland	Sweden
Total area (ha)	840 000	8 639 000	40 827 000
Forest land (ha)	704 000	5 447 000	28 184 000
Forestland cover (%)	84	63	69
Productive forestland (ha)1	676 000	5 071 000	23 441 000
Productive forestland cover (%)	80	58.7	57.4
Average volume (m3ha-1)2	142	178	138
Site productivity (m3ha-1year-1)2	9.0	8.7	5.4
MAI 2011-2015 (m3ha-1year-1)2	5.9	7.2	5.3(?)
Ownership forestland (%)			
Companies	3.1	6.7	22.9
Private	75.1	76	49.1
Other (largely public)4	21.7	17.3	28
Protected areas (%)2,3	5-6	6.1	8.4

[1] $>1m^3ha^{-1}year^{-1}$

[2] On productive forestland

[3] Formal and voluntary protection

[4] The major public owner is the state forest company Sveaskog

[5] >10 % crown cover and minimum height of 5 meter

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The area and cover of forestland is based on the international definition of forest, while productive forestland have a production potential of >1m^{3}ha^{-1}year^{-1}. This distinction is of high practical importance because forest management is not allowed in unproductive forests (<>1m^{3}ha^{-1}year^{-1}). The coverage of the different FMMs described in this questionnaire are therefore expressed as their coverage on productive forestland.

Table 51. Proportion (%) of forest land byu productivity and moisture classes on CSA Kronoberg. Productivity expressed as Site Index (SI) for the most producing trees specie, normally Scots Pine or Norway spruce.

Productivity/ moisture	**Site index (SI) m, and Productivity, (m^{3}ha-^{1}y-^{1})**	**Dry %**	**Mesic %**	**Moist %**	**Wet %**
High	SI 30 m - >10 (m^{3}ha-^{1}y-^{1}))	0.7	1.4	5.9	4.5
Medium	SI 24-30 m 5-10 (m^{3}ha-^{1}y-^{1})	1.9	23.3	19.2	7.9
Low	Si<24 m <5 (m^{3}ha-^{1}y-^{1})	0.8	21.8	8.7	3.9

Tree species in Sweden and in the CSA

Scots Pine and Norway spruce dominates forests in Sweden, together around 80% of standing volume. Broadleaves are nearly 20% with Birch as the important specie, Table 52. The CSA Kronoberg have more spruce, about 50% of standing volume, less pine than whole Sweden. Even if the growing conditions for oak and beech is more favourable in Kronoberg than in Sweden the amount of those species is together less than 4 % and among the broadleaves birch dominates heavily Table 52.

Table 52. Tree species, % of standing volume in CSA Kronoberg, in Götaland (southern "Large-region" of Sweden) and in Sweden. Skogsdata 2016.

Sweden Species (Latin name)	Kronoberg (CSA) (% total volume)	Götaland (southern Sweden) (% total volume)	Sweden (% total volume)
Picea abies	49.2	46	41.3
Pinus sylvestris	30.9	30.8	39.3
Betula spp.	12.1	10.8	12.3
Other broadleaves[1]	3.4	5.5	3.8
Quercus spp.	2.6	3.6	1.2
Fagus sylvatica	1.3	2.2	0.6
Exotic conifers[2]	0.2	2.2	1.2
Other noble broadleaves[3]	0.2	1.3	0.3

9.3.2. General about FMMs used in Sweden and in the CSA Kronoberg

In Sweden clear-felling systems are dominating heavily. In practical forestry more or less all forest are managed with clear-felling. The regeneration methods used are planting or natural regeneration, seeding is rather uncommon. In this report the clearfelling system have been divided in three groups, with short, intermediate and long rotation period. The division is dependent on tree species, actually it is more relevant to talk about variations or adaption of a methods to be used with different tree species than clearly separated forest management methods. Intermediate

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rotation period is used for the most important species, Scots pine and Norway spruce, long rotation period only with oak and short rotation period for a number of broadleaves, mainly birch but also alder, aspen and introduced species as hybrid larch.

Except for Beech in the southernmost parts of Götaland, the seed-tree/shelter wood method is almost exclusively associated with Scots pine. Storm damages to seed trees make method very risky to use with many other species including spruce. Seed trees are also used for regeneration of pine stands but as they normally are harvested as soon as regeneration is established, normally within 10 years, the method is regarded as a variation of the clear-felling system. The clear-felling system is adapted also to different tree species and site fertility.

Factors that favour clearcutting and subsequent planting (almost exclusively with Norway spruce) over the seed-tree/shelterwood method: the prevailing high browsing pressure on Scots pine, different advantages associated with Norway spruce (experience, management simplicity, volume production), higher level of competition from vegetation, the higher productivity makes forest owners more prone to invest in active measures.

The clearfelling system is normally not used for areas with high nature values. Management is based to favour nature values. Sometimes this end with no management at all. But for other areas active management are done and include more or less all silviculture operations (tools) and the use of them is dependent on the stand, the site and the nature values. Below all this is presented as one FMM.

Table 53. The FMM used in CSA Kronoberg. There is no statistics about use of FMM in the CSA or in Sweden, the figures in the table is based on statistics on tree species occurrence as it is closely related to FMM and for seed-tree method, information about regeneration methods used.

Silviculture system	**FMM**	**Common & typical tree species**	**Coverage CSA (% forestland)**	**Coverage country (% forestland)**
Clearcutting systems	Intermediate rotation period	Spruce, Pine	83-88 %	72%
	Long rotation period	Oak		
	Short rotation period	Birch, alder		
Seed-tree method/ (Shelterwood method)		Pine	10%	18%
Nature Conservation	With management	“all” species	5-10%	8,4%
	Without management	“all” species		

Protection of forest is achieved through two pathways, formal protection and voluntary protection through forestland zoning at estate level. The lower proportion of protected forest in the CS-area express the fact that formally protected forests are more widespread in northern Sweden. Since formal protection involves economic compensation, the higher productivity in southern Sweden makes it more costly, whereas it is quite effective (in terms of area) to protect low productive and remote areas in the north. Forest protection in northern Sweden has also been facilitated by a higher share of state ownership and the existence of larger areas of old-growth forest.

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9.4. Other FMMs used in Sweden

The forest management models in Table 53 covers the absolute majority of forest land in Sweden and in CSA Kronoberg. There is an active ongoing discussion about different forms of management that can be characterized as continuous forest cover, CCF. It should be considered as an overall frame gathering a wide set forest management methods, that all have in common that they maintain a continuous cover of trees on the management unit (above the retention level required to meet stipulations in the forest act and the certification standards). Overall the use of CCF in Sweden is very marginal, but there is a growing interest especially among municipalities managing forest close to urban areas. The most widely accepted and developed CCF method in Sweden is called *Blädning* and closely resembles the selection system. Ideally it should be applied in multi-layered stands of Norway spruce and aims to maintain a simplified version of the inverted j-diameter distribution. Relying on natural regeneration the only measure involves harvest of mature spruce trees with a cutting cycle of 10-30 years. There also exist other marginal forest management approaches that involve continuous cover, such system has different fancy names such as "*Naturkultur*". The coverage of CCF in the CS area is unknown, but most likely very marginal. It is important to stress that CCF in practice is applied by both owners that manage according to special management schemes for timber production as well as owners where measures are conducted to obtain/maintain other forest functions. For example, a forest owner may have a stand where aesthetical values are prioritized, the management being characterized by thinning operations to yield some firewood and/or to promote an aesthetically attractive stand structure and species composition.

9.5. FMMs in CSA, Kronoberg

The clear-cutting system could be regarded as one management model used for different species. In Kronoberg mainly spruce and pine, but also other species. It could also be described for different species, but here it is divided into three sub-groups based on the rotation length. Short rotations are used for broadleaves, mainly birch but also some aspen and poplars. Clear cutting with intermediate rotation is more or less synonymous with spruce and pine forestry. Long rotation is used for oak in Kronoberg.

Today 81 % of the regenerations areas in Götaland (no statistics for Kronoberg) are planted and 6 % left with no measure according to the most recent statistics (SFA, 2016a). This does not indicate that 6% of the area actively managed in other management models. Many owners hope for natural regeneration with or without success, and then managed the grown up stand with clearcutting methods form pre-commercial stage.

In the context of southern Sweden this is a good proxy (87 %) for the coverage of clear-cutting on forestland managed for wood-production. This gives a clear-cutting coverage on all forestland (including 6 % protected areas) of 82 % in Götaland. However, based on forest management plans (2013-2016) from Södra the clear-cutting system seems to be more wide-spread in Kronoberg compared with the average for Götaland (see question 3 in uniform-shelterwood system) (Magnus Petersson, Södra). We therefore increase the estimated coverage of the clearcutting system on all forestland in Kronoberg to 83-88 %. After excluding clear-cutting short and long (based on

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assumptions of their coverage) we reach an estimated coverage of clearcutting with intermediate rotation of 80-85 %.

There is a discussion about reducing the areas with spruce, (clearcutting and intermediate rotation period). On fertile sites (G32+) with good water availability regeneration with Norway spruce can be replaced with short rotation broadleaved species (*Populus*, Hybrid aspen, *Betula pendula*) or noble broadleaves (e.g. oak). This would also be a suitable risk-spreading strategy considering the likely event of a future with a warmer climate (Felton et al. 2010). On normal forestland Hybrid larch is a suitable short rotation alternative. Considering that Scots pine often are of quite low quality when managed through clearcutting in this relatively fertile part of Sweden, an increased used of shelter-wood systems with Scots pine is recommended if the goal is to produce high quality timber. More-over, an increased utilization of shelterwood systems or CCF (continuous cover forestry) is recommended to facilitate establishment under adverse conditions (frost, high water table, pine-weevils, competing vegetation) and promote other forest functions than timber production.

The level of both theoretical knowledge and practical know-how is much more advanced for the management of the species, pine and spruce, managed with intermediate rotation period compared for other tree species. This implies that it tends to be used as a blue-print alternative, especially clearcutting followed by establishment of Norway spruce. In addition, external factors such as market demand and a high browsing pressure favours this FMM (but Norway spruce rather than Scots pine), because forest owners consider alternatives to be associated with a higher level of risk and uncertainty.

9.5.1. Ecosystem services

Wood production are by far the most important ESs delivered by forests in Kronoberg. Other ESs exist and are the most important for FMM for nature consideration, Table 57.

Table 54. Ecosystem services for FMM in Kronoberg.

FMM	Typical tree species	Ecosystem services
Clearcutting Intermediate rotation period	Spruce, Pine,	Wood for commodity production, biodiversity (the Swedish complementary conservation model, see question 55)
Clearcutting Long rotation period	Oak	Wood production, recreation, biodiversity (equally important)
Clearcutting Short rotation period	Birch, alder	Wood-for commodity production, recreation and aesthetics biodiversity, Cultural services.
Nature consideration With management	"All"	Biodiversity Recreation *Recreation is relatively more important for this FMM compared with nature conservation with no management.*

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Nature consideration Without management		

9.5.2. Rotation period

In forest act (SFA 2016) is stipulated lowest age for final felling. The age depends on specie and site index, Table 56. For other species than spruce and pine the lowest age for final felling for stands where more than 50% of the volume are birch, aspen, alder :35 years; ash: 50 years; beech: 80 years and oak 90 years.

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Table 55. Lowest age for final felling pine and spruce dominated stands according to forest Act (SFA 2016a). Site index; dominant height at 100 years; e.g. Site index spruce (Gran) G12= Hdom=12m, at 100 years total age.

Pine, site index	**T12**	**T16**	**T20**	**T24**	**T28**		
Spruce, site index	G12	G16	G20	G24	G28	G32	G36
Lowest age for final felling, years (total)	90	80	70	65	60	50	45

The ages given in table above is lower than age for maximal production, or culmination of mean annual increment (MAI). The market for Norway spruce is based on bulk-production and there are very low price premiums for quality timber. This, combined with the risk for storm felling with increasing stand height, as well as root-rot means that relatively short rotations are feasible, and this trend have been more clear after the storm Gudrun 2005.

Scots pine: most often forest owner’s clearfell stand at an age 10-30 years higher than according to Table 56. Since there still exists a substantial price differentiation for different qualities longer rotations are feasible. With Scots pine there is also a lower risk of stand degradation (wind, root-rot) with increasing stand age.

Influences on rotation period

The Gudrun storm in 2005 felled 18.3 % of the standing stock in Kronoberg County. Norway spruce was more severely affected, constituting 80 % of the felled volume (Valinger et al. 2006). Gudrun was followed by the storm Per in 2007, which even not as destructive caused additional severe damages. These storms showed that harvest decisions not only are controlled by forest owners and the MARA e.g. 25-30 % of the areas felled in the Gudrun storm in Kronoberg were younger than 60 years (Valinger et al. 2006). Storms is factor that have and will influence the practical rotation age also in the future.

There is no obligation to conduct final-felling in the forest act. The forest owners can therefore decide if, and when to harvest based on their individual objectives. Kronoberg County is dominated by small-scale private forest ownership, owners that overall not are dependent on the incomes from forestry to support their livelihoods. Overall this implies that the rotations tend to be longer than what is optimal from an economical perspective. This can most likely be attributed to a number of factors such as: lack of time, knowledge and interest in forest management, different objectives than maximizing the economic output from forest management.

Deviations in general can also be attributed to factors that are not captured in guidelines for optimal rotation ages. For example guidelines assumes fixed prices, whereas harvest decisions in practice are influenced by market fluctuations

Size of stand and clearfelled areas

In general there is no upper size of clearfelled areas. There exist a stipulation in the forest act stating that properties above 50 hectares are not allowed to have more than 50 % of the productive forestland (>1m^{3}ha-1year^{-1}) below 20 years of age. However this restriction has recently been softened, and all properties are now allowed to have at least 50 hectares below 20 years (SFA, 2016b)

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These restrictions can indirectly restrict the area allowed for clear-cutting. Forest owners do not need to notify (normal forest stands) or seek permission (noble broadleaves) when final-felling smaller areas than 0.5 ha (SFA, 2016b) i.e. in practice the legal border between a gap and a final-felling. The largest clearfelled areas in CSA Götaland is approximately 15 ha (expert judgment Magnus Petersson Södra). The average area was 2.18 ha, of stands notified for final-fellings in Kronoberg 2015. (SFA, 2015a).

Origin of tree species and tree breeding

Tree species described in the FMMs are all European origin. There are some stands in the CSA with introduced tree species, such as Sitka spruce (*Picea sitchensis*), Grand fir, (*Abies grandis*), and larch species, European (*Larix decidua)*, Japanese (*Larix kaempferi*) and most common the hybrid between them. (*Larix x eurolepis*). For pine mostly Swedish provenances are used and for spruce provenances from eastern or north-eastern Europe, like Poland and Belarus. Often seeds are collected in seed orchards established in Sweden. This way of improving trees, tree breeding, is very common in Sweden for pine and spruce, this most often include transport of seeds more than 100 km.

Genetically modified seeds or trees are not used.

Hybrids are used for larch (Larix) and aspen, the hybrid between European aspen and American aspen (Populus tremula x tremuloides). There is no statistics on the use but in total it is very small areas and proportions.

Pesticides, herbicides and fertilization

Pesticides are used to protect conifers seedlings from Pine weevil damage. However, the use of chemical protection has been gradually decreasing due to requirements in the certification standards, where it after a long period with temporarily extended permits recently was banned. This has stimulated a development of different systems of mechanical protection that gradually replace the use of pesticides.

The use of herbicides is formally allowed on forestland, but associated with so many precautions that it is not used in practice.

No fertilization is currently conducted in Kronoberg (SFA, 2015c). Kronoberg County belongs to a region where the Swedish Forest Agency recommend forest owners to not fertilize (SFA, 2016b) and certified owners are obliged to follow these recommendations. In general southern Sweden annually receives a substantial amount of anthropogenic nitrogen deposition and the production gains that can be achieved with conventional forest fertilization (150 kg/N/ha, one or a few times during the rotation) in Norway spruce are much lower compared with northern Sweden. There is however a positive growth response on Scots pine but fertilization is uncommon or not practiced at all in Kronoberg.

Logging and extraction of wood

100 % of the wood harvest in final fellings and almost 100% in thinnings is fully mechanized (Magnus Petersson, Södra). The small reduction is explained by the some very few forest owners perform thinning (or firewood extraction) by themselves using chain-saw.

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A very small number of forest owners might extract some harvested timber by horses and it can now and then be used in stands close to urban areas, "recreation forest" but close to 100% of the wood is transported from forest to roadside by forwarders or forest equipped tractors.

On 46 % of the area reported for final felling in Kronoberg (in 2013) forest owners also reported that they intended to extract logging residues as biofuels (SFA, 2014). Since this only shows forest owners intentions the actual proportion is lower. The extraction of logging residues has decreased since then and we therefore estimate that 30 % are extracted within this FMM. The extraction of logging residues has decreased from its peak in 2010 due to reduced prices. This can mainly be attributed to a lower market demand when heating plants have shifted from burning domestically produced biofuels to imported garbage. In addition, the increasing supply of electricity from wind power has also resulted in an increased production of electricity at the national level, further contributing to the drop in prices.

Nature conservation

The Swedish conservation model relies on a complementary approach, combining protected areas set-aside from timber production with integrative conservation measures in the forest matrix (Gustafson and Perhans, 2010). These measures are mostly conducted at final felling and required according to stipulations in the forest act and in the voluntary certification standards (PEFC, FSC). This involves green tree retention of single trees and groups, leaving as well as creating deadwood (high-stumps) and the retention of buffer zones along water, mires, and sensitive habitats. The requirements are more quantified in the certification standards, where widely known stipulations requires retention of a minimum of 10 trees/ha and the creation of at least three high stumps per hectare (PEFC 2012, FSC 2010). On average 8.4 living trees/ha are retained and 1,5 high stumps/ha are created after final-felling in Götaland (SFA, 2014). When forest owners notify the Swedish Forest Agency that they will conduct final-felling of a particular stand they are required to specify which conservation measures they will take to fulfil the stipulations in the forest act (SFA, 2016b).

9.6. Clearcutting systems intermediate rotation period

An adequate name is also management models for coniferous stands. This is the totally dominating FMM in both the CSA and Sweden.

Characterization of the model

The main objective is production of conifer timber and pulpwood. It involves clear-cutting followed by scarification and planting of Scots pine or Norway spruce. Pre-commercial thinning(s) are often conducted, the main purpose being to reduce the amount of naturally regenerated birch and remove low quality trees. This is followed by commercial thinning. For Norway spruce it is crucial to consider the risk of storm damages, focusing on intensive early removals or reducing the need for thinning through wider initial spacing.

The minimum age for final felling is stipulated in the forest act and depend on the dominant species and site fertility. The high browsing pressure is currently a major problem in the CSA, favouring the establishment of Norway spruce at the expense of Scots pine.

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Considering that the CSA is dominated by forest owners that overall not are economically dependent on the incomes from forestry it is not surprising that deviations from the ideal exists for all different management activities. Neglected pre-commercial thinning is probably the major concern, having a strong negative effect on the economic outcome in subsequent commercial thinnings.

Tree species and stand composition

Tree species are mainly Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) but admixture of broadleaves becomes more common as certified forest owners need to retain a small proportion (> 10 % FSC, > 5 % PEFC) of broadleaves throughout the rotation (PEFC 2012, FSC 2010).

In general this FMM involves planting of monocultures of Scots pine or Norway spruce directly or a few years after final felling. However the characteristics of the nemo-boreal ecosystem means that additional naturally regenerated seedling, especially birch, establishes after clearance. The forest management ideal, stipulated in the widely adopted certification standards requires that a certain proportion of broadleaves. In general this implies that a typical production stand that meet certification standards should have approximately 10 % volume proportion broadleaves and 90 % conifers, mostly consisting of the conifer species originally planted. To facilitate management simplicity, the forest owner association Södra recommend forest owners to gather the broadleaves in groups and/or along stand borders. This is also applied by the state forest company Sveaskog (Personal communication with Johan Rowell, Planner of pre-commercial thinning at Sveaskog), who owns substantial areas of forests in Kronoberg (58,900 hectares productive forestland).

On sites that are typical for Kronoberg, i.e. average fertility and good water availability Norway spruce is normally the first alternative due to high production. However, substantial proportions of the forestland are also suitable for Scots pine (average/low fertility and a bit drier soils).

The tendency to plant Norway spruce on areas better suited for Scots pine is a consequence of the high browsing pressure, especially by moose. This makes regeneration with Scots pine problematic or impossible in large parts of Kronoberg County.

Regeneration

The clearcutting systems with conifers rely on artificially regenerated seedlings. These seedlings, most often spruce, have superior growth and (often) survival compared to local seed sources. Nursery seedlings have a better nutritional status (nursery effect), their performance have often been improved through breeding programs (selecting for desired traits like growth) and they have sometimes been selected from special regions and Norway spruce originating from Belarus or north-east Poland are often used.

A small amount of seedlings originate from natural regeneration, but the occurrence is uneven and difficult to predict. A lot of naturally regenerated birch generally establish after felling. The regeneration inventories performed by the Swedish Forest Agency do not discriminate between naturally regenerated and planted seedlings. The forest act states a minimum number of seedlings at a certain time after harvest, for Kronoberg typically 2000-2800/ha, the number differ depending on specie and site quality. The proportion of broadleaves in the regenerations in Götaland is 27 % (SFA, 2016a), which is a good proxy for naturally regenerated birch considering the marginal role of

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planted broadleaves. However, a high proportion of the naturally regenerated birches is most often removed in pre-commercial thinning (approx. down to 10 %). This estimation is based on retention of naturally regenerated birches and use of additional naturally regenerated conifer seedlings.

Scarification

Today scarification is used on approximately 70 % of the clear-felled areas. Based on statistics of regeneration methods and scarification in final-fellings in Götaland (SFA, 2016a). This figure includes both clear-cuts that been planted and clear-cuts where no regeneration measures have been conducted. The scarification share for plantations is 74 %. 100 %.

There are many arguments to increase scarification to 100% of the regeneration areas. Scarification is an important measure that increases the likelihood of establishment success. It results in an increased initial growth of the seedlings through better nutritional status (nutrient release when the soil is disturbed, reduced competition from vegetation) and reduced mortality (e.g. frost, pine-weevils, water-logging). Pine-weevils are the major agents causing mortality in conifer plantation, and with proper protection (mechanical or chemical) seedlings can often be planted without scarification. However, scarification is still needed to achieve optimal stand development.

Browsing and fencing

Except during a short period (2006-2010) after the Gudrun storm, when forest owners could receive subsidies for fencing stands designated for naturally regeneration of Scots pine (Wallstedt, 2013), there have never been subsidies available to support fencing of conifers. Fencing is therefore excluded as a potential measure due to the high costs. 0 %

With the current level of browsing the establishment success of Scots pine plantations in Kronoberg would benefit from fencing, and in some areas it is most likely decisive. However, fencing is a very costly measure, involving costs for establishment, maintenance and removal. This cannot be economically justified considering the long rotations and relatively low volume production of Scots pine. In addition, a widespread use of fencing would not solve the problem with browsing damages but rather redistribute the browsing damages to other areas.

Stand management

Pre-commercial thinning

Pre-commercial thinning is decisive measure for the economic performance. It is especially important for the economic outcome of the first commercial thinning i.e. whether or not it yields a net income. Pre-commercial thinning in planted coniferous stand is normally not reducing the density of planted seedling but much more reducing the competition from natural regenerated birch, and controlling the tree species distribution. In some cases, birch are preferred.

There is no data available for Kronoberg. An estimate is that75% of the area is pre-commercially thinned at least once. This figure is based on statistics from Götaland, calculated from the amount of pre-commercial thinning performed on the permanent sample plots of the national forest inventory. This figure was used in the most recent nationwide simulation of the future forest state and associated ecosystem services (Claesson et al., 2015).

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Commercial thinning

Nearly all spruce and pine stands are thinned at least once, most common two or three times. Recommendations for thinning have changed over the last 100 years. Commercial thinning has been an integral part of the Swedish clearcutting-system for a long period of time, there is therefore a tendency to see commercial thinning as self-explanatory measure, disregarding evident risk factors in individual stands.

After the storm 2005 changes in management regimes are discussed; wider initial spacing, less frequent thinnings esp. in the later part of the rotation, reduced rotation period.

In Kronoberg, wood-purchasers and forest management planners, especially from Södra play a big role in promoting thinning among private forest owners. With large-pulp mills Södra represents an organization with a continuous demand for pulpwood. A demand that will increase in the near future due to recent investments. To maximize the profits of the cooperative it is therefore in their self-interest to obtain their pulpwood from relatively cheap small-dimension wood harvested in thinning. Since other organizations sell pulp-wood to Södra and other industrial actors this also affects the advice they provide to forest owners.

Pruning

Pine very rarely are pruned. It is a time consuming and/or expensive measure. The relatively small price differentiation (compared with oak) for different qualities of Scots pine combined with uncertainties regarding future market demand means that it is uncertain that an investment in pruning will pay-off. Moreover, shelterwood systems with natural regeneration are less demanding alternatives for owners that want to produce high quality timber of Scots pine.

For Norway spruce pruning is not even a measure to consider, the risk for fungi and the not existing difference in prize for timber with different properties.

9.7. Clear cutting system with long rotation period

The only specie in Kronoberg with a long rotation is oak. Oak currently constitutes 2.6 % of the standing stock on forestland in Kronoberg County (SFA, 2014). A lot of oak dominated stands are set-aside from timber production due to their high biodiversity and aesthetical values, especially among private forest owners to fulfil the certification requirements (5 % of the productive forestland set-aside from timber production) (FSC 2010; PEFC 2012). This is supported by a study performed by the Swedish Forest Agency, showing that areas classified as noble broadleaved forest constitutes 20 % of the area voluntary set-aside in Götaland (i.e. far higher than the overall proportion of noble broadleaves forest) (Stål et al. 2012). In addition, oak is an admixture species within conifer forest. We therefore estimate the 0.5-1 % coverage of oak dominated stands managed for timber production in Kronoberg County.

On the very best sites (G32++) with good water availability the proportion of oak could increase at the expense of Norway spruce. In addition, this is a suitable alternative for forest owners that want to afforest abandoned agricultural land. Overall, compared with Norway spruce, Oak yields much lower economical incomes, but an increased use is still desirable due to a wide range of other benefits. An increased use of Oak would increase the perceived beauty of the forested landscape. It

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also serves as a suitable risk-spreading strategy considering the risks of storm damages and in the likely event of a future with a warmer climate (Felton et al. 2010). An increase in actively managed oak forests will yield a positive impact on biodiversity, moving the species towards its natural occurrence in southern Sweden (Lindbladh et al 2014). Finally, Oak constitutes the most dominant species among the noble broadleaves and there is a market demand for timber for flooring industry and also for high quality timber.

The level of both theoretical knowledge and practical know-how is much more advanced for the clearcutting system with the native conifers. Oak forestry aiming for high quality timber is management intensive with long-rotation periods i.e. forest owners might therefore regard this FMM as to complicate. The long rotations also make it ill-suited for forestry investments based on economic calculations such as the Faustman-formula, which is a common method when comparing different alternatives within Swedish forestry. In addition, in a region (and country) with a conifer dominated market there are also uncertainties regarding the short- and long term market demand. Finally, according to the current legislation forest owners need to maintain the dominance of noble broadleaves (see intro) in noble broadleaved stands (SFA, 2016a) i.e. regeneration with noble broadleaves is mandatory. A fear of reducing the management freedom for future generations might therefore be a factor that makes forest owners reluctant to establish oak on new sites.

With a historical perspective it is evident that the current proportion of Oak (and broadleaves) is much lower than the “natural level”. This is due to a large number of factors (see Lindbladh et al 2014). Large areas of broadleaved forest in southern Sweden have been lost due to clearcutting followed by establishment of conifer monocultures. Agricultural land also expanded at the expense of broadleaves, and when abandoned, mostly during the last 100 years, they were largely replanted with Norway spruce. The current legislation aiming to safe-guard the existence of noble broadleaves also in the future was established in 1974 and 1980, initiated by a fear that forest of noble broadleaves would be largely lost from southern Sweden (Enander, 2007).

Characterization of the model

Here it is classified as a clearfelling system. There is a lack of data regarding how oak forestry is conducted in practice. In general our overall impression is that ideal Swedish model for management of oak seldom is conducted in Kronoberg County. At this overall level it is most likely so that a lot of oak stands in practice are managed somewhere in between clear-cutting and shelterwood systems. Involving extended rotations and gradual removal of the old-stand in many thinning operations. This can be due to aesthetical values or other forms of individual attachments to particular stands, but can also have an economical rationality. If oak timber is of high quality it is currently the best paid assortments on the market. Given that a stand has an uneven diameter distribution, it can be a good idea to embrace a single tree perspective rather than making decisions based on stand averages (e.g. mean diameter), which is the common practice in Swedish forestry. Gradual removal of single trees when they reach high grading quality can therefore make the rotation period less distinctive.

Tree species and stand composition

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In Sweden there are two species of oak, Quercus robur and Quercus petreae. Both grows in Kronoberg but most common is Quercus robur. Seedling found on the market are most often Quercus petreae.

Stand are normally established by planting or seeding without any admix species. Due to its high value for biodiversity in southern Sweden there are no requirements to have any additional tree species in Oak plantations, neither in the forest act nor in the certification standards. However to achieve high quality timber it is recommended to retain understory trees as quality enhancers (reduce the emergence of epicormics branches), this can involve trees that naturally act as understory e.g. Hazel, Beech, but not are so competitive i.e. Norway spruce. Light demanding trees (e.g. Alder, Birch) can also be used if they are high cut to prevent competition with the crowns of the Oaks.

First of all, according to the legislation the only requirement is that the volume proportion of broadleaves are kept > 70 %, whereof > 50 % noble broadleaves for the stand to remain as noble broadleaved (SFA, 2016a) i.e. there is no obligation to adhere to a management ideal for Oak according to the legislation. On the relatively fertile sites where Oak is growing there is a potential for natural regeneration and good performance of a wide range of species including other noble broadleaves (see intro), trivial broadleaves (alder, birch, aspen) and Norway spruce.

Overall, admixtures with other species is therefore a result of: forest owners using naturally regenerated trees to compensate mortality on planted seedlings, poorly implemented pre-commercial thinning and/or thinning, forest owners that strive for species mixtures due to a wide range of factors (e.g. aesthetical preference, the value attached to having many tree species, quality enhancing understory).

Rotation period for oak

The lowest age for final felling according to the forest act is 90 years but most often the rotation is longer or much longer. The ideal management of Oak should aim at producing high quality timber of large dimensions within the shortest rotation period possible. Planted at fertile sites and with an intensive thinning program, 50-100 crop/trees should reach the target diameter (+60 cm) within 100-140 years of age. Reducing the rotation period is critical for the economic outcome but it is the not possible to get large dimensions and high prizes.

The ideal management program of oak is seldom applied in practice. Too low site fertility and the lack of intensive thinning programs imply that the timber seldom reaches the high grading dimensions within the optimal rotation period (in addition the timber often being of quite poor quality). As described previously, if not set-aside from timber production, Oak stands are also often retained due to aesthetical preferences, the management been characterized by thinnings. Overall this means that Oak forestry is characterized by longer rotation periods than economically optimal and the rotation is often less distinctive compared with other FMMs.

Regeneration

Natural regeneration of oak is not used in Sweden or CSA Kronoberg. (not including naturally regenerated understory tress retained to enhance the timber quality).

Oak is planted or seeded, but a naturally regenerated trees also establish after final-felling, especially naturally regenerated birches. However, a substantial proportion are removed in pre-commercial thinning. We estimate a lower use of naturally regenerated seedlings for this FMM compared with conventional methods (clear-cutting intermediate). The higher risk of mortality (different forms of browsing i.e. ungulates and rodents, competition from vegetation) being compensated by a wide range of factors such as:

Since new plantations of Oak are relatively rare forest owners are probably very orientated towards favouring the Oaks over other species (and they are also required to do so according to the legislation).

The current legislation implies that forest owners are obliged to maintain the dominance of noble broadleaves (SFA, 2016a). Since this force forest owners to regenerate with species with high establishment costs the legislation is supported with subsidies (SFA, 2016b). The subsidies covers 80 % of the regeneration cost (scarification, planting, fencing). The ideal is therefore to utilize the subsidies and plant seedlings from selected proveniences available in nurseries. These proveniences have been selected based on desired characteristics (e.g. quality) and should consequently be favoured throughout the rotation.

When establishing oak on former agricultural land direct seeding can be a suitable alternative regeneration method (not possible on forestland due to seed predation of rodents).

Site preparation/scarification

Site preparation or scarification is very common when establishing oak stands, most probably close to 100%. The proportion of actively regenerated Oak stands that are scarified are most likely much higher compared with regeneration of conifers. Scarification is relatively cheap compared with the costs of oak seedlings and fencing. Subsidies are also available for all establishment measures for oak (SFA, 2016b). In addition, forest owners need to apply for permission for final-felling and financial support to the Swedish Forest Agency (SFA, 2016a). This means that regeneration of noble broadleaves involves a much higher level of exposure to forest consulting compared with conventional methods, and consultants are well-aware of how critical scarification is for regeneration success.

To achieve high quality timber within economically justified rotations Oak should only be planted on fertile sites. On such sites competition from vegetation can be very heavy. Radical scarification is therefore decisive to reduce competition from vegetation and associated problems with rodents. When planting oak on former agricultural land a radical scarification should ideally be complemented with the application of herbicides to further increase the likelihood of regeneration success.

Browsing and fencing

The prevailing high browsing pressure constitutes a big problem for forestry in Kronoberg, especially for Oak that are among the most preferred species by browsers. Utilizing the subsidies that are available for fencing (SFA, 2016b) is therefore critical for regeneration success. The subsidies for fencing therefore constitutes a critical policy instruments, currently maintaining forest management with Oak somewhat economically justified for private forest owners. Fencing is more or less necessary for establishing oak, and it is most often done.

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Stand Management

Pre-commercial thinning

The management scheme for Oak aims at producing high quality timber within the shortest possible rotation. Pre-commercial thinning is an important measure for a number of purposes:

- Removal of competing naturally regenerated trees

- Removal of low quality Oaks i.e. quality selection.

-Early stand density manipulation. Oak is often planted at high densities (e.g. 5000 seedlings/ha), and even though a high spacing is required to achieve good quality (trunk with no branches) pre-commercial thinning is still recommended to give a decent level of diameter growth.

Subsidies are also available that covers 60 % of the costs for pre-commercial thinning (SFA, 2016b).

Estimated that precommercial thinning one or more times are done on the absolute majority of stands.

We estimate a higher level of pre-commercial for this FMM compared with clear-cutting intermediate. Firstly, this is related to the higher initial spacing. Secondly, this FMM is much more demanding compared with management of conifers. We therefore assume that forest owners that chose to harvest and regenerate oak, rather than using them as set-asides in their forest management plans, have a higher interest in forest management than the average owner. Finally, the subsidies that are available make it more attractive to perform pre-commercial thinning for this FMM.

The divergence that we still think exists can be explained by the factors mentioned in clear-cutting intermediate (see question 45 in clearcutting-intermediate).

Pruning

Due to the high prices for high quality timber oak is the only tree species in Sweden were pruning can be economically justified. The use of artificial pruning also implies that heavy thinning programs can be initiated at an earlier stage of stand development, thereby reducing the rotation period and increasing the economic performance of this FMM. The ideal management scheme involves selecting approximately 100-200 oaks/ha (two times the numbers of crop trees) that are pruned to 5-6 m clear bole. The crowns of the crop trees are subsequently favoured by a heavy thinning program, complemented with continuous removal of epicormical branches.

However this is a very intensive and time consuming management program, and forest owners might also plant oak due to other forest functions than timber (biodiversity, aesthetics, recreation). We therefore suggest a 50 % pruning proportion for this FMM.

Management for high quality timber of Oak is a project that spans generations. Combined with uncertainties regarding future market demand it is not surprising that forest owners that not are dependent on the economic revenue from forestry to support their livelihood do not perform this time-consuming measure. In addition, pruning is only meaningful if initiated early or performed on

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trees that already are of high quality (removal of epicormics branches) i.e. on substantial areas of oak forest pruning is not even a measure to consider.

Commercial Thinning

We believe that all Oak dominated stands are thinned at least once during the rotation. However, very few stands are managed according to ideal management schemes, thinnings being conducting less frequent and more random (not promoting a pre-selected number of crop trees).

This FMM should ideally be characterized by frequent thinning's to favour the crown development and diameter growth of 50-100 crop trees. Due to the risk for epicormics branches thinning can't be strong/heavy but instead thinnings are done frequently, approximately every 5-10 years. This is critical to achieve the high grading dimension within a rotation period that can be economically justified.

Harvest and extraction of wood

The forest owner association Södra recommend that Oak > 35-40 cm dbh should be harvested by chain-saw. Trees above this dbh are too heavy for the harvester, and there is a high risk that the harvested timber is destroyed due to cracks. When harvesting Oak stands chain-saw and harvester are often used complementary. Södra estimates that approximately 50 % of the wood harvest of Oak is fully mechanized (from commercial thinning and onwards). Transport of timber is most often done by forwarders. A very small number of forest owners might extract some harvested timber by tractor or horses.

There is no data about use of logging residues of oak.

9.8. Clear cutting system with short rotation period

Another name for this management model could be management of broadleaves. Absolutely most common management of broadleaves are with clearcutting. For beech a method with shelterwoods are used, but the amount of beech is very low in Kronoberg due to the climate.

Characterization of the model

An increased use of pioneer broadleaves (Silver birch, Hybrid aspen, Populus) is suitable on fertile sites (G32+) with good water availability. Populus species and Hybrid aspen (*Populus tremula x tremuloides)* should be planted only on the very best sites. In addition, this is a suitable alternative for forest owners that want to afforest abandoned agricultural land. An increased use of broadleaves would increase the perceived beauty of the forested landscape. It also serves as a suitable risk-spreading strategy considering the risks of storm damages and the likely event of a future with a warmer climate (Felton et al. 2010).

Hybrid larch can be used as a complement to Scots pine and Norway spruce on many sites. Being a fast-growing pioneer species it can yield similar or higher mean annual volume production compared with Norway spruce, but within a substantially shorter rotation, but it can also produce large dimensions with a longer rotation period. Hybrid larch can be used on sites where the high browsing pressure makes establishment of Scots pine problematic and/or impossible (which is currently practiced to some extent in Kronoberg).

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Overall, the use of exotic species (such as Hybrid aspen, Populus and Hybrid larch) is limited in Kronoberg County. However, the interest increased in the aftermath to the storm Gudrun in 2005 (Wallstedt, 2013). In the entire area affected by Gudrun (which is much larger than Kronoberg), 1400 ha of Hybrid aspen and 225 ha of Populus were planted. This is largely explained by the reforestation grants that were available after the storm that compensated for the higher establishment cost of broadleaves. Approximately 4000 ha of Hybrid larch were also planted after Gudrun (in the entire Gudrun area). In addition to being limited in extent, the stands of these species are of young age. To exemplify, exotic conifers in Kronoberg, where Hybrid is by far the most common, only constitutes 0.2 % of the standing stock (SFA, 2014).

Birch is the third most dominant species in Kronoberg County (SFA, 2014). However there is no tradition of forest management of pure Birch stands in Sweden. The vast majority of the birch grows as a mistreated admixture in conifer plantations.

Forestry in Kronoberg is focused on the native conifers, especially Norway spruce. The use of these alternative species is therefore currently restrained by the lack of experience and uncertainties regarding the future market demand.

The use of exotic tree species (i.e. Hybrid larch, Hybrid aspen and Populus) is also restricted in the widely adopted voluntary certification standards (FSC ≤ 5 %, PEFC ≤ 25 % coverage on productive forestland per certified forest holding) (FSC 2010; PEFC 2012). However, the stricter FSC requirement only pertains to stands established after 2009. Birch, Populus and Hybrid aspen are also expensive to establish (artificially), especially since the current level of browsing often implies that fencing is required.

Due to the re-sprouting potential of Hybrid aspen and Populus these species might be managed as coppice in the future. However reported problems with crooked sprouts and the fact that the re-sprouting capacity on Swedish forestland is largely unknown, means that it is hard to tell which silvicultural system these stands will be managed with in the future. In this FMM we will not describe different management alternatives for second generation sprouts of Hybrid aspen/populus.

In the description of this FMM we focus on stand establishment through artificial regeneration i.e. planting. However, the characteristics of the nemoboreal ecosystem implies that naturally regenerated birch generally establish after clearance. Beyond being used as an admixture in plantations, stands can also be established solely relying on naturally regenerated birch. This does not require retention of seeds trees, given that substantial amount of birch is present in the surroundings. The pros with this alternative is self-evident i.e. no regeneration cost. The drawbacks are connected with substantial reduction in growth and quality compared with the genetically improved material. In addition, there is a higher risk of failure.

Tree species and mixture

Most important species in this management models are *Betula* spp (Mainly *Betula pendula*), Hybrid larch, Hybrid aspen, Populus species. Plantations with these species are currently very marginal in Kronoberg County. Most of the birch stands are natural regenerated. Hybrid larch is the most common species to plant within this FMM, followed by birch. However, as already described, birch is a dominant admixture species in the forest landscape of Kronoberg.

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Rotation period

Typical rotation periods are; Hybrid larch 30-45 years, birch 45-55 years and Populus/Hybrid aspen 20-35 years (on forestland, these species are also managed on agricultural land where the rotation need to be kept below 20 years). Very often stands are not managed properly and to get larger dimensions the rotation periods above are prolonged.

The benefits with these species from an economical perspective is connected with the short rotation period (high internal rate of return, short pay-back time).

Due to uncertainties regarding future market demand for timber, Hybrid larch and Populus/Hybrid aspen can also be managed without thinning in short rotations, aiming for bulk assortments such as pulpwood (Hybrid larch can sometimes be sold as pulpwood) and/or bioenergy. The rotations should then be at the lower end of the optimal rotation interval (or even a bit lower).

This FMM involves planting of monocultures directly or a few years after final felling. However the characteristics of the nemoboreal ecosystem means that additional naturally regenerated seedling, especially birch, establishes after clearance.

Regeneration

Scarification is an important measure that increases the likelihood of establishment success. It results in an increased initial growth of the seedlings through better nutritional status and reduced mortality. Since Birch, Hybrid aspen and *Populus* ideally should be planted on fertile forest sites, where herbicides not are used (compared with afforestation on agricultural land), intensive scarification is decisive to reduce competition from vegetation and associated problems with voles.

If used in afforestation of agricultural land, it is recommended to complement the scarification with herbicide treatment to increase the likelihood of regeneration success.

Pine-weevils are the major agents causing mortality in conifer plantation, and with proper protection (mechanical or chemical) seedlings of Hybrid larch can often be planted without scarification. However, scarification is still needed to achieve optimal stand development.

Fencing and browsing

The main argument here is similar to the answer in clearcutting-intermediate. With the current level of browsing most species would benefit from fencing, and it can often be critical for success. The very high cost for fencing and the high browsing pressure most probably reduce the planting of birch and hybrid aspen.

In general a lot of the plantations with Birch, Hybrid aspen and Populus were established in 2006-2010 as a consequence of the subsidies after Gudrun (Wallstedt, 2013). Fencing was both a requirement to obtain financial support and was covered by the amount granted. Since then the interest in planting these species has decreased, mainly due to the lack of financial support for fencing.

Stand management

Pre-commercial thinning

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All the species used with short rotation clear-felling models are fast growing pioneers. If established on suitable sites they should be able to outcompete naturally regenerated tress, such as Birch, and approach merchantable diameters rapidly. In addition, Hybrid aspen and Populus are also generally planted at wider initial spacing than commonly practiced (1000-1500 seedlings/ha).

An alternative is to use natural regenerated birch. Then pre-commercial thinning is a must to create a stand with an even distribution and good number of seedlings. Also to increase the accessibility in future thinning operations and for the purpose of quality selection it can still be a good idea to perform pre-commercial thinning also in planted stands.

Commercial thinning

Commercial thinning is a decisive for achieving the desired dimension within optimal rotation periods (the short rotations being the major advantage with this FMM). With the very short rotations one hard thinning can be adequate for Hybrid aspen and Populus. Hybrid larch and Birch should be thinned more frequent. If the aim is high quality timber production of birch it recommended to embrace a single-tree perspective, favouring a pre-selected number of crop trees with frequent crown enhancing thinnings.

Pruning

Pruning is in general an expensive and/or time consuming activity. For these species there is also a high level of uncertainty regarding the future market demand for quality assortments.

Combined with an intensive management program (frequent crown enhancing thinnings) it can be an interesting alternative for *Betula pendula*. This can be combined with wider initial spacing to reduce the regeneration cost. Since the future market is uncertain it should not be regarded as a safe-investment, rather as an interesting activity for forest owners with a lot of time and interest in forest management. In "practical" forestry, pruning is very limited, if done at al.

Nature protection

The Swedish conservation model rely on a complementary approach, combining protected areas set-aside from timber production with integrative conservation measures in the forest matrix (Gustafson and Perhans, 2010). These measures are mostly conducted at final felling and required according to stipulations in the forest act and in the voluntary certification standards (PEFC, FSC). This involves green tree retention of single trees and groups, leaving as well as creating deadwood (high-stumps) and the retention of buffer zones along water, mires, and sensitive habitats. The requirements are more quantified in the certification standards, where widely known stipulations requires retention of a minimum of 10 trees/ha and the creation of at least three high stumps per hectare (FSC 2010, PEFC 2012). When forest owners notify the Swedish Forest Agency that they will conduct final-felling of a particular stand they are required to specify which conservation measures they will take to fulfil the stipulations in the forest act (SFA, 2016a).

9.9. Management of stands with high nature values

How much forest that needs to be set-aside from timber production to safe-guard biodiversity in Sweden and in Kronoberg is widely debated and an issue of great uncertainty. In addition to the

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requirements of different species a lot of factors influence what can be considered as a suitable level of protection, such as:

The level of ambition, the intensity of forest management and amount of integrative conservation measures (i.e. retention in harvest operations) in the forest matrix, the value of voluntary set-asides (are they long term commitments?), the value of unmanaged unproductive forestland for biodiversity (e.g. mires with sparse tree-cover).

However, considering that the Swedish forest policy currently should be guided by an overall orientation that puts equal emphasis on production and conservation goals (see intro), it is evident that the area designated for nature conservation needs to increase from the current level. This is also reflected in the steadily increasing share of forest designated for this purpose and a recent increase in government funding.

A tool in the work with conservation goals especially the voluntary set aside, is the use of classification of stands depending on goals; management goals. Four classes are used;

Production with general considerations, PG.

Production with stronger considerations, PF.

Nature conservation with management, NS.

Nature conservation, free development/without management, NO.

How much forest that needs to be set-aside from timber production to safe-guard biodiversity is widely debated and an issue of great uncertainty. In addition to the requirements of different species a lot of factors influence what can be considered as a suitable level of protection. The classification above is not mandatory, but very often used.

Approximately 5-6% of the area is classified as nature conservation and it is assumed that 2-3% of this is managed and another 2-3 is without management. These figures are based on the coverage of the different types of formal protection in (nature reserves, habitat protection and nature conservation agreements) in Kronoberg County (about 1.8 %) (SFA, 2016c; SFA, 2014) combined with the most recent estimate of voluntary protection in Götaland (3.9 %) (Stål et al., 2012).

This estimation of voluntary protection includes both certified and uncertified forest owners (Stål et al., 2012). It is common practice that forest owners with forest management plans specify areas set-aside for nature conservation purposes. However, certified forest owners need to set-aside ≥ 5 % of the productive forestland (> $1m^3$ ha^{-1} yr^{-1}) from wood production to fulfil certification requirements (FSC, 2010; PEFC, 2012).

The voluntary set-asides are the most common form of protection in southern Sweden. With a high share of private forest owners forest management plans from Södra provides a good source for estimation the ratio between NO/NS. Forest management plans produced by Södra in Kronoberg County (2007-2013) show a 4.05 % and 3.82 % coverage on productive forestland of NO and NS respectively (Magnus Petersson, Södra). In addition, even though probably not to the same extent, formally protected areas are also sometimes managed to enhance their value for biodiversity (or recreation).

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It is critical that strict protection is complemented with active conservation measures to fulfil conservation goals at both a national and regional level. For example, broadleaved stands dominated by Oak, who host a wide range of threatened species, face the risk of being transformed to conifer dominated stands through secondary succession if left unmanaged. Reintroducing fire as a natural disturbance agent is another important measure in forest dominated by conifers (mainly of Scots pine), thereby securing the conservation status of many fire dependent species.

9.10. Nature conservation with management

This FMM is applied in stands where the active management interventions are needed to enhance and/or maintain the conservation value.

It is estimated that it covers 2 - 3% of the forest area in Kronoberg but it is recommended to increase at least twice.

The management activities in stands with nature values depends on both the existing, and future potential, valuable structures in the specific stand. This means that this FMM can be highly variable and involve any measures that are conducted to promote the conservation value (and sometimes also recreation) i.e. specifying an ideal management scheme is therefore contradictory to the objective of this FMM. Clearfelling might not be very common, but all sort of silviculture systems and cuttings can in principle be used, such as selective and shelterwood systems, commercial and pre-commercial thinnings and more.

In voluntary protected areas measures to promote the conservation value are specified in the forest management plan, together with all other suggested measures for the individual estate. The restrictions in utilization, as well as management activities to promote the conservation value in formally protected areas are often specified in specific management plans.

Tree Species and specie mixture

Management in stands with high nature values is applied independent of tree species, but high nature values are often connected to broadleaved dominated stands. (especially uncommon species as oak). Active measures are often needed to maintain the future dominance of broadleaves.

Examples of different measures

The most common measure in Kronoberg is nature conservation thinning, favouring broadleaves at the expense of Norway spruce. Due to the good performance and shade tolerance of Norway spruce this is often needed to maintain the dominance of broadleaves and associated conservation values also in the future. The first thinning in such stands often involves large removals of Norway spruce and can therefore yield substantial incomes (Magnus Petersson, Södra). After the first thinning the primary target is to keep the stands free of Norway spruce. Subsidies supporting nature conservation thinning in broadleaved dominated stands are available through the Swedish Forest Agency (9000 SEK/ha) (SFA, 2016d).

Other common measures among private forest owners involves releasing large Oaks from competition, and measures conducted in buffer zones along water to enhance their conservation value (Magnus Petersson, Södra).

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Large forest owners (>5000 ha), such as Sveaskog, certified according to FSC are obliged to burn an area corresponding to 5 % of the annual area final-felled on dry/mesic soils (FSC, 2010). This is often conducted on clear-cuts prior to planting but also involves burning standing forest designated for conservation. This is a very effective way to reach the area required since the burned area in such stands should be multiplied by an upward adjustment factor of three. This should ideally be conducted in stands dominated by Scots pine, a species who grow on sites that historically experienced frequent forest fires.

Finally, some protected areas are also important for recreation, and close to cities nature reserves created by municipalities often have this as a primary objective. In such areas management activities to promote the perceived beauty (e.g. favour broadleaves) and/or increase the accessibility are common.

9.11. Nature conservation without management

It can be discussed it this is a forest management model or not. But the concept with Management Objective “nature conservation without management” described above is widely accepted and used in Kronoberg. It is estimated that it cover 2 - 3% of the forest area in Kronoberg but it is recommended to increase at least twice.

This FMM is used in stands where the nature conservation goal is best achieved through no intervention. For example stands of conservation value that are left unmanaged to further increase the quantity and quality of structures of high importance for biodiversity (dead wood, old trees etc.).

9.12. References

Persons involved:

PhD student and LCC Isak Lodin

WP1 leader Professor Urban Nilsson

Anders Ekstrand, specialist in the management of deciduous species at Södra.

SkogDr Magnus Petersson, Head of the department of silviculture and forest technique at Södra.

Johan Rowell, Sveaskog, Planner of pre-commercial thinnings in Kronoberg.

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10. Turkey

10.1. Background and forest history

The planning process has slowly evolved over time and noticeably changed over the last few decades in Turkey. From the first management plan, prepared in 1917, to the late 1990's, forests were man-aged for principally commodity production as maximizing timber production according to classical planning approach. Although some attempts were experienced in some regions as pilot projects such as Mediterranean forest use project (1970s and 1980s), Turkish-German collaborative model (1990s) Forest Resource Information System (FRIS) (late 1990s) and Global Environment Facility Fund (GEF II) (2000s) to replace the negative effects of the classical approach, multiple-use planning has become the Turkish forestry agenda in the last two decades.

By 1960s, forests were managed mostly with a single-tree selection silvicultural system regardless of the biological characteristics of existing commercial trees. For instance, uneven-aged management practices were applied to forests composed solely of light demanding trees (e.g., pine forests) even though those forests reflect single-layered even-aged stand structures. Unregulated and anomalous forest structures were created across the country leaving the forest managers with great dilemma. Realizing the detrimental consequences of inappropriate management actions of the time, even-aged management practices were introduced immediately after 1963. However, foresters were seen only to meet the allowable cut levels, and applied various forms of clear-cut management action. The practitioners unwittingly neglected the renewal of the harvested areas due to heavy administrational duties, short supply of seedlings in nurseries, ill-equipped technical foresters and lack of a control mechanism. As a result, many clear-cut areas were left untreated, exposing them to harsh natural disturbances such as weed competition, soil erosion, and wind blow-down. Thus, the idea of regeneration by either natural succession or plantation was virtually overlooked.

It was after 1971 that both uneven-aged management methods for tolerant trees dominated forests and even-aged for the rest of the forests were implemented across the country. On the other hand, neo-classic area-control or wood production oriented management of forest resources carried important shortcomings besides unresolved ownership, no spatial database established, forest stratification not carried; site, biodiversity, health and capacity inventory not conducted with GIS and RS, conservation of various forest values was not accommodated, decision making process with operations research techniques not conducted, and participation was not materialized. Therefore, modern management initiatives were undertaken later in the late 1990s. Various forms of multiple-use forest planning approaches were used in some forest districts. Since 2008, the planning process in Turkey has completely turned to an ecosystem based forest management concept accommodating biodiversity conservation, participation, multiple uses, and information technologies.

The planning process is centralized, with the planning teams formed each year by the forestry head-quarters and assigned to prepare a management plan for a planning unit. The plans are

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prepared for every 10 years based on management guidelines. Area, increment, and growing stocks of each stand type (identified by species mix, development stage, and crown closure) are measured in forest inventory. The production capacity is determined according to age and dominant height of stands. The current age or size class distribution is determined based on the forest inventory and the future forest structure is determined by the empirical yield tables. Using the area/ size regulation method, a harvest schedule is determined to maximize wood production in a single period, leaving other periods unplanned until the rotation period (Başkent and others 2005b).

Forest cover

In Turkey, forest lands cover 22.3 million ha, or 28 % of the national territory. Almost half of these forest resources are degraded; the other half is productive. High forests account for 88 % of total forest land, and coppice forests for 12 %. High forests contain 97 % of Turkey's standing tree volume, and coppice forests only 3 %. Turkish forests have rich and diverse biodiversity and nature protection values. The productivity of forest resources measured in terms of annual increments averages about 2.0 m^3/ha.

Ownership

The main stakeholders in forest resources are the public along with local communities, few private investors and forest owners. More than 99 % of forest resources are owned by the State, with the remainder owned by public or private entities. While, the first organization of forestry extends back to 1839, during rule of Ottoman Empire, the development of the forest legislation gained momentum after the Forest Law No. 3116 enacted in 1937 made first legal definition of forest and introduced the first set of forest policies. After the experience with private national and foreign contractors of forests for management, all forests were nationalized in 1945. This year marks as one of the important benchmarks of forestry history. Since the beginning, all forestry activities were carried out by single organization, The General Directorate of Forestry (GDF). Some of the functions of forests, such as national parks, protected areas, wild-life and game, have been taken to the responsibility of the "Nature Conservation and National Parks". Protected areas are cover nearly 10% of the forested lands.

Stakeholders' main rights to forest resources are access, exclusion, resources withdrawal, and alienation, with the exception of State forests, which cannot be alienated. In general, forest resources are planned by State authorities, with only very limited participation from other stakeholders. Forest resources management is implemented by the GDF as sustainably as possible, with some activities carried out by local people and private investors, such as afforestation and collection of NWFPs by private investors, and harvesting activities by forest villagers and forest village development co-operatives, according to relevant laws.

10.2. The case study area

The Gölcük study area is located in the Marmara region having broadleaved (generally mixed) productive forests when compared to other regions of Turkey. Climatic condition is very convenient for continuity and viability of forests and forestry activities such as regeneration or planting. Gölcük state forest enterprise owns nearly 91% of the total forest area which is much more when compared to other parts of Turkey. This characteristic is prominent when compared with other

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regions of Tur-key. However, forest owners are not willing to produce timber and private forests managed for other forest values such as aesthetics, recreation and chestnut fruit as a non-wood forest product. Forests having dense, medium and loose crown closure (>10%) comprises nearly 93%, which is quite higher than the Turkish average (nearly 53%). All forests within the CSA managed for even-aged forest management model/system. The annual increment is also nearly 4.7 m3/ha within the CSA, which is two times higher than country average (2 m3/ha).

In Turkey, indirect method is used for the determination of site quality considering the height growth of dominant, free growing trees in the upper forest canopy. There are some studies that accommodate the edaphic, climatic and typographic properties as well, but could not extend throughout the country and also in the case study area. Therefore, there is no information about the soil moisture content of the study area. In addition, nearly 3256 ha of the degraded forest land has no site information. Site index of the degraded stands could not be determined because of the selected method itself (indirect method). Conducted inventory method does not include distribution of productivity to the site. On the other hand, according to designed stand tables; the site productivity ranges from 5 to 7.5 m^3 ha^{-1} yr^{-1} in high site, from 2.5 to 5 m^3 ha^{-1} yr^{-1} in medium site and < 2.5 in low site.

Table 56. Distribution of forest area in high, middle and low production sites and estimate of production (right).

Productivity/soil moisture	Dry	Mesic	Moist	Wet	Productivity
High	15.6 %				5 – 7.5 m^3 ha^{-1} yr^{-1}
Medium	63.7 %				2.5 - 5 m^3 ha^{-1} yr^{-1}
Low	20.7 %				<2.5 m^3 ha^{-1} yr^{-1}

10.2.1. Land area and forest cover

Table 57. Total land area, forest area, standing volumes, productivity and ownership in CSA Turkey.

	CSA Gölcük	Turkey
Total area	81 808.5 ha	78 004 644 ha
Forest land	40 493.5 ha	22 342 935 ha
Proportion of forest land	49.5%	28.6%
High forests	40 126.5 ha	19 619 718 ha (88%)
Coppice	367 ha	2 723 217 ha (12%)
Growing stock	5 022 955 m^3	1 611 774 193 m^3
Productive forests (crown closure <10%)	37 237.5 ha (92.8%)	12 704 148 ha (57%)
Degraded forests (crown closure <10%)	3 256.0 ha (7.2%)	9 638 787 ha (33%)
Increment (m3)	189 858 (m^3)	45 904 083 (m^3)
Allowable cut (m3)	84 866 (m^3)	18 314 621 (m^3)
Forests managed for economical value	27 422.8 (67.7%)	50%
Forests managed for ecological value	10 574.2 (26.1%)	42%
Forests managed for socio-cultural value	3 659.1 (6.2%)	8%
Even-aged management	100%	98%
Uneven-aged management	-	2%
Pure stands	13 966.1 (34.4%)	62%

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Mixed stands	26 527.4 (65.9%)	38%
Forests under state ownership	40 493.5 ha (90.8%)	99%
Private forests	4 109.9 ha (9.2%)	1%
Protected areas	10.7%	7%

10.2.2. Tree species

Beech, *Fagus orientalis* is the by far most important tree species in the CSA. But there is a number of species important for forestry (Table 58).

Table 58. Tree species, proportion of total forest area.

	CSA Gölcük	Region	Country
Species (Latin name)	Proportion (% total volume)	Proportion (% of area as main sp.)	Proportion (% of area as main species)
Fagus orientalis	62.9	36.9	8.5
Castanea sativa	15.2	3.6	0.4
Carpinus betulus	7.3	5.4	0.2
Quercus petraea	3.4	24.8 (Quercus sp.	26.3 (Quercus sp.)
Quercus robur	3.3		
Pinus nigra Crimean pine	1.8	8.6	19.0
Abies nordmanniana	1.7	2.2	2.6 (*Abies* sp.)
Tilia (spp)	1.4	-	0.06
Pinus brutia Turkish pine)	0.7	6.6	25.1
Quercus frainetto	0.6	-	-
Other oaks (*Q. infectoria, Q. cerris, Q. hartwissiana*)	0.6		
Acer spp.	0.4	-	0.01
Exotic species (*Robinia pseudoacacia, Pinus pinaster, Cypress, Pseudotsuga menziesii)*	0.3	2.4	0.01
Other (*Platanus orientalis, Pinus sylvestris*)	0.4	1.5	6.8

Note: The proportion of the total volume refers to all tree species in the forest stands, however the proportion of area refers to the main tree species in the stands. The statistics were taken from forest management plans of the case study area renewed in 2015 and forestry statistics published by General Directorate of Forestry. The volume or area statistics is available for all oak species for the study area. However, region or country level statistics available for the whole Quercus species.

10.3. FMMs in the country and in the CSA Gölcük

Shelter-wood method is the dominant forest management method represented in the CSA Gölcük. Beech is the dominant species and shelter-wood system is applied in the regeneration of beech forests in Turkey. Forests having ES such as soil conservation, water conservation or aesthetics will not fully be regenerated and yet will have certain amount of allowable cut determined with a

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different management models, i.e., small area removal system and were evaluated in the "nature conservation with management". Extended rotation ages are sometimes applied in the conservation forests using shelterwood method. Nature conservation areas include legally declared protected areas such as nature parks, national parks or recreation areas and any forestry activities such as regeneration or thinning is prohibited within the CSA. Four decades ago, 1/3 of Turkish forests were managed with coppice system. Coppice forests have been converted to high forests and some oak forests are subject to this implementation, as the CSA has different kinds of oak species (nearly 8%).

10.4. Alternative FMMs

The silvicultural needs of the tree species presented substantial difference between the CSA and the entire country. The dominant tree species in the study area is beech. The ecological requests of this species necessitate the regeneration method as shelter-wood method. Shrubs, especially such as Rhododendron and cherries cause absence of light and as a result death. On the other hand, Turkish red pine (Pinus brutia) covers 25% of the Turkish forest area and those forests are regenerated via clearcutting. Legally declared nature conservation areas such as national parks, nature parks, national monuments or recreational areas cover larger areas in Turkey than in the CSA.

10.5. FMMs used in the CSA Gölcük

Shelterwood models dominate forest management in the CSA. More than half of the area is man-aged with such models. Management for conservation is used on 24% of the area. Other forest man-agement models used includes clearcutting and coppice systems, Table 59.

Table 59. The major forest management models (FMMs) used in CSA Gölcük, and the use in the CSA and in Turkey.

FMM, Domestic name in English	Corresponding silviculture system	Coverage *CSA* Gölcük (% forestland)	Coverage Turkey (% forestland)
1 Shelter-wood method	Uniform shelter-wood system	56.4	24.0
2 Shelter-wood method, long rotation	Uniform shelter-wood system	7.1	1.0
3 Nature conservation with management	None	24.4	28.0
4 Nature conservation	No intervention	3.9	20.0
5 Conversion of coppice	None	3.3	0.5
6 Medium rotation coppice	Coppice system	3.1	9.4
7 Short rotation coppice	Coppice system	0.9	0.1
8 Clear cutting	Clear cutting system	0.9	15.0

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Eco system services

Table 60. Ecosystem services connected to the four FMMs in CSA Gölcük. Ranking of important ES within each FMM. No ranking between FMM.

Forest manage model (FMM)	Ecosystem services in order, ranking from most (1) to least (5) important				
	1	2	3	4	5
1 Big area long shelter-wood method	Timber production				
2 Big area very long helter-wood method	Soil conservation	Water conservation			
3 Nature conservation with management	Soil conservation	Water conservation	Non-wood products	Aesthetics	
4 Nature conservation	Nature conservation	Nature parks	Recreation	tourism	Seed stands
5 Conversion of coppice (ES when converted to high forest)	None Timber products	Soil conservation	Water conservation	Non-wood products	Aesthetics
6 Medium rotation coppice	Timber products				
7 Short rotation coppice	Timber products				
8 Clear cutting	Timber products				

Introduced species

Forestry in CSA Gölcük is based on species as *Fagus orientalis, Castanea sativa,* Oak *spp. (Quercus petraea, Quercus robur, Quercus frainetto, Quercus infectoria, Quercus cerris,* and *Quercus hart-wissiana), Pinus nigra, Pseudotsuga menziesii*. There only exists 26 ha (among 2974 ha) Pseudotsuga menziesii stands planted nearly 50 years ago. Those stands were established for a test to investigate the availability of extending this species to large areas for timber production. However, there is no attempt to enlarge this species to the region or countrywide now. Besides, silvicultural guideline (Technical principles of silvicultural applications, No: 298) is suggested native species. However, guaranteed resuming the same tree species after regeneration in existing stands.

Non-European species are used very limited. In areas managed with clearfelling, approx. 1% of the total area of the CSA, Caribean pine (*Pinus pinaster*) are used.

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Natural regeneration is a very common method of regeneration and very local seeds are then used.

Genetically improved or modified seedlings

Mostly seed and seedlings originate from areas within 100 km from the CSA are used, except for Pinus pinaster that is introduced to Europe. Seed and seedlings origination from selected trees are used and in that way genetics are improved. No genetically modified seed/seedlings are used in Tur-key.

No tree hybrids are used in Turkish forestry.

Herbicides and chemicals used and fertilization

Herbicides and chemicals are not used in the CSA, however, pesticides are applied at nurseries for the fungus to prevent damping of in Pinus brutia and Pinus pinaster.

Fertilization is not used in the CSA, one reason is the cost and limited time and labour.

10.6. Shelterwood systems with long and very long rotation period

In the CSA two shelter wood systems or models are used. The difference between them are the length of rotation periods. Shelterwoods is the most used forest model in the CSA and Turkey, in the CSA they cover 63% of the area and about 25% on national level.

This shelterwood models is based on retention of overstory trees to act as seed-source and buffer the detrimental effects of a wide range of factors. The shelterwood models is used with almost all species except Pinus brutia in Turkey. Besides, high forests allocated for all values except for timber production are potentially managed with shelterwoods in even-aged forestry. Stands composed of especially beech, oak, chestnut and hornbeam species are covered by a great deal of different under-story species such as Rhododendron, smilax or berries in Turkey. In case of regeneration of those stands via clearcutting method, saplings are faced with lack of light and nutrient deficiency.

Rotation age is typical up to 140 years. There are also some standards to integrate nature protection in the stand-level management such as dead wood thresholds.

The shelterwood method and a longer rotation period is separated from the model described above only because of the length of the rotation. Long rotation periods are used in forests allocated for ecological or social values of ecosystem services with Beech. Conservation forests serving for soil and water conservation are also subject to this management model in the CSA.

Tree species used and tree species composition

The most common species with the shelterwood model are *Fagus orientalis*, *Castanea sativa*, and Oak spp. (*Quercus petraea, Quercus robur, Quercus frainetto, Quercus infectoria, Quercus cerris, Quercus hartwissiana*)

With shelterwood and long rotation most important are *Fagus orientalis, Pinus nigra*, and *Pseudotsuga menziesii*.

Nearly all of the tree species occur natural within the CSA, only 0.3% is exotic species, Pseudotsuga menziesii and Pinus pinaster. According to Technical Principles of Silvicultural Applications Act (No:

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298), all natural forests should maintain the same species mixture after regeneration. If the technical foresters or forest practitioners want to change the main species or species mixture, a report should be prepared and they should obtain permission from General Directorate of Forestry. Therefore, natural (which is actual) structure should be maintained.

Rotation periods

Site index of the regenerating stands should be considered in determining rotation periods. Beech stands reach the requested diameter for timber processing factories at nearly 100 years on good site and 120 years on poor site. Moreover, cavities or holes occur after certain years. On the other hand, foresters responsible for technical forestry activities such as silviculture, planting, forest protection etc. are generally manage large forest areas and leads reducing rotation age as a result of area control method. If the number of foresters increases, the rotation age would be decreased by 40 years. Today the rotation age is determined as 140 years for timber production in the CSA (note that dominant species is oriental beech in those stands).

Today the rotation age is the same in all site classes. If the rotation age is decreased, than the regen-eration area to be harvested will be increased according to "area control method". The planning units (there are six planning units meaning six foresters responsible for technical forestry activities) cover nearly 5000 ha of forest lands each and one forest engineer or silvicultural expert is responsible for the regeneration, maintenance, forest protection, cadastral survey and supervision of all forest lands within the planning unit. Therefore, longer rotation ages are preferred to reduce the area of harvesting for regeneration. In this case, site index is not important since, the desired round wood is reached to that time for all sites.

In the model with shelterwood and long rotation the rotation period today is about 200 years. Two centuries is too long for the sustainability of those forests and rotation age should be shortened. For beech and Crimean pine, 140 years should be enough for soil or water conservation under this management model. Those conservation forests also need regeneration to sustain forest values after collapsing. The determined rotation age is high for healthy regeneration when considering seed source possibilities. In CSA Gölcük, there are limited stands reaching to 200 years although almost all of the stands are natural forests. Forest planners generally give higher rotation ages to avoid giving large regeneration areas allocated to those forest values. However, storms, insects or fungi dam-ages stands and those stands generally collapse before 200 years. For the conservation forests, 140 years seems to be ideal for the CSA.

Size of clearcuts

The size of the regeneration areas calculated via "area control method" for each forest management unit. This formula uses planning parameters as total forest area, rotation age and planning period. Although there is no restriction about harvesting area at one time point. The harvesting areas are distributed into the management unit and are avoided to regenerate adjacent compartments.

There is large variation in the size of the harvested areas in the CSA, the smallest are 1,4 ha, average 9 and largest 46 ha for shelterwood method and for shelterwood and long rotation 9,6, 41,4 and 88ha respectively.

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Forest regeneration

Considering the tree species in this FMM, 100% are natural regeneration. *Fagus orientalis, Castanea sativa* and Oak secies are growing with a high number of different understorey species such as Rhododendron, smilax or berries. In case of regeneration of those stands via clearcutting method, saplings are faced with lack of light and nutrient deficiency.

Site preparation, scarification, is needed and is done on all regenerated areas to get densities for high quality timber production. It is also important to increase the likelihood of regeneration in both models. Browsing and fencing

All areas in CSA Gölcü, also this the two models with shelter wood is fenced to avoid browsing. Browsing originated from game is negligible, however browsing from livestock, belongs to local people, has effects on the regeneration.

*Sta*nd *management*

Pre-commercial thinning

The Shelterwood model have timber production as a management goal. To get target diameters earlier pre-commercial thinning (PCT) is recommended at all stands at least once. By reducing the intensity of competition and to increase the accessibility in future thinning operations as well as for the purpose of quality selection, it is a good idea to perform pre-commercial thinning. In practice about half of the stands PCT are done. One technical forester is responsible for all forestry activities such as regeneration, thinning, protection, management within the planning unit. Therefore, the number of technical staff limits the target. Also forests, far from the roads and with high wood extraction costs could not be thinned. The price of the obtained material is not high enough as expected for application.

Not all but 70-80% of stands managed with shelterwood and long rotation are pre-commercially thinned. Soil and/or water conservation is set as a management goal in this management model. Therefore, the primary aim is not for wood production. However, to get resistant trees for diseases, wind effects or snow break, it is a good idea to perform pre-commercial thinning.

Commercial thinning

Thinning is required in all stands to achieve good diameter growth and get trees with good stability. The obtained material also find buyers from near timber factories. Not all forest, but about 80% are thinned, forest far from the roads and with high wood extraction cost could not be thinned.

Commercial thinning is recommended to be done in 70% of the stands where long rotation period is used. Forest far from roads and with high extraction cost is not thinned.

Pruning

Pruning is not done in any of the two shelterwood models

Harvest, transport and logging residues

Harvesters are not used at all. Chain saw is used for felling operations. Wood is extracted by forest tractor (60%) and my animal power and man power (40%). In very steep conditions small or middle

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size cranes or sledge-yarders are also used. Forest residues are not extracted, but they are generally collected by local people.

Nature protection

Silvicultural guidelines (Technical Principles of silvicultural Applications, No: 298) require some stand level targets towards dead wood management on the field. For instance, in economically designated areas for wood production, 1-3 dead wood trees per ha is to be retained in all managed are-as. When available, small areas of islands (<3ha) is promoted or left out for "aging islands".

All deadwoods in the areas 50-80 meters away from the top of the timber line is strictly left un-touched in ecologically designated areas. Any silvicultural implementations should target up to 15 deadwood trees per ha, with ecological corridors. Small open lands in the forests should be left to nature and should not be regenerated. Thinning activities should be moderate in stands with a 25-50 m strip adjacent to narrow-based streams and in stands with a 50-100 m strip adjacent to broad-based streams. Besides, regeneration is prohibited in water conservation forest far from 300 m to stream.

10.7. Nature conservation with and without management

Nearly 25% of the forest area in the CSA is managed for nature conservation and another 4% is set aside for nature conservation. A model for forests having values other than timber, such as soil conservation, non-wood forest products, water conservation and aesthetics are predominant in this FMM. Final felling or harvesting is not currently applied, however, a certain lower amount of allow-able cut is taken from stands according to prominent forest values. The amount of allowable cut changes depends on the different conditions such as volume, increment, stocking, as well as forest values. *Fagus orientalis, Quercus petraea, Castanea sativa, Quercus robur, Pinus brutia and Quercus frainetto* are the dominated tree species in the CSA. Rotation age is determined extremely high between 180-200 years for beech and between 120-180 years for chestnut stands to have very small area for final harvest/felling and regeneration according to area control strategy, which is the pre-dominant forest regulation system. In fact, those stands should be regenerated earlier to sustain most of other forest values. Therefore some areas need to be more actively managed and the area managed with the model "nature conservation for nature consideration" is suggested to be reduced to 15% and the area for nature values without any management reduced from 4 to 2%.

Tree species used and tree species composition

Stands with *Fagus orientalis, Quercus petraea, Castanea sativa, Quercus robur, Pinus brutia, Quercus frainetto* included in the model for nature conservation with management and stands without any management are dominated by *Fagus orientalis, Castanea sativa, Quercus robur*.

Stands are typically mixed stands. All kind of mixtures are found.

Rotation periods

Rotation period is determined considering both forest values and rotation ages. For beech, oak and Crimean pine, 140 years is enough and besides for Turkish pine, chestnut and hornbeam 100 years is enough to sustain forest values after collapsing of the stands when considering seed source possibilities. In practice, rotation period is determined as 180 years for soil protection, 180 years for

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water protection, 180 years for aesthetics and 120 years for non-wood forest products. However, currently, there is no stands reaching those ages and there is no regeneration area in nature conservation stands. In this FMM, includes protection forest values such as soil conservation, water conservation and aesthetics, forest authority is not willing to apply regeneration activities and only maintenance activities such as thinning or pruning is carried out. Therefore, extremely high rotation years are determined to avoid regeneration.

In the core zone of the protected areas where no management is done, or in recreation sites, there is no need to determine rotation ages. On the other hand, nature conservation with management should be applied in other parts of the protected areas or recreation areas according to prominent forest value and tree species. In brief, considering the CSA, there is no need to determine a rotation period for the core zone of the protected areas and recreation sites. For beech, oak and Crimean pine, 140 years is enough, besides, for Turkish pine, hornbeam and chestnut, 100 years is enough to sustain forest values after collapsing of the stands when considering seed source possibilities.

In practice, rotation period determined as 180 years for recreation areas and 200 years for nature parks. However, there is no stands reaching those ages and there is no regeneration area for this FMM in the CSA. In this FMM, includes protected areas and recreation sites, forest authority is not willing to apply any forestry activities in terms of both maintenance and regeneration. Therefore, extremely high rotation years are determined.

Size of clearcuts

There are harvest and no regeneration activities in this model and therefor no clear-cut areas.

Forest regeneration

No activities to perform regeneration is performed.

Browsing and fencing

No regeneration and therefor no need for fencing

Stand management

Pre-commercial thinning

Nature conservation with management includes pre-commercial thinning. About 70% of the area is recommended to pre-commercially thinned. Stands in this FMM are allocated for soil conservation, water conservation, non-wood forest products, and aesthetics. Pre-commercial thinning is not suggested for aesthetics. However, stands allocated to other values needs pre-commercial thinning to get resistant stands to external risks and reach stands according to desired structure. Today 50-60% of the stands are pre-commercially thinned.

Commercial thinning

Nature conservation with management includes also commercial thinning. About 70% of the area is recommended to commercially thinned. Commercial thinning is not suggested for aesthetics. However, stands allocated to other values needs commercial thinning to get resistant stands to

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external risks and reach stands according to desired structure. Today 50-60% of the stands are pre-commercially thinned. The areas thinned is limited by lack of foresters.

Pruning

Pruning is not recommended and is not done.

Harvest transport and logging residues

Harvesters are not used at all. The topography and getting harvester cost is not suitable. Chain-saw is used for all precommercial thinning or thinning operations.

Nature protection

Nature protection is not only integrated, it is the objective of the management with this two FMM-. Most typical, silvicultural guidelines (Technical Principles of Silvicultural Applications, No: 298) require that all deadwoods in the areas 50-80 meters away from the top of the timber line are strictly left untouched in ecologically designated areas. Any silvicultural implementations should target up to 15 deadwood trees per ha, with ecological corridors. Small open lands in the forests should be left to nature and should not be regenerated. Thinning activities should be moderate in stands with a 25-50 m strip adjacent to narrow-based streams and in stands with a 50-100 m strip adjacent to broad-based streams.

10.8. Two models for coppice

On a minor part of the area in CSA Gölcük coppice systems are used, one system with a rotation of about 20 years and one with a much shorter rotation, 4 years. The two systems differ only in length of the rotation. The models is not applied over 60% terrain slope.

On 3% of the area coppice with medium rotation period are grown. Pole-wood demand is met via coppice method with rotation period of 20 years. The size of the area is sufficient to meet the demand.

The management method is based on clearing all shoots after reaching 20 years and providing new shoots. Timber production (pole woods or construction board) is set as management goal. The model is suitable for oak species and chestnut, however, chestnut is preferred in the CSA but it is not applied over 60% terrain slope.

Four year shoots of the chestnuts is used in the production of hand-craft chairs. Therefore a certain amount of flexible young shoot wood is demanded by the local tradesman. The 1% of the land in the CSA is managed with this model. This management model is based on cutting the shoots after reaching 4 years and providing new shoots. The shoots of the chestnuts is used in the production of hand-made chairs. Therefore a certain amount of flexible young shoot is supplied by the forest service. The model is suitable for oak species and chestnut, however, flexible young chestnut shoots is preferred.

Tree species used and tree species composition

The specie used is chestnut (*Castanea sativa*). The stands are monocultures.

Rotation periods

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Most common is rotation period of 20 years. The desired round wood will be used for pole production and fire wood and the time period is enough for the desired wood material.

Wood for chair production as furniture is available in 4 years. Therefore, rotation period should be four years for some stands of chestnut.

Size of clear-cuts

There are no regulation of size of logging areas, the average size is 14 and 46 ha for stand with 20 year and 4 year rotations are used, maximum 55 and minimum 6,5 ha.

Regeneration

All new shoots/trees originate from shoots/coppice.

To fill gaps in stands and replace the old stumps scarification is needed at a certain rate.

Browsing and fencing

Trees are originated from shoots. Young shoots are fast growing and recover from deleterious effects of browsing originated from livestock. (Browsing by game is not important). Therefore fencing is not done.

Management

Pre-commercial thinning

No pre-commercial thinning is done today. But when rotation is longer, (20 years) all stand are recommended to be pre-commercial thinned. Fire wood production is set as one of management goal in this management model. To get maximum wood material, it might be a good idea to perform pre-commercial thinning to remove weak shoots and to increase the accessibility in future thinning operations. But this is not done due limiting number of foresters.

There is no need for pre-commercial thinning when rotation is short, four years. Stand could not reach pre-commercial stands in four years.

Commercial thinning

With a rotation period of four or 20 years there is no need for thinning, the stands are cut and re-generated again when they reach commercial dimensions.

Pruning

Pruning is not recommended and is not done.

Harvest transport and logging residues

Chainsaw is used. For extraction forest tractor is the leading method as nearly 80%. Besides, animal power and man power are used in very steep conditions.

With short rotation there are no residue branches to collect. In coppice stands with 20 year rotation age, there is limited forest residue as branches > 5cm. However, available forest residues are generally collected by local people.

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10.9. Conversion of coppice to high forest

In the past nearly 30 % of the Turkish forest land was managed with the coppice system. However, from the beginning of the 2000s, those forest lands have been converted to high forests. Those areas are now generally young and in pre-commercial stage. In the future, after conversion to high forests, those areas should be turned to uniform shelterwood system Today the nearly 3% of the forest area is under conversion from coppice to high forest.

Tree species used and tree species composition

The specie are oak species, (*Quercus petraea, Quercus robur, Quercus frainetto*) while the more valuable coppice specie chestnut (*Castanea sativa*) still is used for coppice (see Table 58).

The stands are monocultures but in the future some admixture is recommended, species like horn-beam, maple or chestnut.

Rotation periods

Regeneration is not permitted until the conversion of high forests is fulfilled. However, thinning for the maintenance of stands is applicable. Therefore, a nominal rotation period is determined as 80 years for this planning period. After conversion, a realistic or practical rotation period will be determined according to target ecosystem service.

Regeneration

The aim is conversing coppice stands to high forests, therefore this can be regarded as a temporary process rather than a model. After conversion of coppice to high forest the purpose of the method will be completed. Regeneration is also not permitted until the conversion of high forests. The trees growing, the new high forest is established as coppice.

Stand management

Pre-commercial thinning

Although the management goal is not defined for this method and the only aim is conversion of coppice, it is important to make maintenance applications to reach high forest. Pre-commercial thinning is one of the tools while conversion of coppice to high forests and should be done in all stands. Today only 60-65% of the stand is pre-commercially thinned due to lacking forest technicians.

Commercial thinning

Thinning is another tool while conversion of coppice to high forests. It is also important to get trees with good stability. The obtained material is also used by near timber factories. 75-80% of the stands are thinned. Forest far from roads and where extraction cost is high is not thinned.

Pruning

Pruning is not done, as it is not suggested for broadleaves.

Harvest transport and logging residues

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The topography is not suitable for harvesters and the cost is high. Chain-saw is used for all maintenance operations. For extraction forest tractor is the most common method. Besides, animal power and man power are used. In very steep conditions small and middle size cable cranes or sledge yarders are also used

Forest residues are not extracted; however they are generally collected by local people.

Nature protection

Converting from coppice stand to high forest is a way to increase nature values. Forest value such as wood production, water conservation or soil conservation will be determined after conversion. Forest values are very efficient or determinative in integration of nature protection in the stand-level management.

10.10. Clear cutting model

Nearly 1% of the forest area is managed with a clearcutting system. The dominant tree species are Turkish pine (*Pinus brutia*) and maritime pine, (*Pinus pinaster*).

Tree species used and tree species composition

Turkish pine (*Pinus brutia*) and maritime pine, (*Pinus pinaster*) (exotic) should be used. Those species are fast growing and appropriate for the wood production.

More or less pure stands with Turkish pine as main specie and in most cases maximum 25 % admixture of maritime pine.

Rotation periods

Rotation age is regulated and in practice determined as 60 years regardless of the site index. However, on best sites, lower rotation age, as 50 years, is recommended to use. There is no need to wait extra 10 years in good site.

Size of clear-cuts

The size of the regeneration areas is calculated via “area control method” for each forest management unit. This formula uses planning parameters as total forest area, rotation age and planning period. Second, there is a “25 ha” size restriction about harvesting area at one time point. The maximum clearfelled are is 25 ha, the smallest 7 ha and the average 18 ha.

Regeneration

90 % of the seedlings reaching pole stage are planted, 10 % are natural regeneration. The management goal is maximum timber production and dominating species Turkish pine and maritime pine are both eligible for artificial regeneration and there is no problem for growing young stands.

Scarification is important to increase the success of establishment and are done in all clear-cuts. It results in an increased initial growth of the seedlings through better nutritional status and reduced mortality.

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Browsing and fencing

Browsing originated from game is negligible, however browsing from livestock, belongs to local people, has effects on the regeneration therefore all regeneration areas after clearfelling is fenced.

Stand Management

Pre-commercial thinning

Turkish pine and maritime pine are fast growing pioneers. To get target diameters earlier by reducing the intensity of competition and to increase the accessibility in future thinning operations as well as for the purpose of quality selection, it is a good idea to perform pre-commercial thinning. It is also important for reducing the fire risk in pine stands.

About 50-60% of the stands are pre-commercially thinned. Lack of forest technicians limit the areas pre-commercially thinned.

Commercial thinning

Thinning is required to achieve good diameter growth and trees with good stability. The obtained material can also be sold to buyers from near timber processing firms. It is also important for reducing the fire risk in Turkish pine and maritime pine stands. 80-90% of the stands are thinned. Forests, far from the roads and with high wood extraction costs could not be thinned.

Pruning

Pruning is not as it is not suggested.

Harvest transport and logging residues

The topography and harvester cost is not suitable. Chain-saw is used for all maintenance operations. For extraction forest tractor is the leading method as nearly 60%. Besides, animal power and man power are used. In very steep conditions small size cable cranes, middle size cable cranes or sledge yarders are also used

Forest residues are not extracted; however they are generally collected by local people.

Nature protection

Silvicultural guidelines (Technical Principles of Silvicultural Applications, No: 298) require some stand level targets towards dead wood management on the field. For instance, in economically designated areas for wood production, 1-3 dead wood trees per ha is to be retained in all managed are-as. When available, small areas of islands (<3ha) is promoted or left out for “aging islands”.

10.11. References

Persons involved:

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II. Ranking of Ecosystem Services (ES)

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Abbreviations used

AWF – Augsburg Western Forest (Germany)
BAU – Business as usual
CC – Clearcutting
CCF – Continuous Cover Forestry
CS – Cultural Services
CSA – Case study Area
DSS - Decision Support System
ES – Ecosystem Services
FMM – Forest Management Model
FPM – Freshwater pearl mussel
FSC – Forest Stewardship Council
FVZ – Forest Vegetation Zone (Slovakia)
IFM – Integrated Forest Management (the Neatherlands)
LCC – Local Case Coordinator
LFN - Lieberose Schaubetal Neuzelle (Germany)
MAI – Mean Annual Increment
MARA Minimum Allowable Rotation Age
NGO - Non-Governmental Organizations
NP – National Park
NWS – Native Woodland Sites
PCT – Pre-Commercial Thinning
PEFC - The Programme for the Endorsement of Forest Certification
SFE - State Forest Enterprise (Lithuania)
SFIMPI - State Forest Inventory and Management Planning Institute, (Lithuania)
WP – Work Package
ZIF Forest Intervention Zones (Zonas de Intervenção Florestal) (Portugal)

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1. Introduction to methodology

1.1. Ecosystem services and FMMs

Ecosystem services (ES) were ranked for each current stand-level FMM. A simple and efficient approach was used for providing an approximate ranking of the current stand level FMMs for each of the ES assessed in each ALTERFOR partner. Each ES leader provide a method, based on some important components connected to ES. The methods behind the ranking are built upon modified versions of the ES guidelines, adapted specifically to enable each participating LCC to evaluate the relative ES provisioning capacity of their FMMs, with or without the use of DSS.

The ES were biodiversity, carbon sequestration, cultural services, regulatory services and water related services. Important factors connected to and describing the ES was listed as help for the LCC to do the ranking. The ES experts used different number of factors or indicators. For example for biodiversity three indicators were recommended to use, while for carbon sequestration 18 attributes was listed. Indicators used differ between CSAs. For example risk for fire was used mainly in CSAs situated in south Europe.

The ranking of ES was done for CSA and FMMs can be compared within a CSA but not between CSAs. A high ranking of a FMM in one CSA does not indicate that it better than a corresponding FMM in other CSA.

1.1.1. Biodiversity

Here we do not rank biodiversity per se but rather habitat provisioning capacity in production forests. To do this, three key determinants of habitat available were identified and recommended to use. The components, all important for biodiversity were: tree species composition, forest structure and spatial-temporal disturbance patterns. Partners could use additional factors necessary to consider when evaluating habitat availability but it was suggested to limit the numbers or indicators used.

A scale from 1 to 7 was used. The average of these three scores gave a ranking.

The average of the indicator gave scores for each FMM to provide the resultant rank. Two distinct FMMs can result in the same or similar summary scores, provided this outcome is consistent with the FMMs being approximately equal in biodiversity value. An equivalent biodiversity value does not indicate that the same species will benefit. It only indicates an approximate equivalence in terms of closing the targeted gap between the habitat requirements of native flora and fauna (the biodiversity goals as above), and the habitat provision of an FMM.

1.1.2. Carbon

FMM ranking was based on the capacity to sequester carbon in forest and in forest products. Carbon can be stored in living pools, above ground and below ground, in deadwood and also in harvested material. Availability of data was an important limiting factor, which was of the reasons

to allow each case study team to adapt the analysis according to the existing conditions and data available for each CSA.

1.1.3. Cultural

Cultural services were ranked based on six key factors or concepts. They were: stewardship, naturalness/disturbances, complexity, visual scale, historicity/imageability and ephemera (Table 1).

Table 1 Indicators used for evaluation of cultural services for stand level FMMs

Concepts	Dimensions	Attribute	Indicator used	Data source	Direction
Stewardship	Sense of care	Amount of residue from harvesting and thinning	index (absent (0), low (0.25), medium (0.5), considerable (0.75), high (1))	expert judgement	negative
Naturalness/ disturbances	Alteration /impact	Area of final felling	Stand size index (<0.1 ha (0) to > 0.5 ha (1)	area class index	negative
Naturalness/ disturbances	Alteration/ impact	Frequency of final felling	Frequency index (0 = very often to 1 = no final felling)	expert judgement	negative
Naturalness/ disturbances	Natural Value	Naturalness of forest stands	hemeroby index (0 = natural, to 1 = monoculture, plantations)	Expert judgement	negative
Naturalness/ disturbances	Wilderness	Amount of natural dead wood	volume of standing deadwood	dead_volume_m3_ha	positive
Naturalness/ disturbances	Intrusion	Naturalness of forest edges/edge effects	index (straight edges (0), to inherent, natural borders (1))	expert judgement	positive
Complexity	Diversity	Tree species diversity within stand	shannon diversity index	shannondivindex	positive
Complexity	Variety	Variation of tree size within stand/age structure	CV of dbh	CV_dbh	positive
Complexity	Spatial pattern	Variation in tree spacing within stand	index (Regular (0), to irregular (1))	expert judgement	positive
Visual scale	Openness	Visual penetration/density of obstruction	Number of trees per ha	live_stemdensity_ha	negative
Visual scale	Visibility	Presence of understory in stand	Understory cover index (none (0), to > 50% (1))	understory_c	negative
Historicity/ imageability	Historical richness	Age of trees in stand	Stand age	age	positive
Historicity/ imageability	Historical continuity/ place identity	Age of current landuse	Number of sequential historical maps showing forest	GIS-Work to be done	positive

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Concepts	Dimensions	Attribute	Indicator used	Data source	Direction
Ephemera	Seasonal change	Presence of broadleaves	Percentage of coniferous trees	coniferous_fraction_ba	negative

Many of these factors consist of more than one attribute. A list of the 14 attributes are presented in Table 1. Some of the indicators were calculated e.g. **Shannon** index, some judged by experts. Some of these indicators indicate similar things, e.g no intervention are positive for "stewardship" and naturalness while visual scale/openness are in conflict with complexity and naturalness.

1.1.4. Regulatory

Regulatory services deal with risk for trees, stands and forestry. The ranking of the risk for different risks based on expert judgement, also supported by earlier research and information regarding the local forest management practices. The ranking should be based on general characteristics of the different FMMs. The importance of various risks differs a lot among CSAs, therefore different case study teams use different priorities in the risk analyses. Most typical and most frequently reported are risk for winddamages. Other risk factors included in the reports are risk for fire, bark beetles, snow, and diseases.

1.1.5. Water

Detailed quantifications of FMM effects on water provision were not possible given the time and resource constraints within the project. Therefore, the analysis relied on expert judgement. In most cases the judgement was done by a group of researchers consisting of several different fields of expertise. The indicators were: water yield, flood protection, water flow maintenance, erosion control and chemical conditions.

1.2. Summary of findings

1.2.1. Biodiversity

Tree species composition was an indicator evaluated and should have an effect on the result. But the differences are in many cases not large. In general, mixed stands got a higher ranking for biological values. An example of this is Ireland, where pure conifer stands got ranking, 2, spruce with admixture of other conifers got 2.67 and in admixture with deciduous trees 3.33 (Table 7). The Italian CSA reported ranking 4 for pine stands and 4.7 for mixed forest within the same FMM (Table 12). In Sweden, in FMM with intermediate rotation pure spruce 2.0, pure pine 3.0, mixtures of pine and spruce 3.5 and mixtures including deciduous 3.8 (Table 39). The small differences indicate that the available tree species and proportions of their mixtures are only one among many factors that influence biodiversity values.

The overall picture is that stands and FMMs dominated by broadleaves got a higher ranking than FMMs dominated by coniferous. An example of this is Turkey where FMMs including pine got ranking of 2.66 and 3.0 while FMMs characterised by high forest of broadleaves hade rankings from 4.66 to 5.66. On the other hand, it also illustrated that tree species itself don't give high biodiversity as coppice with oak and chestnut got the lowest values of all in Turkey, 1.66 and 2.66 respectively, (Table 47). An example for Germany shows that management can be more important than tree

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species. Pine and spruce forest managed by private owners got ranking 1.7 and 2.0 while pine and spruce managed by state got ranking 5.2 and 5.0 respectively, (Table 2).

There is trend that rotation period have an effect of forest structure and disturbance regime and FMMs with longer rotation have in general a slightly higher ranking but the differences are very small. Lithuania and Sweden have used rotation period to classify FMMs. The three FMMs in Lithuania with long rotation have in average a ranking of 3.5, five with medium rotation 3.5 and with short rotation 3.1. The figures for Sweden are 5.0, 3.1 and 2.3 for FMMs with long, medium and short rotation, respectively Table 39. It is important to take into consideration that rotation period and trees species are closely correlated and the figures above indicate not only the influence of rotation but also tree species.

The overall trend is that coppice systems have lowest ranking of biodiversity, clearcutting systems follows and highest values have selective systems. Non-uniform shelter system and models combining one or more systems also have high ranking. The example from Turkey indicates that biodiversity score reduced with coppice system (Table 47) and the examples from Germany (Table 2) and Lithuania (Table *23*), where selective systems and clear-felling systems are compared, show a higher ranking of selective systems.

It is not possible to separate the effect of the system itself from the tree species and the rotation periods. Coppice systems in general have short rotations and is used with only some species, clear-felling systems are often used for coniferous and selective systems are often used with deciduous trees or mixtures.

1.2.2. Carbon

It is a general agreement among scientists that forest may play an important role in mitigating climate change through carbon sequestration and through substitution effects. However, there is less agreements when it comes to which FMMs are is best for the combined effects of sequestration and substitution. This is also shown in this evaluation of the effects on carbon sequestration and substitution of various FMMs in the CSAs.

Both carbon sequestration and substitution depend on growth, harvest and on how the harvested products are used. With increased growth, biomass can either be stored in living trees or be harvested with subsequent substitution effects. Therefore, assumptions about differences in growth between FMMs will be very important for the carbon sequestration and substitution ranking of FMMs. Substitution can of course be higher if growth is high and if a large part of the growth is harvested. In addition, substitution depend on the products and how they are used and are higher for long-lived products replacing carbon intensive materials such as concrete or steel than for short-lived products like paper and bio-energy.

In this analysis, different silvicultural systems are compared. Therefore, storage of carbon in living biomass must be equalized. A continuous cover forest will of course have higher carbon storage when compared to a clearcut but not when compared to an old Norway spruce stand just before final felling. Therefore, it is necessary to compare storage and substitution over a whole generation for clearcutting (CC) systems and over several cutting cycles for continuous cover systems (CCF) and to include sources of carbon such as decomposition of harvest residuals on clear-cuts.

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A final remark before the individual CSAs estimate of carbon sequestration and substitution is that mitigating climate change can only be done if the combined effects of sequestration and substitution are increased compared to an initial value. The climate mitigation effects of a second-generation Norway spruce plantation will increase compared to the previous generation if the harvested biomass is used more efficiently from a substitution point of view (i.e. building material instead of paper) or if growth is increased (i.e. by the use of improved genetic material or fertilization). Conversion to continuous cover system from a homogeneous clearcutting system will increase mitigation if growth is increased or if the average landscape net effect of carbon storage in living material, carbon storage in the soil and carbon release during decomposition is increased.

Another complicating variable when it comes to comparing mitigation effects of different FMMs is that different FMMs are suitable on sites with different properties. On average, growth is lower for Scots pine than for Norway spruce which makes the former tree species less suitable for mitigating carbon. However, the difference in growth is mainly because Norway spruce is grown on fertile soils whereas Scots pine often is grown on dry and more infertile soils. Therefore, these tree species are not always exchangeable and it is difficult to compare them with regard to climate change mitigation.

With all the above difficulties, an attempt was made to rank the different FMMs in each CSA with respect to carbon sequestration and substitution. In most cases, the ranking was done using a 5- or 7-level scale but the variables used for the ranking varied between CSAs. In some cases, the ranking was based on simulation with a decision support system but in most cases expert judgement was used.

In many of the CSAs, the combined ranking varied relatively little between the different FMMs. In Germany, ranking varied between 3.5 and 5.5 on a 7-level scale. However, the lowest ranking was given to Scots pine forests which probably was due to lower site productivity in these forests. The Slovakian and Swedish CSA also used a 7-level scale and here most of the FMMs received average ranking between 3.5-5.5. On a 5-level scale, the ranking varied between 2.17 and 3.04 in Ireland and between 1.7-1.9 in Italy.

From the ranking, it is difficult to find FMMs in the individual CSAs that are substantially better than others from a climate change mitigation point of view. One reason for this is that so many variables are affecting sequestration and substitution and that these variables often are in conflict with each other. E.g. in the Slovakian CSA, the fir-beech FMM has high score on biomass production but a low score on substitution whereas the oak-timber FMM has a low score on biomass production and high score on substitution. The net effect of the overall assessment was that both FMMs received about equal overall rating.

A problem with this kind of ratings is that all variables have the same weight irrespective of the importance for sequestration and substitution. Therefore, it would be good to use a weight for the variables depending on their importance for either sequestration or substitution.

It is possible to compare similar FMMs over the different CSAs. In Germany, oak and beech FMMs received the highest rankings whereas in Sweden, the Norway spruce plantation FMM received higher ranking than the oak FMM. In Ireland and Sweden, the no intervention FMMs received low rankings while a similar FMMs in Slovakia and the Netherlands received high rankings. The

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differences in overall ranking for similar FMMs may depend on differences in site conditions in the CSAs and differences in the expert judgements.

In conclusion, it is not possible on the basis of this analysis to undisputably say that one FMM is much better than other FMMs with regard to climate change mitigation effects. However, because short rotation coppice forestry combines low carbon storage in the stand with low substitution effects, these FMMs probably are less suitable if mitigating climate change is a major aim. Another general conclusion may be that FMMs that combine high growth and long-lived products, such as oak forestry in Germany, may be among the top FMMs for mitigating climate change. However, it is important to note that high climate change mitigation effects with this FMM is only possible on highly productive sites. If fertility is lower, the oak-FMM will suffer from low productivity compared to many conifer species.

1.2.3. Cultural

Outcome of the ranking of cultural values shows that they are connected to tree species and rotation period and not primary with silviculture system used in the different FMMs. But as there are correlations between FMM and rotation period, thinning program and tree species it is difficult to separate the effects from different factors.

In Ireland lowest values were obtained for clearfelling systems of conifers in pure or mixed stands but also nature consideration connected to open areas had low values. For Lithuania there are not very big differences but all FMMs for coniferous have lower cultural values than FMMs for broadleaves. For Sweden the trend is that coniferous and short rotations decrease the cultural values. Long rotation that is applied for oak have high values and also the stands with management for nature values.

Cultural values can have more to do with the management than other factors. An example of this is Germany where the cultural values have more to do with management dictated by the owner than tree species and rotation. Private owners focus on economics while State forest in Germany are obligated to multiple use by forest law. Cultural values for FMMs presented by Germany in Table 3.

In Italy small differences were reported, with highest cultural values for riparian forests. The small difference might be explained that only one management model is used and the size of CSAs is small.

Coppice system have in general low cultural values. Turkey and Portugal reported lower cultural value than other FMMs in respective country.

Stand variation, expressed as naturalness and complexity were low in some specially management stands, example Slovakia where the lowest value for cultural values was for FMM for water purification (Table 36). This was explained by the even and homogenous spruce stands that are characteristic for management for water purification. If special management has other aim the result can be high cultural values as in Sweden where management for high natural values also result in high ranking for cultural values (

Table 44).

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An interesting result is showed from the Netherlands, where cultural values differ between trees species or group of tree species but for each specie or group of specie are higher in production forest than in nature forests (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

1.2.4. Regulatory services

Tree species seems to be the most important factor for risk for damages. Coniferous stands out with a higher risk for wind damages and fire than broadleaves. Compared to tree species, management models or other factors have a low impact. Only one partner, Lithuania, have added risk for diseases. With the experience of elm disease and the last decade experience of ash disease it can be discussed if all partners should include such severe events when describing risks.

In Germany the FMMs for coniferous stands have the highest risks and deciduous trees oak and beech lower risks. Spruce in clearcutting systems, with high risks for damages by bark beetles, wind and snow together give a higher risk than other tree species and FMMs. Spruce managed with selection systems have got a lover ranking of the risks, especially for wind and snow, than managed with clearfelling system. The risk for wind in that system was judged to be lower also compared with pine in shelterwood system (Table 5).

Lodgepole pine stands in the Irish CSA are not thinned and this have reduced the risk for winddamages. The risk is higher for other coniferous, mainly Sitka spruce, due to thinning and the fact that they normally reach a larger tree height then lodgepole pine. For the conifers risk for fire are highest in t*he thicket stage* and becomes lower when stands are older, Table 9.

In the Netherlands, the ranking was done regarding risks for wind damages and fire. There was a clear difference between broadleaves and coniferous, with a higher risk for damages with coniferous than for broadleaves. No difference between natural forests and production forests were reported (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

1.2.5. Water

As for several other ES, assessment of protection of water quality, water availability, flooding and erosion is difficult to do at this preliminary stage of the project. An additional problem regarding water related issues is that none of the DSSs include direct modeling of water. Instead, development of the forest stand has to be used as an indicator for the FMMs effect on this ecosystem service. However, in some CSAs available DSSs will be further developed to more directly handle e.g. water quality.

Overall, FMMs containing broadleaves have been ranked higher that conifer dominated FMMs. The reason for this is two-fold. Firstly, conifer stands produce higher concentrations of dissolved organic carbon (DOC) leading to higher levels of leakage and brownification. Secondly, since broadleaves often have longer rotations, the area in clearcuts will be lower than for conifers resulting in reduced runoff and risk for erosion.

Undisturbed FMMs generally have a high ranking for water related ecosystem services. The continuous cover of trees reduces the risk for runoff and erosion. In addition, not harvesting these areas eliminate the negative effect on water quality by soil-damage caused harvesting machines. However, unmanaged broadleaved forests rank higher than unmanaged conifer forests.

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Not all FMMs are exchangeable and should therefore be compared with caution. Oak forests ranked high for water in Sweden whereas Scots pine forests received low ranking. However, it is not practically possible to grow oak on the poor, dry sites where Scots pine is dominating making the comparisons between these two FMMs questionable.

The Irish CSA contains a FMM specifically designed to buffer watercources from human land-use management interventions. Also, the Slovakian CSA has a FMM designed to protect water from leakage of nutrients and water protection is an important part of the Italian FMM.

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2. Country reports

2.1. Germany

2.1.1. Biodiversity

For the FMMs in Germany the attainment of three key biodiversity characteristics were ranked on stand level with a 7-point scale (1 least, 7 maximum attainment). The ranking was done by forming a small expert team with silvicultural, forest dynamics, forest biology and ecosystem services background at the Chair for Forest Growth and Yield, Technische Universität München. The team assessed the FMMs based on the currently accepted knowledge among forest scientists and practitioners in Germany.

Table 2 Six German FMMs and associated subcategories ranked in terms of their relative capacity to close the gap between the habitat provided in production forests and the habitat requirements of forest dependent flora and fauna, 1 least, 7 maximum attainment.

FMM	FMM subcategory	Tree species composition (Native trees, broadleaf trees, tree species diversity)	Forest structures (older / larger trees coarse woody debris)	Disturbance regime (emulate natural disturbance regimes spatially and temporally	Rank out of 7
Selection system combined with non-uniform shelterwood system	Scots pine state forest	5.5	6	4	5.2
	beech state forest	6	5	4.5	5.2
Clear cutting system	pine large private forest	1	1	3	1.7
Clear cutting system combined with uniform and non-uniform shelterwood system	spruce large private forest	1	2	3	2.0
	oak state forest	5	3.5	3.5	4.0
Selection system	spruce state forest	5	6	4	5.0

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Selection system combined with non-uniform shelterwood system – Scots pine state forest

In terms of tree species composition, this concept was highly ranked, because the state forest actively promotes the establishment and preservation of native broadleaf species in conifer stands. Similarly, the concept earned a high rank for forest structures, larger trees and coarse woody debris, as the combination of a selection system with a non-uniform shelterwood system generates highly vertical and horizontal stand structures. A few large trees are preserved in such stands, when they die they are left in the stand. One of the intentions of this silvicultural systems is to partly emulate small scale disturbances like the death of large single trees, trying to keep the forest in a state which is also observed in unmanaged stands, but only transitional there.

Selection system combined with non-uniform shelterwood system – beech state forest

In principle, the same applies as for the Scots pine state forest FMMs. However, this FMM was slightly higher ranked than the one for Scots pine, as its tree species composition is in general nearer to the local natural tree species (Germany, without human intervention would be almost totally covered with beech-dominated forests. In terms of Forest structures we gave a slightly lower rank, as beech forests strongly tend to form close canopies with strong light interception. This can put trees below the dominant trees' crown layer at risk. The emulation of disturbance regimes was ranked slightly higher than for the pine state forest concept, as the death of large single-trees due to external influences was considered more typical for beech than for pine forests.

Selection system – spruce state forest

Again, the same general considerations apply as for the two state forest concepts mentioned above. However, among the state forest concepts, this one got the lowest rank, as the main tree species – Norway spruce – is not a native (dominating) tree species on the largest part of the areas where it is cultivated. As spruce, in mixture with other shade tolerant (beech, silver fir) or intermediately shade tolerant species (sycamore) can well be managed to form uneven-aged structured stands, this FMM got a higher ranking for forest structures than the beech state forest FMM. On the other hand, deliberately emulating natural disturbances in spruce forests (or – more general - conifer forests) could be riskier than for beech. Thus, this concept was given the same rank as the Scots pine state forest FMM.

Clear cutting system combined with uniform and non-uniform shelterwood system – oak state forest

While this concept was ranked quite highly for its tree species composition (oak together with other species like hornbeam, beech, sometimes rare Sorbus species), its ranking for forest structures is lower than for the previously mentioned state forest concepts. The reason being that uneven-aged forest management does not work well as with oak like it does for beech, spruce, and pine. Similarly, also the emulation of natural disturbance regimes is weaker there.

Clear cutting system – pine large private forest

Due to their main goal of obtaining income, large private forest owners are usually not interested in spending money for establishing or preserving additional tree species in monocultures of the locally most productive species. Thus this concept's ranking for tree species composition is very low. The same applies to forest structures and coarse woody debris, as this kind of management leads to homogeneous forest stands with only small amounts coarse deadwood. Disturbances are not

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actively emulated, however, they regularly occur (frequently defoliations by insects) and foresters heavily counteract in order to prevent greater economic losses. Therefore, our ranking in this section is comparably low.

Clear cutting system combined with uniform and non-uniform shelterwood system – spruce large private forest

This FMM ranks between pine large private forest and oak state forest, being in all considered criteria nearer to the former than to the latter.

Summary

In terms of biodiversity, the three state forest FMMs for Scots pine, beech, and spruce obtain the highest ranks. The state forest concept for oak has an intermediate rank, while spruce and pine as managed mostly in large private forest are ranking lowest.

2.1.2. Cultural

The attainment of six key cultural service provision characteristics of the German stand level FMMs were ranked on a 7-point scale (1 least, 7 maximum attainment). The ranking was done by forming a small expert team with silvicultural, forest dynamics, forest biology and ecosystem services background at the Chair for Forest Growth and Yield, Technische Universität München. The team assessed the FMMs based on the currently accepted knowledge among forest scientists and practitioners in Germany.

Table 3 Six German stand level FMMs and associated subcategories ranked in terms of their contribution to the provision of cultural ecosystem services (1 min, 7 max).

FMM	FMM subcategory	stewardship	naturalness/disturbances	complexity	visual scale	historicity/ image ability	ephemera	Rank out of 7
Selection system combined with non-uniform shelterwood system	scots pine state forest	5.5	6	6	5	5	5	5.5
	beech state forest	6	6	6	5	5	6	5.7
Clear cutting system	pine large private forest	3	3	2	3	2	2.5	2.9
Clear cutting system combined with uniform and non-uniform shelterwood system	spruce large private forest	3.5	3	2	3	2	2.5	2.9
	oak state forest	5	6	5	3	7	5.5	5.5
Selection system	spruce state forest	6	6	6	3	5	6	5.7

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The considerations underlying the ranking of the single characteristics were as follows:

Stewardship

In general, the large private forests are used more intensive than the state forest resulting e.g. in lower amounts of residues from harvesting and thinning.

Naturalness

State forest aims for maintaining, introducing, and preserving more native tree species in mixture with the main species. More deadwood is allowed to accumulate, clearcuts are avoided.

Complexity

Close-to-nature uneven-aged structures are strived for in the state forest, leading to more complex, vertically and horizontally structured stands with higher tree size variation and higher species diversity than in the large private forests.

Visual scale

The FMMs in the large private forest and the state forest lead to visually different forest stands, even for the same (main) tree species. The private forest stands have a more plantation-like appearance (very similar tree sizes in the same stand, not much understory, if any) then state forest stands. Usually, recreationists prefer the esthetics of the latter ones.

Historicity

In average, trees in continuous cover forestry (as strived for in the state forest FMMs) get older than under even aged systems in Germany. The share of such stands is higher in the state forest.

Ephemera

In the state forest additional species are always promoted. Private owners prefer pure stands with the most productive species.

Ranking outcomes

The overall ranking results shows evidently higher ranks for the state forest FMMs, only with slight differentiation among the main tree species. The large private forest FMMs are on the other end of the scale. This, clearly does not come as a surprise, as the state forests are obliged to multiple-use forestry by law, while generation of income for the forest owners must be the dominant requirement in the large private forests.

2.1.3. Carbon

The attainment of three key C-Sequestration properties of the German stand level FMMs were ranked on a 7-point scale (1 least, 7 maximum attainment). The ranking was done by forming a small expert team with silvicultural, forest dynamics, forest biology and ecosystem services background at the Chair for Forest Growth and Yield, Technische Universität München. The team assessed the FMMs based on the currently accepted knowledge among forest scientists and practitioners in Germany. The result is presented in Table 4.

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Table 4 Six German FMMs and associated subcategories ranked (min 1, max 7) in terms of their relative capacity for C-sequestration. We differentiated between C stored in a stand's living trees ("stand"), in deadwood, and in harvested wood products.

FMM	FMM subcategory	stand	deadwood	harvested products	Rank out of 7
Selection system combined with non-uniform shelterwood system	Scots pine state forest	4.5	3	4	3.8
	beech state forest	5.5	6	5	5.5
Clear cutting system	pine large private forest	5	2	3.5	3.5
Clear cutting system combined with uniform and non-uniform shelterwood system	spruce large private forest	7	2	4	4.3
	oak state forest	5	6	6	5.7
Selection system	spruce state forest	6	3	4	4.3

Selection system combined with non-uniform shelterwood system – Scots pine state forest

The amount of C stored in a stand's living trees results from the stand volume per unit area on the one hand, and the wood density on the other hand. This FMM got the lowest rank here, because compared with other species, both values are low for pine, and due to the goal of achieving uneven-aged forests, stand densities are lower in this FMM than they are with even-aged pine concepts (see pine large private forest below). As for deadwood, the state forest in general considers more ecological aspects than the private forests do, thus, there is more deadwood and consequently more C stored in that. For the harvested wood products a similar consideration applies as for the stand: The more is harvested and the denser the wood, the more C is stored in there. But in addition, the longevity of the wood products has to be taken into account as well. This ranking also considered, that the usage time of conifer wood products is in general shorter than for hardwoods, and that large private owners generally more strive for mass products, while the state forest strives for higher quality. For these reasons this FMM was ranked slightly higher for C-sequestration in harvested wood products than the Scots pine FMM for large private forests.

Selection system combined with non-uniform shelterwood system – beech state forest

Tendentially stand volumes are higher in beech forests than in pine forests together with a considerably higher wood density. This leads to a higher rank in terms of stand-level C- storage. Also the high ranking for C in deadwood results from the higher density and the by trend higher deadwood amounts in these beech forests. Ditto for the harvested wood products, higher ranking for beech than for pine because of higher wood density, but also higher usage time.

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Selection system – spruce state forest

Wood density for spruce is somewhat lower than for pine, but the stand densities and therefore standing volumes are much higher, storing considerably more C. Deadwood and harvested wood products are ranked the same as for pine.

Clear cutting system combined with uniform and non-uniform shelterwood system – oak state forest

Despite the high density of oak wood, this FMM got a rank just slightly beyond pine state forest, as the low stand volumes outweigh the former. Vice versa, the deadwood of oak is very durable and thus accumulates to comparably high amounts. Wood products made from oak are in average the most durable ones compared to those provided by the other main species covered by the German stand level FMMs.

Clear cutting system – pine large private forest

As the private forest owners do not strive for vertically rich structured stands, they can keep higher levels of stand volumes and therefore more stored C. Under this kind of management, less deadwood accumulates compared to state forest, thus, the ranking of deadwood-stored C is lower. The higher share of shorter-living mass products form the private forests leads to a lower rank for C in harvested wood products compared to the state forest concept for the same species.

Clear cutting system combined with uniform and non-uniform shelterwood system – spruce large private forest

The even-aged, dense spruce stands as resulting from the large private forest FMM have very high stand densities and accordingly store large amounts of C, this results in the top rank in this category. For deadwood, we see no considerable difference with pine in the private forests, as production potential is higher for spruce, C stored in harvested wood products is ranked higher than for pine in the private forests. It is, due the products' shorter lifetime, however, lower ranked than beech and oak in the state forest.

Summary

Overall, the oak, and beech state forest FMMs rank highest in terms of C-sequestration, followed by both, the state and private spruce FMMs and the pine FMMs, whereby pine large private forest ranks lowest.

2.1.4. Regulatory

We ranked the attainment of four regulatory service characteristics of the German stand level FMMs on a 7-point scale (1 least, 7 maximum attainment). The ranking was done by forming a small expert team with silvicultural, forest dynamics, forest biology and ecosystem services background at the Chair for Forest Growth and Yield, Technische Universität München. The team assessed the FMMs based on the currently accepted knowledge among forest scientists and practitioners in Germany.

The considerations underlying the assessment were as follows:

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Bark Beetle

Bark beetles (by far most important the spruce bark beetle *Ips typographus*) belong to the most dangerous harmful organisms affecting forest management in Germany. Mainly, they affect conifers (most important Norway spruce). In monospecific, even aged forests the risk of mass outbreaks is highest. Without countermeasures, large forest areas can be devitalized in short time. Thus the large private forest FMM for Norway spruce was given the highest rank in terms of bark beetle risk. Due to the less bark-beetle friendly stand structures created in the state forest spruce FMM, the latter concept is ranked slightly lower, however, still bearing a considerable risk of bark beetle infestations.

Wind

Wind breakage is a very common damage in German forests, conifers are more endangered than hardwoods, most affected is Norway spruce. Often wind breakage creates ample breeding material for bark beetles which may considerable increase the damage. Even-aged, monospecific stands usually are at higher risk than more complex structured stands due to a lack of individual tree stability and a higher tendency of air turbulence at steep stand edges. Thus the state forest FMMs for spruce and pine have lower ranks (lower risks) compared to the private forest FMMs.

Snow

The risk of snow breakage is very similarly distributed among the FMMs as is the wind breakage risk. Even-aged stands with a dense canopy can break down on larger areas while less homogeneous stands usually contain more individually stable trees which can bear higher snow loads. Breakes of whole areas are less frequent than in homogeneous stands. In both cases, snow and wind damages, the uneven-aged focused state forest FMMs result in more resilient stands. Usually dominant and co-dominant trees are broken in such events, and if there are waiting trees in the layers below, the losses can be more easily covered compared to the even-aged large private forest FMMs.

Fire

Fire damages are a prominent risk especially in the North-East German case study. Most exposed are pine stands which are often found on very dry, i.e. sites with a high wildfire risk. Young pine stands are at an especially high risk due to their dry dead branches covering almost the whole length of the stem below the living crown. Mixed stands are less vulnerable (hardwood admixtures reduce solar radiation reaching the ground, thus preventing the growth of grasses which, in dry summers, are highly flammable), which means a slight advantage for the pine state forest FMM compared to the large private forest pine FMM. Spruce is much less endangered by wildfires as its cultivation is not an option on such dry sites. Hardwoods in general contain more moisture than pine even in dry summers, making them considerably less inflammable.

Outcome of the ranking

The highest overall risk comes together with (the most productive) large private forest FMM for Norway spruce due to its susceptibility to the classic damaging agents bark beetle, wind, and snow. The second-highest overall risk is connected with the state forest pine FMM, here bark beetle risk is lower, but counterweighted by a high wildfire hazard. Due to the reasons given above, the state

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forest conifer FMMs are considerably less risk-prone, actually, risk mitigation is an important motivation behind these FMMs. Hardwood stands in general are much less vulnerable, thus the beech and oak FMMs rank lowest.

Table 5 Six German FMMs and associated subcategories ranked in terms of their relative risk to be affected by damaging agents, (1 min risk "best" to 7 max, "high risk").

FMM	FMM subcategory	bark beetle	wind	snow	fire	Rank out of 7
Selection system combined with non-uniform shelterwood system	scots pine state forest	3.5	4	4	5	4.1
	beech state forest	2	3	3	2	2.5
Clear cutting system	pine large private forest	4	5	5	5.5	4.9
Clear cutting system combined with uniform and non-uniform shelterwood system	spruce large private forest	5	6	6	3	5
	oak state forest	2	2	2	2	2
Selection system	spruce state forest	4	3.5	3.5	3.5	3.6

2.1.5. Water

The attainment of five water-related characteristics of the German stand level FMMs were ranked on a 7-point scale (1 least, 7 maximum attainment). The ranking was done by forming a small expert team with silvicultural, forest dynamics, forest biology and ecosystem services background at the Chair for Forest Growth and Yield, Technische Universität München. The team assessed the FMMs based on the currently accepted knowledge among forest scientists and practitioners in Germany.

Compared to the other ES considered, less is known and information is more ambiguous about water related ES. Possibly more important for water related services than FMMs is the question whether an area is covered with forests or other vegetation.

Considerations behind the ranking:

Water yield, water flow maintenance

Groundwater recharge is considered higher in stands with oak or beech compared to pine and spruce dominated stands, but the difference that makes is under debate, see (https://www.lwf.bayern.de/mam/cms04/boden-klima/dateien/a66-wasserverbrauch-von-waeldern.pdf).

Flood protection

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Scots pine is considered to have a lower rainfall interception than the other species, leading to a higher runoff. Thus, pine forests (both pine-based FMMs) rank lowest in terms of flood protection. In vertically structured stands interception is generally higher than in even aged ones. This is why the state forest spruce FMM ranks higher than the pine FMMs in general and the even-aged spruce in large private forests. For the same reason, the hardwood-focused FMMs rank higher than pine.

Erosion control

Here, our ranking covers the concept that mixtures of shallow rooters (spruce), deep rooters (pine, oak), and intermediate rooters (beech) have a stronger soil-stabilizing potential than monospecific stands which typically stabilize one soil layer only. The highest weights were therefore attributed to the (comparably rich in additional species) state forest FMMs for spruce and pine followed by beech. The even-aged large private forest spruce and both pine FMMs were given a similar comparably low rank.

Chemical conditions

Hardwood stands dominated by beech and oak are generally associated with a lower nitrate seepage than conifers due differences in key processes (interception, nitrate uptake).

Overall ranking outcome

Generally, due to often unclear information, we were cautious against introducing too high contrasts in the ranking of water related services. Currently we are performing orienting simulation studies with a process-based model whose results will allow us to be more precise when evaluating the ALTERFOR scenario runs.

However at the time being, our ranking is favors the state forest FMM for oak followed by the state forest concepts for spruce and beech. The lowest overall rank comes out for the even-aged spruce FMM of large private forests together with both pine FMMs.

Table 6 Six German FMMs and associated subcategories ranked in terms of their relative capacity to provide water-related ecosystem services (min 1, max 7).

FMM	FMM subcategory	water yield	flood protection	water flow maintenance	erosion control	chemical conditions	Rank out of 7
Selection system combined with non-uniform shelterwood system	scots pine state forest	4	3.5	4	3.5	3.5	3.7
	beech state forest	5	4	5	4	4	4.4
Clear cutting system	pine large private forest	4	3.5	4	3.5	3.5	3.7
Clear cutting system combined with uniform and non-uniform	spruce large private forest	4	3.5	4	3.5	3.5	3.7
	oak state forest	5	4.5	5	4.5	4	4.6

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FMM	FMM subcategory	water yield	flood protection	water flow maintenance	erosion control	chemical conditions	Rank out of 7
Shelterwood system							
Selection system	spruce state forest	4	4.5	4	4.5	3.5	4.3

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2.2. Ireland

2.2.1. Contrasting the relative biological diversity of Ireland's stand level FMMs

Clearcutting FMMs

A clearfell FMM is a rotation-based system which involves 4 growth stages. Each clearfell FMM roughly follow these stages and the difference between them will be described more distinctly in the remainder of the document.

- **Establishment stage** is where light reaches the ground, providing food and habitat for bird species (Wilson et al., 2009) *inter alia.* In larger forest blocks that are present in the CSA, these areas mixed in between maturing stands helping to form a structural mosaic pattern on the landscape (O'Callaghan et al., 2016), i.e. useful for biodiversity;
- **Thicket stage** is when the forest canopy has closed, no mortality has taken place yet and no thinning has been carried out. The forest floor is restricted from sun light and although providing cover for some species (O'Halloran et al., 2011; Smith et al., 2005), the biodiversity value is quite low;
- The **Commercially maturing** stage is where thinning has been carried out/or mortality has set in. The forest canopy is more uneven and there are gaps in places allowing sun light to reach the ground. Some natural regeneration may occur from this point on;
- **Commercially mature**. Here stands have reached financial maturity and may have undergone several thinnings. In either case, there are at least some openings in the forest canopy making the canopy structure diverse. When a stand is clearfelled, broadleaf trees (which may have regenerated naturally throughout the latter stages of the rotation) are retained and some harvesting residue is left on site.

Ireland has relatively short-term rotations 30 – 60 years. This means that disturbance events are relatively frequent as are changes between the four changes in structure described above. The retention of naturally regenerated broadleaves within a stand during clearfell is now common practice. This will mean that more mature trees will benefit biodiversity into subsequent rotations. But it is not expected to reach the biodiversity levels of some other FMMs. For example, native woodland sites, watercourse bufferzones.

Clearcutting conifer – Spruce monoculture

Sitka spruce is an exotic and conifer species. This sub-FMM is the most dominant in the CSA and it has little species diversity. This FMM is not permitted for establishment into the future as there must be some form of species diversity measures from now on at establishment stage (alternative FMMs are described). The stand is even-aged and the production focus means that commercial thinnings are carried out where financially feasible meaning that there is little mortality for natural deadwood. At the end of a rotation (age can vary depending on a site's productivity and spatial location), residue may be removed from site (on fertile mineral sites mainly) or windrowed (on exposed sites), both practices will benefit plants at re-establishment stage. Considering this FMM to be the predominant one in the landscape, it will be considered as the baseline for the Irish FMM assessment Table 7 below.

Clearcutting conifer – Spruce with 10% diverse conifer mix

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This is the first sub-FMM commonly used as an alternative to the spruce monoculture sub-FMM. It comprises an intimate mix of Sitka spruce and/or lodgepole pine together with a suitable diverse conifer. The diverse conifer content must be at least 10% of the total number of trees planted. This diverse species can be intimately mixed through the forest or planted in groups through the forest, or a combination of both where silviculturally compatible with the main species (Forest Service, 2015). The additional conifer species adds some species diversity to this FMM. In some cases, there is an option to establish Scots pine (*Pinus sylvestri*s) as the diverse conifer meaning that this FMM can contain some native species.

Clearcutting conifer – Spruce with 10% broadleaf mix

This is the second sub-FMM commonly used as an alternative to the spruce monoculture FMM. It comprises an intimate mix of Sitka spruce and/or lodgepole pine together with a suitable broadleaf species. The broadleaf can be established intimately if growth rates are comparable or in groups (Forest Service, 2015). The broadleaf species are chosen from an approved list containing mostly native species, e.g. Cherry (*Prunus avium*), common alder (*Alnus glutniosa*), sycamore (*Acer pseudoplatanus*) birch (*Betula spp.*). The addition of broadleaves increase stand level species diversity, structural diversity and also native trees.

Clearcutting conifer – Diverse conifer

This sub-FMM comprises an acceptable diverse conifer species at establishment e.g. Scots pine, Douglas fir (*Pseudotsuga menziesii*), Western red cedar (*Thuja plicata*). Considering the Sitka spruce and lodgepole pine dominated landscape, this FMM is considered to create more tree species diversity in the CSA. If Scots pine is chosen, this would also increase the area of native tree species.

Clearcutting lodgepole pine

This FMM is monoculture lodgepole pine. This species is not thinned as it responds by producing large side branching which means that thinning will not increase the economic viability of the crop. This means that there is typically more natural deadwood at the commercially maturing and commercially stages due to mortality. Considering the monoculture nature of this FMM it's biodiversity is relatively low. Like the spruce monoculture, this FMM must also be reforested with either of the 10% mixes described above, however the main species is lodgepole pine and no thinning takes place.

Nature conservation and biodiversity protection – Open space

These are areas, sometimes within stands and sometimes separated. They are scrub like in appearance and very often provide suitable areas for foraging while also allowing for cover in nearby stands. There may be woody shrubs present. If these areas are within another forest stands, attempts will be made to re-establish them, meaning that they have a similar level of permanence to the clearcut FMMs however, considering the diversity, the biodiversity value of these areas is considered to be relatively high.

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Table 7 Summary of ranking Biodiversity values Ireland. 1 Lowest value, 7 highest.

FMM	FMM subcategory	Tree species composition (native trees, broadleaves, tree species diversity)	Forest structures (older/larger trees coarse woody debris)	Disturbance regime (emulate natural disturbance regimes spatially and temporally	Rank out of 7
Clear cutting conifer	Spruce monoculture	2	2	2	2
	Spruce with 10% diverse conifer mix	3	3	2	2.67
	Spruce with 10% broadleaf mix	4	4	2	3.33
	Diverse conifer	3	3	2	2.67
Clear cutting lodgepole pine	Unthinned. 10% diverse mix required for reforestation	1	3	2	2
Nature conservation and biodiversity protection	Open space	2-5	1-5	2	2.17
	Watercourse bufferzone	2-5	3-7	7	4.5
	Bog habitat	0	0-2	7	2.67

Nature conservation and biodiversity protection – Watercourse bufferzone

These areas are riparian buffers. They contain small proportions of native broadleaves and the remainder of the area is scrub. The intention is to buffer the effect of nearby forest stands and management operations carried out on them. However, the areas themselves provide wildlife corridors which are beneficial for *inter alia* foraging animals etc. and the biodiversity value of these areas is relatively high. However, once established, it will not be disturbed as is the case with the clearcut FMMs. It is possible that the trees will eventually mature, naturally regenerate and form a diverse structure.

Nature conservation and biodiversity protection – Bog habitat

Some areas in the CSA have been restored from an afforested forest site to the area’s most-likely previous peatland habitat. Approximately 11% of the CSA has a bog land-use and hence from a diversity perspective, more of this sub-FMM is not expected to add much. However, once established, it will not be disturbed as is the case with the clearcut FMMs. Where bog habitat was restored on very young sites, whole trees are left on site meaning that deadwood content is high.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 676754.

2.2.2. Contrasting the relative carbon of Ireland's stand level FMMs

Clearcutting FMMs

A difference between the carbon ES and others is that carbon can both be stored in living pools during a clearcutting FMM's rotation and also in pools of harvested material and deadwood. The living carbon pools quantified for ALTERFOR are described below and are grouped into one 'living carbon' pool for this analysis:

- **Aboveground carbon** – The carbon stored in living trees that is above the ground, it includes carbon stored in stem, bark, branch and leaf;
- **Belowground carbon** – The carbon stored in living trees that is below the ground, i.e. roots.

The non-living carbon pools are listed below. A certain proportion of each of these pools is considered to decay annually:

- **Natural deadwood** – The deadwood that typically happens from mortality in Ireland's plantation-based FMMs, it includes both above ground and below ground natural deadwood;
- **Harvest residue** – The material that is left on site post harvesting events, also includes below ground deadwood from harvesting;
- **Harvested wood products** – The carbon that is stored in processed products. The products are divided into paper and pulp, wood-based panels and sawlog products but are totalled and presented as one pool in this analysis.

A measure of the relative quantities of carbon emissions replaced from cement and steel and fossil fuels is also provided.

Clearcutting conifer – Spruce monoculture

A monoculture of Sitka spruce with a productivity of 16 m^3 ha^{-1} yr^{-1} is used for this analysis. There are 4 commercial thinnings carried out with a clearfell at the age of 42 years (Figure 1).

Until clearfell, the total living carbon increases as the stand matures. There is a slight increase in the non-living pools from commercial thinnings throughout the rotation. There is stand mortality throughout the rotation increasing the natural deadwood carbon pool. Decay factors on these non-living pools accounts for a decrease in their carbon content over time. The clearfell event at age 42 means that the living carbon pool is completely removed and some of this carbon moves into the non-living carbon pools.

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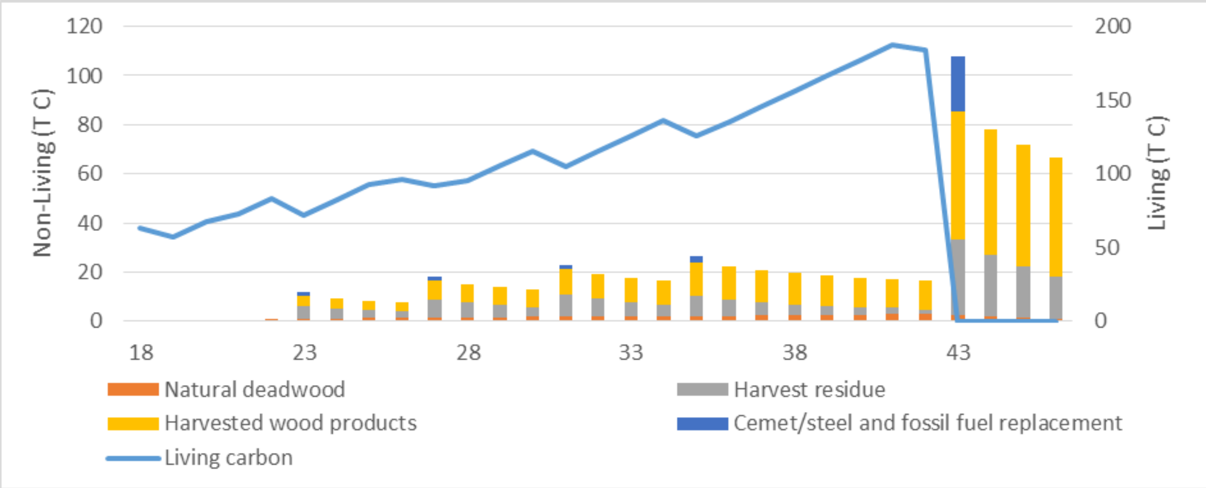

Figure 1 A per-age (x-axis) carbon assessment (T C ha^{-1}) for the clearcutting conifer - spruce monoculture sub-FMM

Clearcutting conifer – Spruce with 10% diverse conifer mix

A monoculture of Sitka spruce with a productivity of 16 m^3 ha^{-1} yr^{-1} and 10% Douglas fir with a productivity of 14 m^3 ha^{-1} yr^{-1} is used for this analysis. There are 4 commercial thinnings carried out with a clearfell at the age of 42 years).

Typically Sitka spruce will have the highest yield class for any site in Irish forest management. For this reason, the slightly less productive diverse conifer (used in this analysis) means that the carbon storage potential is slightly lower than the spruce monoculture sub-FMM.

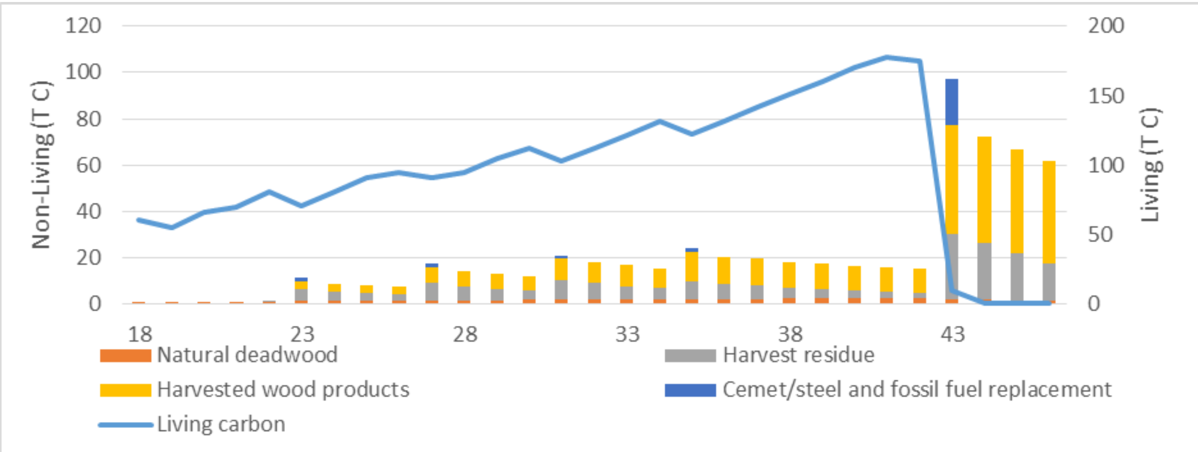

Figure 2 A per-age (x-axis) carbon assessment (T C ha-1) for the clearcutting conifer – spruce with 10% diverse conifer mix sub-FMM

Clearcutting conifer – Spruce with 10% broadleaf mix

A mixture of 90% Sitka spruce with a productivity of 16 m^3 ha^{-1} yr^{-1} and 10% birch with a productivity of 6 m^3 ha^{-1} yr^{-1} is used for this analysis. There are 4 commercial thinnings carried out with a clearfell at the age of 42 years (Figure 3).

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Over the course of a 42 year rotation, Sitka spruce will grow much quicker than the 10% broadleaf mix in this sub-FMM and hence, living carbon is lower than the monoculture or diverse mixture sub-FMMs. When harvested, birch material is used for firewood which is not considered to be a harvested wood product nor replace cememt/steel or fossil fuels for this analysis.

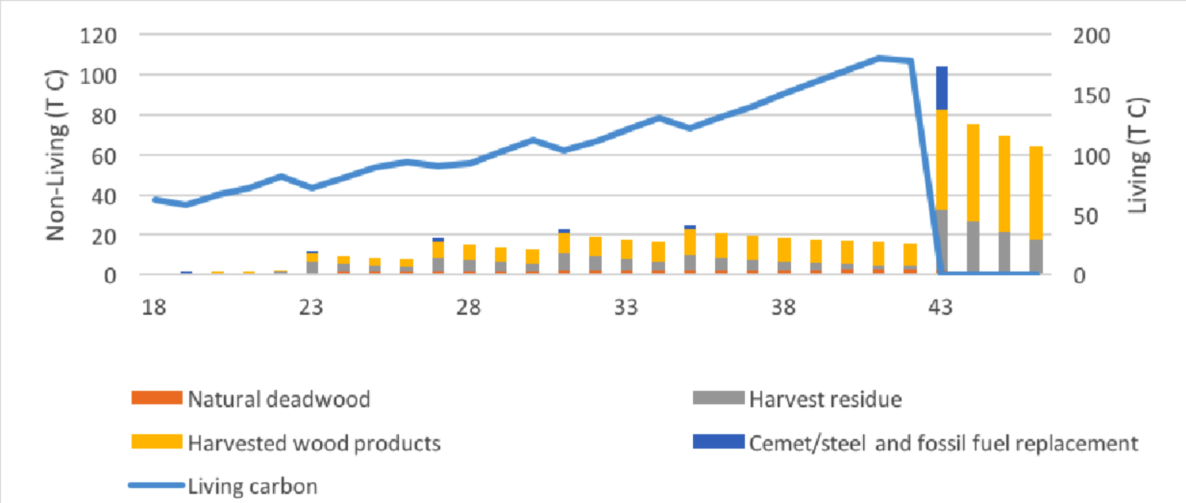

Figure 3. A per-age (x-axis) carbon assessment for the clearcutting conifer - spruce with 10% broadleaf mix sub-FMM

Clearcutting conifer – Diverse conifer

A monoculture of Douglas fir with a productivity of 14 m^3 ha^{-1} yr^{-1} is used for this analysis. There are 4 commercial thinnings carried out with a clearfell at the age of 42 years (Figure 4). The diverse conifer is not as productive as Sitka sprue meaning that there is less carbon stored.

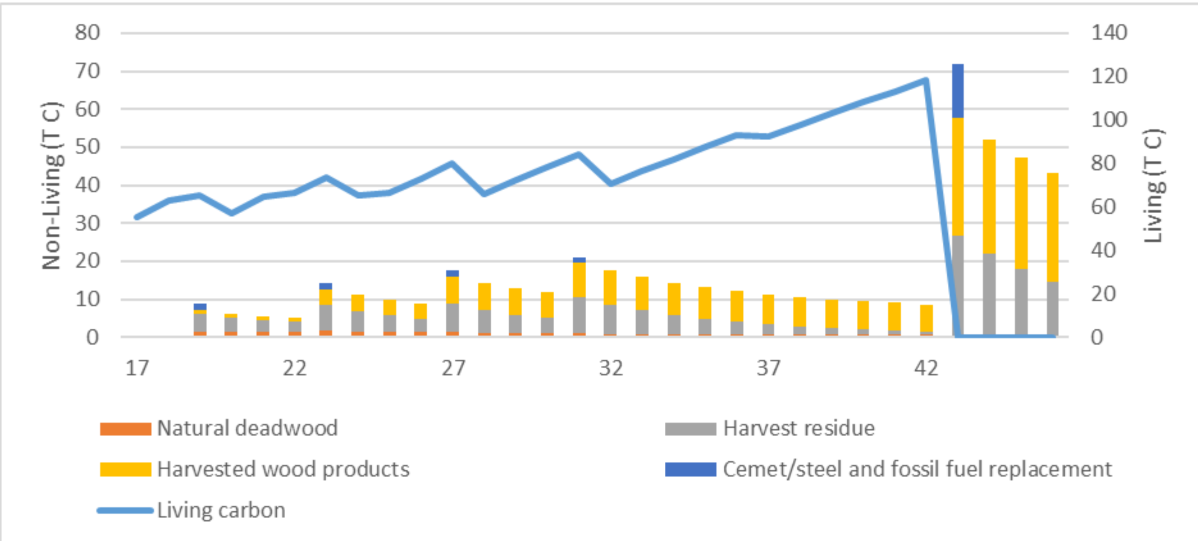

Figure 4. A per period carbon assessment for the clearcutting conifer - Diverse conifer sub-FMM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Clearcutting lodgepole pine

A monoculture of Lodgepole pine with a productivity of 10 m^3 ha^{-1} yr^{-1} is used for this analysis. No thinning takes place for this FMM and there is a clearfell at the age of 45 years (Figure 5).

Lodgepole pine is less site sensitive to Sitka spruce and it is chosen for sites that are not suitable for Sitka spruce. However, it will not reach the same productive capacity or meet the same timber quality indicators required for sawlog products. Instead, 90% harvested is used for panel products while 10% is used for biofuel (Clarke, 2017, Business Area Unit 2 Team Leader, Coillte Forest *Pers. Comm.* to Lundholm, A.) which is included in this analysis.

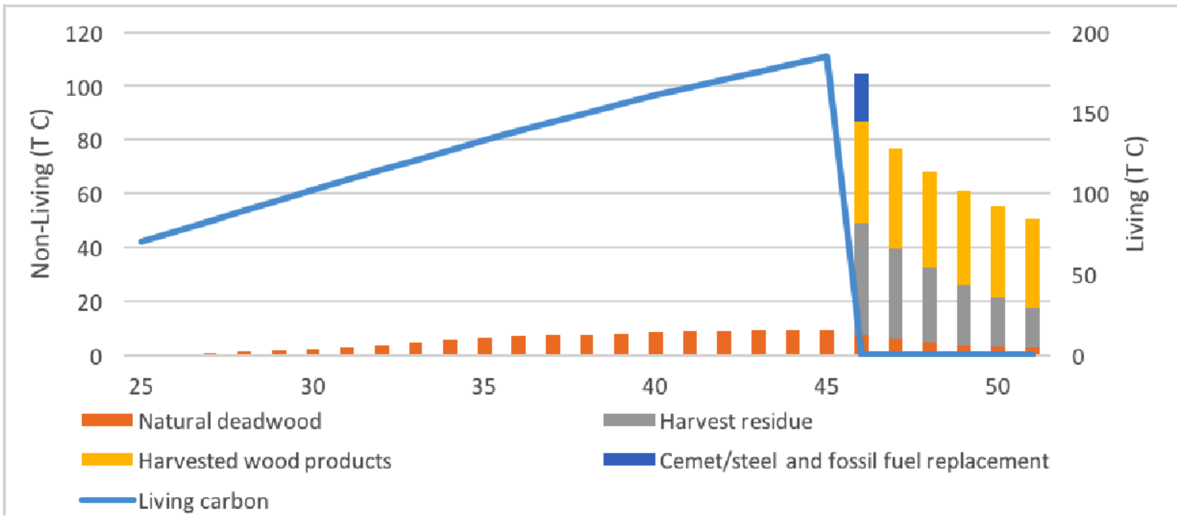

Figure 5 A per-age (x-axis) carbon assessment for the clearcutting lodgepole pine FMM

Nature conservation and biodiversity protection FMMS

Carbon from non-forest sources is not calculated for Ireland's analysis. This means that the open space and bog FMMs are assumed not to have any carbon fluctuations. The watercourse buffer zone used within 6 km hydrological distance of a freshwater pearl mussel breeding site is established with 20% broadleaf species. These trees will never be harvested which means that only living carbon and natural deadwood is accounted for in this assessment (Figure 6).

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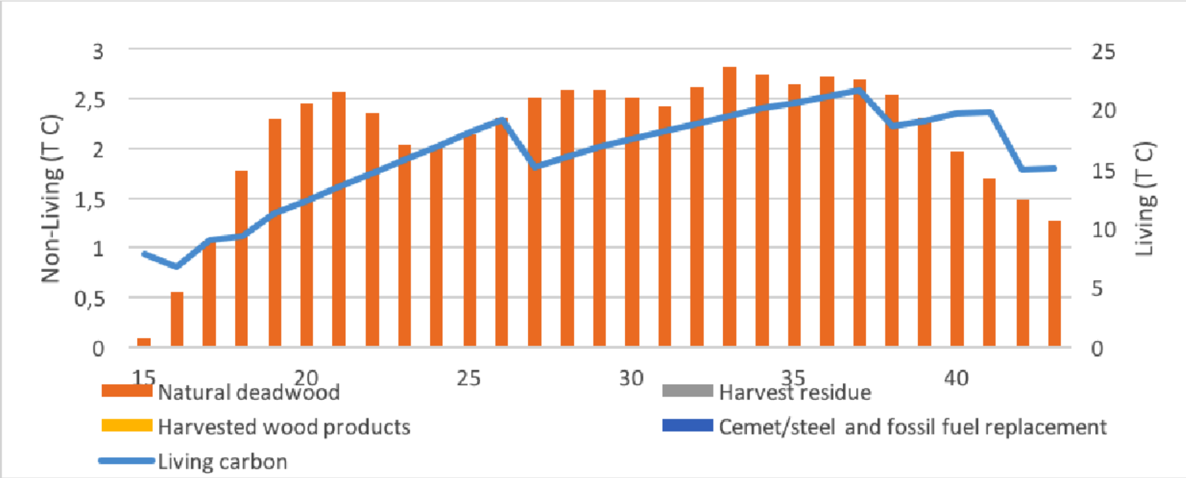

Figure 6 A per-age (x-axis) carbon assessment for the Nature conservation and biodiversity protection – buffer zone sub-FMM

Ranking FMMs

Each sub-FMM has been ranked according to the guidelines set out by the carbon ES expert

Table 8 Ecolocigal service - Carbon, Ranking of FMMs

FMM	FMM subcategory	Rank
Clear cutting conifer	Spruce monoculture	2.56
	Spruce with 10% diverse conifer mix	3.09
	Spruce with 10% broadleaf mix	3.04
	Diverse conifer	2.89
Clear cutting lodgepole pine	Unthinned	2.17
Nature conservation and biodiversity protection	Open space	N/A
	Watercourse bufferzone	0.56
	Bog habitat	N/A

These numbers were produced using the model provided by ALTERFOR's Carbon ES expert Dr. Kevin Black.

The growth and yield curves used to produce the carbon storage were developed by Coillte using Grofor (Irish stand level dynamic yield models) for their modelling process and provided to UCD for ALTERFOR.

2.2.3. Cultural Values

Outcome of ranking of cultural values are showed in Figure 7. The result is difficult to evaluate and the figure shoiw the complexity of "cultural values".

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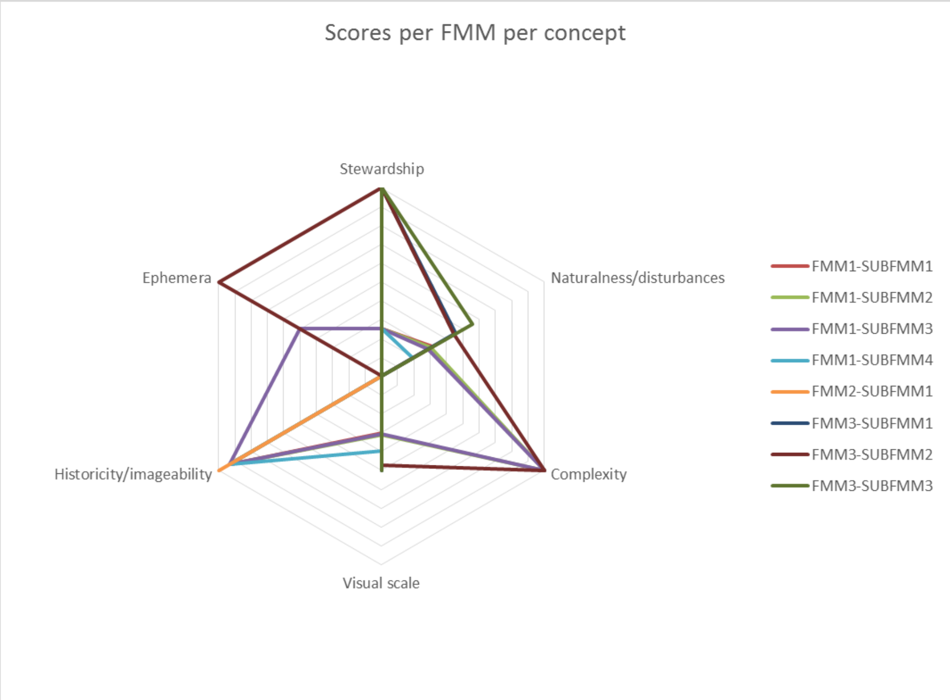

Figure 7 Cultural values for FMM and subFMM.

2.2.4. Contrasting the relative regulatory services of Ireland's stand level FMMs

Wind risk

Site characteristics

Certain site characteristics can alter the windthrow risk. The windthrow probability model used in this ecosystem service (ES) assessment was developed by Ní Dhubháin et al. (2009) and includes coefficients for soil type, elevation and wind risk zone (Miller, 1986). The predominant soil type in the CSA is blanket peat an even though there are coefficients for a wider range of soils, only this soil type is used for this assessment. Elevations of 50 m and 200 m were used to show the effect of this parameter. Similarly, the wind risk zones B and D/C were assessed as they were the only one present in the CSA. The more extreme wind risk zone, B, having higher wind risk probability.

Clearcutting FMMs

A clearfell FMM is a rotation-based system which involves 4 growth stages. Each clearfell FMM roughly follow these stages and the difference between them will be described more distinctly in the remainder of the document.

- **Establishment stage** and **Thicket stage -** Although at very young ages plants can be affected by wind causing basal sweep (Forest Service, 2002).
- The **Commercially maturing** stage is where thinning has been carried out/or mortality has set in. To represent this stage in Table 9 below, the age at with first thinning takes place according to our growth and yield models (BFC, 1973 to 1980) was used;

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- **Commercially mature**. Here stands have reached financial maturity which is typically the age of maximum mean annual increment – 20% of age (years) and may/may not have been thinned. In either case, there are at least some openings in the forest canopy and combining this with tall trees increases the probability of stand windthrow.

Clearcutting conifer

The species in this FMM (i.e. Norway spruce, Douglas fir, etc.) produce relatively straight knot-free timber than the lodgepole pine FMM even when thinned which makes this FMM more susceptible for windthrow. In addition, the yield class of this species is typically higher meaning that trees reach greater height which increases their windthrow probability.

Clearcutting lodgepole pine (always unthinned)

This FMM is monoculture lodgepole pine. This species is not thinned as it responds by producing large side branching which means that thinning will not increase the economic viability of the crop. The decision not to thin this FMM means that windthrow probability is typically lower than the clearcutting conifer FMM. This species typically has a lower yield class than the clearcutting conifer FMM also which further reduces the wind risk in comparison.

Table 9 The probability of windthrow occurring with a variety of factors that are typical characteristics for stands located in the CSA.

FMM	Thinned	Windzone	Elevation	Age	Windthrow Probability***
Clear cutting conifer: Sitka spruce Yield class 16 Blanket peat/gley soil type*	Y	B	50	21	0.16
	Y	B	50	42	0.93
	Y	B	200	21	0.45
	Y	B	200	42	0.98
	Y	D/C	50	21	0.05
	Y	D/C	50	42	0.80
	Y	D/C	200	21	0.18
	Y	D/C	200	42	0.94
	N	B	50	21	0.05
	N	B	50	42	0.78
	N	B	200	21	0.17
	N	B	200	42	0.94
	N	D/C	50	21	0.01
	N	D/C	50	42	0.50
	N	D/C	200	21	0.05
	N	D/C	200	42	0.81
Clear cutting lodgepole pine**: Yield class 10	N	B	50	25	0.06
	N	B	50	45	0.64
	N	B	200	25	0.21
	N	B	200	45	0.88
	N	D/C	50	25	0.02

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FMM	Thinned	Windzone	Elevation	Age	Windthrow Probability***
Blanket peat/gley soil type*	N	D/C	50	45	0.34
	N	D/C	200	25	0.07
	N	D/C	200	45	0.68
Nature conservation and biodiversity protection	Open space				N/A
	Watercourse Bufferzone				N/A
	Bog habitat				N/A

*The predominant soil type category in Irelands CSA;

**The windthrow probability model was developed using Sitka spruce only. The ages used for this FMM are the typical first thin (although not thinned for this FMM) and clearfell ages for this species and yield class;

***The probability of significant windblow occurrence. For example a probability of 0.50 means that 50 stands out of 100 with these attributes will suffer windblow.

Fire risk

Background and site characteristics

The upland and/or bog areas with grassland and commonage land of low fertility have been historically used for sheep farming in Ireland. Heather is traditionally burned in spring to increase the palatability for grazing sheep (Tubridy, 2013). This time coincides with the most vulnerable time of year for wildfire as land-cover is at its driest. Until the 1950's, much of these upland landscapes in Ireland did not contain forest (Neeson, 1991). This means there was little risk burning affecting forest land. More recently, sheep farming in these areas has become less economically viable. This is, in part, from lack of burning practices permitted under current legislation (Irish Uplands Forum, 2015), and hence land-owners are choosing not to farm their land. This means higher fuel loads than there have been in the past. The effect of this change is that when fires happen they are typically more severe than they have been historically.

Clearcutting FMMs

A clearfell FMM is a rotation-based system which involves 4 growth stages. Each clearfell FMM roughly follow these stages and the difference between them will be described more distinctly in the remainder of the document.

- Whether at an afforestation or reforestation **Establishment stage,** fuel loads build up before canopy closure. This makes this stage the most vulnerable and damage can be quite severe (Forest Service, 2002);
- **Thicket stage** is where trees have closed canopy and the living crowns of trees are also close to the ground. This means that it is relatively easy for ground fires to spread into the canopy and also from adjacent land-uses and damage can be quite severe (Menning and Stephens, 2007)*;
- The **Commercially maturing** and **Commercially mature** stages are where thinning has been carried out/or mortality has set in. There is a well-established canopy which is further away from the ground than thicket stage meaning a reduced risk from ground fire. A risk for

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these stages is the possibility of fires spreading from adjacent land-uses and laddering from ground to canopy using side-branches of edge trees (Menning and Stephens, 2007)*

*The risk of fire spreading from adjacent land-uses greatly decreases if adequate fire breaks (length of fire breaks should be proportional to potential flame length) and pruning of edge trees is carried out

Clearcutting conifer

The species in this FMM (i.e. Sitka spruce, Norway spruce, Douglas fir, etc.) produce relatively straight knot-free timber than the lodgepole pine FMM even when thinned. In addition, the yield class of this species is typically higher meaning that trees reach greater height which increases their windthrow probability.

Clearcutting lodgepole pine (always unthinned)

Lodgepole pine has evolved thinner bark and uses fire as a mechanism to release seeds from cones (Lotan et al., 1985). Its thinner bark means that fires are far more damaging than other conifers such as Scots pine (Zackrisson, 1977).

Nature conservation and biodiversity protection – Open space

These are the areas that may contain high fuel loads, they can catch fire easily and are the predominant land-use that is ignited for the burning of vegetation (Forest Service, 2002).

Nature conservation and biodiversity protection – Watercourse bufferzone

These areas contain small groups of broadleaf trees and can have high fuel loadings. The spatial location of these areas and their proximity to forests mean that they can act as a fire corridor helping to distribute fires throughout a landscape. However, these areas are managed as forest land and hence it is not common for fires to be ignited within this land-use type.

Nature conservation and biodiversity protection – Bog habitat

Bog contains seasonal grasses. In spring, the previous years growth dries out and will ignite, similar to open space.

Table 10 Fire risk for FMMs and subcategories.

FMM	FMM subcategory	Fire risk (0 – 5)*
Clear cutting conifer	Establishment / thicket stage	4
	Commercially maturing / commercially mature	0
Clear cutting lodgepole pine	Establishment / thicket stage	5
	Commercially maturing / commercially mature	2
Nature conservation and biodiversity protection	Open space	5
	Watercourse bufferzone	3
	Bog habitat	4

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*At this stage (deliverable 1.1 due for May 31st 2017) the exact vulnerability classes used for fire risk in Ireland's DSS are undergoing a refinement phase with experts in this area. Hence, the fire risk classes in this table should be treated tentatively.

2.2.5. Water

2.2.6. Contrasting the relative biological diversity of Ireland's stand level FMMs

Water sedimentation risk

There are 4 factors used to determine water sedimentation risk in Ireland's DSS: soil type, upslope contributing area, distance to watercourse and land-use based on Sivertun and Prange (2003). Soil type, upslope contributing area and distance to watercourse are inherent to a site, they will influence water sedimentation risk although they will not change over the modelled planning horizon. The land-use factor is most relevant for ALTERFOR as it is applied dynamically in the model depending on land management actions. This factor will be described and the water sedimentation risk factors for a combination of land-use and inherent factors are presented in Table 11.

Land-use

Both the clearcutting conifer and clearcutting lodgepole pine FMMs have two land-use factors for water sedimentation risk within their rotation. The only distinction in terms of water sedimentation risk between these two FMMs is rotation length, i.e. the longer the rotation (i.e. the less clearfelled forest area there is), the lower the water sedimentation a risk a stand will have over the planning horizon.

- **Clearfelled forest**. Here stands are clearfelled (or disturbed from site-preparation for afforestation). This stage continues for 4 years post clearfell (or post afforestation) and is the highest risk land-use for water sedimentation (Risk Factor = 0.4);
- **Undisturbed forest** is where forest is growing and soil is not disturbed, it has a much lower risk than clearfelled forest (Risk Factor = 0.005).

There are also land-use factors for non-forest land which relate to the minor FMMs.

- **Bufferzone and bog**. Bufferzones are designed to buffer watercourses from human land-use management interventions (Forest Service, 2000). They reduce water sedimentation risk from land-use management practices and hence these are the lowest land-use factor for water sedimentation risk. The bog land-uses are also a permanent undisturbed vegetation layer and hence have similar characteristics to Bufferzones (Risk Factor = 0.004);
- **Agricultural land and scrub**. These land-uses may (some scrubland is not grazed) have annual land-use management practices and hence have a higher risk than undisturbed forest but much less than clearfelled forest (Risk Factor = 0.01).

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Table 11 Water sedimentation risk for a range of factors typcial to the CSA

Land-use	Soil type (K)	Distance to water course (0 is over 1 km, while 1 is adjacent to watercourse)	Slope length (S, dimensionless unit)	Water sedimentation risk factor (P)*
Undisturbed forest	Till	0	50	0.10
Undisturbed forest	Till	400	50	0.03
Undisturbed forest	Till	900	50	0.00
Undisturbed forest	Clay	0	50	0.11
Undisturbed forest	Clay	400	50	0.04
Undisturbed forest	Clay	900	50	0.00
Undisturbed forest	Organic	0	50	0.08
Undisturbed forest	Organic	400	50	0.02
Undisturbed forest	Organic	900	50	0.00
Cleared forest	Till	0	50	0.76
Cleared forest	Till	400	50	0.25
Cleared forest	Till	900	50	0.00
Cleared forest	Clay	0	50	**0.90****
Cleared forest	Clay	400	50	0.30
Cleared forest	Clay	900	50	0.00
Cleared forest	Organic	0	50	0.60
Cleared forest	Organic	400	50	0.20
Cleared forest	Organic	900	50	0.00
Bufferzone	Till	0	50	0.08
Bufferzone	Till	400	50	0.03
Bufferzone	Till	900	50	0.00
Bufferzone	Clay	0	50	0.09
Bufferzone	Clay	400	50	0.03
Bufferzone	Clay	900	50	0.00
Bufferzone	Organic	0	50	0.06
Bufferzone	Organic	400	50	0.02
Bufferzone	Organic	900	50	0.00
Agricultural	Till	0	50	0.19
Agricultural	Till	400	50	0.06
Agricultural	Till	900	50	0.00
Agricultural	Clay	0	50	0.23
Agricultural	Clay	400	50	0.07
Agricultural	Clay	900	50	0.00
Agricultural	Organic	0	50	0.15
Agricultural	Organic	400	50	0.05
Agricultural	Organic	900	50	0.00

**P* the sediment loss risk, K the soil type, S the slope length factor, W the proximity to watercourse and U the land-use.*
*** Highlights the maximum water sedimentation risk in the table*

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2.3. Italy

2.3.1. Assessment of biodiversity by the stand level FMMs in the Italian case study

The ranking of FMMs in the Italian case study has been developed based on biodiversity proxies and indicators (determinants) defined by guidelines for biodiversity Table 12; tree species composition, forest structures, and spatial-temporal disturbance patterns. Following the same approach adopted for the Swedish case study, each of the three determinants has been qualitatively ranked 0-7 (0=very bad, 7=very good) based on expert judgment i.e. no DSS or quantitative data has been used in the assessment. A summary rank has then been defined based on the average of the three scores.

Data have been sourced from the forest management plan for the case study area, including High Conservation Value (HCV) identification -namely HCV 1, HCV 2 and HCV 3- for the aims of forest certification according to FSC standards.

Table 12 Qualitative assessment of biodiversity values associated with FMMs in the Italian case study

FMM/Concept*		Tree species composition (Native trees, broadleaf trees, tree species diversity)	Forest structures (older / larger trees coarse woody debris)	Disturbance regime (emulate natural disturbance regimes spatially and temporally)	Average
Selective cutting					
Coastal forests (pine and holm-oak forests)	Mixed stands	5.0	3.0	6.0	**4.7**
	Pine stands	3.0	3.0	6.0	**4.0**
Oak-hornbeam forests		6.0	4.0	6.0	**5.3**
Riparian forests		6.0	6.0	6.0	**6.0**

As a general remark all FMMs have been scored 6 with reference to the disturbance regime because –as indicated by the forest management plan- management operations are clearly oriented to favor a shift towards more natural forest conditions, simulating natural evolution processes. Nonetheless in some cases management operations might be forced/made more intense to boost the process or different solutions (e.g. planting) might be adopted. Due to this, it was decided not to give a score equal to 7.

Coastal forests

Coastal forests have an average score ranging between 4,3 and 5, i.e. lower than oak-hornbeam and riparian forests. However, it should be noted that coastal forests spatially occur at the end of

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the natural plant succession that from the sea goes to the inland. The succession includes in the first part the vegetation communities of *Cakiletum* and *Agropiretum,* that have the strategic ecologic role of steady the soil with roots. Because of these plants, the sand can behind accumulate in dunes and allow the settlement of *Ammophilia arenaria,* which creates effective barriers for sand and wind. After the dunes, in a protected microenvironment, both occur xeric species such as *Thymus longicaulis* and *Stachys recta,* and, in sites with more water, the vegetation community of *Schoenetum,* with species such as *Erianthus ravennae* and *Juncus littoralis.*

Even if the coastal forests score a relatively low value of biodiversity with respect to other lowland forests, by considering the whole natural succession of plants, which play a strong ecological role, the score would be higher.

In the coastal forests *sensu stricto,* higher biodiversity value has been attributed to mixed (i.e. holm-oak and pine) stands. The general orientation, indeed, is to favor pine and mix-pine stands evolution towards "native" holm-oak coastal forests by removing pine trees progressively. Harvesting operations should remove wilting/unstable (pine) trees and facilitate natural holm-oak regeneration. In the case of pine forests on xeric soils and pine forests planted on/just behind sandy dunes this can be achieved through the creation of small-medium clearings (3-400 m^2). Since holm-oak natural regeneration results a bit problematic, planting (artificial regeneration) is needed. It shall be noticed, however, that holm-oak is less effective in contrasting invasive species, including alien ones, therefore in some cases planting pine might slow a bit the naturalization process but, at the same time, reduce the risk of invasive species spreading.

Moreover in some cases full pine stand conversion is not possible due the role played by pine trees in terms of protection and recreational services. In particular, with their thick and broad canopies, pines provide shadows during the hot summer season. Pines stands play a relevant role as windbreaks and/or aerosol interceptors, and where they support recreation and tourism activities (camping, shadow for visitors, etc.). Native pine species (i.e. black pine in the Tagliamento river area) should also be favored when they occur.

Oak-hornbeam forests

Oak-hornbeam forests represent the most common lowland forest typology within the case study area. Forest management operations try to facilitate natural regeneration, removal of invasive species (where present) and ensure adequate species diversity (including species in the understory). Especially in early stages hornbeam normally tends to prevail and oak regeneration shall normally be supported through appropriate operations (e.g. clearings to support regeneration, thinning, etc.). Harvesting and thinning operations should remove wilting trees and facilitate natural oak regeneration. Oak tends to prevail (or even dominate) in areas that are periodically submersed by water. Depending on water availability and, more in general, on edaphic conditions additional broadleaf species include elm, ash, maple, alder, linden, cherry, etc. and forest management operations try to preserve this species diversity. Biodiversity conservation should also be seen in terms of fauna protection, as selective cutting aims also to maintain favorable conditions for animal species such as amphibians (e.g. *Rana dalmatina*, *Tritus* spp etc.) including rare and endemics ones (e.g. *Rana latastei*, that is included within the IUCN national red list), reptiles (e.g. *Natix natix, Lacerta bilineata* etc.*),* micromammal such as *Sorex arunchi* and several birds (e.g. *Carduelis carduelis* , *Turdus iliacus* etc.).

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Some of these forests are located close to urban areas and used for recreational purposes by local population and visitors in general. As a consequence management operations sometimes are oriented towards ensuring safe conditions for users and this might have marginal trade-offs with biodiversity conservation at a very punctual scale (e.g. removal of dead trees or trees that might be dangerous because of their instability).

Riparian forests

Forest management operations on riparian forests within the case study area tend to be minimal and basically consist of limited clearing of the understory, thinning and partial removal of dead trees. Management operations aim to eliminate invasive/exotic species and favor recovery towards better functionality and more stable and natural conditions in terms of both composition and structure. Thinning operations might imply some diversification of the forest structure, with a slight differentiation into layers and support to larger trees (mostly willow and poplar).

Harvesting operations should also remove trees and residues that might obstruct water flow and increase hydrogeological risks (thus also maintaining regulatory services), while favoring the development of the forest structure and composition. Isolated big trees should be released (not in a detached position exposed to strong water streams) to favor saproxylic invertebrates (e.g. *Osmoderma eremita*, *Lucanus cervus*, *Cerambyx cerdo* and *Morimus funereus*).

It shall be considered that, as for the case study area, these forests constitute relic riparian forests included within a broader protected area (Regional Park) and as such subject to stricter management conditions and regime.

2.3.2. Assessment of carbon sequestration capacity by the stand level FMMs in the Italian case study

The carbon sequestration capacity has been assessed based on a ranking ranging from 0 (low) to 5 (high) of different forest stand indicators indicated by *ad hoc* developed guidelines developed by ALTERFOR ES experts and including:

1) stand productivity

2) disturbances

3) cultivation and site preparation

4) silvicultural systems

5) harvesting operations and

7) wood utilisation properties.

Table 13 Qualitative assessment of carbon sequestration capacity associated with FMMs in the Italian case study.

FMM/Concept	P	S	C	H	D	HWP	Sb	Average

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Coastal forests (pine and holm-oak forests)	Mixed stands	0.0	2.9	5.0	0.0	4.0	0.0	0.0	1.7
	Pine stands	0.0	2.9	5.0	1.5	4.0	0.0	0.0	1.9
Oak-hornbeam forests		0.0	2.9	5.0	2.5	4.5	0.0	0.0	1.9
Riparian forests		0.0	2.9	5.0	2.0	4.5	0.0	0.0	1.9

P = productivity; S = silviculture; C = cultivation; H = harvest; D = disturbance; HWP = harvested wood products; Sb = substitution

Table 13 summarizes the findings. For each indicator, average values have been computed based on range values defined by the guidelines and stand data reported within the forest management plan. Values shall be treated carefully and as very preliminary and need to be further elaborated. Moreover indicators regarding rotation period were not taken into account due to the fact that management operations within the forest area do not make reference to a rotation period.

The models considered for the assessment present similar partial and average values. This is mainly due to the fact that:

- in all cases is adopted a selective cutting system

- wood production is not the main function/aim of forest management operations

- management operations and in particular thinning are not very intense

- wood assortments only include firewood

2.3.3. Assessment of the provision of cultural services by the stand level FMMs in the Italian case study

The ranking of FMMs in the Italian case study has been developed based on criteria defined by guidelines for cultural services (Table 14). Following the same approach adopted for the Swedish case study, attributes have been qualitatively ranked 0-1 (0=very bad, 1=very good) based on expert judgment i.e. no DSS or quantitative data has been used in the assessment.

Table 14 Concepts, dimensions, attributes used to rank the aesthetic/recreational

Concepts	Dimension	Attribute	Indicator	Effect
Stewardship (S)	Sense of care	Amount of logging residue	Frequency of thinning/final felling. Very high (0) – No intervention (1).	-
Naturalness/ disturbances (N)	Alternation/ impact	Frequency of final felling	Frequency of final felling. Very high (0) – No intervention (1).	-
Complexity (C)	Diversity	Tree species diversity within stands	Monoculture (0)- Highly Mixed (1)	+

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Concepts	Dimension	Attribute	Indicator	Effect
Complexity (C)	Variety	Variation in tree size within stands	Even aged (0)- Uneven aged (1)	+
Visual scale (V)	Openness	Visual penetration	Extremely dense (0)- Open (1)	+
Historicity/ imageability (H)	Historical richness	Age of trees in stands	Relative age/size* at final-felling. Very low (0) - Similar to "natural" conditions (1)	+
Ephemera (E)	Seasonal change	Presence of broadleaves	Totally absent (0)- 100 % broadleaves (1)	+

**Relative to the species lifespan and growth pattern, because a fast growing species will reach the size associated with higher aesthetical/recreational values faster.*

In general terms cultural services are very much important for the case study area due to closeness to periurban areas, thus making these areas very much appreciated by local communities as green areas for recreation opportunities, and tourism sites/infrastructures.

Table 15 Qualitative assessment of the recreational/ aesthetical values associated with FMMs in the Italian case study.

FMM/Concept*		S	N	C	V	H	E	Average
Selective cutting								
Coastal forests (pine and holm-oak forests)	Mixed stands	0.90	0.90	0.63	0.60	0.80	0.70	**0.75**
	Pine stands	0.80	0.80	0.33	0.35	0.80	0.45	**0.59**
Oak-hornbeam forests		0.75	0.75	0.60	0.45	0.60	1.00	**0.69**
Riparian forests		0.95	0.95	0.50	0.30	0.60	1.00	**0.72**

**s= Stewardship, N= Naturalness/disturbances, c= Complexity, v= Visual scale, h= Historicity/imageability, e= Ephemera*

Coastal forests

Overall coastal forests show the higher average score among the three models taken into account. The range in terms of average scores reflects different compositions in terms of broadleaf/conifer mixtures which also affects visual penetration and complexity (both in terms of tree species diversity and structure). It shall be considered, however, that as a matter of fact some pure (or almost pure) pine stands have high relevance in terms of cultural services when focusing in particular on tourism (e.g. parcel 11 -*Pineta Santa Margherita*- that hosts a camping size and parcel 9 -*Pineta di Eraclea*).

Oak-hornbeam forests

The average score corresponds to 0,69, however the situation is a bit nuanced when comparing different examples within the case study area. In some cases (e.g. forest sub-parcel 4.2, *Bosco di Via Carrer*) the forest area presents a string recreational function, while in some other cases forest

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stands are still quite young and their cultural value is still not fully expressed, although, based on empirical evidence, it can be assumed that proximity to urban areas increases quite a lot the relevance of cultural services for locals.

Riparian forests

The average score for riparian forests is 0,72, being mostly influenced by the high presence of broadleaves and very limited (almost absent) management operations. These forests are marginally represented within the case study (sub-parcel 3.1) and despite their environmental relevance as a wet area and a relic riparian forest included within a broader protected area (Regional Park) they are almost abandoned and partly degraded.

2.3.4. Assessment of regulatory services by the stand level FMMs in the Italian case study

As regards regulatory services with regard to the Italian case study area, reference is made in particular to prevention of/protection against forest fires.

Additional regulatory services for the case study area include protection against:

- marine aerosol, in particular by coastal forests and more specifically by pine stands;
- pests; and
- spreading of alien invasive species.

For the aims of this assessment the focus is on prevention of/protection against forest fires. Although no significant fire events occurred within the case study area during the last fifteen years, fire risk is taken into account by the forest management plan as one of the main risks in particular for costal forests and for afforested/reforested areas especially when left unmanaged. This is even more relevant considering the importance of many of the forests within the case study area for tourism/recreational activities. Being located close to Venice and other touristic places along the northern Adriatic Sea, the area is visited every summer by about 3 millions of tourists. Another 0.5 million live within the municipalities hosting the forest area and neighboring ones.

Marine aerosol is a relevant issue when considering that the area just behind coastal forests hosts some of the most fertile and productive agriculture lands in Italy and Europe.

Alien invasive species, such as *Ailanthus altissima* may conflict with strict biodiversity goals but also with all other silvicultural goals, as these species can outcompete native tree species. The European Union Regulation on invasive alien species (Regulation (EU) 1143/2014), entered into force on 1 January 2015, underlines the importance of prevention, early warning, and control measures. These measures encompass silvicultural practices such as shelterwood or selection systems of management which are applied in a close-to-nature silviculture, while on the contrary the spread of alien species may be connected with abandonment and wrong forest practices.

Attributes that have been taken into account with reference to regulation of fire risk include species composition and forest types (based on Ciancio *et al.*, 2007), intensity of thinning/harvesting, density (presence of gaps), and structure (number of layers) of the stand. These attributes might partly be informative also for other regulatory services (protection against marine aerosol, pests and invasive alien species), however they have not been explicitly addressed here. Data have been retrieved from the forest management plan for the case study area, while the ranking of the forest management models is based on expert judgment. Each of the four

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determinants has been qualitatively ranked 1-5 (1=lower risk, 5=higher risk). A summary rank has then been defined based on the average of the scores.

The assessment does not take into consideration relevant variables influencing ignition risk, such as climatic conditions, and socio-economic factors (Ganteaume *et al*., 2013).

Results are summarised in Table 16 and briefly commented for each model taken into consideration.

Coastal forests

Coastal forests are the most exposed to forest fire risks and require specific management measures. This includes, in particular, clearings and reduction of the understory to reduce ignition risk. For similar reasons harvesting residues should normally be removed or released in limited amounts. Deadwood is also limited to normally 5 m^3/ha. Mixed stands tend to present lower risks due to the presence of gaps, while high density can be a critical factor for pure or close-to pure pine stands.

Oak-hornbeam forests

Oak-hornbeam forests are not very much exposed to fire risks unless left abandoned. Thinning operations that are normally implemented for favoring oak regeneration and the removal of less valuable trees contribute also to the reduction of fire risks. Release of deadwood to support microfauna might increase fire risk and should normally be limited to 5 m^3/ha.

Since many of this forests are used for recreational purposes, the presence of trails and other infrastructures for users might contribute to gaps in tree coverage, thus reducing the overall fire risk.

Riparian forests

These forests are less subject to fire risk due to the fact that they grow in sites rich in water and where conditions are normally less favorable to ignition. Thinning and clearing operations reduce stand density and create gaps that help reducing the risk while at the same time favoring some diversification of the forest structure, with a slight differentiation into layers and support to larger trees (mostly willow and poplar). Removal of deadwood and other materials that might obstruct water flow and increase hydrogeological risks is also functional to the reduction of fire risk.

Table 16 Qualitative assessment of regulatory service (fire risk) associated with FMMs in the Italian case study (1-5)

FMM/Concept*	Tree species composition (forest type)[a]	Intensity of thinning/ harvesting operations	Density of the stand and presence of gaps	Structure (number of layers)	Average
Selective cutting					

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FMM/Concept*		Tree species composition (forest type)[a]	Intensity of thinning/ harvesting operations	Density of the stand and presence of gaps	Structure (number of layers)	Average
Coastal forests (pine and holm-oak forests)	Mixed stands	3.0	4.0	3.0		**3.3**
	Pine stands	4.0	3.0	4.5		**3.8**
Oak-hornbeam forests		1.0	3.5	3.5		**2.7**
Riparian forests		0.5	3.5	4.0		**2.7**

A reported in Ciancio et al., 2007

2.3.5. Assessment of effects on the chemical and ecological status of water resources by the stand level FMMs in the Italian case study

ALTERFOR guidelines for water-related ecosystem services potentially provided by forests address five different aspects:

- Provision of surface water for drinking\non-drinking purposes
- Mass stabilization and control of erosion rate; Buffering and attenuation of mass flow
- Hydrological cycle and water flow maintenance
- Flood protection, and
- Chemical condition of freshwaters.

Building on data sourced from the forest management plan for the case study area, this assessment focuses on the provision of surface water for drinking\non-drinking purposes and flood protection.

Provision of surface water is mostly affected by evapotranspiration that, besides climatic parameters, is influenced by tree species composition (and forest density). In general terms evapotranspiration for broadleaf forests is less than that for coniferous forests and evergreen forests could have higher evapotranspiration than deciduous ones (McPeel *et al*., 2010).

As for flood protection (and, more broadly, management and control of the hydrogeological regime) evapotranspiration and canopy interception were taken into consideration, as per forest species composition and density resulting from the harvesting regime.

Different forest management models have been assessed in qualitative terms by attributing a score (1 to 5 range) to the two attributes taken into account (species composition and harvest intensity): average figures have then been computed for each model. Results of the assessment are reported in Table 17.

As for water-related ecosystem services in general, it shall be noticed that, as reported by the forest management plan for the case study area, no harvesting operation shall be performed close to streams and other water bodies.

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Table 17 Assessment of relative suitability (1-5) of different FMMs for provision of surface water and flood protection (1= very bad, 5=very good).

FMM/Concept*		Tree species composition	Harvest intensity	Average
Selective cutting				
Coastal forests (pine and holm-oak forests)	Mixed stands	3	4	**3.5**
	Pine stands	2	3	**2.5**
Oak-hornbeam forests		4	3.5	**3.8**
Riparian forests		4	4.5	**4.3**

Coastal forests

Coastal forests present the lower score among the three different models taken into account for the aims of this assessment. Pure (or close-to pure) pine stands show worse performance due to both three composition and possible higher harvesting intensity. Indeed, in the case selective cutting consists in creating forest clearings (e.g. in the case of pine forests planted on/just behind coastal sandy dunes) the recommended minimum size of clearings in order to maximize naturalization effects should be 1,000 to 1,500 m^2.

Oak-hornbeam forests

Planted oak-hornbeam forests within the case study area tend to present medium to low density when they are intended mostly for recreational purposes, being characterized by a combination/patchwork of areas covered by trees and uncovered areas. Species only include deciduous broadleaves, with very limited exceptions. The intensity of harvesting operations is limited and affects small portions of forest areas. While these forests tend to poorly contribute to runoff generation, their position close to urban/peri-urban areas effects on run-off propagation might be influenced by density of road trails or, for forests located within/close to agricultural areas density of ditches.

Riparian forests

These forests only include deciduous broadleaves and harvesting operations are quite limited. Operations should remove dead trees and residues that might obstruct water flow and increase hydrogeological risks (thus also maintaining regulatory services), while favoring the development of the forest structure and composition. Due to their position along rivers/streams riparian forests also play a relevant role as buffers influencing quality of water resources through filtration and purification.

The consumption of land in the plain, following a widespread type of settlement, has dramatically increased the hydrologic risk. One solution is to create space for water by developing controlled floodable zones. In these zones, unlike agricultural crops, forests would not suffer for damages created by water. These areas with forests and a maze of hedges and ditches help in limiting the

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intensity of floods and in maintaining a regular water flow, providing more time for water to deeply infiltrate.

The species suitable for these areas are broadleaves such as willow, alder, ash, poplar, white hornbeam and oak. Forest planning should avoid to expose big detached trees to strong water streams and should also include bushy vegetation.

2.3.6. References

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2.4. Lithuania

Case Study Telšiai Summary

Twelwe forest management models identified in Lithuanian CSA: Telsiai were investigated for the provision of ecosystem services. Ecosystem services were quantified using guidelines developed by ALTERFOR's ES experts or applying own approaches which are detalized in this report.

All regarded ecosystem services strongly varied among evaluated FMMs. Still, the average values didn't represent all variation, which was present both between FMMs and within single FMMs.

The most important in terms of timber provisioning from final cutting are forest management models combining the clear and non-clear cutting systems. Clear cutting based systems in coniferous forests deliver largest values per area unit, however, in deciduous forests, the most efficient in this sense are the forest management models, combining clear and non-clear cutting. Mandatory non-clear cutting in spruce forests is related to twice lower value of timber, compared with the clear cutting based FMM. Commercial value of timber final harvesting in special purpose forests is relatively low. The pre-commercial thinning involves only the costs to conduct the silvicultural treatment no matter the FMM. Relatively highest timber values are achieved from the commercial thinning in spruce forests with non-clear final cutting and in special purpose forests. The pre-commercial thinning and harvesting operations cost more than the value of timber extracted in short rotation deciduous forests, low timber values from thinning may be expected from medium rotation deciduous forests, too. The value of timber avaiable from thinning cuttings is positively related to the rotation age.

The FMMs for coniferous forests seem to be related with highest forest fire risks, while the fire risk on deciduous forests is relatively small. Relatively diverse conditions in respect the fire risk are present in forests with limited forest management activities. The most vulnerable to catastrophic events seem to be forest stands managed under short rotation deciduous FMMs. Restricted forest management does not clearly result in increased or decreased resistance to catastrophic events. Departure from forest management assumed by natural disturbance regimes (as in non-clear cutting in spruce stands) may have some effects on decreased stand resistance.

The highest relative biological diversity could be observed within forests with no intervention. Long rotations and the possibility to choose between clear-cuttings and shelter-wood systems had positive effect on the relative biological diversity. In short rotation deciduous forests within clear-cut or shelter-wood FMM was the highest tree species diversity, what also resulted in the relatively high overall score, though usually this FMM is considered as a result of "unsuccessful" forestry. On the contrary, in the short rotation deciduous forests within clear cutting FMM were recorded the lowest scores for 6 parameters from 8, what also resulted in the lowest relative biological diversity.

The FMMs in Lithuanian CSA do not differ very much in provisioning water related ESs. Lowest grades are given to FMMs with clear-cutting system and the non-clear cutting system, especially in coniferous forests, increases the share of stands more productive in terms of provisioning water related ESs. Stands with relatively low water and soil protection potential dominate in medium

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rotation deciduous forests. The water related ESs in forests with no active management are valuated lower than the CSA average.

The most valuable in terms of providing cultural services is the forest management model assuming no active management. Banning the clear final cuttings in National Parks and along the roads, expected to to support the forest cultural services, does not result in higher values in coniferous forests, compared to the models with clear cutting allowed. We also experienced, that the evaluation of cultural services is very sensitive to the attributes used for validation and mathematical treatment of data, like indexing, normalization.

The approaches to quantify diferent ecosystem services were adopted for use with Lithuanian forestry decision support system Kupolis.

General case study information: Telšiai

The case study area (CSA) corresponds to the area managed by Telšiai SFE. The association with Telšiai SFE is rather formal and relates basically to the nomenclature used for identification of forest stands in the Lithuanian State Forest Cadaster. This means that the area includes both state forests managed directly by Telšiai SFE and other forests, including private ones, owned and managed by other legal and physical persons. The CSA is located in the north-western part of Lithuania and belongs to Žemaitija. Žemaitija (literally "*lowlands*") or Samogitia is one of the five ethnographic regions of Lithuania. General characteristics of the landscape are: medium productive mixed spruce forests dispersed on relatively unproductive agricultural land. The CSA feature hilly landscapes, limited agricultural interests, and relatively large areas of low productivity agricultural lands, potentially suitable for afforestation. The CSA has also a huge potential for tourism development, due to its natural beauty, cultural and historical heritage. The traditional Lithuanian culture is closely related with forest.

The CSA covers an area of 253,983 ha or represents around 3.9% of the Lithuanian area. The CSA is located basically in two municipalities or districts: Telšiai (53%) and Plungė (44.8%), however, some minor parts on the edges belong to Rietavas (1.5%) and Skuodas (0.7%) municipalities (further these two municipalities are often omitted from the analyses). The population in CSA was 77,821 people in 2016 (Statistics Lithuania, http://osp.stat.gov.lt/). The hilly landscape is characterized by forestry and agricultural production which contribute to 87% of land use. 35% of the case study area is covered by forests. The forest ownership structure in the CSA is: private and other forests (still reserved for restitution) – 60.5%, state-importance forest managed by SFE, national park and state reserves – 37.48%, state forests managed by Ministry of defence – 0.3%, municipal forests – 0.1%, state-importance forests managed by other legal entities – 0.1%.

The main forest manager in the CSA is Telšiai SFE with 42,801 ha. Coniferous stands prevail in Telšiai SFE (52.4 %). Softwood deciduous forests cover 35,093 ha (42,8%) and hardwood deciduous forests – 3,929 ha (4.8%). The dominant tree species are spruce (27,636 ha), birch (20,179 ha) and pine (15,114 ha). Telšiai SFE manages also forests of Žemaitija National park (8.6% of the area) and two regional parks – Varnių (10.1%) and Salantų (0.1%). The Žemaitija National park is a protected territory with the main goal is to preserve landscape complexes of national importance and cultural heritage that represent peculiarities of Žemaitija's nature and culture in the ethno cultural context, ensure balanced use and recovery of natural resources, provide conditions for educational tourism, scientific research and environmental monitoring (www.zemaitijosnp.lt). Forest distribution by

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groups defining the forestry regime is as follows: Group I – strict reserves forests – 1,812 ha (2.0 %); Group II – forests of special purpose, including A – ecosystem protection forests on 11,616 ha (13.0 %) and B – recreational forests on 772 ha (0.9 %); Group III – protective forests – 22,472 ha (25.3 %) and Group IV – commercial forests – 52,295 ha (58.8 %).

The CSA has well-developed industries such as food processing, wood and timber products, furniture, textiles arts and crafts. Forestry is an important industry of Telšiai CSA, too. The forests contain a fairly large number of recreational facilities: educational, recreational and specialised paths, viewpoints, places of respite, recreational zone. It has an important significance in the development of tourism in the region.

General information on FMMs in Lithuanian CSA

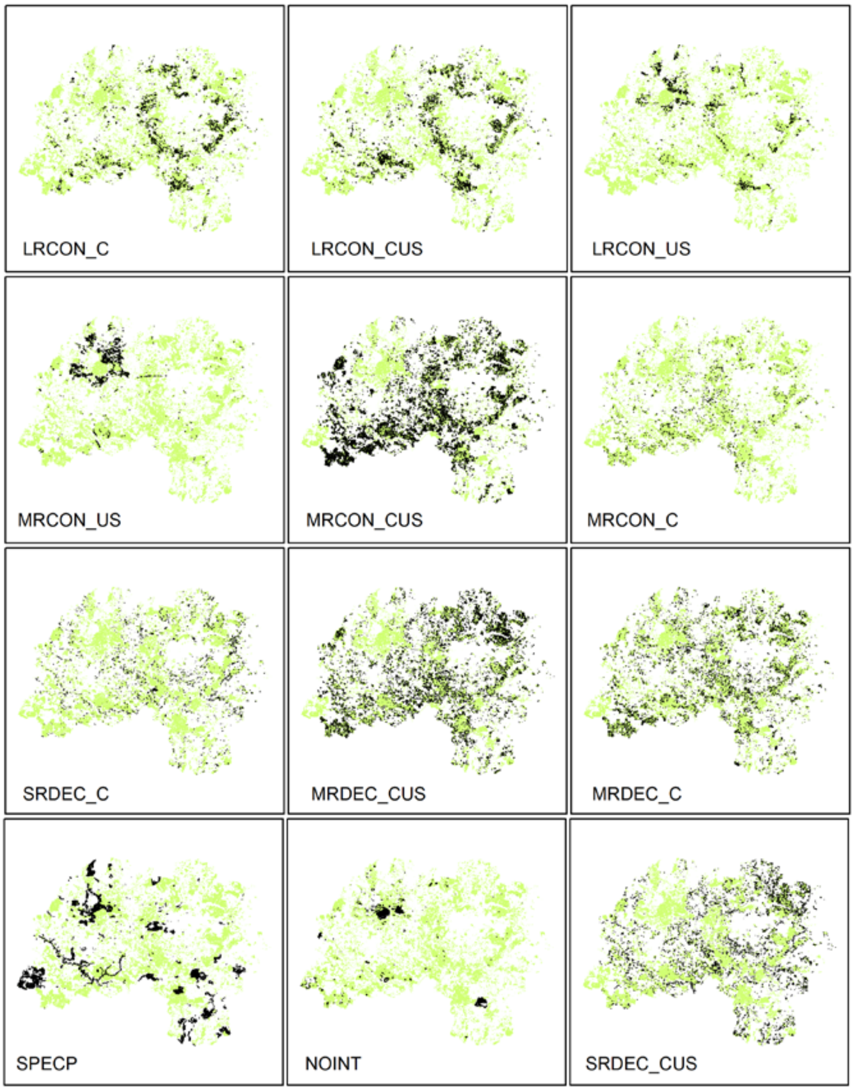

Figure 8. Territories covered by the 12 main FMMs

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There are 12 FMMs in the list covering 93.4% of the CSA (Figure 8). There are also 5 minor FMMs, which were united into one category and regarded together. Each FMM has an abbreviated name, containing the species category, rotation and final felling type. Further we will describe each FMM in more details.

LRCON_C (Long rotation clear cuttings in coniferous forests)

This FMM is dominated by Scots pine forests with a small admixture (less than 1%) of Larch, which are intensively managed during the whole rotation period, and occupies 5.5% of the whole CSA area. The main aim of this FMM is timber production.

LRCON_CUS (Long rotation uniform shelter-wood OR clear cuttings in coniferous forests)

As well as the previous FMM, this FMM is also dominated by Scots pine. The difference from the previous FMM is that the silvicultural principles suggest non-clearcut management in such areas; however, clear-cutting is not prohibited there. Non-uniform shelter-wood FM system may be applied on very low productivity dry soils with the groups of pine undergrowth. This FMM is also aimed mainly for the timber production and occupies 6.8% of the whole CSA area.

LRCON_US (Long rotation uniform shelter-wood in coniferous forests)

This FMM is associated with using non-clear cutting in Scots pine dominated forests due (i) legal requirements (e.g. no clear cutting in National Parks, along major roads and around reserves and (ii) political will of forestry administration to increase the share of non-clear cutting. The 2nd option is related to so-called Labanauskas cutting, which is nationally important FMM and used by default in dry low productivity pure Scots pine stands. Though this FMM occupies only 3% of the CSA territory, it is very important for forest management in Lithuania on the national level, so we included it into the list of the main FMMs. The target ecosystem servise of this FMM is timber production.

MRCON_C (Medium rotation clear cuttings in coniferous forests)

This FMM is associated with Norway spruce dominated stands, occupying 2% of the whole CSA territory. Usually it is applied on the mesic fertility soils within the areas without any specific environmental restrictions. The target ecosystem servise of this FMM is timber production.

MRCON_CUS (Medium rotation uniform shelter-wood OR clear cuttings in coniferous forests)

This FMM is currently dominating in the CSA with 22.7% of the whole CSA territory. The idea is to cut starting in groups and expand the groups during subsequent occasions. Other systems may be used, i.e. there are no restrictions for clear cutting (A) or uniform shelter-wood (B). Usually clear cutting is prioritized, basically due to economic reasons. Target ecosystem services are timber production and fuelwood supply.

MRCON_US (Medium rotation uniform shelter-wood in coniferous forests)

This FMM is applied in the coniferous forests located in the areas with the cutting restrictions, i.e. in National parks, around the reserves and along major roads. Usually the cuttings are performed in gaps, and there are two possible systems applied: group-occasional cutting, when the initial size of gap should be under 0.3 ha and total area of gaps should not exceed 30% of the stand area, and

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group-selective cutting, when the group (gap) size shall not exceed 0.1 ha. FMM occupies 3.6% of the whole CSA territory, and target ecosystem services are timber production and fuelwood supply.

NOINT (No intervention)

The target ecosystem service of this FMM is biodiversity protection and biosphere monitoring, and it occupies 3.3% of the CSA. In this FMM any human intervention is allowed only in case of forest fire, epizooty and mass pest distribution threats (Protected areas law).

SPECP (Special purpose forests)

This FMM relates to the special purpose forests (such as genetic, botanical, zoological and landscape reserves) and recreational forests. Some non-clear occasional gap cuttings can be applied here; also sometimes the selective cutting system (in recreational forests) is applied. This FMM is aimed for sustaining and recovering of forest ecosystems or specific components of ecosystems and occupies 13.4% of the total CSA area.

MRDEC_C (Medium rotation clear cuttings in deciduous forests)

This FMM is dominated by the birch and black alder stands, with small admixture of hornbeam and lime and occupies 8.3% of the CSA area. Target ecosystem services are timber production and fuelwood supply.

MRDEC_CUS (Medium rotation uniform shelter-wood OR clear cuttings in deciduous forests)

This FMM is mainly applied on the territories with natural multi-layered deciduous forests, which are intended to be converted into the coniferous stands. The dominating species here are also birch and black alder with small admixture of hornbeam and lime, as in the previous FMM. The share of the area, occupied by this FMM, is 14.4% from total CSA area, and target ecosystem services are timber production and fuelwood supply.

SRDEC_C (Short rotation clear cuttings in deciduous forests)

This FMM is applied in the nearly pure stands of aspen and gray alder with possible admixture of willows, which are considered to be the species with low commercial value. Currently this FMM dominates in private forests, and its area covers 2.8% of the total CSA area. Target ecosystem service for this FMM is fuelwood production.

SRDEC_CUS (Short rotation uniform shelter-wood OR clear cuttings in deciduous forests)

This FMM is applied in the mixed multi-layered stands of aspen and grey alder with possible admixture of willows. Such stands can be also marked for the understorey with presence of species of high commercial value. Usually this FMM is related to “unsuccessful” forestry, and its area reaches 7.9% of the total CSA area. Target ecosystem service for this FMM is fuelwood production.

OTHER

This category unites such FMMs as long rotation clear cuttings in deciduous forests, long rotation uniform shelter-wood OR clear cuttings in deciduous forests, long rotation uniform shelterwood in deciduous forests, medium rotation uniform shelterwood in deciduous forests and short rotation uniform shelterwood in deciduous forests. Though the small shares of these FMMs are present in

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the CSA, the areas are not significant (common share is 6.6% of the total CSA area), so further these FMMs will be regarded in a united category.

2.4.1. Assessment of the contribution of FMMs on the timber supply from final cutting

Assessment of FMMs by their inputs to timber supply was split into two parts – this is dealing with the timber available from final cutting, another chapter is dedicated to timber potentially available from thinning cuttings.

Methodological approach

Only forest stands (parts of stands) with planned final cutting during 5 years period from 2017 were included into the evaluation. State stand-wise inventories in Lithuania are conducted every 10 years for all forests of some administrative unit, however, the management planning is carried out for forest owners/managers within the frames of separate project. Thus, even we have detailed inventory data for the whole Lithuanian CSA, final cuttings are thoroughly planned just for state forests managed by Telsiai State Forest Enterprise (SFE). Therefore, we focused our investigation only on part of CSA, expecting, that it represents also management on private forests, too.

For the estimation, we received detailed list of forest stands (parts of stands) assigned for final cutting starting from year 2017 and ending in 2021. The management planning was conducted by SC State Forest Inventory and Management Planning Institute (non-academic ALTERFOR partner, SFIMPI) based on special contract with Telsiai SFE. This list contained also detailed information on tree species to be harvested, their total volumes, harvested and extracted volumes, in addition to the detailed stand descriptions which are available from State Forest Cadaster. The economic evaluation of timber available from final cutting was conducted using the procedures of internal forest management planning for SFEs and used by SFIMPI.

The evaluation procedure is based on timber value models with independent parameter – mean diameter by tree species (Table 18). The models are built using assortment prices during the period 2014-2016 and direct timber harvesting, extraction and transportation as well as selling administration costs in Lithuanian State forestry sector.

Table 18. Models to evaluate the value of timber available from final cutting based on mean diameter by tree species

Tree species	Model parameters
Pine	$y = -0.0379x^2 + 2.9058x - 14.052$
Spruce	$y = -0.0477x^2 + 3.3354x - 18.053$
Oak	$y = -0.09x^2 + 7.8975x - 70.561$
Ash	$y = -0.0168x^2 + 2.0771x - 6.2107$
Birch	$y = -0.0465x^2 + 3.5192x - 24.345$
Black alder	$y = -0.0287x^2 + 2.0695x - 9.9709$

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Tree species	Model parameters
Aspen	$y = -0.0182x^2 + 1.2806x - 3.9681$
Gray alder	$y = -0.0069x^2 + 0.8537x - 1.7379$

So, using the information on forest stand characteristics and the models introduced above, the timber value for each area with planned final cutting was estimated. The contribution of FMMs on the timber value from final cuttings is evaluated using only the records with actually planned final cutting for next 5 years. These figures incorporate annual final cutting amount, environmental restrictions, etc. I.e. we do not discuss the overall final cutting potential - there are also more mature stands present in all FMMs but, following current forestry practice, they are not supposed to be harvested.

Contribution of FMMs on the timber value available from final cutting

The FMMs assuming combination of clear and non-clear cutting (CUS) clearly dominate according to final cutting areas and total volumes to be harvested (Table 19 and Figure 9). No final cutting is assumed under NOINT FMM. Final cutting area under SPECP FMM is also very small.

Table 19. The amounts of harvested volumes and values of timber available from final cutting, 5 years' period

Forest management model	Total area of the FMM*, ha	Final cutting area, ha	Total volume to be harvested, m^3	Value of timber, EUR	Volume to be harvested per ha, m^3	Value of timber per ha, EUR	Value of 1 m^3, EUR
LRCON_C	4470.9	73.2	12870	485072	175.8	6627	37.7
LRCON_CUS	5529.5	317.7	48859	1876800	153.8	5907	38.4
LRCON_US	2417.8	71.8	11049	429273	153.9	5979	38.9
MRCON_C	1603.1	81	17405	639772	214.9	7898	36.8
MRCON_CUS	18541.9	618.1	109964	4296211	177.9	6951	39.1
MRCON_US	2922.9	115.8	11875	455754	102.5	3936	38.4
MRDEC_C	6749.3	207.4	30644	864875	147.8	4170	28.2
MRDEC_CUS	11781.7	445.1	66221	2253804	148.8	5064	34.0
SRDEC_C	2297.5	37.8	5847	86364	154.7	2285	14.8
SRDEC_CUS	6477.9	151.9	26641	639690	175.4	4211	24.0
NOINT	2671.3	-	-	-	-	-	
SPECP	10981.4	16.8	1519	46803	90.4	2786	30.8

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Other	5362.4	93	9668	289784	104.0	3116	30.0
All	81807.6	2254	355117	12454629	157.5	5526	35.1

* note, that total area of FMM refers to the whole CSA, while final cutting is evaluated on state owned forests managed by Telsiai SFE

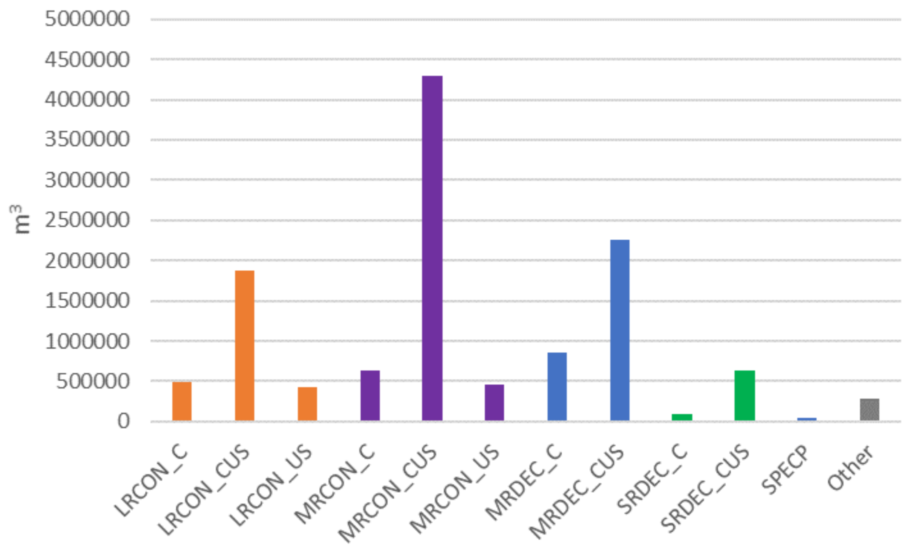

Figure 9. Total volumes to be harvested during next 5 years by final cutting in Telsiai SFE by FMMs

Largest volumes per 1 ha in coniferous forests are harvested using clear cutting system (Figure 10). However, introducing non-clear cuttings in deciduous forests seems to increase the volumes per ha to be harvested. Relatively low volumes per ha are available for harvesting under non-clear cutting in spruce forests. Should be noted, that non-clear cutting in spruce forests no matter the availability of lower tree layers is required near roads and in National parks and this frequently disagrees with the natural disturbance regime for such forests. Volumes, available for harvesting in short rotation deciduous forests are relatively high, even exceeding the average value for the whole area. Not surprisingly, that lowest volume per ha, which is available for harvesting, is available in special purpose forests with non-intensive non-clear cutting.

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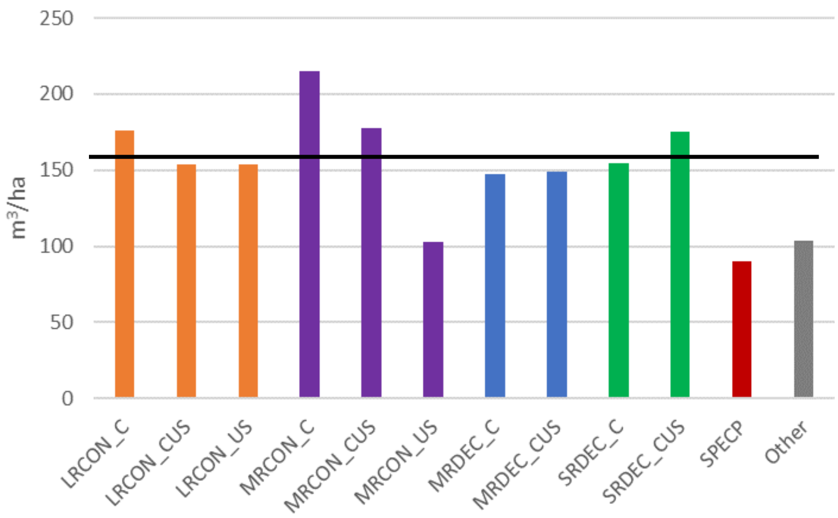

Figure 10. Average volume per 1 ha to be harvested during next 5 years by final cutting in Telsiai SFE by FMMs. Black horizontal line refers to the average value for the whole CSA

The most valuable FMM if using value per ha criterion is the clear cutting based forestry in spruce dominated stands (Figure 11). Introducing non-clear cutting in spruce forests seems result in value drop. The difference in value per harvested area in clear cutting and non-clear cutting forestry in spruce stands is double. This difference in pine forests is much less. Clear cutting in deciduous forests is less valuable due to the availability of more valuable tree species under "CUS" FMMs, especially in aspen and grey alder (SRDEC) forests – here the clear felling is usually applied in relatively pure, thus cheapest in timber price, stands. The value per ha of timber, harvested in special purpose forests, is also relatively low.

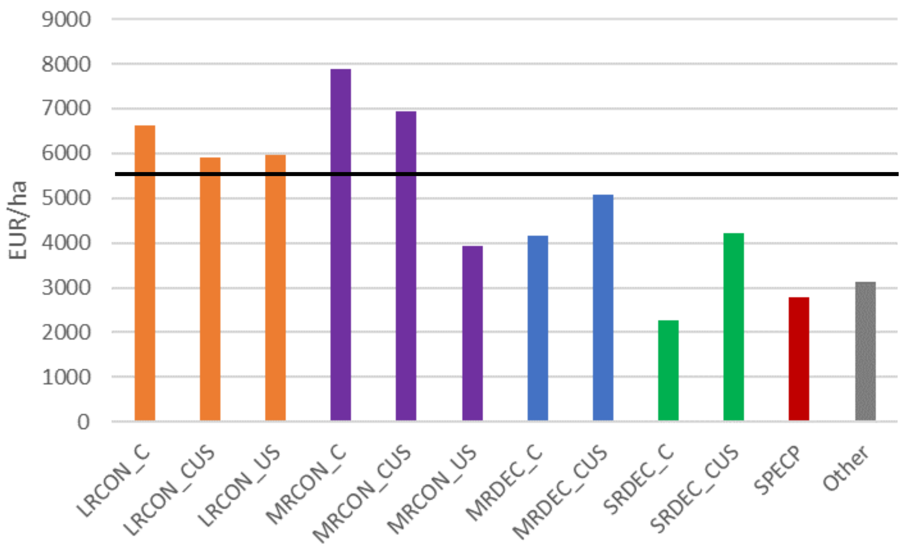

Figure 11. Value of timber per 1 ha to be harvested during next 5 years by final cutting in Telsiai SFE by FMMs. Black horizontal line refers to the average value for the whole CSA

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Values of timber per 1 m^3 to be harvested during next 5 years by final cutting are quite levelled in coniferous forests (Figure 12). Lowest value of 1 m^3 harvested timber volume is in short rotation deciduous forests. These figures, however, more refer to the values of different assortments rather management regimes.

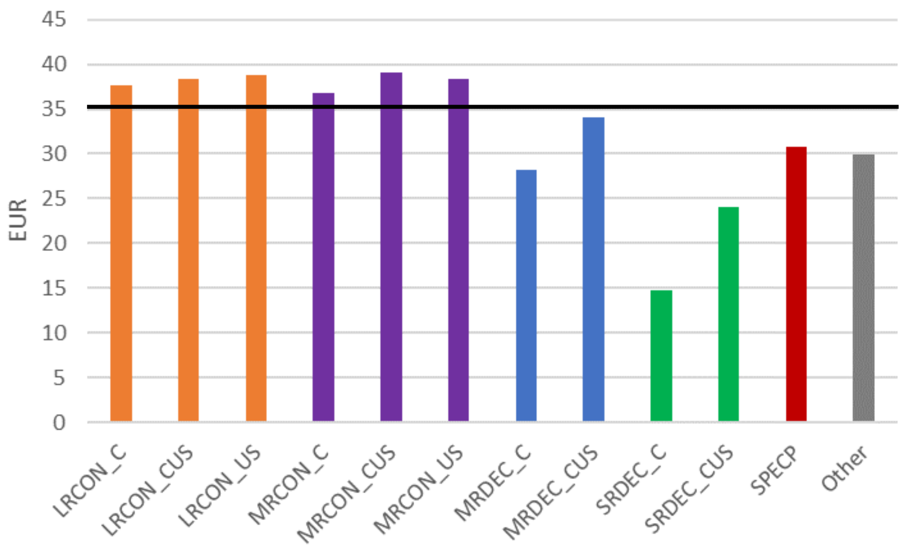

Figure 12. Value of timber per 1 m3 to be harvested during next 5 years by final cutting in Telsiai SFE by FMMs. Black horizontal line refers to the average value for the whole CSA

To summarize, the most important in terms of timber provisioning from final cutting are forest management models combining the clear and non-clear cutting systems. Clear cutting based systems in coniferous forests deliver largest values per area unit, however, in deciduous forests, the most efficient in this sense are the forest management models, combining clear and non-clear cutting. Mandatory non-clear cutting in spruce forests is related to twice lower value of timber, compared with the clear cutting based FMM. Commercial value of timber final harvesting in special purpose forests is relatively low.

2.4.2. Assessment of the contribution of FMMs on the timber supply and additional forestry costs from thinning cuttings

Thinning cuttings were assessed separately from final cutting, as some types of cutting involve only costs with no income for timber.

Methodological approach

To estimate the timber value available from thinning cuttings the same approach as for final cuttings was utilized with some modifications:

- Thinning cuttings are automatically planned by the State Forest Cadaster IS based on dendrometric characteristics of the stand, thus every forest compartment records contained information on whether there is a need for thinning during coming 10 years or not. Information on the share of volume to be thinned is also given.

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- Some adjustments were made in harvesting costs. To avoid any potential misunderstanding, the following definitions are used to identify the thinning: pre-commercial thinning (in Lithuanian "jaunuolynų ugdymas"), 1st commercial thinning (in Lithuanian „retinimo kirtimai") and 2nd commercial thinning (in Lithuanian "einamieji kirtimai"). Harvesting costs were reduced by 2.3 EUR/m^3 for the 1st commercial thinning and by 1.45 EUR/m^3 for the 2nd commercial thinning.
- To estimate the costs of pre-commercial thinning all stands – candidates for thinning – were grouped into 3 groups: i) pine stands on poor soils (Na, Nb, Lb) – amount of timber cut – 80 volumetric m^3/ha and the harvesting costs 120 EUR/ha; ii) spruce, larch and hardwood deciduous stands with 180 volumetric m^3/ha cut volume and 200 EUR/ha; iii) remaining young stands with 140 volumetric m^3/ha and the harvesting costs 160 EUR/ha. The volumes of cut timber and harvesting costs were provided by Telsiai SFE.
- Differently from the final felling, the thinning cuttings cover all forests of the CSA.

Evaluation of FMMs in respect of costs and incomes from thinning cuttings

Thinning cuttings are evaluated according to the costs to thin and timber values by FMMs (Table 20). The 2nd commercial thinning is not used in short rotation deciduous forests, this some cells are left blank. We do also not take into consideration some forest compartments with relatively lover stocking index and thus with no thinning cuttings planned.

Table 20. The amounts of harvested volumes and values of timber available from thinning cutting

FMM	Area of thinning, ha			Volume cut, m3			Value, EUR		
	Pre-comm.	1st comm	2nd comm	Pre-comm	1st comm.	2nd comm.	Pre-comm	1st comm.	2nd comm.
LRCON_C	165.4	213.4	455.3	17362	5339	21524	-22628	87680	698417
LRCON_CUS	130	141.3	395.5	13130	3348	17092	-17420	48736	601299
LRCON_US	69.3	55.1	222.3	5922	1528	9630	-8568	25354	328056
MRCON_C	20	44.8	74.9	2820	879	3547	-3220	11727	96721
MRCON_CUS	2175.8	1552.9	1650	318472	46742	90997	-361988	798753	2576159
MRCON_US	166.2	201.3	292.8	23596	7559	18978	-26920	154506	579533
MRDEC_C	425.5	193.6	404.7	59570	4109	11594	-68080	38092	204726
MRDEC_CUS	1575.4	900.1	848.4	220556	19859	25033	-252064	215942	541149
SRDEC_C	49.9	13.8		6986	495		-7984	4254	
SRDEC_CUS	542.6	233.7		75964	7448		-86816	65675	
SPECP	291.3	398.9	829.2	41166	11803	35614	-47424	211245	1166117
Other	259,2	3012,4	2724	36696	4956	25334	-15528	49931	1629057
All	5871	4139,1	5944	822240	114064	259344	-944992	1711894,9	8421233

	Value per 1 ha, EUR			Total values		
	Pre-comm.	1st comm.	2nd comm.	Area, ha	Value, EUR	Value per 1 ha, EUR
LRCON_C	-136.81	410.87	1533.97	834.1	763469	915.32
LRCON_CUS	-134.00	344.91	1520.35	666.8	632615	948.73
LRCON_US	-123.64	460.14	1475.74	346.7	344842	994.64
MRCON_C	-161.00	261.76	1291.34	139.7	105228	753.24
MRCON_CUS	-166.37	514.36	1560.74	5379.3	3012924	560.10
MRCON_US	-161.97	767.54	1979.28	660.3	707119	1070.91
MRDEC_C	-160.00	196.75	505.87	1023.8	174738	170.68
MRDEC_CUS	-160.00	239.91	637.85	3323.9	505028	151.94
SRDEC_C	-160.00	308.24		63.7	-3730	-58.56
SRDEC_CUS	-160.00	281.02		776.3	-21141	-27.23
SPECP	-162.80	529.57	1406.32	1519.4	1329937	875.30
Other	-161.57	262.52	2114.56	1219,8	1637109	1342.11
All	-160.97	413.59	1416.74	15953,8	9188136	575.92

Pre-commercial thinning is usually related to the costs of implementation and no commercial timber available (Figure 13). Thus, the values are negative. Average pre-commercial thinning costs per ha are rather similar for all FMMs. Pre-commercial thinning is cheapest on pine stands and relatively most expensive in spruce and special purpose forests (with mixed spruce – deciduous stands). The 1st commercial thinning generates values approx. 3 times less than the 2nd commercial thinning. Relatively largest value of timber harvested by the 1st commercial thinning is under MRCON_US FMM. The same FMM produces largest timber values per ha in 2nd commercial thinning, too. The 1st commercial thinning in pine stands seems to produce rather similar values being approximately at the level of CSA average. The 1st commercial thinning in medium rotation deciduous forests results lower timber values than the same type of cutting in short rotation deciduous forests. This is much to the relatively larger stem dimensions but also much likely to the fact, that there is no 2nd commercial thinning carried out under SRDEC FMM. The value of timber available from the 2nd commercial thinning in birch and black alder stands (MRDEC FMM) is ~twice less than the average value for the CSA. Thinning cutting seems to be relatively the most important way to produce timber in special purpose forests, as the importance of final cutting is relatively low. Relatively high values of 2nd commercial thinning in other FMMs, which are not discussed in more details in this report, is due to relatively larger dimensions of stems and commercial value of assortments available on long rotation hardwood deciduous stands, which make the largest share of "Other" FMM.

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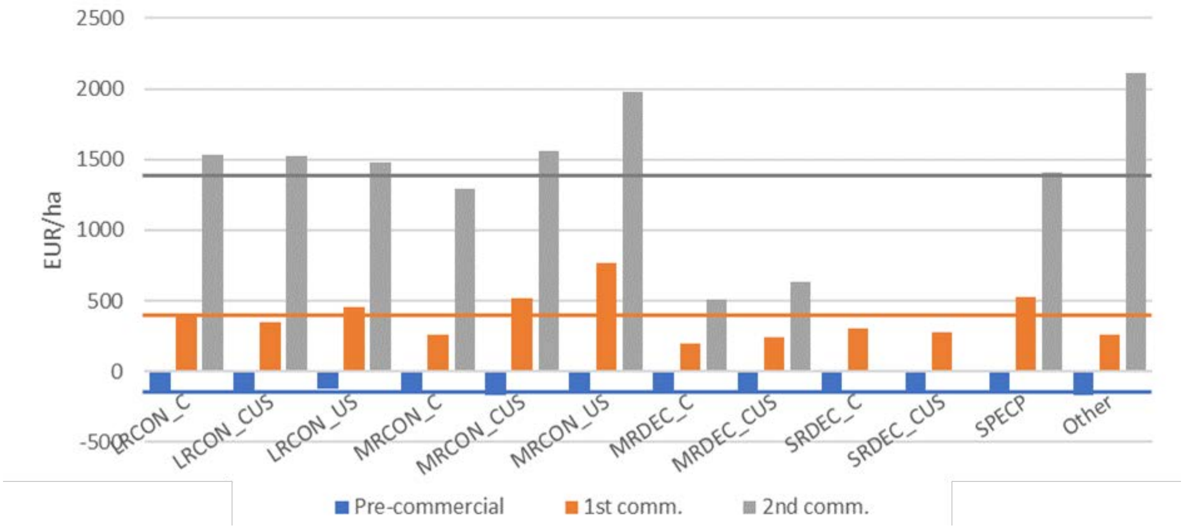

Figure 13. Costs and harvested timber values from thinning cuttings per 1 ha by FMMs

Figure 14 provides summarized timber values available from thinning cutting. Should be noted, that the values here are estimated considering the areas of each type of thinning in the CSA. Thinning cuttings results in highest timber values under other FMMs, then in spruce forests with no clear-cutting allowed. Pine forests do also result in values of timber, available from thinning cuttings, over the CSA average. Thinning in short rotation deciduous forests of the CSA usually mean costs exceeding the price paid for timber produced. The overall value of timber from thinning in medium rotation deciduous forests is ~3 times less than the average value for CSA. So, the value of timber from thinning cuttings is very much dependent on the 2nd commercial thinning. The longer rotation automatically means the longer period for 2nd commercial thinning, larger dimensions of harvested trees and supply of more valuable assortments.

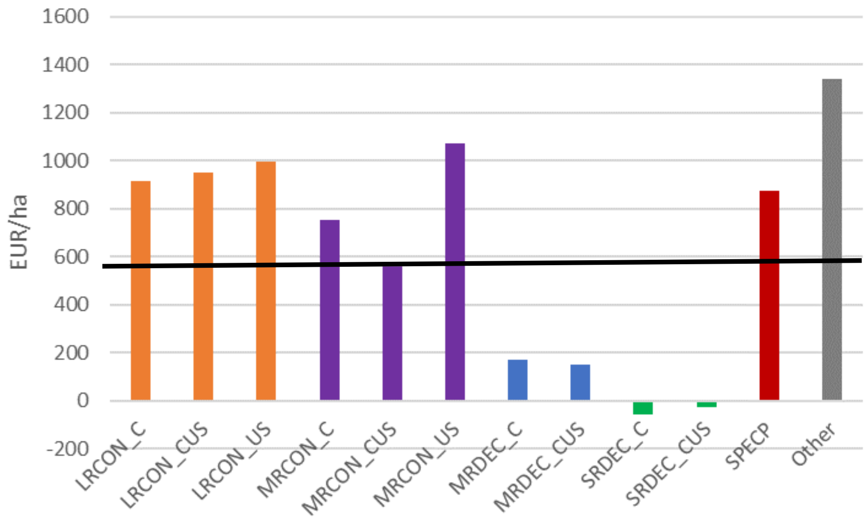

Figure 14. Average value of timber available from thinning cutting, taken into consideration the whole thinning area

To summarize, the pre-commercial thinning in Lithuanian CSA involves only the costs to conduct the operation no matter the FMM. Relatively highest timber values are achieved from the

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commercial thinning in spruce forests with non-clear final cutting assumed and in special purpose forests. Thinning cuttings in short rotation deciduous forests are related with negative timber values (i.e. the pre-commercial thinning and harvesting operations cost more than the value of timber extracted), low timber values from thinning may be expected from medium rotation deciduous forests, too. Bearing in mind current age structure of forests in SCA, the value of timber from thinning cutting is positively related to the rotation age.

2.4.3. Assessment of the contribution of FMMs to mitigate impacts of catastrophic events and provide regulatory service

The vulnerability to the following catastrophic event events was taken into consideration while evaluating the FMMs in Lithuanian CSA:

- Forest fire risk;
- The risk of tree mortality due to diseases;
- Wind damage risk;
- The risk of tree mortality due to internal tree competition.

Other catastrophic events causing forest damages are related to insects, game, human, snow, low temperatures and humidity occur much less frequent and thus have not been considered in this study.

Methodological approach

The guidelines for the selection of stand and landscape level indicators to assess the contribution of FMMs to mitigate impacts of catastrophic events were followed with some modifications. The models to compute (continuous) vulnerability indicators based on the inventory data were used for all event types, except the forest fire risk (in fact the models were elaborated also for forest fire risk, however they were on the margin to be statistically significant).

The models to compute vulnerability indicators were developed for this study using approaches described by Garcia-Gonzalo et al. (2011) and Marques et al. (2012). As the input data source for model development we used Lithuanian NFI data from permanent sample plots. All plots are remeasured every 5 years starting since 1998. The records for each sample plot contains detailed forest stand attributes and information on tree mortality recorded for each plot with identification the reason. I.e. all trees that died during 5 years between inventory periods are inventories recorded. We developed binary logistic regression models for the mortality due to one of reasons listed above using variables as model predictors which are identical in NFI and stand-wise forest inventories. The variables were: soil fertility gradient, soil humidity gradient, age, height and diameter of prevailing tree species in the stand, mean height and diameter of the stand, site index, ownership and forest group (forest group defines the forest management regime). Models were developed for 8 tree species groups (pine, spruce, birch, black alder, aspen, gray alder, oak and ash), all they were statistically significant. Mortality models are planned to be further improved to be published.

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In addition to the tree mortality risks all forest stands were assigned to one out of three forest fire risk classes used in operational Lithuanian forest management planning. Class 1 is assumed to be associated with potentially highest forest fire risk and class 3 – lowest forest fire risk.

Contribution of FMMs to mitigate impacts of catastrophic events in Lithuanian CSA

Area weighted average values of vulnerability indicators by FMMs are provided in Table 21. Not surprisingly, that highest forest fire risk classes were given to FMMs with coniferous trees. Average class for models with assumed clear cutting indicates somewhat lower forest fire risk much since clear final cutting in coniferous forests is prioritized on wet soils. Practically all stands with deciduous tree species dominating are assigned to the lowest forest fire risk class – the average value is approaching 3. Forests with no active forest management rather well describe all forest conditions in respect forest fire risk and are given average class value close to the overall average. Very diverse forest conditions are present in special purpose forests managed under SPECP FMM, thus the average fire risk class is between the figures for coniferous and deciduous dominated FMMs.

Table 21. Area weighted average vulnerability indicators by FMMs

Forest management model	Average fire risk class	Average probability of mortality due to		
		Diseases	Wind	Competition
LRCON_C	1.90	0.133	0.119	0.220
LRCON_CUS	1.52	0.120	0.110	0.159
LRCON_US	1.38	0.120	0.101	0.177
MRCON_C	1.96	0.090	0.172	0.175
MRCON_CUS	1.54	0.077	0.132	0.157
MRCON_US	1.64	0.103	0.140	0.187
MRDEC_C	2.86	0.080	0.159	0.159
MRDEC_CUS	2.82	0.079	0.138	0.136
SRDEC_C	2.99	0.136	0.264	0.268
SRDEC_CUS	2.99	0.135	0.268	0.256
NOINT	2.25	0.122	0.141	0.161
SPECP	2.35	0.127	0.178	0.198
Other	2.97	0.120	0.141	0.148
All	2.24	0.103	0.155	0.176

Lowest mortality probabilities due to diseases are found on medium rotation deciduous forest stands (i.e. basically dominated by birch and black alder). Highest risk for diseases seems to be on pine and grey alder and aspen dominated stands (correspondingly LRCON and SRDEC FMMs). Higher mortality probabilities due to diseases within the same tree species are predicted for FMMs

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using clear cutting. However, the exception is MRCON_US FMM, i.e. uniform shelter-wood cutting in spruce dominated forests. Here, the non-clear felling is frequently required due to location of the stand e.g. in National Parks and disagrees with the specifics of natural spruce forest development and contradicts the natural disturbance regimes for such forests. “No Intervention” and “Special Purpose” FMMs are also associated with increased mortality risks due to diseases, potentially due to reduced human influence in preventing forest diseases.

Highest wind damage risks in coniferous dominated forests are predicted in clear cutting based FMMs. Logically, the FMMs with combinations of clear and non-clear cutting (_CUS) should produce higher wind mortality than non-clear cutting only based FMMs, however, this is true for pine forests. Non-clear cutting in spruce dominated forests seems to be associated with higher wind damage risk than the one predicted for MRCON_CUS. The probability of wind caused mortality in short rotation deciduous forests is predicted to be near twice larger than the average value for CSA. Most likely not only grey alder or aspen trees are to be damaged but also the admixtures of other species, especially spruce, which are found in tree species composition in small proportions.

The mortality probability due to internal competition among the trees in the stand seems to be highest also in short rotation deciduous forests. It was also relatively high in pine forests supposed to be harvested by clear felling. This increased competition is likely to be due to relatively larger initial densities of pine plantations (pine plantations with clear pine dominance are associated with the LRCON_C FMM as they are supposed to target timber production ES first). Should be noted, that mandatory non-clear cutting in spruce dominated forests is associated with highest mortality risk due to competition among all medium rotation length coniferous FMMs. Mortality probabilities on “No Intervention” forests are somewhat less the ones for “Special Purpose” forests no matter less human intervention.

All forest fire risk classes are present in forest managed under LRCON_C FMM in similar proportions, while the lowest risk class (“3”) is practically absent in pine FMMs with non-clear cutting allowed or required (Figure 15). This is since some pine forests on wet soils are usually cut by clear cutting, thus resulting in some share of reduced fire risk class. Otherwise, the FMMs with pine trees are under the largest forest fire risks, especially the ones to be cut by non-clear cutting. Spruce forests are distributed by forest fire risk classes in a similar fashion as the pine forests, with somewhat lower proportion of highest (“1”) forest fire risk class. Forest fire risk is low in deciduous forests. NOINT and SPECP FMMs exhibit rather similar distribution of forest fire risk classes – with smallest share of class “1” and largest area of class “3”.

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Figure 15. Area proportions of fire risk classes by FMMs

Mortality risk classes were constructed using recommendations from ESs experts and local forest management planning experts. As all forest compartments were provided with modelled mortality probability. We divided all mortality probabilities into 5 classes using quantile classification approach resulting in similar number of observations in each class as the CSA level. Then the stand area was summarized grouping by FMM and mortality class. Finally, we calculated area proportion of each mortality probability class within each FMM. Figures 2-4 display the area proportions of mortality risk classes due to specific reasons by FMMs.

If the mortality due to diseases is taken into consideration, the area proportion of largest mortality probability class dominates in FMMs on pine forests and, especially, in short rotation deciduous forests and areas, managed by NOINT and SPECP FMMs (Figure 16). Lowest mortality probability class dominates in birch and black alder stands (MRDEC FMMs). FMMs in spruce dominated stands

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are associated with rather equal shares of 1-4 mortality probability classes and relatively lower share of the 5th probability class, indicating the highest mortality probability.

Figure 16. Area proportions of mortality risk classes due to diseases by FMMs

The 2nd and 3rd mortality probability classes dominate in pine FMMs if the wind damage is taken into consideration (**Fehler! Verweisquelle konnte nicht gefunden werden.**). The shares of increased wind caused mortality probability classes (4-5) are rather small under these FMMs. The 3rd and 4th classes dominate in spruce forests, indicating somewhat higher wind damage risks than in pine FMMs. There is significant share (~30%) of class "1" in stands managed by FMMs MRDEC (birch and black alder). The proportions of classes 4-5 are also seen here. Common forestry practice, especially under MRDEC_CUS FMM is to convert the forest into coniferous dominated

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forest – this practice seems to relate to increasing wind vulnerability of the forest. The most vulnerable to wind effects is the forestry on short rotation deciduous forests. Forests with no intervention seem to be more resistant to wind than the special purpose forests, both FMMs exhibit rather similar proportions of all classes.

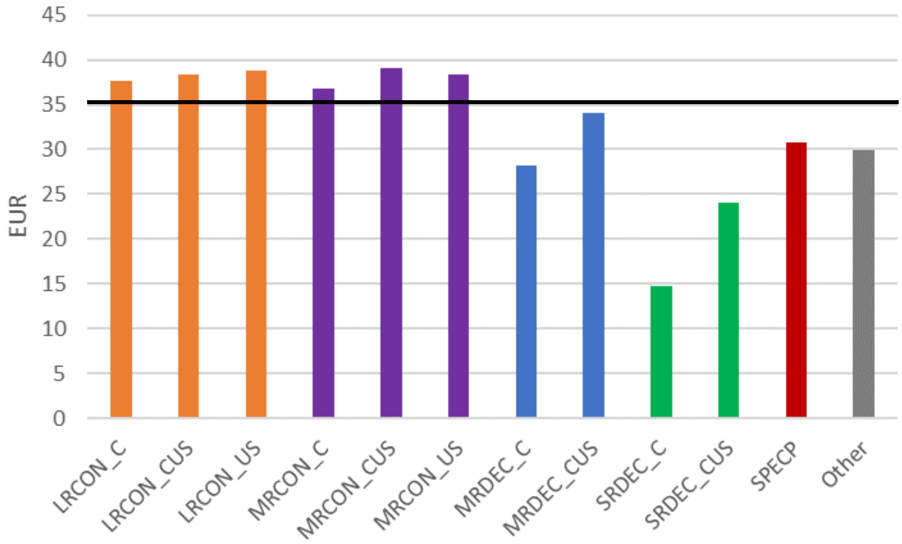

Figure 17. Area proportions of mortality risk classes due to wind damages by FMMs

Except the FMMs for short rotation deciduous forests, the area proportions of mortality risk classes due to competition are rather similar for all FMMs (Figure 18). This suggests that the forest management practice has limited influence on the mortality caused by competition among the trees. Exceptions are SRDEC FMMs where the influence of thinning cuttings is lowest among all FMMs. Also, relatively large shares of the 4-5th mortality probability classes in stands under LRCON_C FMM are explained by the practice to plant more pine trees when artificially regenerating commercial pine forests.

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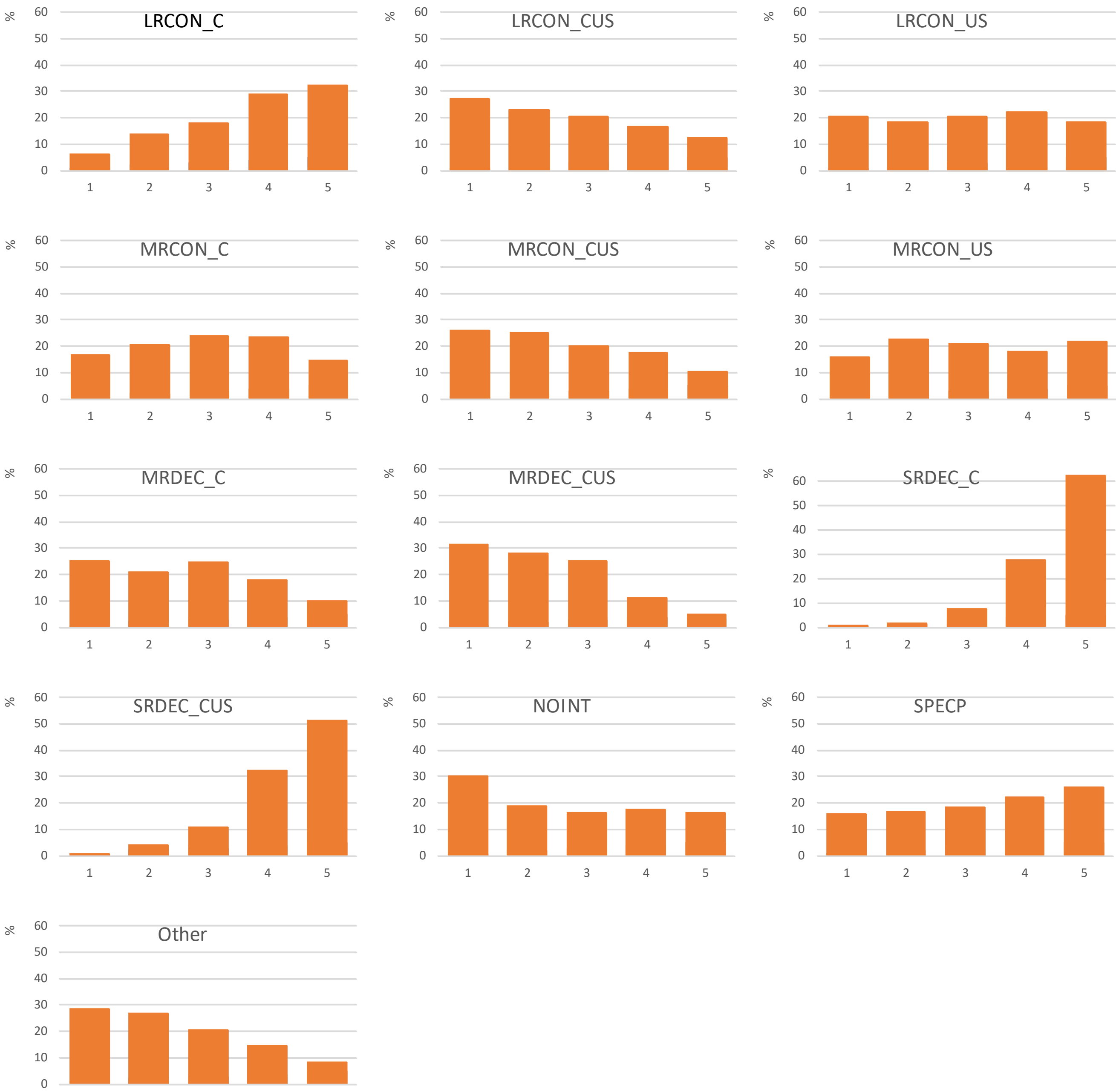

Figure 18. Area proportions of mortality risk classes due to competition by FMMs

To summarize, the FMMs for coniferous forests seem to be related with highest forest fire risks, while the fire risk on deciduous forests is relatively small. Relatively diverse conditions in respect the fire risk are present in forests with limited forest management activities. The most vulnerable to catastrophic events seem to be forest stands managed under short rotation deciduous FMMs. Restricted forest management does not clearly result in increased or decreased resistance to catastrophic events. Departure from forest management assumed by natural disturbance regimes (as in non-clear cutting in spruce stands) may have some effects on decreased stand resistance.

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2.4.4. Contrasting the relative biological diversity of Lithuanian stand level FMMs

Methodological approach

Three standard biodiversity indicators were used: tree species composition, forest structures, and spatial-temporal disturbance patterns. Each of the indicators was described using several attributes for each compartment in the CSA:

- Tree species composition:
  - Adjusted number of tree species in a stand, estimated using the following approach: Actual tree species number in a stand PLUS Adjustment due to broad-leaved species (Broad-leaved species – maple, elms, lime, hornbeam, apple, wild cherry, pear; willows (*Acer platanoides*, *Ulmus* spp., *Tilia cordata*, *Carpinus betulus*, *Malus sylvestris*, *Prunus avium*, *Pyrus communis*, *Salix* spp.) present in the dominating canopy layer - if present, then the count for certain species is doubled) MINUS Adjustment due to non-native species (if present, then it is not accounted in the tree species composition).
  - Tree species diversity in the stand: Shannon-Wiener index.
- Forest structures:
  - Natural deadwood per year in a stand, m^3/ha.
  - Age difference between tree species in the main layer: Class: 1 - all species of the same age; 2 - age differs 1-9 years, 3 - age differs 10-19 years, 4 - age differs 20-29 years, 5 - age differs 30-39 years, 6 - age differs 40-49 years, 7 - age differs more than 50 years.
  - Large trees present in the stand: Class: 1 - no large trees, 2 - trees with mean dbh 30-39 cm present; 3 - trees with mean dbh 40-49 cm present, 4 - 50-59, 5 - 60-69, 6 70-79 and 7 - trees with dbh >79 cm present.
  - Mean DBH – cm.
- Spatial-temporal disturbance patterns:
  - Volume removed by harvesting - the proportion of volume removed per harvest during nearest planning period.
  - Expert given grade on FMM fitting the natural disturbances (
  -
  - Table 22). Class: 1 - complete disagreement with the natural disturbance type, 2 - poor agreement - if natural disturbance assumes non-clear cutting but FMM does, 3 - fair agreement - if natural disturbance allows clear cutting but FMM does not; 4 - moderate agreement with the natural disturbance type, 5 - good agreement - if natural disturbance assumptions and FMM fit; 6 - high agreement with the natural disturbance type, used on special purpose forests mainly; 7 - excellent agreement with the natural disturbance type (only for no management).

Table 22. Site types as accommodating development phases and disturbances (in Italic) (Source Angelstam, 2007).

	a	b	c	d	f

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N	Multi-cohort *fire*	Succession *fire*	Succession *fire, wind*	Gap-phase *wind,* *diseases, insect outbreaks*	Gap-phase *wind,* *diseases, insect outbreaks*
L	Succession *fire*	Succession *fire*	Succession *fire, wind*	Gap-phase *wind,* *diseases, insect outbreaks*	Gap-phase *wind,* *diseases, insect outbreaks*
U		Succession *fire*	Succession *fire, wind*	Gap-phase *wind*	Gap-phase *wind*
P	Succession *Fire, physiological draught*	Gap-phase *wind*	Gap-phase *wind*	Gap-phase *wind*	

All attributes were indexed or normalized to fall in the range 1-7, with 7 being the optimal score. Then area weighted average was calculated for each FMM. Average grade was provided for each indicator by simple averaging of corresponding attribute. Overall FMM score was given by calculating average value of indicator-level grades (Table 23).

Relative biological diversity of Lithuanian stand level FMMs

Table 23. Average estimates of biodiversity indicators in Lithuanian CSA

Forest management model	Tree species composition			Forest structures					Spatial-temporal disturbance patterns			Overall average
	Adjusted number of tree species in a stand	Tree species diversity	Average	Natural deadwood per year in a stand	Age difference between tree species in the main layer	Large trees present in the stand	Mean DBH	Average	Volume removed by harvesting	Fitting the natural disturbances	Average	
Long rotation clear cutting in coniferous	1.98	2.31	2.14	2.57	1.92	1.20	5.55	2.81	6.12	3.98	5.05	3.33
Long rotation uniform shelter-wood OR clear cutting in coniferous	2.77	3.57	3.17	3.05	2.71	1.57	6.75	3.52	5.77	5.00	5.39	4.03
Long rotation uniform shelter-wood in coniferous forests (Labanauskas felling)	1.91	2.21	2.06	3.03	1.74	1.33	6.34	3.11	5.64	3.10	4.37	3.18
Medium rotation clear cuttings in coniferous	1.80	1.96	1.88	2.89	2.04	1.31	5.93	3.04	4.87	4.36	4.62	3.18

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Forest management model	Tree species composition			Forest structures					Spatial-temporal disturbance patterns			Overall average
	Adjusted number of tree species in a stand	Tree species diversity	Average	Natural deadwood per year in a stand	Age difference between tree species in the main layer	Large trees present in the stand	Mean DBH	Average	Volume removed by harvesting	Fitting the natural disturbances	Average	
Medium rotation uniform shelter-wood – clear cuttings in coniferous forests	2.96	3.54	3.25	2.28	2.83	1.37	4.94	2.85	6.15	5.00	5.57	3.89
Medium rotation uniform shelter-wood in coniferous forests	2.63	3.10	2.87	2.60	2.63	1.43	5.80	3.12	6.55	2.29	4.42	3.47
No intervention	2.67	3.19	2.93	2.64	3.48	1.52	6.05	3.42	6.22	7.00	6.61	4.32
Management in special purpose forests	2.93	3.35	3.14	2.33	2.96	1.40	5.69	3.09	6.71	5.53	6.12	4.12
Medium rotation clear cutting in deciduous	2.15	2.50	2.32	1.66	1.86	1.07	4.31	2.22	5.43	3.22	4.32	2.95
Medium rotation uniform shelter-wood OR clear cutting in deciduous forests	3.33	3.99	3.66	1.69	2.65	1.27	4.91	2.63	5.49	5.00	5.25	3.85
Short rotation clear cutting in deciduous	1.72	1.79	1.75	1.91	1.67	1.08	4.08	2.19	3.35	3.44	3.39	2.44
Short rotation uniform shelter-wood OR clear cutting in deciduous forests	3.55	4.05	3.80	1.94	3.05	1.26	4.68	2.73	4.14	5.00	4.57	3.70
Other	3.40	3.77	3.58	1.95	3.19	1.56	5.91	3.15	6.35	4.16	5.25	3.99

Long rotation clear cutting in coniferous forests

Though this FMM is not dominating in the CSA, it is still an important source of commercially valuable wood and, therefore, of a high share of the income from forests in the CSA, what results in the high harvesting volumes. Regular thinnings (especially in the state forests) and often cultural origin of the stands result in the low age difference between the trees and tree species diversity. Deltuvas et al. (2003) suggested the economic maturity age for pine stands to be dependent on the site index: 70-80 years for IA-I sites and 80-90 for II-III sites and 110-120 years for IV-V sites. They also suggested technical maturity ages based for sawn logs – 70-80 and 90-100 years for site types IA-I and II-III, respectively, as well as financial maturity ages based on present net value (80-90 (IA-III), 110-120 (IV-V)) and soil expectation value – 70-80 (IA-I), 80-90 (II-III) and 110-120 (IV-V). The

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uniform stand structure and usage of economic and technical maturity ages resulted in the absence of larger trees in the stand.

Long rotation uniform shelter-wood OR clear cutting in coniferous forests

The presence of areas with shelter-wood management systems in combination with long rotation ages on the soils with low expectation value resulted in the highest score for the mean DBH and the large trees presence in the stand from all FMMs. Usually such trees are the seed trees, remaining from the previous generations. These two factors bring this FMM to a third place by the overall range.

Long rotation uniform shelter-wood in coniferous forests (Labanauskas felling)

The idea of the FMM is to remove significant amount of the main layer leaving 80-100 pine trees per ha to initiate natural pine regeneration (Juodvalkis 2011). A higher number of seed trees, left after the first cutting, resulted in slightly lower mean DBH, than within the previous FMM, however, the amount of deadwood was the highest from all FMMs.

Medium rotation clear cuttings in coniferous forests

Dense canopies of spruce trees and acid soils under them create unfavourable conditions for other tree species (Augusto et al. 2003), so both the number of tree species and Shannon-Wiener index were quite low for this FMM. As well as for the Scots pine, such stands are mostly artificially regenerated, so the average age difference was also low. High shade-tolerance and regular thinnings (at least in the state forests) of Norway spruce resulted in lower amount of deadwood. Low amount of large trees could also be explained by the rotation ages. The economic maturity age for spruce stands are also dependent on the site index: 60-70 years for IA-I sites and 70-80 for II-III sites. The technical maturity ages for sawn logs are 60-70 and 70-80 years for site types IA-I and II-III respectively, what is even less, than for the Scots pine (Deltuvas et al. 2003).

Medium rotation uniform shelter-wood OR clear cuttings in coniferous forests

This FMM is applied only in some areas of the CSA. Usually it implies group-occasional cuttings, which later transform into the uniform shelter-wood cuttings due to lack of supporting informational materials, machinery and tools. Clear-cuttings can also be performed on these areas, as long as there are no restrictions, prohibiting clear cuttings. The scores for the spatial-temporal disturbance patterns for this model are slightly higher than for the medium rotation clear cuttings in coniferous forests due to the lower single-time cutting volumes and possible creation of gaps, which raise the score for fitting the natural disturbances (Noss 1999, Lindenmayer and Franklin 2007). Such gaps also may be the reason of higher species diversity. Also as well as for the Scots pine stands there are higher scores for mean DBH and larger trees amount.

Medium rotation uniform shelter-wood in coniferous forests

The volume removed by harvesting is relatively low in such areas, and the mean DBH is quite high. Still, on the large part of the territory the FMM poorly corresponds to the natural disturbances on the certain types of the soils.

No intervention

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As it could be expected, this FMM reached maximal overall score of 4.32. In this FMM any human intervention is allowed only in case of forest fire, epizooty and mass pest distribution threats (Protected areas law). This explains the fact, that some volume is still removed during the fellings. This model also reached highest scores in the age difference between tree species in the main layer and, obviously, in the correspondence to the natural disturbances.

Management in special purpose forests

This FMM takes the second place by the overall score after the “No intervention” model, mainly because of the highest score for the volumes, removed by harvesting. The trees within this model have relatively high mean DBH, and the correspondence to the natural disturbances within this model varies from good to high.

Medium rotation clear cutting in deciduous forests

Relatively short rotations (70-80 years for IA-I sites and 80-90 for II-III sites for birch and 70-80 years for black alder on all stands (Deltuvas et al. 2003)) and smaller potential DBH of the prevailing species resulted in the smallest amount of large trees in the stands among all FMMs. Also this model was marked for the smallest amount of deadwood. Such lack of forest structural components made this model second from the end by the overall score.

Medium rotation uniform shelter-wood OR clear cutting in deciduous forests

Due to the fact that in this FMM the stands usually have non-uniform structure, both overall score and the scores for the separate indicators for this model are higher, than for the previous one. As it could be expected, the biggest differences are in the Shannon-Wiener index and tree species diversity, mainly due to the natural stand origin. Also notable higher score is for the correspondence to the natural disturbances. Still, there are only minor differences in the scores for the presence of large trees in the stands and for the amount of deadwood.

Short rotation clear cutting in deciduous forests

Despite this FMM is applied mostly on wetlands, it can be marked for the lowest overall score. Usually the stands of such type have low amount of layers, what resulted in the lowest Shannon-Wiener index and tree species diversity. The same fact could also be the reason for the low age difference between tree species in the main layer. Poor growth conditions, short rotations (50 years for European aspen, 40 years for grey alder and 31-41 years for the willow species) and the characteristics of the species resulted in the lowest mean DBH. Still, the wet conditions, unfavorable for logging, resulted in lower removed volume, than possible.

Short rotation uniform shelter-wood OR clear cutting in deciduous forests

Rich understorey resulted in the highest Shannon-Wiener index and tree species diversity from all FMMs. Due to the same reason the age difference between tree species in the main layer was also significantly higher than for the previous FMM.

Other

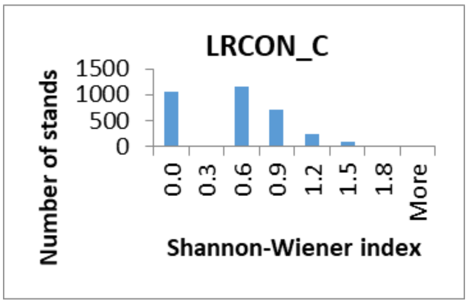
This category unites several FMMs, thus the variation of scores for the criteria was rather high, what resulted in average results for all indicators. Rather low scores were obtained for the large

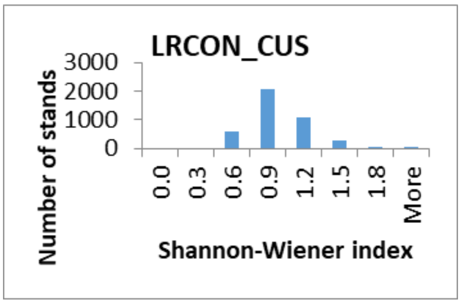
trees presence in the stand and for the amount of deadwood. However, if we regard the united FMMs separately, the results could differ drastically. Still, the areas of these FMMs within the CSA are minor, so their influence on common situation is inconsiderable.

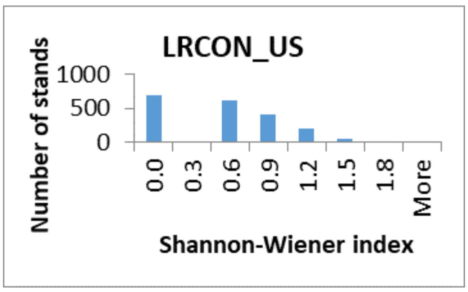
Though the assessment methodology consisted only of comparison of the average values, during our assessment we could notice a high variety of scores for every criterion even within FMMs. In order to provide more detailed and exact data on the relative biological diversity of Lithuanian stand level FMMs, in this part of our report we present frequency histograms for all indicators. We evaluated the distribution of scores for every indicator within the plots for every FMM. If the indicator was continuous numeric (e.g. mean DBH), we evaluated the number of plots within the certain values of this indicator. If the indicator was qualitative and divided into classes (e.g. correspondence to the natural disturbances), we evaluated the area, occupied by each class.

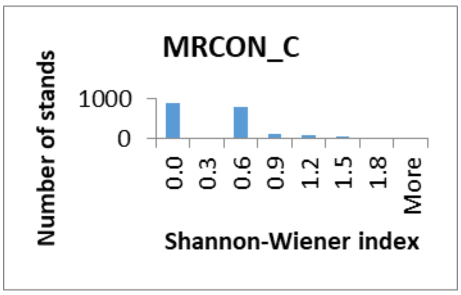
Adjusted number of tree species in a stand

As it was mentioned before, the adjusted number of trees in a stand was grounded on a Shannon-Wiener index. In coniferous forests within clear-cut FMMs biggest number of stands had a Shannon-Wiener index from 0.6 to 0.9, however, there was also a big share of areas with the Shannon-Wiener index close to 0. In coniferous forests within shelter-wood FMMs biggest number of stands had a Shannon-Wiener index from 0.9 to 1.2 with smaller amount of stands with the Shannon-Wiener index close to 0. In deciduous forests biggest number of stands also had a Shannon-Wiener index from 0.6 to 1.2, and the big share of areas with the a Shannon-Wiener index close to 0 could be observed only within clear-cut FMMs. In the forests with no intervention and forests of special purpose Shannon-Wiener index mostly varied from 0.6 to 1.2, the proportion of areas with the Shannon-Wiener index close to 0 was smaller.









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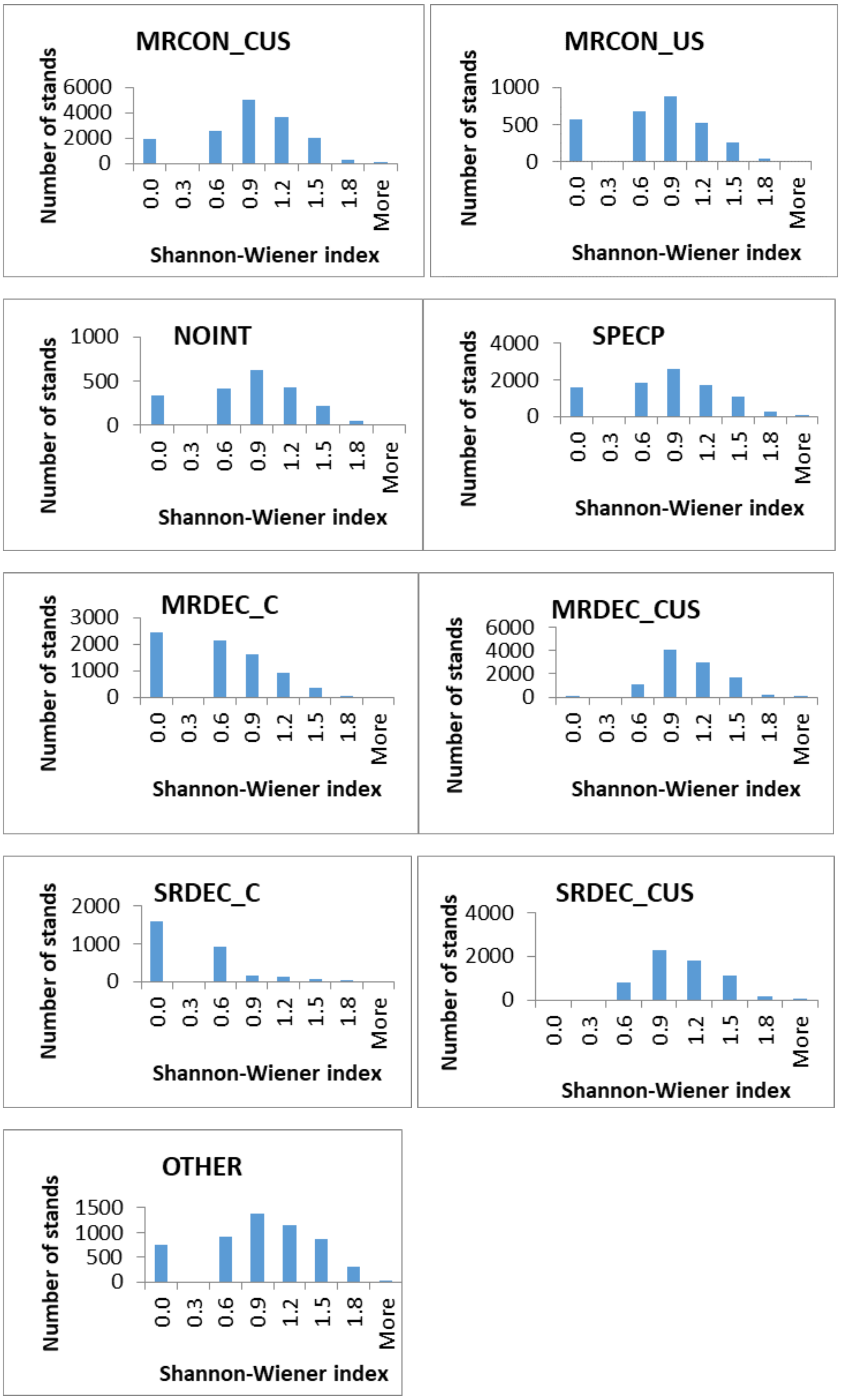

Figure 19. Distribution of stands by adjusted number of tree species in a stand by FMMs

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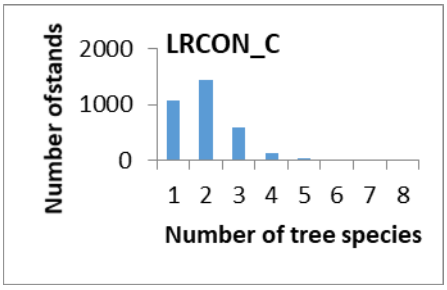
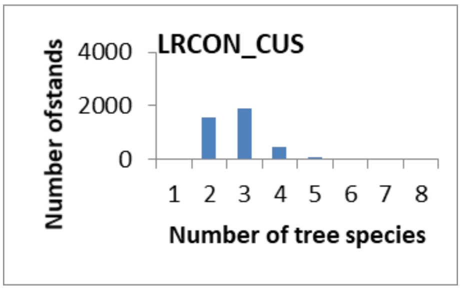
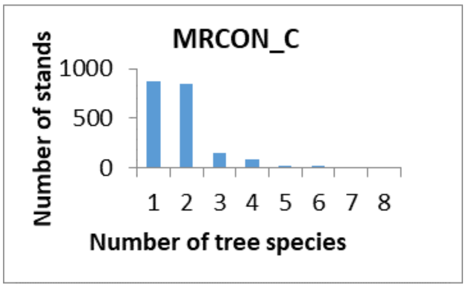
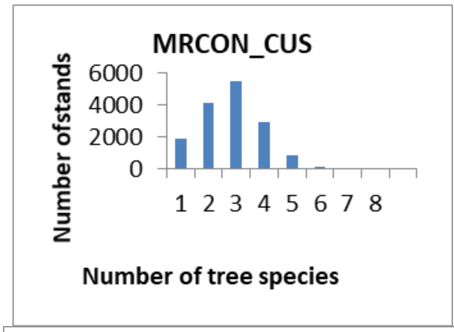
Tree species diversity

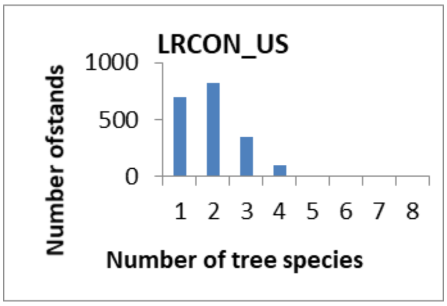
In long rotation coniferous forests the biggest number of stands had 2 tree species. The exclusion is the clear-cut OR shelter-wood FMM, where the biggest number of stands had 3 species. In medium rotation coniferous forests most stands also had 2-3 species, as well as in the forests within no intervention FMM and in the forests of a special purpose. In deciduous forests within clear-cut OR shelter-wood FMM both in medium and short rotations most stands had 3 species. In medium rotation deciduous forests most stands had 2 species, in short rotation deciduous forests – 1 specie. The biggest number of 8 species was reached in some stands in medium rotation coniferous forests within clear-cut OR shelter-wood FMM and in the forests of a special purpose.

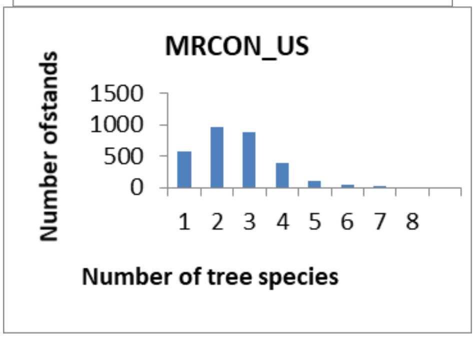


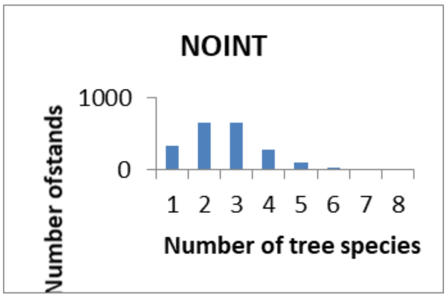


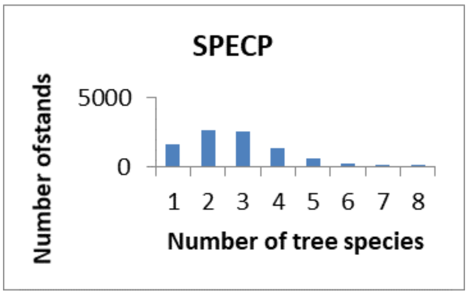












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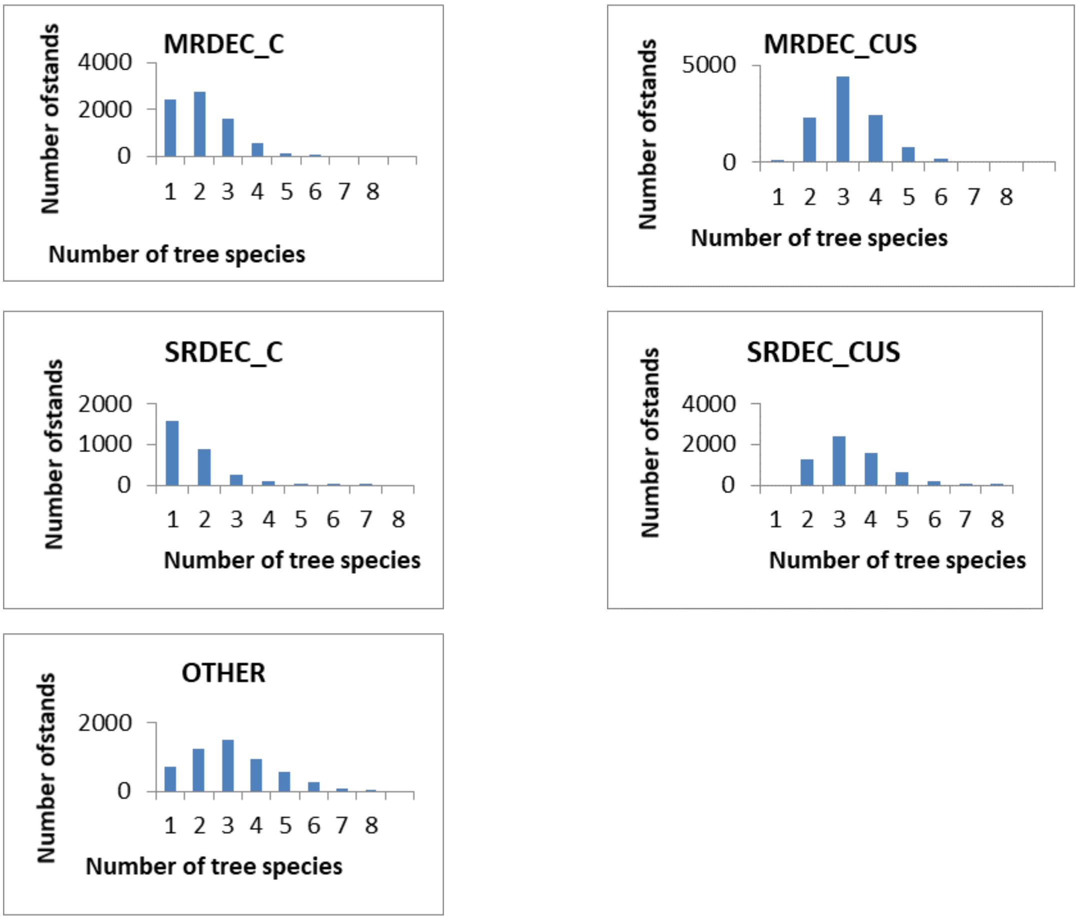
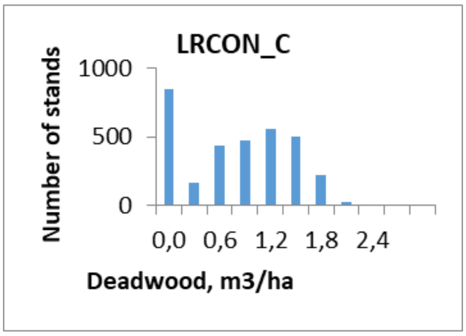
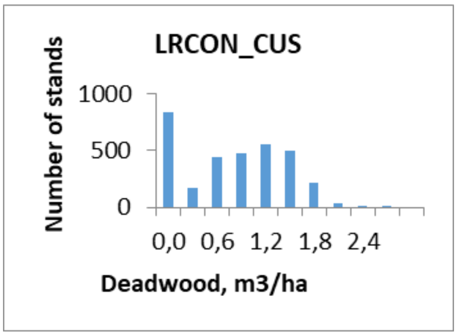


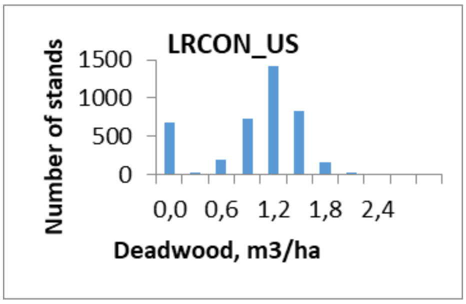
Figure 20. Distribution of stands by number of tree species by FMMs

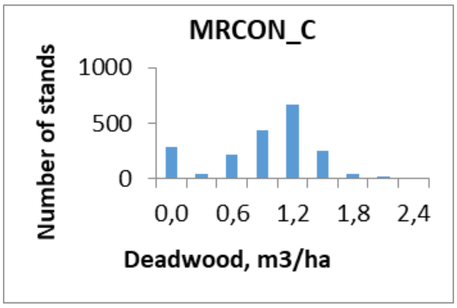
Natural deadwood per year in a stand

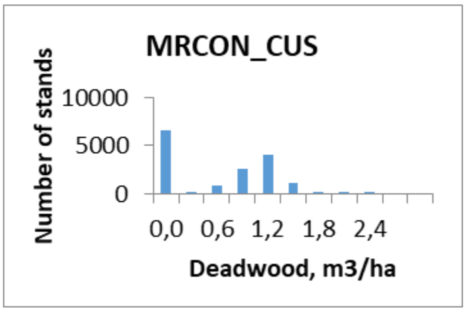
In long rotation coniferous forests within clear-cut and clear-cut OR shelter-wood FMMs the biggest number of stands had amount of deadwood close to 0. In long rotation coniferous forests within shelter-wood FMM and medium rotation coniferous forests within clear-cut FMM the biggest number of stands had about 1.2 m^3 of deadwood per year in a stand. In medium rotation coniferous forests within clear-cut and clear-cut OR shelter-wood and shelter-wood FMMs biggest number of stands had amount of deadwood close to 0. In the forests with no intervention the biggest amount of stands had from 0.6 to 1.2 m^3 of deadwood per year in a stand. In the forests of special purpose and all deciduous forests FMM the biggest number of stands had about 0.6 m^3 of deadwood per year in a stand. The biggest amount of 2.4 m^3 of deadwood per year in a stand was reached in some stands in coniferous forests, in the forests with no intervention and in the forests of special purpose.

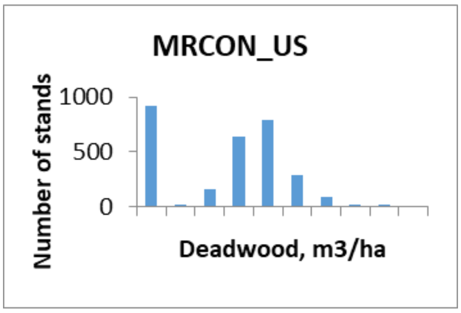


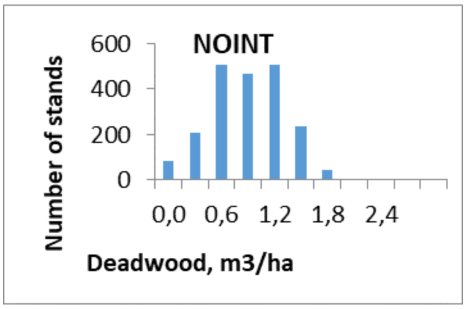


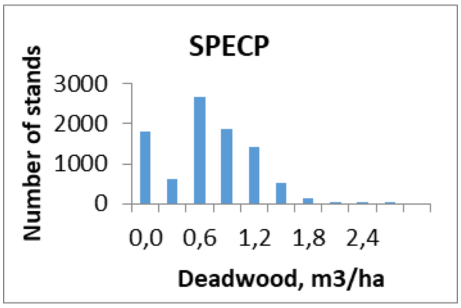


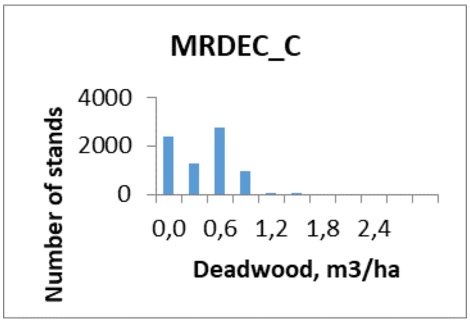


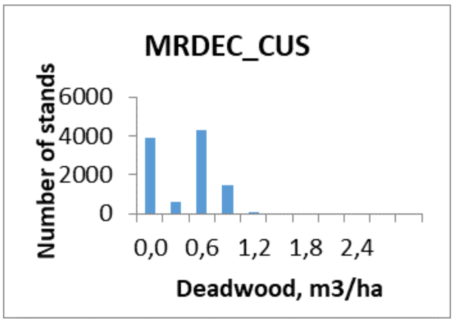












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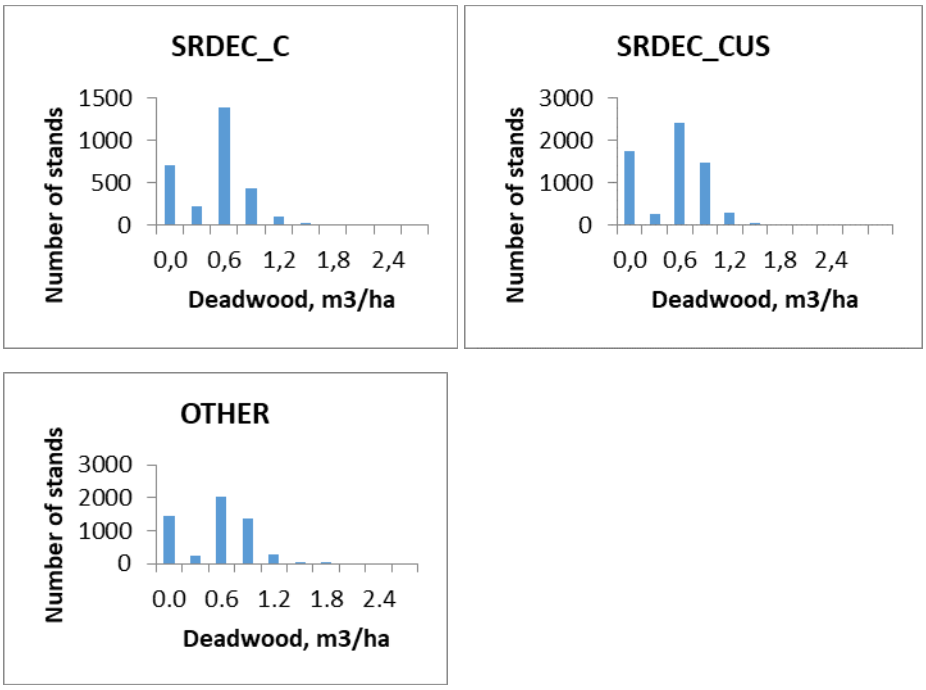
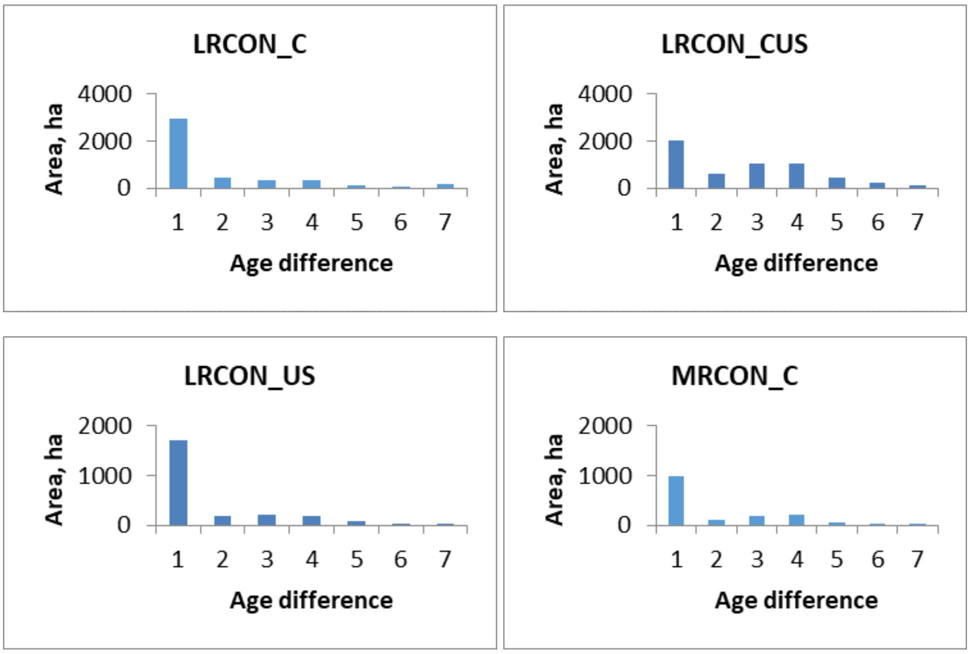


Figure 21. Distribution of stands by amount of natural deadwood per year by FMMs

Age difference between tree species in the main layer

In all forests prevailed the areas, where all the species were of the same age, what can be the consequence of popularity of artificial regeneration on Lithuania. Still, we could observe bigger age variations within clear-cut OR shelter-wood FMM both in coniferous and deciduous forests and in the forests of special purpose.



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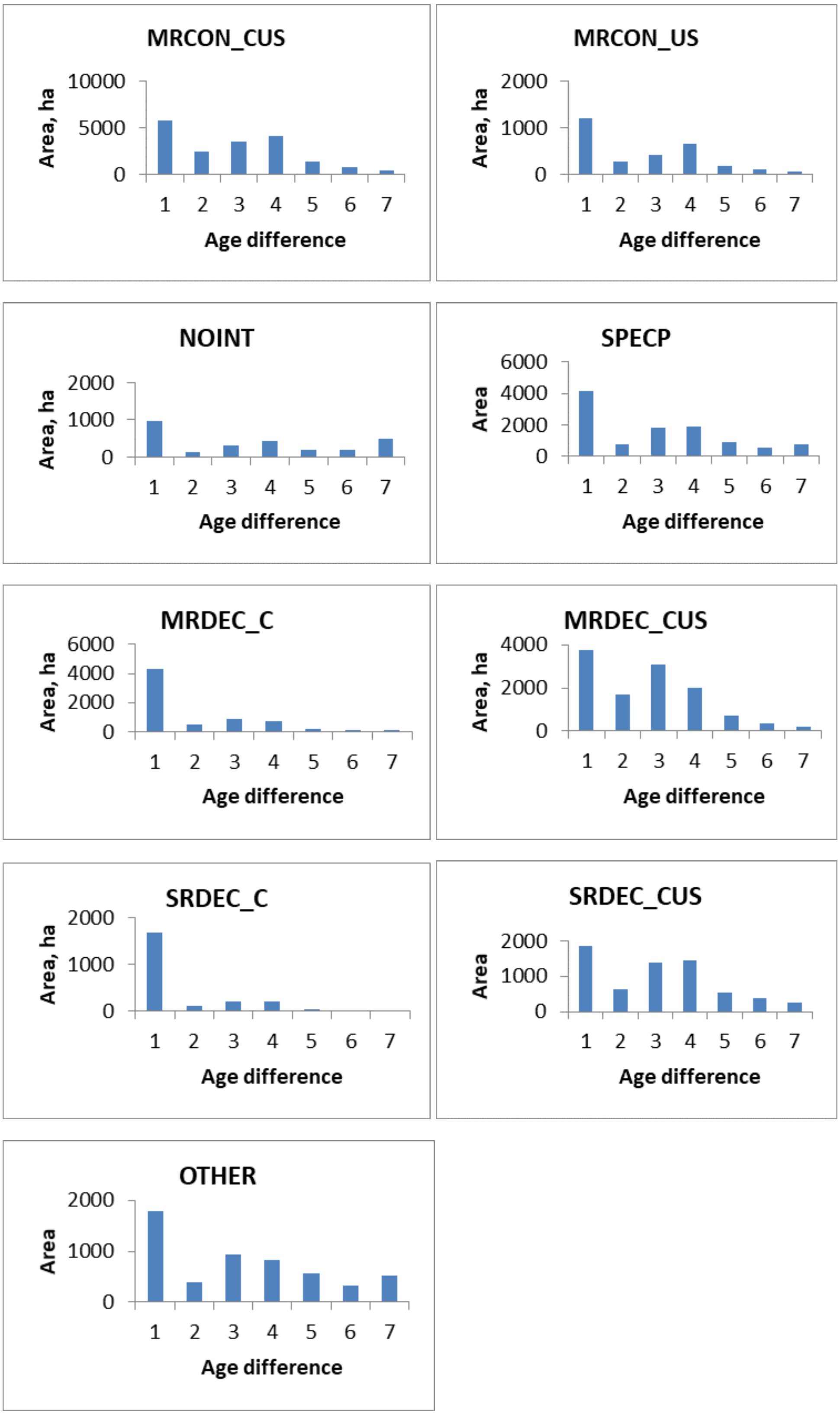

Figure 22. Area proportions of age difference classes by FMMs

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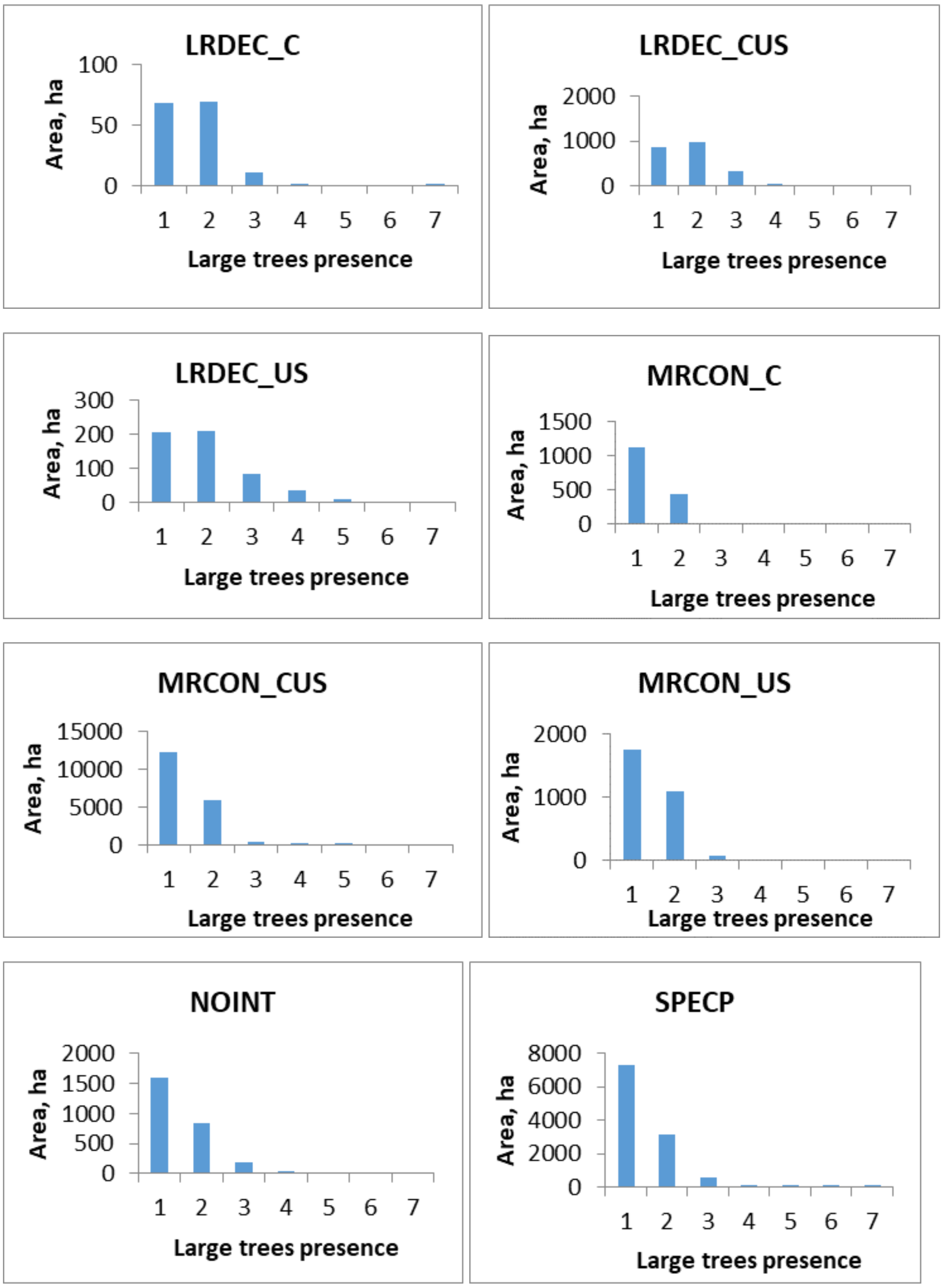
Large trees present in the stand

In the coniferous forests with long rotations the biggest share occupied the territories with no large trees or the trees with DBH 30-39 cm. In all other forest types were prevailing the territories with no large trees. There were some territories with trees with mean DBH 40-49 and 50-59 cm within the forests with no intervention, however, their share was not significant.



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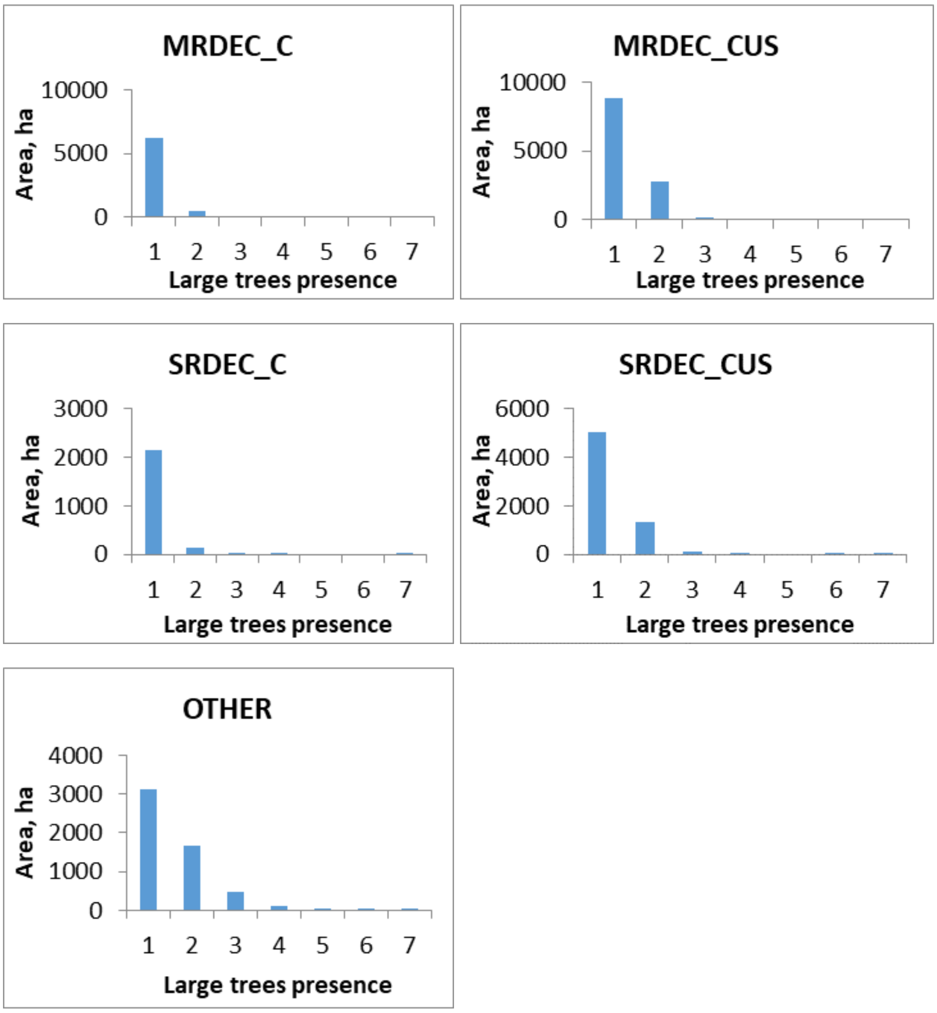
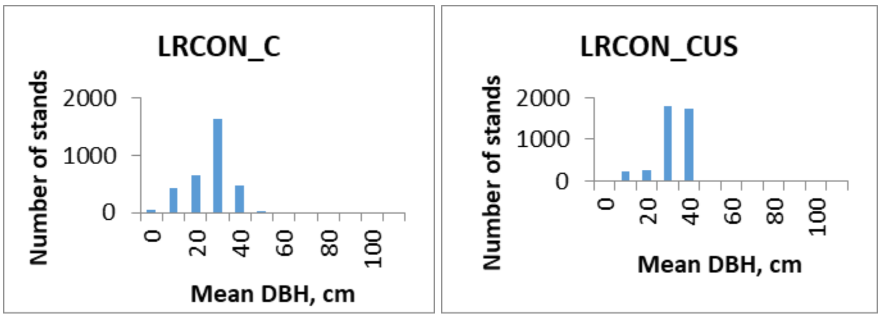
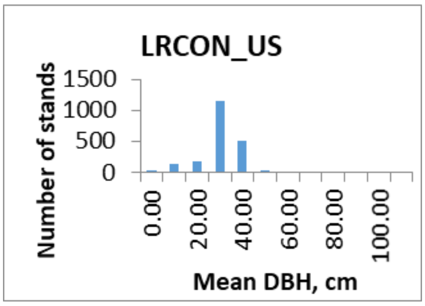


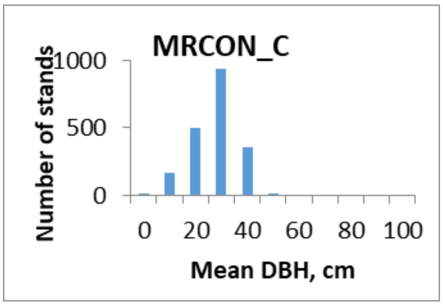
Figure 23. Area proportions with large trees by FMMs

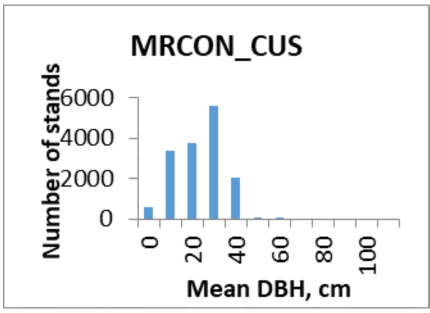
Mean DBH

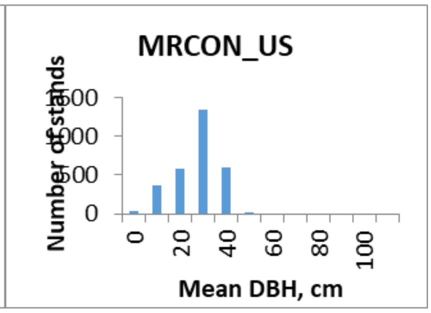
In most FMMs prevail the stands with average DBH of 30 cm. The exceptions are medium rotation deciduous forests within clear-cut FMM and all short rotation deciduous forests. Fot these 3 FMMs mean DBH is 20 cm. There are some stands with mean DBH of 40-80 cm within no intervention FMM, however, their share is insignificant.

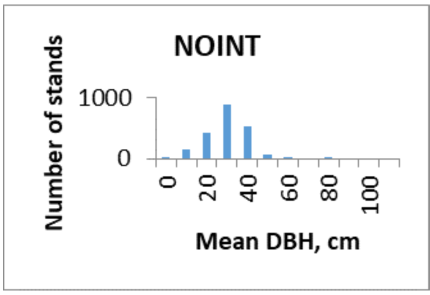


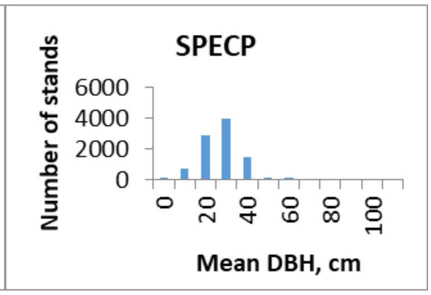


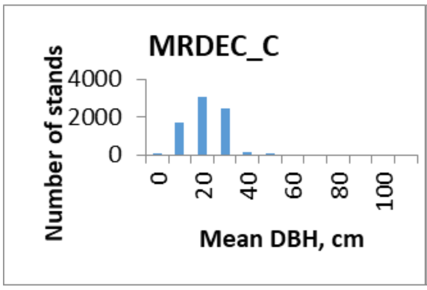


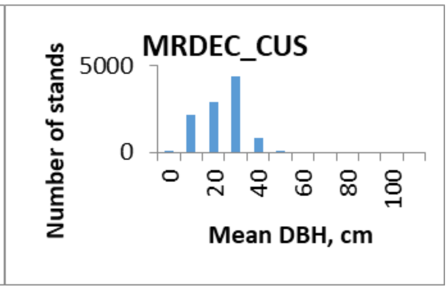


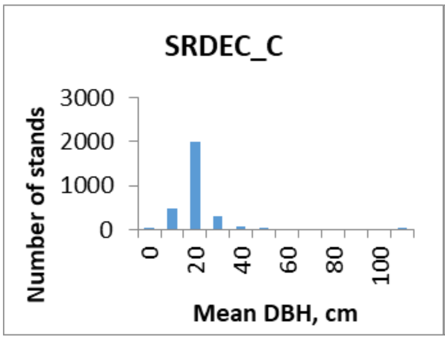


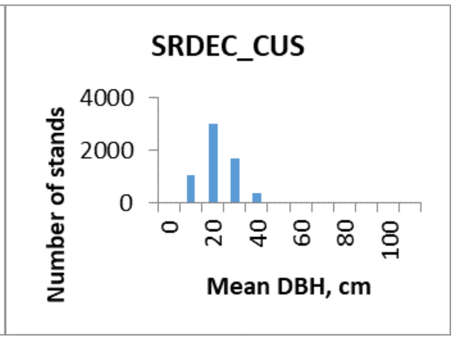












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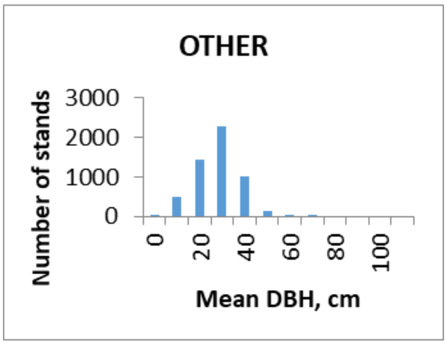
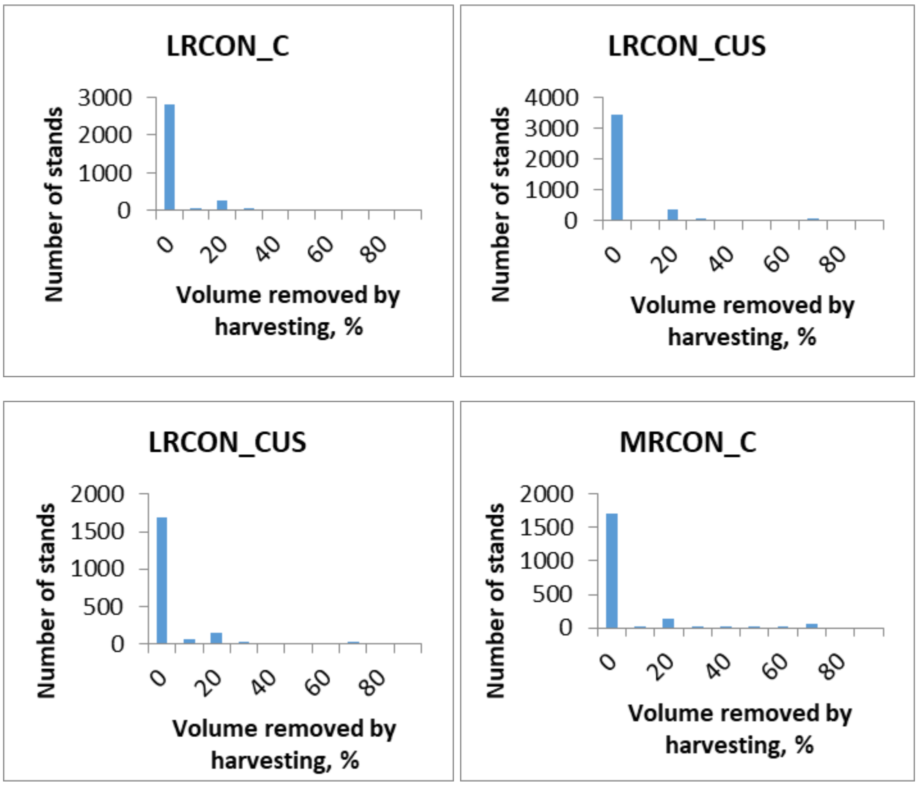


Figure 24. Distribution of stands by mean DBH by FMMs

Volume removed by harvesting

In all forests prevail the stands, where no volume is planned to be removed per harvest during nearest planning period. The following prevailing value in most forests is 20%, what can be explained by the current forest age structure in Lithuania.



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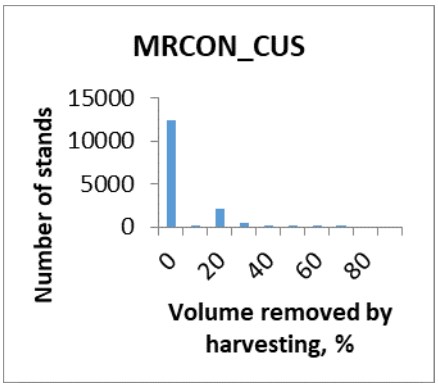

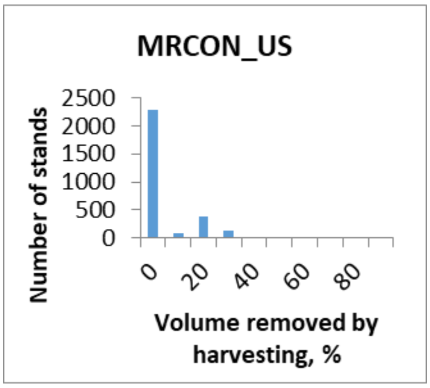

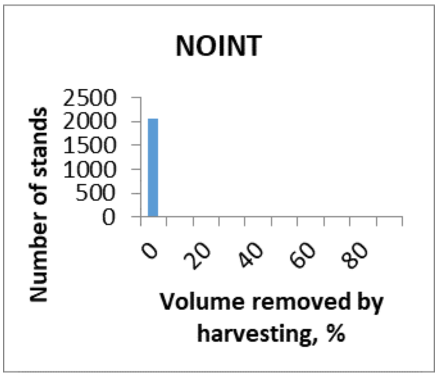

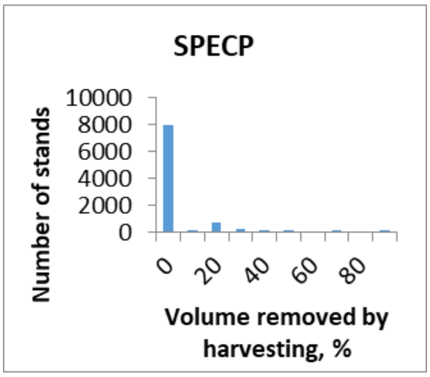

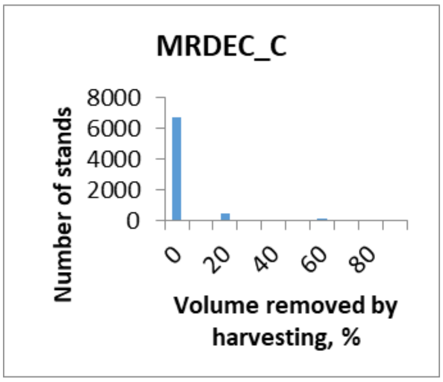

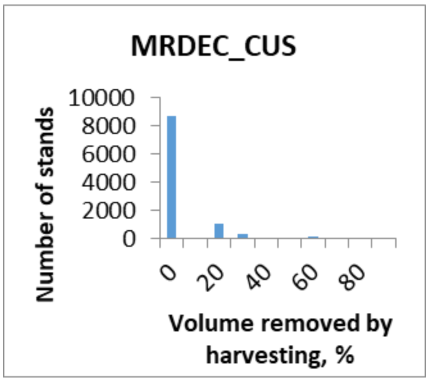

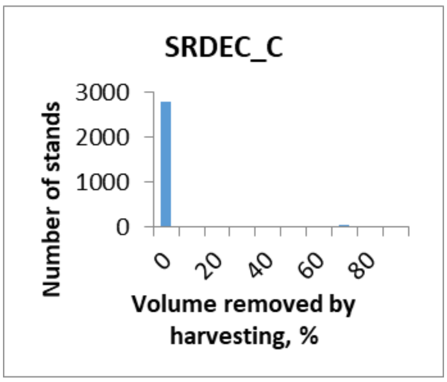

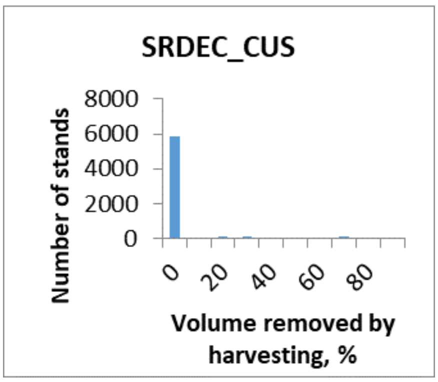

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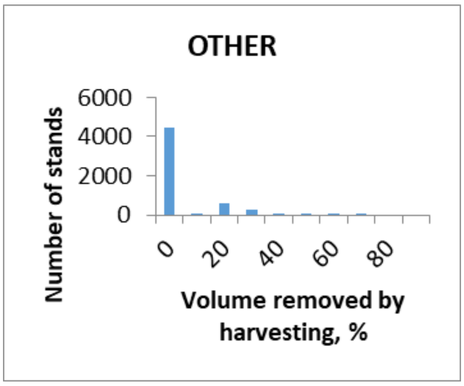

Figure 25. Distribution of stands by the proportion of volume removed per harvest during nearest planning period by FMMs

FMM fitting the natural disturbances

There is a variation of areas fitting the natural disturbances even within single FMMs. So, for the long rotation coniferous forests prevail the areas with good agreement with natural disturbances. Still, within this FMM there are some territories which poorly fit natural disturbances. Long rotation coniferous forests within clear-cut OR shelter-wood FMM are all in good agreement with natural disturbances. Long rotation coniferous forests within shelter-wood FMM are mostly in fair agreement with natural disturbances, and there are little shares of the territories with poor agreement and high agreement. Medium rotation coniferous forests within clear-cut and clear-cut OR shelter-wood FMMs are mostly in fair agreement with natural disturbances. For the medium rotation coniferous forests within shelter-wood system prevail the areas with poor agreement with natural disturbances. We assume that the clear cutting would better emulate the natural disturbance regimes here, than the mandatory requirement to avoid clear cutting due to the location of the stand in NP or along the roads. All forests with no intervention are in excellent agreement with the natural disturbances, and the forests of special purpose – in good or high agreement. In the medium rotation deciduous forests within clear-cut FMM prevail the territories with poor agreement with natural disturbances, however, there is also a high share of territories with good agreement. In the short rotation deciduous forests within clear-cut FMM prevail the territories with fair agreement with natural disturbances, however, there is also a high share of territories with good agreement. All deciduous forests within clear-cut OR shelter-wood FMM are in good agreement with natural disturbances. In other FMMs prevailing were the territories with good agreement with natural disturbances, while the variation was from complete disagreement to high agreement. Still, the territory, occupied by those FMMs in the CSA is insignificant.

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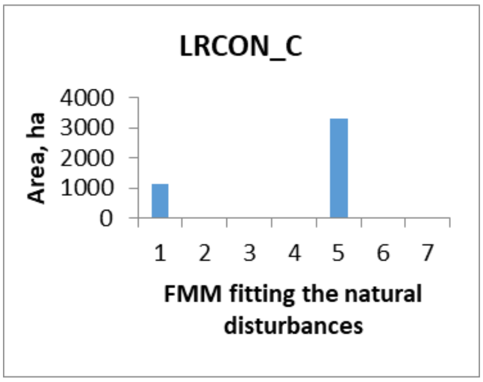

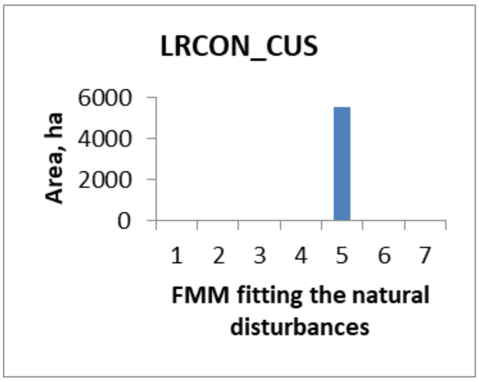

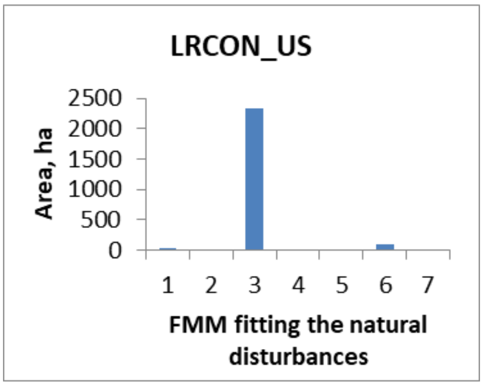

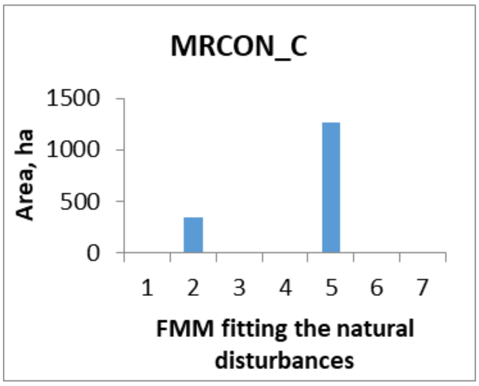

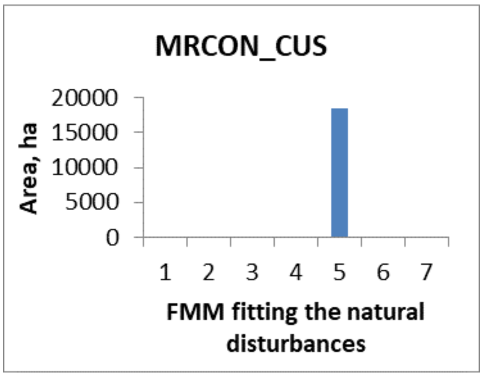

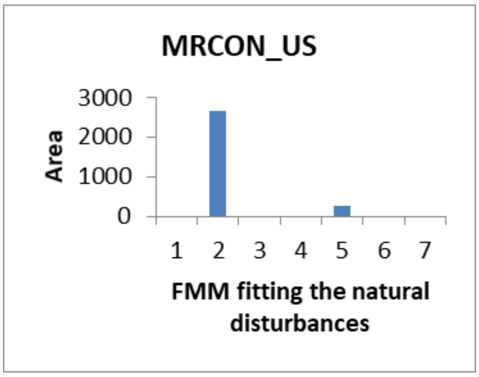

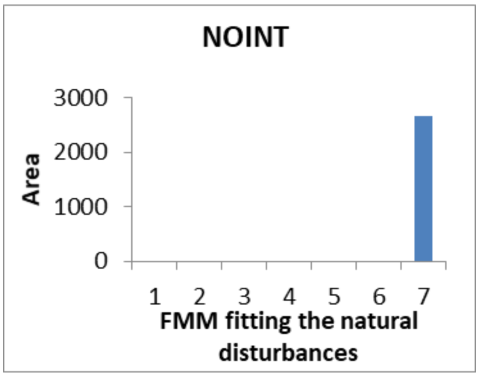

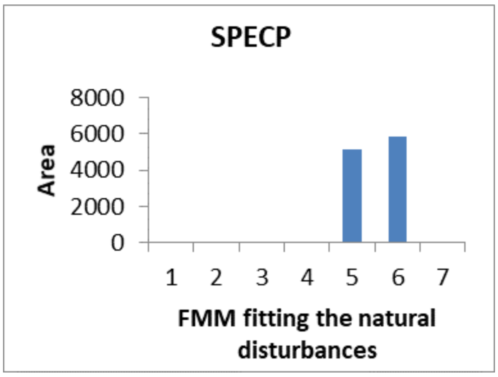

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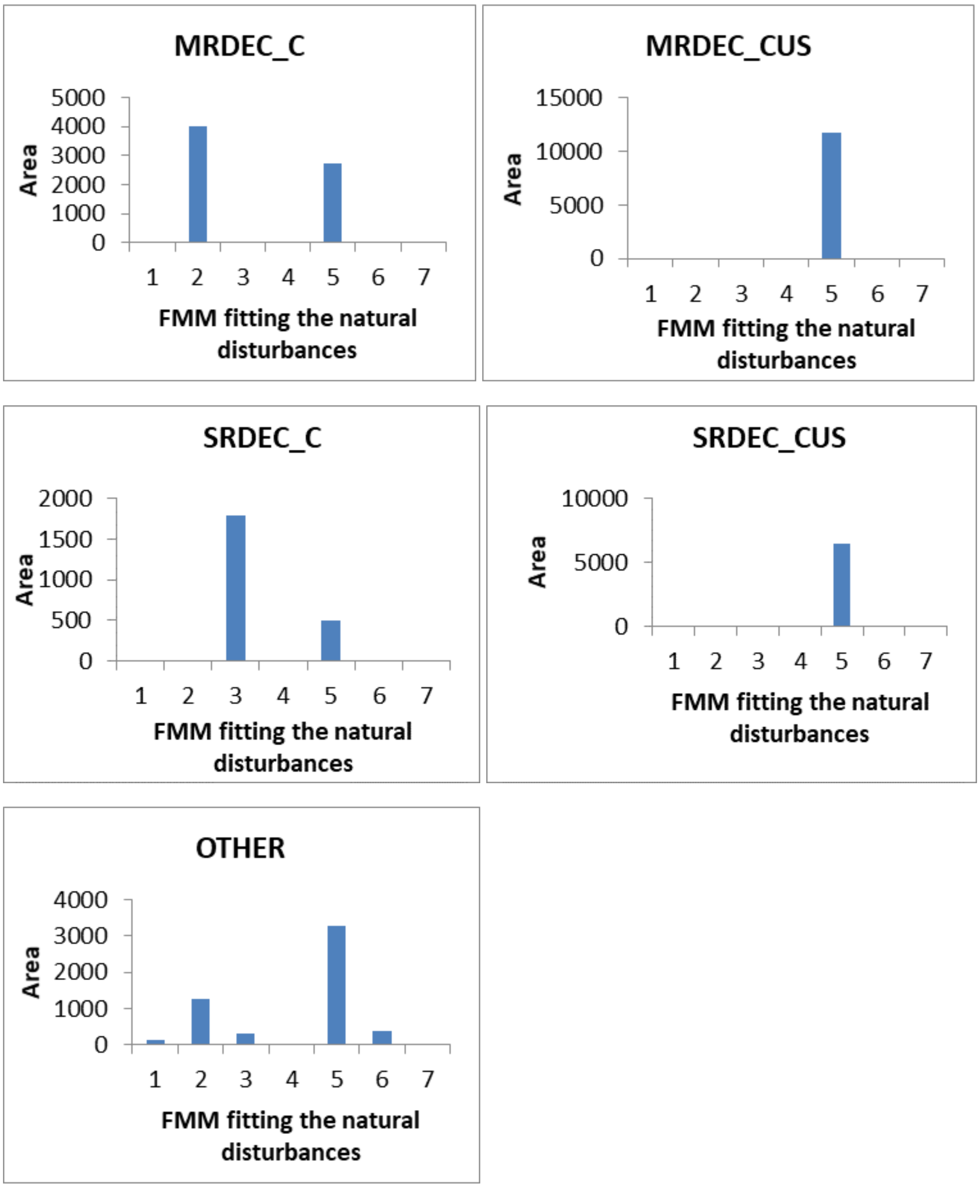

Figure 26. Area proportions by fitting the natural disturbances by FMMs

To summarize, the highest relative biological diversity could be observed within forests with no intervention. Long rotations and the possibility to choose between clear-cuttings and shelter-wood systems had positive effect on the relative biological diversity. In short rotation deciduous forests within clear-cut or shelter-wood FMM was the highest tree species diversity, what also resulted in the relatively high overall score, though usually this FMM is considered as a result of “unsuccessful” forestry. On the contrary, in the short rotation deciduous forests within clear cutting FMM were recorded the lowest scores for 6 parameters from 8, what also resulted in the lowest relative biological diversity.

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2.4.5. Assessment of the contribution of FMMs on the carbon sequestration

To describe the FMMs by the amount of carbon accumulated in the above and below ground biomass in forest stands managed by different FMMs simplified approach based on the use of biomass conversion factors was utilized.

Methodological approach

The carbon, accumulated in live trees was considered. The above ground biomass (AGB) was calculated:

AGB = GS x WD x BEF

Where: GS – growing stock volume, including the bark, m^3;

WD – wood density (tones dry matter/m^3 fresh volume). For pine – 0.42, spruce – 0.4, oak – 0.58, larch – 0.46, ash – 0.57, hornbeam – 0.63, birch – 0.51, alder – 0.45, aspen – 0.35, lime – 0.43 and other softwood deciduous – 0.45.

BEF – the above ground biomass and stem biomass coefficient, for coniferous 1.221, for deciduous 1.178.

The biomass below the ground (BGB) was estimated:

BGB = AGB x R,

Where: R – coefficient, for coniferous trees 0.26, for deciduous trees – 0.19.

The coefficient to get the amount of carbon was 0.5. So, the volume of growing stock and its distribution by tree species was available from State Forest Cadaster.

Some modifications in approaches to estimate the biomass before converting into carbon values will be used in further studies. Currently there are some allometric functions to estimate the tree biomass and distribute it among stem, branches, leaves and needles using height and diameter as inputs under development. The functions are available for pine, spruce and birch, the later option is suggested for other deciduous trees. However, the performance of such functions is not fully validated, thus very simplified approach was used here. It has been used for National carbon reporting and in INTEGRAL project.

Findings

Total values of carbon accumulated in above and below ground biomass of forests stands by FMMs (Table 24and Figure 27) are reported here to provide general view of the attribute being analysed – the area and other stands characteristics are different for the FMMs. One can easily see that the amount of carbon accumulated in 1 ha is relatively larger in FMMs applied coniferous forests and no intervention and special purpose forests due to larger average ages for these FMMs (Figure 28).

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Table 24. Amounts of carbon accumulated in forest stands by FMMs

Forest management model	Total area, ha	Average age, years	Total carbon mass, tones	Carbon mass per 1 ha, tones
LRCON_C	4470.9	63.7	338614	75.74
LRCON_CUS	5529.5	76.9	523993	94.76
LRCON_US	2417.8	65.9	215398	89.09
MRCON_C	1603.1	64.0	141103	88.02
MRCON_CUS	18541.9	47.3	1365943	73.67
MRCON_US	2922.9	57.3	259712	88.85
MRDEC_C	6749.3	40.7	341835	50.65
MRDEC_CUS	11781.7	43.5	644030	54.66
SRDEC_C	2297.5	31.9	109001	47.44
SRDEC_CUS	6477.9	37.5	347176	53.59
NOINT	2671.3	77.4	206488	77.30
SPECP	10981.4	60.0	835614	76.09
Other	5362.4	55.1	337830	63.00
All	81807.6	52.3	5666736	69.27

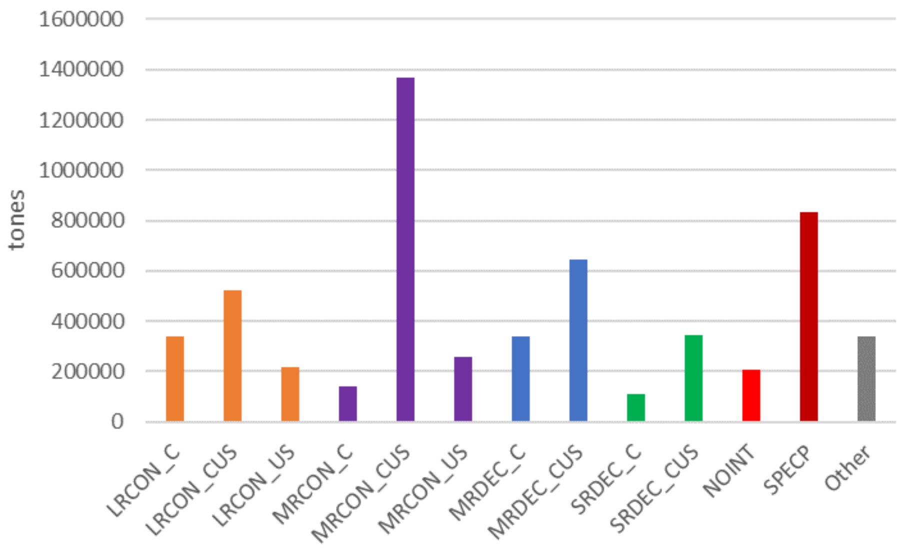

Figure 27. Total mass of carbon accumulated in Lithuanian CSA by FMMs

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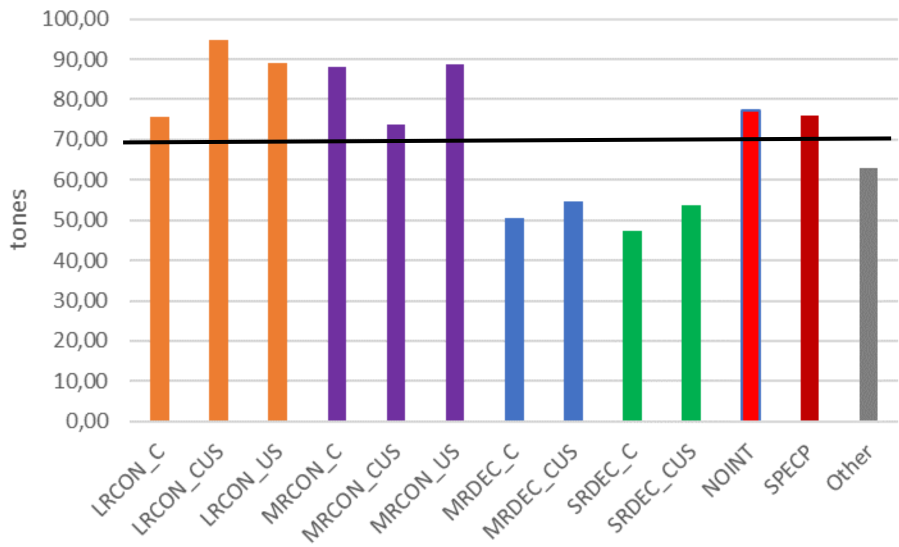

Figure 28. Average carbon mass per 1 ha in Lithuanian CSA by FMMs. Black horizontal line refers to the average value for the whole CSA

Except for spruce, all FMMs with clear cutting system tend to accumulate relatively less carbon than the FMMs with non-clear cutting possible or required. Of course, the average age is also less here. In spruce stands, this could most likely true as well, if not relatively lower average age of stands managed by MRCON_CUS and MRCON_US FMMs.

Even the average age of forests under medium rotation deciduous FMM is 5-10 years higher than in short rotation deciduous forests, the amount of carbon dos not differ as it could be expected if age only is considered. I.e. age normalized carbon accumulation under SRDEC FMMs is relatively higher than under MRDEC FMMs.

To summarize – the amount of carbon accumulated in forests of Lithuanian CSA depends on the rotation age which is imbedded in the definition of FMMs. Forest management models with clear cutting system are less productive in terms of this ES.

2.4.6. Assessment of the contribution of FMMs to provide water related ecosystem services

Identification of water related ecosystem services under Lithuanian conditions is somewhat different from other ALTERFOR CSAs. E.g. provision of surface water for drinking and non-drinking purposes is not relevant for Lithuania as well as flood protection potential is not relevant too if estimated at the stand level. Lithuanian ALTERFOR team asked for a support from local expert in hydrology and provided comments and questions to ALTERFOR's water related ES expert. Unfortunately, there was no response received. Thus, to evaluate the contribution of FMMs to provide water related ESs we used approach that was proposed two decades ago (Pauliukevičius and Kenstavičius, 1995) and was successfully implemented in INTEGRAL project.

The following factors were considered when quantifying the water and soil protection related ESs: elevation and location of forest compartment on the slope, soil mechanical properties, location of forest compartment regarding the shoreline of water bodies, location of forest compartment regarding agricultural fields, industrial objects and roads, and characteristics of forest stands, such

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as tree species composition, stoking index and age. Each parameter was evaluated using special grading system – Table 25. Each forest compartment was evaluated against each factor and factor-level grades were summed.

Table 25. Grades used to evaluate water and soil protection potential of forest compartments (adopted from Pauliukevičius and Kenstavičius, 1995)

Forest growing conditions				Soil mechanical properties				Location on the slope		Distance to nearest available forests			Distance to industrial objects		Distance to roads		Tree species composition of stand					Relative stocking index			Age of forest stand		
				Sand and gravel	Sandy loam and light and medium loam	Heavy loam and clay	Peat	Lower part	Tops of the hills	200-400	400-800	>800	<100	100-250	<30	30-200	Spruce stands	Pine and mixed pine-spruce	Mixed (coniferous and deciduous)	Hardwood deciduous, lime, single trees	Softwood deciduous	< 0.5	0.5-0.9	>0.9	Young	Middle-aged, premature or mixed age	Mature and over mature
		Slope steepness		Relative evaluation grade																							
Relief	Flat	$<2^0$		14	8	4	2			8	15	25	12	8	10	6	10	10	8	14	4	4	8	8	4	6	4
	Wavy	$2\text{-}5^0$	4	14	8	4	4		2	8	15	25	12	8	10	6	8	6	8	14	6	4	8	8	4	6	4
	Hilly	$5\text{-}10^0$	6	12	8	4	4	4	6	10	20	28	10	6	8	4	4	6	8	14	10	4	8	6	4	8	2
		$10\text{-}15^0$	8	12	8	4	6	6	8	12	25	35	10	6	8	4	4	6	8	14	10	4	8	6	4	8	2
		$15^0>$	12	14	8	6	8	6	8	15	25	35	10	6	8	4	4	6	8	14	12	2	8	6	6	8	2
Location regarding the water bodies	River and lake banks	$<5^0$	10	12	8	6		5		4	8	10	10	6			4	6	8	12	10	2	8	6	6	8	4
		$5\text{-}10^0$	15	16	8	4		6		6	10	15	12	6			4	6	8	14	12	4	8	6	6	8	4
		$>10^0$	18	18	8	4		6		6	10	15	12	6			4	6	8	10	12	4	8	6	6	8	4

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Data (existing data, metrics and format of the data)

The following data sources were used:

- Information available from State Forest Cadaster, originating from stand-wise forest inventory and including the information on forest stand characteristics required to evaluate some grades: soil properties, tree species composition, relative stocking index and age of forest stand.
- To determine the location of forest compartment regarding other geographic objects, some external sources were mobilized:
    - Digital elevation model (Figure 29) was developed using contours and height points available from the GIS database LTDBK5000-v (http://www.gis-centras.lt/gisweb/index.php?pageid=213). The interval between contours was 10 m, the cell size of resulting grid was 25 m. Digital elevation model (DEM) was created using TopoToRaster function of ArcGIS software. Information on streams and lakes was available from the same LTDBK50000-v GIS database.

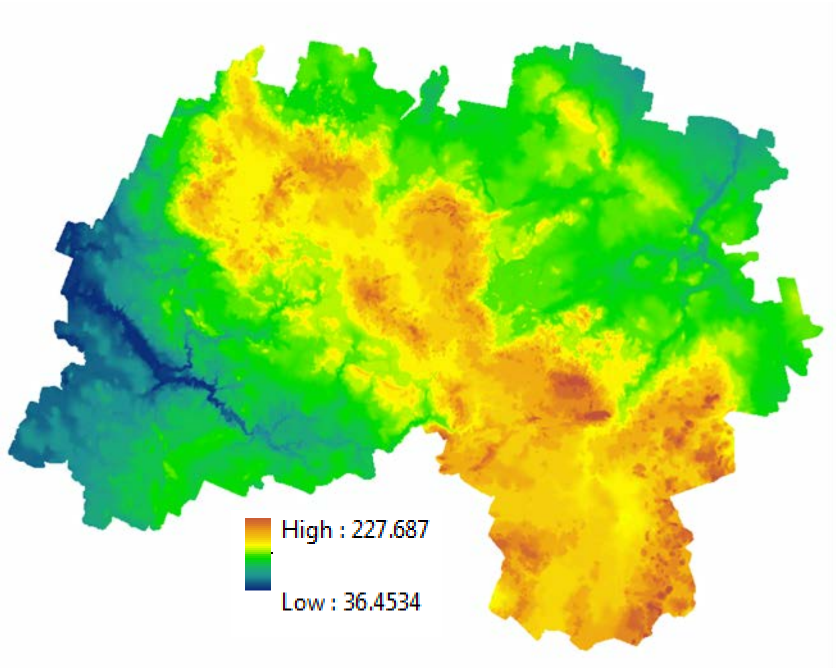
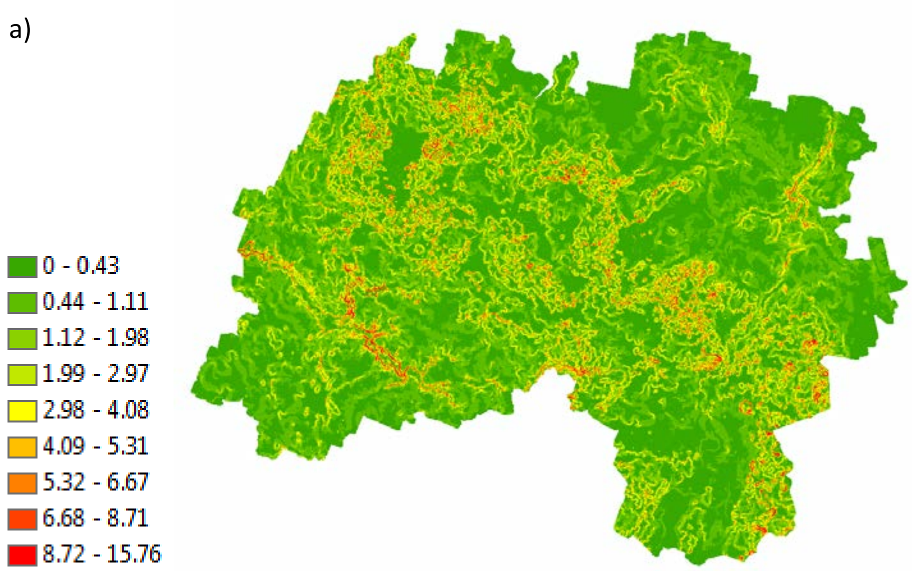


Figure 29. Digital elevation model of Žemaitija case study area

- The slope in degrees was calculated using the DEM as an input (Figure 30). Later, slope grid was reclassified to have the slope classes <2, 2-5, 5-10, 10-15 and >15 degrees. The slope class was assigned for each forest compartment using Zonal Statistics function of ArcGIS and the Maximum rule – i.e. the highest-class value (corresponding to the steepest slopes) was assigned for each compartment if there were more than one class present in its area.

a)



b)

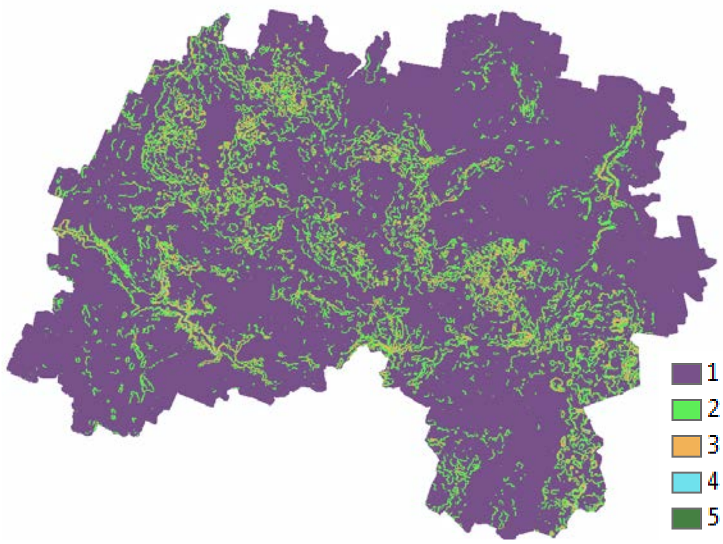


Figure 30. Slope steepness in Žemaitija case study area; a) in degrees, b) slope classes used for evaluation the importance of forests in protecting the environment

- The location of forest compartment on the slope was determined using the following procedure: whole case study area was divided into two parts – one corresponding to upper parts of the hills and another to lower part of the valleys (Figure 31). Such division was achieved having estimated potential surface water flow direction and flow accumulation grids. Flow direction grid contains the information of flow direction from each cell to its steepest downslope neighbour, the flow accumulation grid is a raster of accumulated flow to each cell, as determined by accumulating the weight for all cells that flow into each downslope cell. Then the flow accumulation grid was reclassified into two classes – below and above the mean value of flow accumulation grid. The idea is that the cells having value below the mean value have more downstream areas, thus they are potentially higher in the relief and vice-versa.

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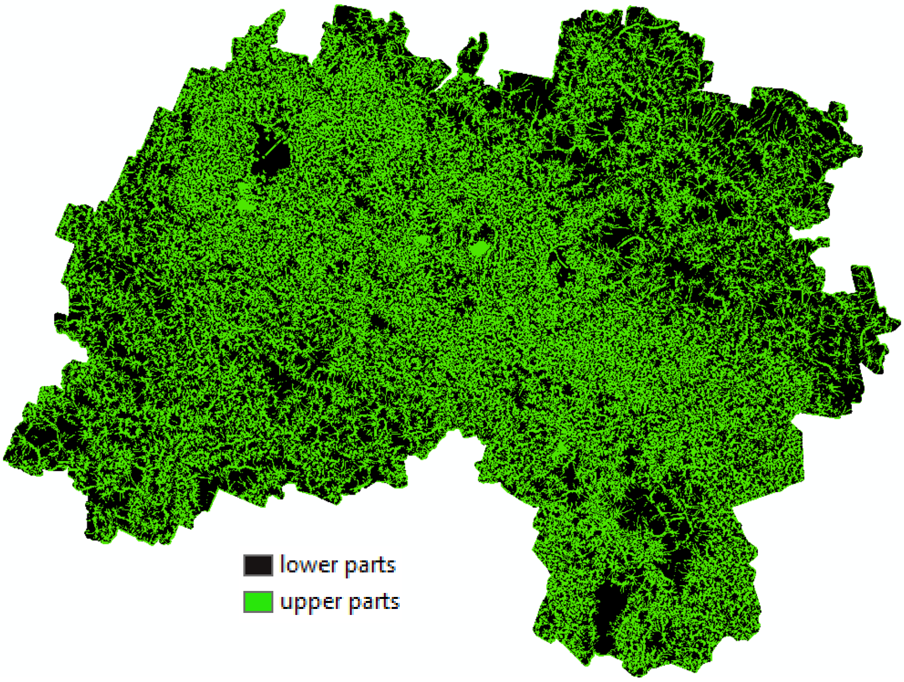

Figure 31. Upper and lower parts of the terrain

- Distance to nearest closest forest was used detect isolated forest compartments in agricultural landscape. Euclidean distances between groups of forest compartments with an area below 5 ha were calculated and compartments with nearest neighbours further than the values indicated in Table 18 were selected and supplied with corresponding grades.
- All forest compartments were within uniform distance to industrial objects as there were no large such objects in the proximity.
- Euclidean distance from the roads was calculated using special road database developed for Lithuanian University of Agriculture (Aleksandras Stulginskis university nowadays). This database was designed to solve forest logistics tasks, it originated from the Lithuanian geo-reference database GDB10LT (currently GDR10LT, http://www.geoportal.lt) and GIS information developed during the stand-wise forest inventories. Then the minimum distance value for each forest compartment was estimated and it was used to determine the grades.
- Soil mechanical properties were determined from the description of soil type – this information is available for all compartments from the State forest cadaster data.
- Forest compartments intersecting 30 m buffer zone around the shorelines of water bodies were located on river and lake bands.

Having the grades for location of forest compartment assigned, the evaluation of the role of forests in protecting the environment involved just simple database queries and calculation of field value.

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Contribution of FMMs to provide water related ecosystem services

Average grades used to evaluate water and soil protection potential do not differ very much among different FMMs of Lithuanian CSA (Table 26). Should be noted, that water and soil protection potential in all forests except short rotation deciduous dominated ones increases introducing clear cutting restrictions. I.e. the lowest average grades are given to FMMs with clear-cutting system, the grades are higher in stands with combination of clear and non-clear cutting and finally they are highest in stands with non-clear cutting systems. FMMs for medium rotation deciduous forests were given lowest grades among all FMMs, much due to species composition and soil properties (wet black alder dominated forests are managed under this FMM). Should be noted, that the water related ESs in forests with no active management are valuated lower than the average value for whole CSA.

Table 26. Evaluation of FMMs to provide water related ESs

Forest management model	Water and soil protection potential			Average grades of contributing factors							
	Min	Max	Average	Slope steep-ness	Soil prope r-ties	Locatio n on the terrain	Distan-ce to forest	Distan-ce to roads	Species compo-sition	Relative stockin g	Age
LRCON_C	18	63	35.88	2.28	9.14	0.85	0.01	2.68	8.60	7.75	4.56
LRCON_CUS	18	61	37.62	2.07	10.75	0.70	0.00	2.84	8.49	7.89	4.87
LRCON_US	22	61	40.90	3.16	12.33	1.22	0.02	3.64	8.17	7.76	4.60
MRCON_C	18	56	35.46	2.45	8.27	0.93	0.04	2.37	8.35	7.62	5.42
MRCON_CUS	18	66	35.63	2.70	8.45	0.98	0.02	2.49	8.18	7.76	5.04
MRCON_US	18	61	39.76	3.95	9.92	1.92	0.01	3.66	7.48	7.66	5.14
MRDEC_C	14	64	31.26	2.80	5.87	1.00	0.05	2.13	6.66	7.64	5.12
MRDEC_CUS	14	65	34.23	2.90	7.39	1.03	0.06	2.19	7.65	7.76	5.26
SRDEC_C	14	63	38.33	5.68	7.21	1.96	0.10	1.74	7.60	7.68	6.36
SRDEC_CUS	16	69	37.59	4.50	7.47	1.68	0.08	2.23	7.81	7.75	6.07
NOINT	14	63	34.00	3.45	7.09	1.34	0.00	1.65	8.08	7.67	4.71
SPECP	14	64	36.34	5.09	6.97	1.89	0.01	2.06	7.87	7.71	4.73
Other	14	64	37.72	4.77	7.13	1.91	0.09	2.66	8.52	7.58	5.05
All	14	69	35.93	3.43	8.00	1.28	0.04	2.41	7.93	7.73	5.11

The system used to grade the water related ESs will be revised later. The most important factor seems to be the one related to soil properties, i.e. it will be not changing when modelling the forest development under different forest management scenarios. Dynamic factors – tree species composition, relative stocking level and stand age – have largest cumulative input on the grade, but their average values do not differ very much among different FMMs. To better compare the FMMs to provide the water related ESs we used 5 water and soil protection potential classes. They were achieved using quantile classification approach resulting in similar number of observations in each

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class as the CSA level. Figure 32 displays the area proportions of water and soil protection potential classes by FMMs.

Shortly, in coniferous forests with non-clear forest cuttings classes with highest level of water related ESs (i.e. the 4-5th classes) are dominating. The share of the 1st class is relatively small. Clear cutting in coniferous forests seems to introduce some shift of dominating class towards the left – i.e. the area of most productive in terms of water related ESs stands tends to decrease.

Figure 32. Area proportions of water and soil protection potential classes by FMMs

Largest area in medium rotation deciduous forests is taken by two least productive in provisioning water related ESs classes. Short rotation deciduous forests, practically no matter the final cutting system, contain lowest share of class 3, i.e. the one being in the middle of distribution (the same tendency is seen in SPECP and other FMMs with large shares of deciduous forests). The areas of classes are relatively equal in forests with no active management and special purpose forests. Should be noted, that the least productive in provisioning water related ESs 1st class dominates in NOINT FMM.

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To summarize, the FMMs in Lithuanian CSA do not differ very much in provisioning water related ESs. Lowest grades are given to FMMs with clear-cutting system and the non-clear cutting system, especially in coniferous forests, increases the share of stands more productive in terms of provisioning water related ESs. Stands with relatively low water and soil protection potential dominate in medium rotation deciduous forests. The water related ESs in forests with no active management are valuated lower than the CSA average.

2.4.7. Assessment of the contribution of FMMs on the cultural services

Assessment of cultural services was carried-out following the Guidelines for Cultural Services (CS) assessments of the FMMs in each country (Hoogstra-Klein & Hengeveld, 2017). However, some attributes and indicators were slightly adjusted to fit the specifics of Lithuanian forestry and, especially, the data available.

Methodological approach to assess the cultural services

For the assessment, we used information on all forest compartments in the CSA available from State Forest Cadaster. This information is based on stand-wise forest inventory carried out in 2015. Several hundred of descriptive characteristics are provided by the inventory, all stands are also captured in a GIS. Each forest compartment was assigned FMM identification, thus, the study involved valuating them for cultural services provided and later summarizing and averaging the data to get FMM level statistics.

Indicators used for stand level evaluation of the FMMs in Lithuanian CSA are summarized in Table 27. The table also contains more detailed explanations on the estimation approaches used. Should be noted, that some final felling indicators refer to the state owned forests managed by Telsiai SFE. This is due to the fact, that stand-wise forest inventory and forest management planning are implemented in Lithuania as different projects. I.e. the stand-wise forest inventory is financed by the state and it is carried-out for all forests in some administrative district. It delivers the materials required for forest management planning, including the final felling planning. However, the development of forest management plan is on the responsibility of forest owner or manager. The internal forest management plan for Telsiai SFE has recently been developed and adopted, thus some attributes to evaluate cultural and other services were available for ALTERFOR team. However, majority of private forest owners have not updated their forest management plans. Thus, data related to final felling was available for forests of Telsiai SFE. We accept that private forest owners may manage in a different way than the state forest managers do and interpretation of cultural services under specific FMM is state and private forests may differ.

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Table 27. Indicators used for stand level evaluation of the FMMs for cultural ES

Concepts	Dimen-sions	Attribute	Indicator used	Data source	Direc-tion	Comment
Stewardship	Sense of care	Amount of residue from harvesting and thinning	Volume of harvesting residues m^3/ha	State Forest Cadaster Information System (SFCIS) and internal forest management plan for Telsiai SFE, private forests considered to be managed in the same way as state ones	negative	Only state owned forests are fully described using data on planned harvesting during 5 next years period. If no harvesting planned – amount of harvesting residues = 0. Cutting residues estimated calculating the amount of non-merchantable stem wood and branches, utilizing models of Lithuanian forest management planning
Naturalness/ disturbances	Alteration /impact	Area of final felling	Final felling area in ha	SFCIS and internal forest management plan for Telsiai SFE, private forests considered to be managed in the same way as state ones	negative	Only state owned forests are fully described using data on planned harvesting during 5 next years period. Stands outside the final felling were not accounted. Final felling is conducted by rectangular strips or cutting while or part of the stand area. There are regulations for the width and total area of final cutting areas. Thus, the area is equal of less the area of compartment, assigned for final felling.
	Natural Value	Naturalness of forest stands	Index (1 - stand with recorded non-natural origin (plantation) and no natural trees; 0.66 - planted stand containing some natural trees, 0.5 - natural stand with some planted trees, also in lower layers; 0.33 - natural but managed stand with no planted trees; 0 - unmanaged stand, group 1, natural origin)	SFCIS	negative	All compartments in the CSA covered
	Wildernes s	Amount of natural dead	Volume of natural deadwood per year, m^3/ha	SFCIS and models for deadwood	negative	All compartments in the CSA covered. Deadwood models include stand age and

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Concepts	Dimen-sions	Attribute	Indicator used	Data source	Direc-tion	Comment
		wood				tree species
	Intrusion	Naturalness of forest compartment borders	Fractal dimension D=2log(p)/log(a)	SFCIS (GIS data)	positive	All compartments in the CSA covered (not used in the report)
			Shape index p/2sqrt(3.141592xa)	SFCIS (GIS data)	positive	All compartments in the CSA covered
Complexity	Diversity	Tree species diversity within stand	Shannon diversity index	SFCIS	positive	All compartments in the CSA covered
	Age structure	Presence of trees from different generations in the main layer	0 - if all forest elements are of the same generation (age differs 0-19 years); 0.5 - 2 generations (age differs 20-39 years); 1 - 3 and more generations (age differs 40 and more years)	SFCIS	positive	All compartments in the CSA covered
	Spatial pattern	Variation in tree spacing within stand	Index (0 - regular - only planted trees; 0.5 - quasiregular plantations with natural trees; 1 irregular - naturally regenerated stands)	SFCIS	positive	All compartments in the CSA covered
Visual scale	Openness	Visual penetration/density of obstruction	Relative stocking index of the main layer	SFCIS	negative	All compartments in the CSA covered. The relative stoking index refers to the ratio of basal areas – actual and the ideal for normal forest. It closely correlates with tree density
	Visibility	Presence of understory in stand	Abundance of understory: 0 - high, 0.33 - moderate, 0.66 - low, 1 - absent	SFCIS	positive	All compartments in the CSA covered
Historicity/ imageability	Historical richness	Average age of trees in the main layer	Age, years	SFCIS	positive	All compartments in the CSA covered. Average age of all tree species in the main layer based on volume proportions

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Concepts	Dimen-sions	Attribute	Indicator used	Data source	Direc-tion	Comment
	Historical continuity / place identity	Age of current land-use	Index (0 - afforested after 1990; 0.5 - afforested during 1950-1990, 1 - afforested before 1950)	SFCIS, NFI IS and forest cover in 1950 GIS database	positive	All compartments in the CSA covered. Forest cover in the 1950s GIS DB is created in nominal scale 1:10000 and using the same forest definition as nowadays. It is based on orthophoto maps produced just after WWII. Lithuanian NFI conducts annual forest cover mapping, which is used to report the carbon related statistics. Forest cover dynamics was recovered until 1990.
Ephemera	Seasonal change	Presence of broadleaves	Percentage of broadleaves in forest stand	SFCIS	positive	All compartments in the CSA covered. Estimated based on tree species in the compartment and their volume proportions

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The contribution of FMMs on the cultural services

Four levels of abstraction as required in the Guidelines for CS assessments of the FMMs were used to provide the estimates: concept – dimension – attribute – indicator. More detailed figures are available in MS Excel file prepared using the template provided by the CS experts.

Table 28 lists the scores of CSs per FMMs at attribute level. The main concerns regarding this table are related to indexing and normalization issues. All continuous values were rescaled so that the indices range from 0 to 1. Some nominal attributes were given already in a form of discreate classes having numeric ids in a range 0 to 1 and corresponding the best-worst interpretation. However, if continuous variables were rescaled to the range from 0 to 1, we removed the 5% of largest values to get the upper value limit and the rescaled value was calculated:

Rescaled value = 1 – (initial value/95th quantile value).

Then, if needed, transformations were made 1 to denotes the best and 0 to denote the worst for an indicator.

We hesitate about suitability to use such rescaled values to compare between the attributes, but they can be used to compare between the FMMs at certain level of abstraction.

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Table 28. Scores of CSs per FMMs at attribute level

Concepts	Dimensions	Attribute	Indicator used	Forest management model													
				All forests	LRCON_C	LRCON_CUS	LRCON_US	MRCON_C	MRCON_CUS	MRCON_US	NOINT	SPECP	MRDEC_C	MRDEC_CUS	SRDEC_C	SRDEC_CUS	Other
Stewardship	Sense of care	Amount of residue from harvesting and thinning	Volume of harvesting residues	0.45	0.60	0.51	0.55	0.32	0.38	0.36	1.00	0.48	0.57	0.56	0.62	0.46	0.56
Naturalness/disturbances	Alteration/ impact	Area of final felling	Final felling area in ha	0.82	0.79	0.79	0.80	0.86	0.81	0.83	1.00	0.85	0.86	0.80	0.86	0.85	0.92
Naturalness/disturbances	Natural Value	Naturalness of forest stands	Index	0.54	0.41	0.61	0.39	0.67	0.34	0.39	0.74	0.55	0.61	0.65	0.66	0.67	0.63
Naturalness/disturbances	Wilderness	Amount of natural dead wood	Volume of natural deadwood per year	0.72	0.71	0.89	0.90	0.82	0.56	0.69	0.77	0.59	0.31	0.32	0.40	0.43	0.44
Naturalness/disturbances	Intrusion	Naturalness of forest compartment borders	Shape index	0.69	0.65	0.66	0.67	0.64	0.66	0.66	0.70	0.72	0.68	0.69	0.75	0.74	0.70
Complexity	Diversity	Tree species diversity within stand	Shannon diversity index	0.47	0.27	0.55	0.27	0.19	0.51	0.43	0.47	0.47	0.31	0.62	0.15	0.63	0.54
Complexity	Age structure	Presence of trees from different generations in the main layer	Index	0.18	0.10	0.18	0.08	0.11	0.20	0.20	0.36	0.24	0.08	0.16	0.05	0.22	0.25
Complexity	Spatial pattern	Variation in tree spacing within stand	Index	0.69	0.65	0.66	0.67	0.64	0.66	0.66	0.70	0.72	0.68	0.69	0.75	0.74	0.70
Visual scale	Openness	Visual penetration/ density of obstruction	Relative stocking index of main layer	0.28	0.27	0.29	0.28	0.30	0.25	0.27	0.30	0.29	0.30	0.29	0.28	0.30	0.31
Visual scale	Visibility	Presence of understory	Abundance of	0.58	0.71	0.67	0.66	0.72	0.71	0.68	0.74	0.58	0.56	0.50	0.40	0.37	0.45

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Concepts	Dimensions	Attribute	Indicator used	Forest management model													
				All forests	LRCON_C	LRCON_CUS	LRCON_US	MRCON_C	MRCON_CUS	MRCON_US	NOINT	SPECP	MRDEC_C	MRDEC_CUS	SRDEC_C	SRDEC_CUS	Other
		in stand	understory														
Historicity/imageability	Historical richness	Average age of trees in the main layer	Age	0.50	0.62	0.74	0.64	0.61	0.46	0.55	0.76	0.57	0.41	0.43	0.32	0.37	0.46
Historicity/ imageability	Continuity/ place identity	Age of current land-use	Index	0.73	0.74	0.84	0.71	0.85	0.80	0.81	0.91	0.74	0.65	0.72	0.44	0.62	0.67
Ephemera	Seasonal change	Presence of broadleaves	% of broadleaves in forest stand	0.54	0.07	0.12	0.05	0.07	0.20	0.13	0.35	0.56	0.94	0.86	0.99	0.94	0.91

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Scores per FMM per concept are summarized in Table 29. The numbers from Table 29 are transformed into illustrations presented in Figure 33. If having a look at the evaluation of Stewardship, the NOINT FMM jumps out in terms of sense of care, which was evaluated using amount of residue from harvesting and thinning. It is obvious, that the harvesting residues are not present in forest compartments managed by this FMM as there is no active management allowed here. This FMM is used on natural reserves with no human activity allowed (even the admittance is limited). Relatively lowest stewardship values are associated with FMMs on spruce dominated stands. Special purpose forests with rather limited final harvesting intensities but with thinning cuttings seems too contain relatively more cutting residues that other FMMs (except the ones for spruce). FMMs with clear cutting system in pine and softwood deciduous forests are given slightly higher estimates than the models with non-clear felling, explaining this that cutting residues are easier to remove in clear-cutting.

Table 29. Scores per FMM per concept

FMM	Average per FMM	Overall Average Cultural Services					
		Stewardship	Natural-ness/dis-turbances	Comple-xity	Visual scale	Historicity/ image-ability	Ephemera
LRCON_C	0.47	0.60	0.64	0.34	0.49	0.68	0.07
LRCON_CUS	0.52	0.51	0.74	0.47	0.48	0.79	0.12
LRCON_US	0.46	0.55	0.69	0.34	0.47	0.68	0.05
MRCON_C	0.45	0.32	0.75	0.32	0.51	0.73	0.07
MRCON_CUS	0.46	0.38	0.59	0.46	0.48	0.63	0.2
MRCON_US	0.45	0.36	0.64	0.43	0.47	0.68	0.13
MRDEC_C	0.57	0.57	0.62	0.36	0.43	0.53	0.94
MRDEC_CUS	0.58	0.56	0.61	0.49	0.39	0.58	0.86
SRDEC_C	0.55	0.62	0.67	0.32	0.34	0.38	0.99
SRDEC_CUS	0.57	0.46	0.67	0.53	0.33	0.49	0.94
NOINT	0.67	1.0	0.80	0.51	0.52	0.83	0.35
SPECP	0.55	0.48	0.68	0.43	0.44	0.66	0.56
Other	0.60	0.56	0.67	0.50	0.38	0.57	0.91
All	0.53	0.45	0.69	0.45	0.43	0.62	0.54

The most “natural” forests following the understanding of assessment concepts are forests without active management. The next FMM having highest grades per this concept is the clear cutting based forestry in spruce stands – we discuss this model as the best emulating natural disturbances on the soil types best suited for spruce forests. Relatively lowest grades for “naturalness/disturbances” are given to the FMMs on birch and black alder stands. In principle, all FMMs do not deviate much in average grades from the CSA average value. The FMMs with coniferous trees dominating are given lowest grades for “Complexity”. It is also clearly seen that the least complex forests are associated with clear final cutting system. The clear final cutting is prioritized on close to monocultures plantations. The non-clear final cutting is usually used in

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stands with natural regeneration potential, usually having more tree species. In respect of “Visual scale” all FMMs relatively similar with exception short rotation deciduous forests, potentially due to large amount of brush vegetation, lesser attention on thinning cuttings. High grades for “Historicity/ image ability” given to NOINT FMM may be first explained by relatively longest age of current land use – practically all reserves are established on a continuing forest land cover for more than 60 years. Of course, average age of due to no active management does also go up compared with other FMMs. The rotation period is positively correlated with the grade for average age of trees in the main layer. Should be noted, that relatively large share of short rotation deciduous forests have relatively shorter history as continuing forest land – most likely they are on abandoned agricultural lands naturally grown with forest. Seasonal changes were evaluated by the share of deciduous tree species in tree species composition of stands – naturally, the highest grades are given to FMMs with deciduous tree species dominating. It is also seen that in coniferous forest stands with final clear and non-clear cutting systems used (i.e. not strictly required clear cutting or non-clear cutting) there are relatively more deciduous trees present.

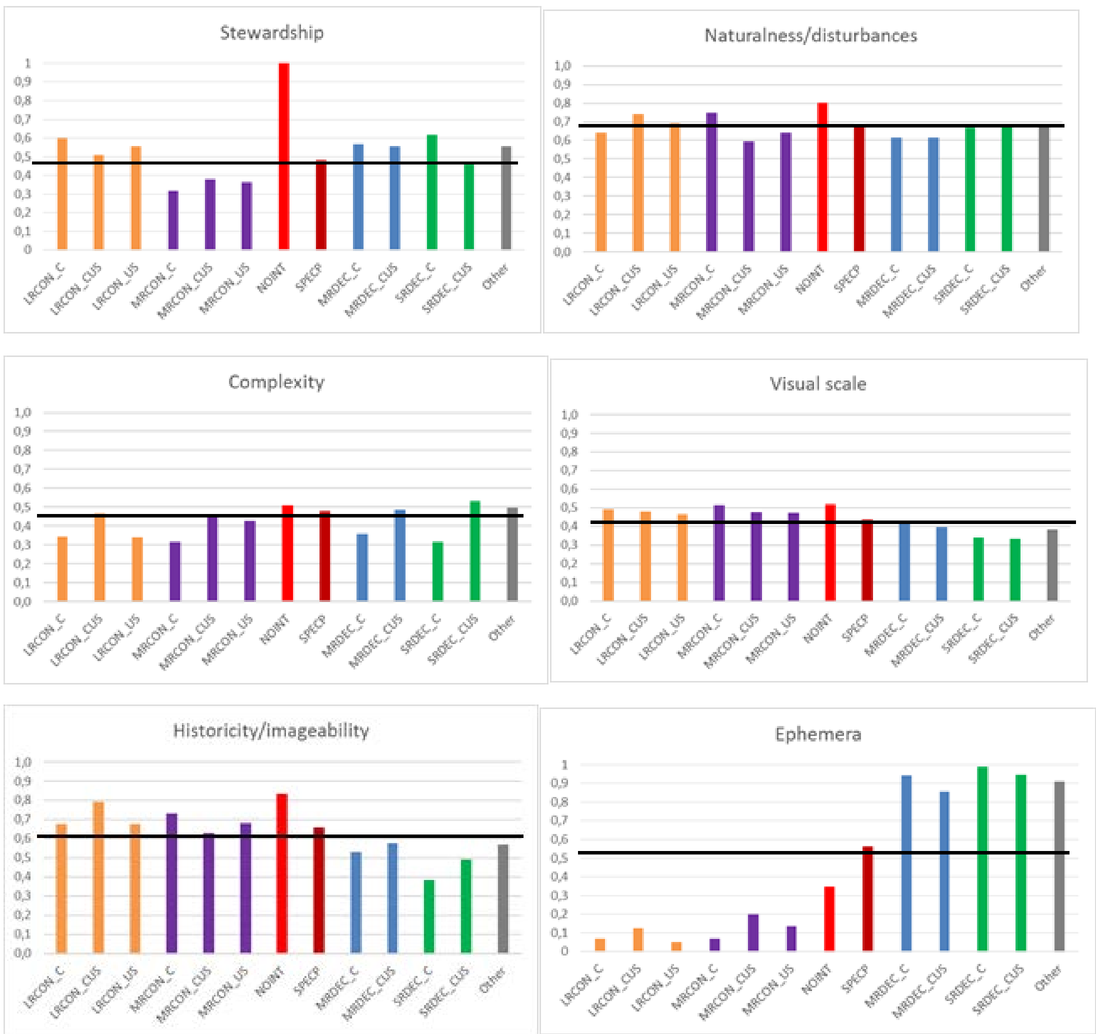

Figure 33. FMM scores at a concept level. Black line indicates the average value in CSA

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The average FMM estimates given at concept level are rather uniform for Naturalness/disturbances and Visual scale (standard deviation of average grades for all FMMs is 0.06), Complexity (0.08) and Historicity/imageability (0.12) – **Fehler! Verweisquelle konnte nicht gefunden werden.**. High stewardship grade for NOINT increases the variance of grades for FMMs, however, this grade was awarded by expert judgement assuming, that no management automatically means no residues from harvesting and thinning. The largest variance of FMM level estimates is for Ephemera (standard deviation 0.40). Very differing estimates for seasonal change based on the share of deciduous trees could be a reason which resulted higher overall values for cultural services for FMMs with deciduous tree species compared to models with coniferous trees (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

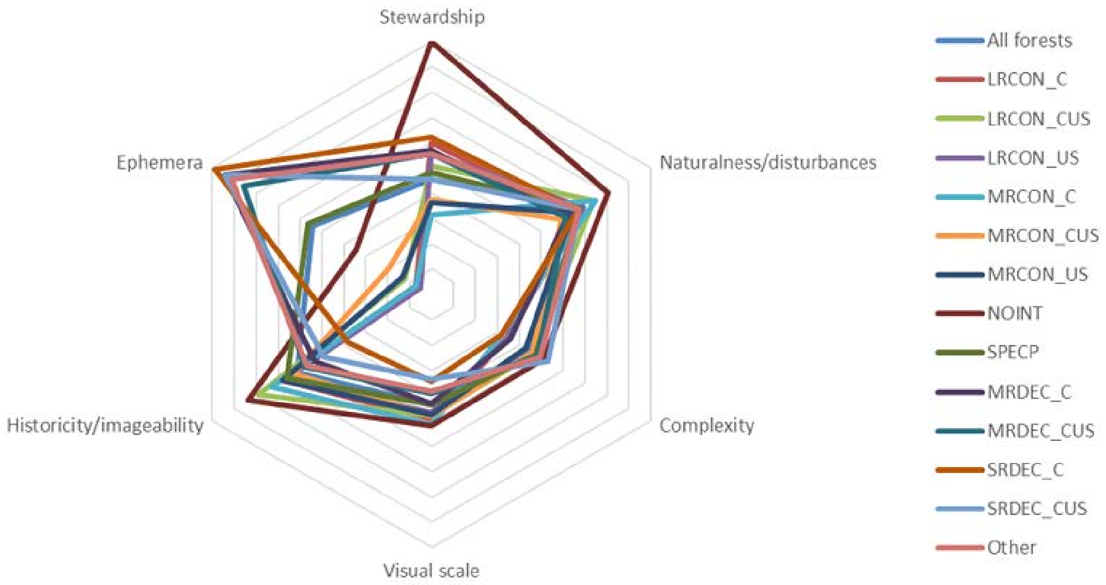

Figure 34 Average scores of CSs by FMMs and concepts

The most valuable in terms of provisioning CS seems to be the NOINT FMM, assuming no active management. The average grades for this FMM exceeded the ones for FMMs in deciduous forests no matter relatively large share of coniferous stands. If comparing FMMs on stands with the same species and rotation lengths, introduction of non-clear final cutting results always in slightly higher average grades than the ones on FMMs with clear cutting system only. Should be also noted, that mandatory restriction of clear final cutting in coniferous forests does not increase the overall grade for CS compared to the FMMs with clear cutting systems. We remind, that the LRCON_US and MRCON_US FMMs are basically in National Park and along major roads, i.e. the introduction of this restriction is assumed to support first of all the cultural services provided by the forest.

If the Ephemera estimates are not included into calculating overall grade for CS, the dominance of NOINT FMM increases (**Fehler! Verweisquelle konnte nicht gefunden werden.**). The relative cultural value of pine forests increases and the value of deciduous, especially the short rotation ones, goes down.

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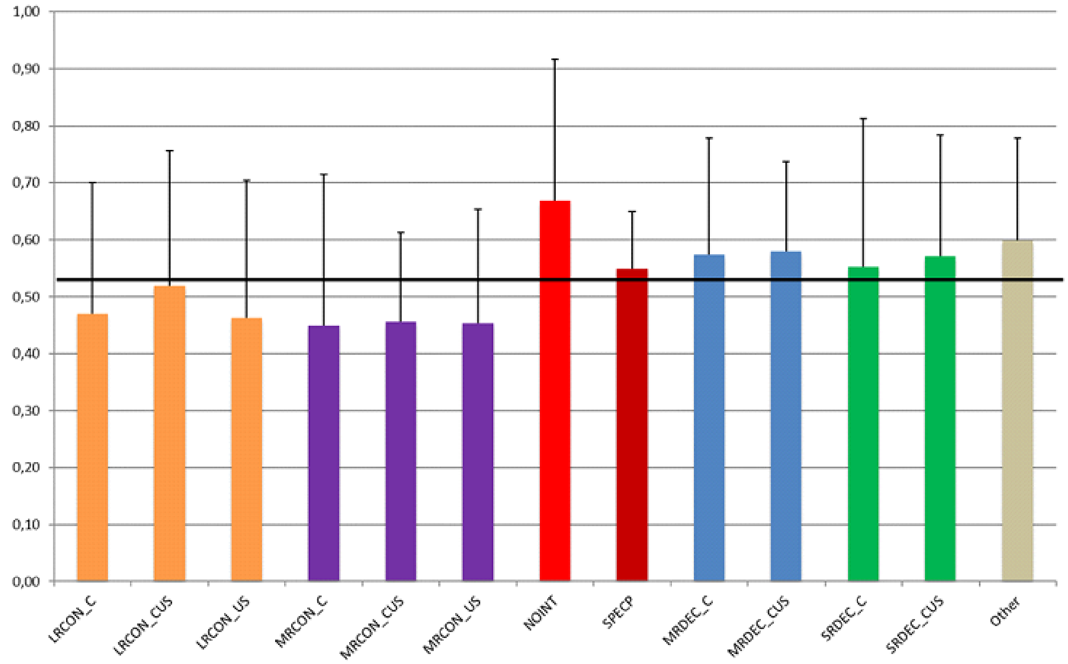

Figure 35. Overall average values of Cultural Services per FMM. Black solid line indicates the average score in SCA (0.53), Y-error bars are the standard deviations of grades for 6 CS concepts by FMMs

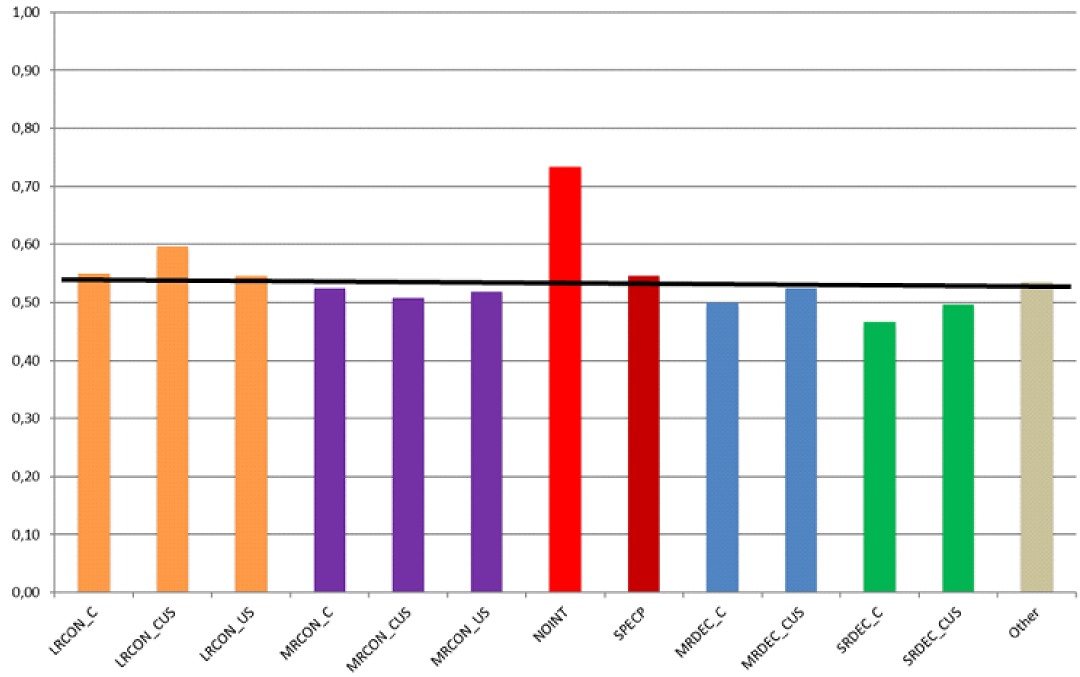

Figure 36. Overall average values of Cultural Services per FMM not including the Ephemera estimates. Black solid line indicates the average score in SCA (0.53)

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To summarize, the evaluation of Cultural Services seems to be the most difficult and dependent on methodological approaches chosen. We accept that the concept in principle is working, however, the evaluation is very dependent on the attributes used for validation and mathematical treatment of data, like indexing, normalization. Also, some expert based weighting on concepts, dimensions and attributes could be introduced. Anyway, the key finding is that the most valuable FMM in terms of providing CSs is the NOINT, i.e. the forest management assuming no active management. Banning the clear final cuttings in National Parks and along the roads – political measure aimed to support the CSs provided by the forest – does not result in higher CS grades in coniferous forests, compared to the FMMs with clear cutting allowed.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

2.5. The Netherlands

Initial ranking of the Forest Management Models for the Dutch Case study area in ALTERFOR

Based on the data of the NBI6 and some additional GIS and qualitative assessments by the authors, preliminary assessments of the ecosystem service indicators were made for five ecosystem services: Biodiversity, Cultural Services, Water, Carbon and Risk Reduction.

2.5.1. Approach taken

When possible, the guidelines were followed explicitly. Because the FMMs proposed are data-based, and no official schedules for the application of the FMMs exist, we assess the ecosystem service indicators on the FMMs using a space for time replacement by averaging over all observed plots in the NBI6. Attributes that cannot be assessed based on the NBI6 are qualitatively assessed at FMM level.

All indicators are build up from a number of concepts, that can be measured along one or several dimensions. These dimensions are represented by one or several attributes. To avoid overrepresentation of concepts with multiple dimensions and attributes, each indicator is calculated as the unweighted average of the underlying concepts, which is turn is the unweighted average of the dimensions it is measured along, which is turn are the unweighted average of their attributes.

For many of the attributes it is difficult to identify absolute boundaries, or the observations only occur in a limited range of the possible extend. Other attributes are indicated by index values, or fractions with very clear upper and lower boundaries. To be able to calculate averages, and because the current calculation is only intended for an initial ranking of the FMMs, all observed attribute values were rescaled and normalised using the formula:

$$\frac{x - \mu}{2\sigma}$$

Which was subsequently truncated to the range [0,1]. As a result outliers in the observations (e.g. the extreme 5%) are cut-off and the average for all observations is set to 0.5. As a consequence of skewed observations this can lead to strange cut-offs. This is to be solved later, but the current approach will do for this assessment.

Additional data used

Next to the data reported in the NBI6 database, some additional datasets were used.

1. The age of forest-landuse was assessed using a number of (historical) landuse maps: HGN1900[1], HGN1960, HGN1970, HGN1990, LGN4, LGN6 and LGN7[2]

[1] http://www.wur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/Environmental-Research/Faciliteiten-Producten/Kaarten-en-GIS-bestanden/Historisch-Grondgebruik-Nederland.htm

[2] http://www.wur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/Environmental-Research/Faciliteiten-Producten/Kaarten-en-GIS-bestanden/Landelijk-Grondgebruik-Nederland.htm

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2. Carbon calculations and coefficients used therein were based on the Dutch reporting for UNFCCC and Kyoto protocol (Arets et al. 2015)
3. Vulnerability classes for individual trees were loosely based on Schelhaas et al. (2010) in combination with the Dutch growth and yield tables of Jansen et al. (1996)

2.5.2. Ecosystem Service calculation

The full overview of subindicators used and how they are hierarchically nested into attributes, dimensions and concepts into indicators is given in Table 30. Most subindicators are derived from the NBI6. Specific additional calculations are explained per indicator below. The FMMs used are based on the SNL subsidy system in the Netherlands. Three levels of protection are recognised: Nature area (SNL Nature forest), Production area (SNL Production forest) and Other (no SNL, or a non-forest SNL). For both the protection status and the felling frequency, default values are attached to the subsidy level, rather than at individual FMM level. Values are shown in Table 31.

Biodiversity

The guidelines were followed as explicitly as possible. Based on FSC and SNL guidelines, exotic species were: Abies alba, Abies grandis, Acer platanoides, Chamaecyparis spp, Exotic broadleaved, Larix decidua, Larix kaempferi, Other Abies, Other conifers, Other picea, Other pinus, Other Quercus, Picea abies, Picea omorika, Picea sitchensis, Pinus contorta, Pinus nigra laricio, Pinus nigra nigra, Pinus pinaster, Pinus rigida, Pinus strobus, Platanus spp, Prunus serotina, Pseudotsuga spp, Quercus rubra, Robinia pseudoacacia, Tsuga spp.

Carbon

Plotlevel above and below ground biomass is calculated using the main tree species and the total volume of timber reported for the plot, following the Dutch LULUCF guidelines for UNFCCC and Kyoto (Arets et al. 2015). No forest soil carbon pools are reported in the Netherlands, due to lack of data. Harvested wood products are neglected in this assessment because it no data is available on the differential allocation to the different HWP categories for the different FMMs.

Cultural Services

The guidelines were followed as explicitly as possible. Landuse age was determined using the available maps from the Historical landuse and landuse maps for the Netherlands (HGN and LGN series). These maps are the most consistent set available for the years 1900, 1960, 1970, 1980, 1990, 2000, 2004, 2009. A classification was made based on the number of consequetive maps (starting from the most recent) the pixel that a NBI6-plot is located on was classified as forest.

Risk Reduction

Two risks are taken into account: risk of wind damage and risk of fire damage. In general risk can be assessed using three dimensions: hazard, vulnerability and exposure. For the current assessment only vulnerability is assessed. Hazard is mainly external to the FMM applied (in the case of wind and fire risk they are mostly climatic, Schelhaas et al. 2010). Exposure will be added in a later stadium.

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Vulnerability is assessed through three attributes: tree level vulnerability, stand susceptibility and stand structure. For the tree level vulnerability, the vulnerability of individual trees in the stand is assessed using a diameter class index loosely based on Schelhaas et al. (2010), Table 30. Stand susceptibility to wind damage is expected to be indicated by the dominant height of the stand, to fire damage is expected to be indicated by the understory cover. Stem density is taken as a stand structural attribute dampening the vulnerability to wind damage. The Gini index on basal area is taken as stand structural attribute dampening the vulnerability to fire damage (with less variability decreasing the vulnerability).

Water

Grazing data were not available. Grazing in forests is mainly due to game (roe deer, red deer, boar) and (semi) free roaming cattle and horses. Forest fire data are sparsely available, but forest fire frequencies are generally low. No FMM specific data are available. Chemicals are rarely used in the Dutch forests.

Table 30 overview of indicators, concepts, attributes and subindicators.

Indicator	Concept	Dimension	Attribute	Subindicator	Direction	Data source
Biodiversity	Composition	Diversity	Tree species diversity	Shannon evenness	positive	NBI6
Biodiversity	Composition	Local species pool	Proportion of exotics	Basal area share of exotic species	negative	NBI6
Biodiversity	Structure	Deadwood	All deadwood	Total deadwood	positive	NBI6
Biodiversity	Structure	Deadwood	Large deadwood	total standing deadwood with DBH > 30 cm	positive	NBI6
Biodiversity	Structure	Large trees	Volume of large trees	Total volume of trees with DBH > 30 cm	positive	NBI6
Biodiversity	Structure	Large trees	Basal area of large trees	Total basal area of trees with DBH > 30 cm	positive	NBI6
Biodiversity	Structure	Structural diversity	Volume diversity	Gini index calculated over volume of trees	positive	NBI6
Biodiversity	Structure	Structural diversity	Basal area diversity	Gini index calculated over basal area of trees	positive	NBI6
Biodiversity	Disturbance	Harvest	Frequency of final fellings	Frequency of final fellings	negative	Default
Biodiversity	Disturbance	Harvest	Area of felling	Stand area index	negative	NBI6
Biodiversity	Disturbance	Harvest	Proportion removed	Harvest / standing stock	negative	NBI6
Biodiversity	Protected area	Protected area	Protection status	Protection index	negative	Default
Cultural	Stewardship	Sense of care	Harvest residues	Residue index	negative	Default
Cultural	Naturalness	Alteration	Area of felling	Stand area index	negative	NBI6
Cultural	Naturalness	Alteration	Frequency of final fellings	Frequency of final fellings	negative	Default
Cultural	Naturalness	Natural value	Naturalness of the stand	Naturalness index	positive	Default
Cultural	Naturalness	Wilderness	Amount of Deadwood	Total deadwood	positive	NBI6

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Indicator	Concept	Dimension	Attribute	Subindicator	Direction	Data source
Cultural	Naturalness	Intrusion	Naturalness of forest edges	Forest edge index	positive	Default
Cultural	Complexity	Diversity	Tree species diversity	Shannon evenness	positive	NBI6
Cultural	Complexity	Variety	Tree size variation	Gini index calculated over basal area of trees	positive	NBI6
Cultural	Complexity	Spatial pattern	Tree spacing	Tree spacing index	positive	Default
Cultural	Visual scale	Openness	Visual penetration	Stem density	negative	NBI6
Cultural	Visual scale	Visibility	Understory density	Understory index	negative	NBI6
Cultural	Historicity	Historical richness	Age of the stand	Stand age	positive	NBI6
Cultural	Historicity	Historical continuity	Age of land use	Land use age index	positive	NBI6/GIS
Cultural	Ephemera	Seasonal change	Presence of broadleaved	Basal area share of broadleaved species	positive	NBI6
Water	Water yield	Harvest	Proportion removed	Harvest / standing stock	positive	NBI6
Water	Water yield	Species composition	Presence of broadleaved	Basal area share of broadleaved species	positive	NBI6
Water	Flood protection	Harvest	Proportion removed	Harvest / standing stock	negative	NBI6
Water	Flood protection	Grazing	Intensive grazing	Intensive grazing index	negative	Default
Water	Flood protection	Burning	Frequency of fires	Fire frequency index	negative	Default
Water	Flow maintenance	Harvest	Proportion removed	Harvest / standing stock	positive	NBI6
Water	Erosion control	Burning	Frequency of fires	Fire frequency index	negative	Default
Water	Erosion control	Grazing	Grazing	Grazing index	negative	Default
Water	Chemical condition	Chemicals	Amount of chemicals used	Chemical use index	negative	Default
Water	Chemical condition	Harvest	Proportion removed	Harvest / standing stock	negative	NBI6
Water	Chemical condition	Burning	Frequency of fires	Fire frequency index	negative	Default
Water	Chemical condition	Species composition	Presence of broadleaved	Basal area share of broadleaved species	positive	NBI6
Water	Chemical condition	Forest age	Age of the stand	Stand age	Optimum	NBI6
Carbon	Carbon stock	Biomass	Aboveground Biomass	Total carbon in aboveground biomass	positive	NBI6
Carbon	Carbon stock	Biomass	Belowground Biomass	Total carbon in belowground biomass	positive	NBI6
Carbon	Carbon stock	Biomass	Deadwood mass	Total carbon in deadwood	positive	NBI6
Risk reduction	Wind risk	Vulnerability	Tree vulnerability	Average wind vulnerability index per tree	negative	NBI6

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Indicator	Concept	Dimension	Attribute	Subindicator	Direction	Data source
Risk reduction	Wind risk	Vulnerability	Stand susceptibility	Dominant height	negative	NBI6
Risk reduction	Wind risk	Vulnerability	Stand structure	Stem density	positive	NBI6
Risk reduction	Fire risk	Vulnerability	Tree vulnerability	Average fire vulnerability index per tree	negative	NBI6
Risk reduction	Fire risk	Vulnerability	Stand susceptibility	Understory index	negative	NBI6
Risk reduction	Fire risk	Vulnerability	Stand structure	Gini index calculated over basal area of trees	positive	NBI6

Table 31 Qualitatively assessed default values per FMM

FMM	Felling residues	Felling fre-quency	Natural-ness stand	Natural-ness edges	Tree spacing	Grazing	Intensive Grazing	Burning fre-quency	Che-micals	Pro-tection status
FMM1	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM2	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM3	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM4	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM5	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM6	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM7	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM8	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM9	0.5	0.5	0.5	0.5	0.5	0.25	0	0.01	0	0.5

Table 32 Vulnerability per diameter class per species group for wind and fire damage.

Concept	Species group	DBH<10	DBH<20	DBH<30	DBH<40	DBH<50	DBH>50
wind	conifers	1	1	2	3	4	4
wind	populus	1	2.5	4	4	4	4
wind	broadleaved	1	1	1.5	2	2.5	3
wind	picea	1	3	5	6	6	6
fire	conifers	3	2.5	2	1.5	1	1
fire	broadleaved	2	1.5	1.5	1	1	1
fire	pinus	4	3	3	2	2	2

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2.5.3. Results

In total 3077 plots are used in this assessment (which is the total national forest inventory of the Netherlands).

The final results are shown in Figure 37 and **Fehler! Verweisquelle konnte nicht gefunden werden.**. From these results the two oak FMMs rank first and second, while the coniferous forests rank lowest. In general the production forests rank lower than the nature forests.

Looking in more detail per Ecosystem service indicator, we see that biodiversity is mostly associated with the subsidy type, and the other services are mostly associated with the main species of the FMM, with strong interactions for some (e.g. water, carbon) and less interactions for others (e.g., risk reduction).

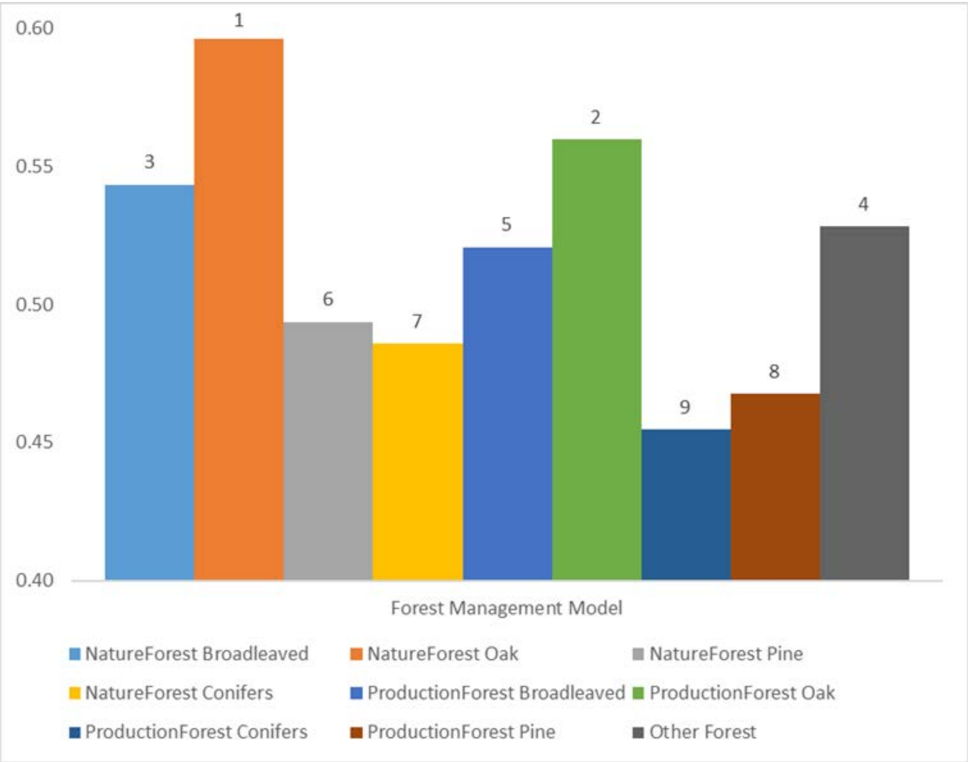

Figure 37 Final ranking of the FMMs over all Ecosystem services. Y-axis shows the average index, numbers above the bars show rank of the FMM.

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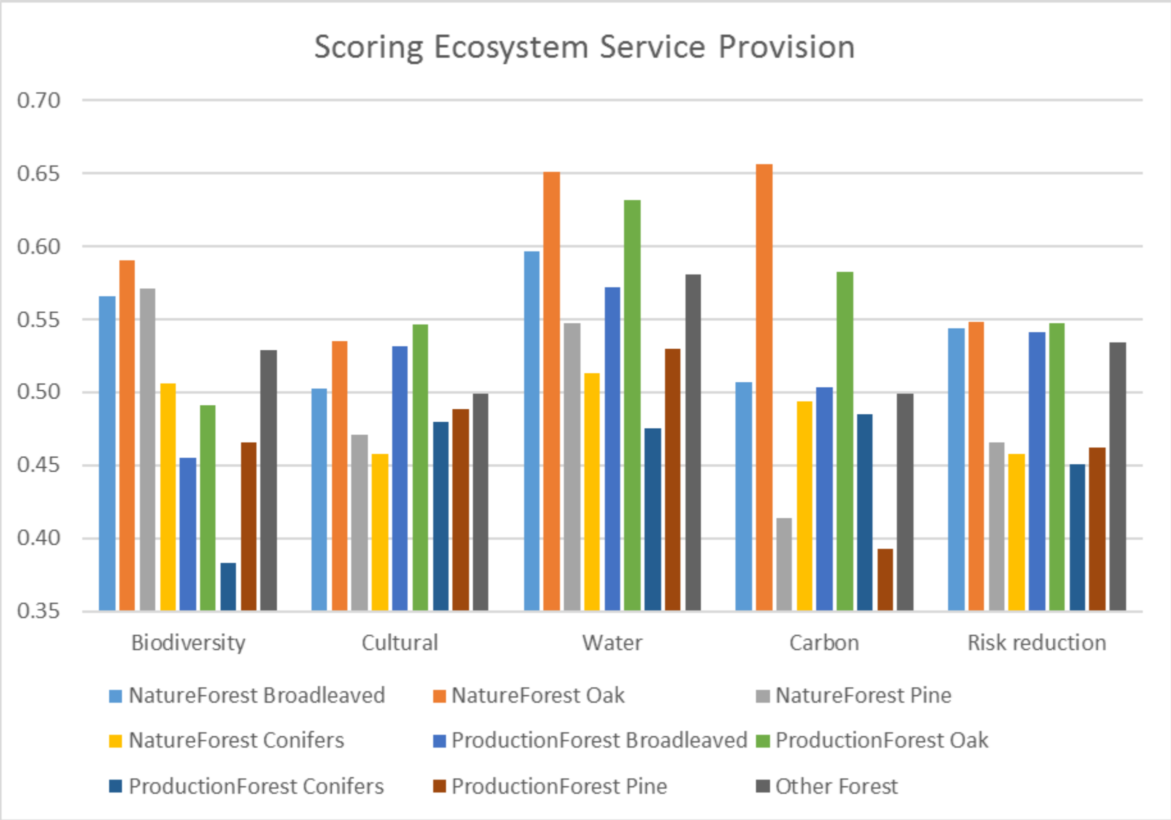

Figure 38 Final ranking of the FMMs over all Ecosystem services. Y-axis shows the average index, numbers above the bars show rank of the FMM.

2.5.4. References

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2.6. Portugal

2.6.1. Assessment of the contribution of stand-level Forest Management Models to the provision of ecosystem services in Vale do Sousa CSA.

The Vale do Sousa CSA is located in the southern part of the Sousa Valley, and extends over an area of 14,840 ha corresponding to the following ZIF separated by the Douro River: Entre-Douro-e-Sousa (north of the Douro River) and Paiva (south of the Douro River). The Vale do Sousa CSA was chosen for its representativeness of forest management practices and forest ownership structure of the North-Western Portugal forest, i.e. over 85% of the forest area in Portugal is privately owned (mostly by small non industrial private forest owners) and blue gum/ eucalypt (*Eucalyptus globulus* Labill) and maritime pine (*Pinus pinaster* Aiton) are two of the main forest species. Its forests are thus mainly dominated by eucalypt (pure and mixed), followed by maritime pine. In pure stands, it covers 2/3 of the area. In a mixture with maritime pine it grows on another 1/3. Chestnut grows on a limited area, approx. 1%. In terms of volume, the dominance of eucalypt is even more striking, approx. 90% of the volume in the CSA.

Four forest management models (FMMs) are identified in the Vale do Sousa CSA, three encompass eucalypt. The remaining area is occupied by hardwoods, mostly chestnuts (FMM 3). A mixture between maritime pine and eucalyptus characterize two different models: FMM1 and FMM2. In the case of FMM1, maritime pine is dominant, approx. 8180 m^3 (73%) and eucalyptus 3065 m^3 of the standing volume (27%). In FMM2 eucalypt is the main specie approx. 14150 m^3 (67%) and eucalyptus 7100 m^3 (33%), and FMM 4 – pure eucalypt plantations. These four FMMs cover the entire CSA.

The schedule of forest operations in these FMMs may be summarized as follows:

- The maritime pine prescriptions assumed plantations with 1,400 plants per hectare and rotations of 40 and 60 years, with thinnings occurring every five years between 20 and 50 years of age (up to 5 years before the final harvest) based on a Wilson factor (FW) of 0.27.
- The eucalypt prescriptions were plantations of 1,400 trees per ha with rotations based on three coppice cycles ranging from 10 to 14 years in length. A stool thinning option was included that leaves an average of 2 shoots per stool at year 2 of each cycle.
- Chestnut prescriptions assumed plantations of 1,250 trees per ha and alternative thinning periodicities of 5 or 10 years starting at age 15. Rotations range from 40 to 70 years.

For more details about each FMM, the reader is referred to the document ISA (Vale do Sousa) contribution to D11 Part 1 (Marques and Borges 2017)

2.6.2. Approach to characterize the contribution of each FMM to the provision of ES

Each Vale de Sousa FMM encompasses a huge number of prescriptions (e.g. alternative fuel treatment schedules, thinning regimes, rotation ages), and the variability across prescriptions (within each FMM) makes it infeasible to rank FMMs based on their contribution to the provision of

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each ES. In fact, the variability of these contributions across prescriptions within a FMM is often higher than the variability across FMMs. Further that contribution varies over time within the same prescription thus complicating further the assessment. Finally, the contribution varies also across stands. Therefore, this report will characterize the provision of ecosystem services by each FMM by a) selecting a stand that is representative of the location of each FMM in the CSA (e.g. based on site index), b) selecting a set of 4 rotations based on the range of fuel treatments' periodicity and of rotation ages that characterizes each FMM (**Fehler! Verweisquelle konnte nicht gefunden werden.**) and c) reporting the chronological sequence.

Table 33 Prescriptions used to assess the contribution of each FMM to the provision of ecosystem services in the Vale do Sousa CSA, Portugal.

FMM#	Short name	Species Forest cover (%)	Rotation range RA – rotation age	Weight (% of forest area)
FMM1	Mixed maritime pine + Eucalypt forest system	Pinus pinaster Aiton x Eucalyptus globulus Labill Maritime pine (73%)	RA = 40 years. No fuel treatments	16,00%
			RA = 40 y. Yearly fuel treatments	
			RA = 60 y. No fuel treatments	
			RA = 60 y. Yearly fuel treatments	
		Eucalypt (27%)	Cycle = 10 y. No fuel treatments	
			Cycle=10y. Yearly fuel treatments	
			Cycle = 12 y. No fuel treatments	
			Cycle=12y. Yearly fuel treatments	
FMM2	Mixed Eucalypt + maritime pine forest system	Eucalypt (67%) Eucalyptus globulus Labill x Pinus pinaster Aiton	Cycle = 10 years. No fuel treatments	17,00%
			Cycle = 10 years. Yearly fuel treatments	
			Cycle = 12 years. No fuel treatments	
			Cycle = 12 years. Yearly fuel treatments	
		Maritime pine (33%)	Rotation age = 40 years. No fuel treatments	
			Rotation age = 40 years. Yearly fuel treatments	
			Rotation age = 60 years. No	

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			fuel treatments	
			Rotation age = 60 years. Yearly fuel treatments	
FMM3	Chestnut forest system	Castanea sativa Mill 100%	Rotation age = 40 years. No fuel treatments	1%
			Rotation age = 40 years. Yearly fuel treatments	
			Rotation age = 70 years. No fuel treatments	
			Rotation age = 70 years. Yearly fuel treatments	
FMM4	Eucalypt forest system	Eucalyptus globulus Labill 100%	Cycle = 10 years. No fuel treatments	66%
			Cycle = 10 years. Yearly fuel treatments	
			Cycle = 14 years. No fuel treatments	
			Cycle = 14 years. Yearly fuel treatments	

2.6.3. Contribution of CSA stand-level FMMs to the provision of ES

This report assesses the contribution of each stand-level FMM to the provision of carbon storage, wood production, water services, cultural services, biodiversity, and regulatory services. The assessment was based on the ALTERFOR guidelines. It considered the CSA inventory data available and took advantage of the functionality of available models and decision support tools. Results are reported in separate excel files, one for each ES:

Below, we outline further the assessment framework, namely how the availability of data and information conditioned the implementation of the guidelines. For more information please check earlier reports by the Vale do Sousa CSA research team.

Biodiversity

As reported earlier there is no data or models available to quantify some specific indicators, such as: Forest Structure - Dead wood and Forest Structure - Large trees. All 4 Vale do Sousa stand-level FMMs involve an even-aged system thus no 'large trees' are left standing after a clearcut. We report data and expert scores based on tree species composition, shrub biomass accumulation, and disturbance. Ongoing research will fine tune the assessment of the contribution of shrub biomass to biodiversity.

Carbon Storage (Mg ha^{-1})

No belowground (BG) carbon storage data is available. Carbon pools reported include only aboveground biomass (AG) (i.e. all living biomass above soil including stem, branches, bark and leaves from trees with dbh above 7.5 cm).

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Cultural services

We considered the three concepts:

- Naturalness/disturbances
- Complexity
- Visual scale
- Historicity / imageability
- Ephemera

Yet there are no data or models available to address the concept Stewardship as well as to estimate the contribution to several dimensions of the five other concepts. Moreover, no model or expert knowledge is available to an overall score of concepts and dimensions.

Regulatory services - Wildfire resistance

The vulnerability of stands to wildfire criteria was assessed according to the specific stand wildfire resistance (Ferreira et al. 2015; Marques et al. 2017) that is based on wildfire occurrence and post-fire mortality probability models available in our research group (e.g. Marques et al, 2011; Garcia-Gonzalo et al. 2011).

Water services

As reported earlier it is not possible to perform a quantitative evaluation of the ES at the basic level. Our CSA can report the variation of the raw DSS outputs but the net contribution to the indicators is not provided as no model or expert knowledge is available for that purpose. Our DSS provides information regarding forest cover type, stand age distribution and harvested area in each planning period and yet we have no model nor expert knowledge to check the impact of those outputs on total supply of water per forest area, runnof time, water distribution, erosion protection and water quality either at the stand-level. The burned area was estimated using fire occurrence models (through biometric variables, percentage of shrub biomass and topographic data) developed within our research group (e.g. Marques et al. 2011). Nevertheless, we have no models or expert knowledge that might link those variables to quantify water related ES at an advancel-level.

Wood production (m^3 ha)

We report the pine, eucalypt and chestnut timber volume produced in each period, i.e. eucalypt pulpwood (m^3), pine sawlog (m^3), chestnut sawlog volume (m^3). All stands are even aged yet please note that in the case of mixed stands the harvests of eucalypt and maritime pine are performed independently, when the species reach the harvest age.

2.6.4. References

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2.7. Slovakia

2.7.1. Biodiversity services assessment

Qualitative rating of biodiversity protection and enhancement for each FMM was performed by a panel of scientific experts (members of our ALTERFOR team) based on Biodiversity assessment guidelines and evaluation example from Adam and Matts All provided ratings were discussed, and the final rating is a consensual agreement. By Biodiversity example, we used the scale 1-7 for assessment, where one means the worst impact on biodiversity and seven is related to the maximal support of biodiversity.

The assessment respected the suggestions of the Swedish team, and three major dimensions were considered. For each dimension, we used the following indicators relevant for Slovak CS according to our opinion:

- Tree species compositions– total tree species diversity, proportion of broadleaves (for some FMM and forest types)
- Forest structures – horizontal and vertical tree distribution, number of tree layers, tree age distribution, height and diameter differentiation
- Spatio-temporal patterns – degree of natural disturbance emulation, proportion of older stands

Within the evaluation process, the secondary spruce monoculture was taken as a comparative benchmark with the lowest biodiversity. Moreover, we assumed the validity of following assumptions, relations and known facts:

- Regarding tree species composition – the growing number and evenness of tree species participating on tree species compositions and increased proportion of broadleaves in forests with the artificially enlarged presence of conifers were considered as positive for biodiversity. The spruce monocultures were rated by value 2 or 3 because we did not suppose the existence of genetically improved or breeded trees on our CSA.
- Regarding forest structure – the FMM supporting the greater variation in tree age, horizontal distribution, dimensions and vertical arrangement in growing space were assessed as biodiversity promoting. The presence of deadwood was considered only marginally due to its absence in the majority of FMM. The value 1 (the worst rating) was reserved for short-term industrial plantations, spruce even-aged monocultures were rated as 2, and old-growth native forests in natural reserves has been rated by value 7 (best rating).
- Regarding spatiotemporal patterns – the FMM using the thinning and harvest strategies similar to natural disturbance patterns were considered as positive for biodiversity protection. Therefore, three FMM using no intervention or individual tree selection interventions were assessed as superior to others. Contrary, FMM based on active management were a slight difference in regard this criterion due to the relatively high

uniformity of final fellings – all models use the non-uniform, small-area, two – or three-phase shelterwood cuttings to achieve and maintain the natural regeneration of stands.

Table 34 Biodiversity services assessment, Slovakia

ES	Indicator	FMM									
		I - oak_timber	II - oak-beech_timber	III - beech_timber	IV - fir-beech_timber	V - spruce-fir-beech (timber)	VI - spruce-fir-beech (close-to-nature)	VII - spruce (timber)	VIII - soil (protection)	IX - no intervention	X - water purification
Biodiversity	tree species composition	6	6	4	6	7	7	3	4 - 7	4 - 7	2
Ranking 1 - 7	forest structure	2	4	3	5	6	7	2	3 - 7	3 - 7	2
1 worst - 7 best	disturbance regime	4	4	4	5	5	6	5	6	7	3
	Overall ranking	**4**	**5**	**4**	**5**	**6**	**7**	**3**	**4-7**	**4-7**	**2**

FMM I Oak – wood provision

The model supports the presence of native broadleaves in stand species compositions, although oak dominance is predetermined by site and habitat conditions.

Due to natural oak dominance as fast-growing light demanding species in main tree layer and even-aged character of managed stands, the spatial and dimensional variability is not too large i.e. the uniformity is rather high.

The degree of natural disturbance regime emulation is average, clear-cuts are prohibited, spatial uniformity is allowed but not preferred and longer regeneration periods are usually applied.

FMM II Oak-beech - timber provision

The similar evaluation was used as in the previous case. The model supports the presence of native broadleaves in stand species compositions. The main tree layer is composed of two main species which dominance is predetermined by site and habitat conditions.

The spatial and dimensional variability is higher than in the previous case due to complementary nature of faster-growing, light-demanding oak and slower-growing, shade tolerant beech. On the other hand, the even-aged character of forest reduces the spatial, structural and dimensional variability of trees to an average level.

The degree of natural disturbance regime emulation is average, clear-cuts are prohibited, spatial uniformity is allowed but not preferred and medium regeneration periods are usually applied.

FMM III Beech – timber provision

The species composition of stands managed by the model has rather low diversity. The beech in given natural conditions shows clear tendency to form monocultures with the almost exclusive dominance of European beech. Together with the even-aged character of managed forests, the high species, spatial and structural uniformity similar to spruce monocultures appears. The smaller degree of uniformity is expected compared to spruce monocultures due to the greater incremental plasticity of beech trees and higher proportions of overstorey thinnings against the spruce.

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Natural disturbance emulation is similar to previous cases – once again, spatially non-uniform shelterwood cuttings with medium length of regeneration period is preferred

FMM IV Fir-Beech – wood and timber provision

The high species diversity characteristic for forests managed by the model is intentionally supported. Main tree layer is usually formed by broadleaved European beech and coniferous Sliver fir, an admixture of other valuable (elm, ash, maple) is very frequent.

The species diversity supports also high structural and spatial diversity of trees even within the frame of even-aged concept. The utilization of growing space is high due to different demands of different species in different developmnetal life stages.

Degree of natural disturbance regime emulation is average or slightly above average due to use of prolongated regeneration periods within non-uniform shelterwood system aiming to natural regeneration of trees.

FMM V Spruce-Fir-Beech – timber provision

The description of the previous model is almost completely valid also for this model. The differences lie in even greater species diversity of the main tree layer also manifested in greater dimensional and spatial variability of trees within the even-aged stands. The degree of natural disturbance regime emulation is equal to the previous case and reaches above-average level.

FMM VI Spruce-Fir-Beech – Close to nature

The high species diversity of forest consisting of main tree species in upper canopy layer is supported. Large age, structural and spatial diversity is intentionally supported and maintained. Low intensity, individual selection cuttings irregularly distributed in space quite precisely mimics the natural disturbance patterns.

FMM VII Spruce – Timber

The lower species diversity is characteristic for forests managed by the model regardless of whether they are natural or artificial. Subsequently the dimensional and structural diversity of even-aged monocultures is only at lower than average level even when they are regenerated by non-uniform shelterwood systems.

FMM VIII Soil protection

The species composition diversity in the forests managed by this model is very high due to only slight human interventions of natural processes. The model is used in a broad range of site conditions covering all species composition when prevention of soil erosion is needed. Due to slight human interventions and low commercial utilization the tree species diversity varies between average level (in natural „monocultures“ – oak-dominated stands at lower altitudes, beech dominated stands at medium altitudes or spruce-dominated stands at higher altitudes) and high level (mixtures of conifers with broadleaves at higher elevations or species-rich mixtures of broadleaved at lower elevation). Equivalently to species diversity varies the spatial, structural and dimensional variability of almost natural forests – from average to high levels. The natural disturbance patterns are almost completely emulated.

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FMM IX Nature conservation/No intervention

The species diversity of the forest is very high; the forests managed as natural reserves are intentionally situated in the localities and ecosystems with high species, structural and dimensional diversity. At the same time, they are intentionally exposed to natural disturbance regime. The protection of the natural disturbance regimes is the essence of the model. Despite this assessment, the range of ratings was given for two reasons: (i) old-growth forests are characteristic by the change of three developmental stages – ingrowth, optimum and decay phase on small patches. Moreover, especially the optimal phase is characteristic by the smaller dimensional diversity of trees for a certain period. (ii) Larger scale disturbance is also expected and possible in old-growth forest. When such options occur, the character and diversity of the next tree generation are very similar to even-aged forests.

FMM X Water purification

The forests managed by the model have a nature of artificial even-aged spruce monocultures tended to create the highly unified structure and dense stands. Moreover, the small area clear cuts and frequent large-scale disturbances associated with artificial regeneration of stands are frequently used or needed.

2.7.2. Carbon sequestration assessment

Qualitative assessment of CC sequestration capacity of each FMM was performed by a panel of scientific experts (members of our ALTERFOR team) taking into account Kevin Black's C sequestration Guidelines and some CS area specificities. That means all provided ratings were properly discussed and the final rating is a consensual agreement. By Biodiversity example, we used the scale 1-7, where one means the worst C sequestration ability and seven is related to the maximal level of C sequestration.

The assessment respected the three main C pools agreed to concentrate in Zvolen. For each category, we identified the following driving factors affecting the carbon sequestration:

- Above and below ground biomass – site fertility, rotation age and species compositions
- Deadwood – amount of natural deadwood, amount of harvest residues
- Harvested wood product – the proportions of round wood, pulpwood and fuelwood on growing stocks

Within the assessment process, we assumed the validity of following assumptions, relations and known facts:

- C sequestration is better on good quality sites – we were taken into account knowledge about the spatial distribution of individual FMM on CS area predetermining increased occurrence of lower quality sites in particular FMMs.
- The longer rotations mean more C sequestrated and maintained in growing stocks - the Slovakian rotation ages are determined to utilise of site potential to produce wood biomass fully. Therefore no over-mature forests with lowered sequestration ability exist on CSA, and

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longer rotations mean higher average growing stocks simply due to a longer time of biomass accumulation.

- The different tree species have different ontogenetically given potential to produce biomass - three main species (Norway spruce, European beech and Silver fir) are considered as equivalent from biomass point of view (conifers have a higher volume but lower wood density and vice versa), but oaks and Scots pine are worse (75 % and 60 % from maximum, Sedmák 2013, Halaj, Petráš 1998, STN 480010). Subsequently, if some FMM and their sites supports spruce, fir or beech, they were assessed as better for C sequestration.
- FMM based on active management actions result in a less amount of natural deadwood but a higher volume of harvest residues, but we expected that amount of natural deadwood (if it is left in the area) is always greater than an amount of harvest residues. At the same time, a *higher amount of deadwood was considered as positive from C sequestration point of view because we expected that mean half-live and decay time of Deadwood is larger than half-live of industrial product mix produced from harvested wood.* Due to this, FMM based primarily on passive approaches were assessed as better. Differencing among active FMM was hard due to similar character intensity of thinnings and nature of final cuttings (usually two or three phase non-uniform shelterwood cuttings) and tendency to fully utilise of wood for commercial purposes.
- Regarding harvest products, the proportion of three broad assortment classes (roundwood, pulpwood and fuelwood) on growing stocks and harvests were estimated. We expected that life cycles of products made from roundwood are longer in general than from pulpwood and pulpwood products have longer life cycles than fuelwood ones. The FMM with higher proportions of round- and pulpwood were considered as better for C sequestration.

Table 35 Carbon sequestration assessment Results Slovakia

ES	Indicator	FMM									
		I - oak_timber	II - oak-beech_timber	III - beech_timber	IV - fir-beech_timber	V - spruce-fir-beech (timber)	VI - spruce-fir-beech (close-to-nature)	VII - spruce (timber)	VIII - soil (protection)	IX - no intervention	X - water purification
C sequestration	site fertility	2	3 - 4	4 - 6	7	7	4 - 5	4 - 7	2 - 5	4 - 7	4
Ranking 1-7	species composition	4	5	7	7	7	7	7	4 - 7	7	7
1 worst - 7 best	rotation age	4 - 6	2 - 4	2 - 4	3 - 5	3 - 5	5	1 - 3	7	7	1
	biomass production	**3-4**	**3-4**	**4-6**	**6**	**6**	**5-6**	**5-6**	**4-6**	**6 - 7**	**4**
	deadwood	**4**	**4**	**4**	**4**	**4**	**4-5**	**4**	**6-7**	**7**	**4**
	roundwood	45	40	30	35	40	50	40	-	-	30
	pulpwood	35	50	60	55	50	40	50	-	-	60
	firewood	10	10	10	10	10	10	10	-	-	10
	products	**5**	**4**	**2**	**3**	**4**	**5**	**4**	**6**	**7**	**2**
	Overall ranking	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**6**	**7**	**3**

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FMM I Oak – wood provision

The forests managed by the model have a slightly lower-than- average or average biomass production potential, mainly due to oak-dominance and lower than the average fertility of sites (long-term pressure of local consumption, grazing, litter extraction, ...). Contrary, very long rotation ages (up to 170-180 year) support C sequestration and partly off-set the negative effects of lower fertility of sites.

The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood). This justification is fully valid for all FMM which are based on active management of normal age class forests oriented to financial incomes from wood and biomass market.

Assortment structure is rather favourable. The long rotations and orientation of silviculture on the production of thicker, highly valuable oak assortments increase the roundwood proportions obtained from harvests, although this tendency is partly offset by the lower quality of sites covered by oak-dominated forests.

FMM II Oak-beech - timber provision

Similar to the previous model, forests managed by FMM II have slightly lower-than- average or average biomass production potential, but the main reason is changed – the typical rotation ages are much shorter than in the previous case (up to 120 years). At the same time, the presence of oak as the species with smaller biomass production potential in the species compositions is still remarkable. On the other side, typical site fertility is better in comparison to oak-dominated stands, and the beech has a greater biomass production potential than oak in general.

Evaluation and justification of deadwood are equal to the previous case. The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood).

Assortment structure is a little less favourable in comparison of oak-dominated forests, the proportion of roundwood is smaller. The main reasons are shorter rotation ages in combination with the higher presence of beech on species composition which results in a higher proportion of trees with smaller dimensions at the end of the rotation period. However, the difference is not large due to the somewhat higher fertility of sites covered by oak-beech forests.

FMM III Beech – timber provision

The forests managed by the model have average to higher biomass production capacity, mainly due to beech-dominance and good quality of sites. Rotation ages are average and typical for beech stands in Slovak conditions (up to 120 years).

The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood).

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Assortment structure is less favourable. The smaller proportion of roundwood in favour of a higher proportion of pulpwood is expected due to general tendency of beech produce less valuable assortments (the creation of heartwood at rather young ages is a frequent problem).

FMM IV Fir-Beech – wood and timber provision

The forests managed by the model have higher biomass production capacity because main tree species (beech, fir) have the high biomass production potential, and mixed stands are more productive than monoculture due to better use of growing space and greater ability to mainly due to beech-dominance and good quality of sites. Rotation ages are average and higher-than-average due to fir presence in species composition which is typically managed by longer rotations (up to 140 years) due to its slow rate growth nature, low requirements for light and great increment plasticity even in older ages.

The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood). The fir residues are frequently burned on site to prevent random fire risks.

The good quality of sites and participation of Silver fir on species composition lead to a higher ratio of roundwood in growing stocks in comparison to beech-dominated stands. Still, the percentage of roundwood remain lower than it was for FMM with the oak presence (shorter length of rotation).

FMM V Spruce-Fir-Beech – timber provision

The highly-productive species composition characteristic for forest managed by the model is partly negatively balanced by shorter rotation periods of Norway spruce (90-110 years) and somewhat less fertile sites (higher altitudes). Overall, the biomass production capacity is above-average approaching the environmentally given maximum.

The amount of deadwood and harvest residues left in stands is rather low (minimal requirements of FSC certification) due to effort maximally utilise of wood production. The Norway spruce and Silver fir harvest residues are frequently burned on site to prevent random fire risks.

The proportion of roundwood is the same as it is in mixed broadleaved stands due to higher participation of conifers with less stem form variability, good site conditions and average or less than the average length of rotation.

FMM VI Spruce-Fir-Beech – Close to nature

The favourable tree species composition managed to support species, dimensional and spatial variability and longer rotation ages (close to 160-180 years) initially determine high biomass productivity. On the other hand, the effort to maintain continual regeneration of stands lead to the selection of lower quality sites for the model application (to prevent the weed problem). Overall, the biomass production capacity of the model is still above average, although not to such level as it was in the previous case in the forest with similar species composition.

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The amount of deadwood left in the stands is a higher than in previous models, harvest residues are all left in the stand whereas harvest interventions have a character of selection cut and removal of harvest residues encounters a series of technical obstacles.

The longer rotation periods and assessment of tree felling maturity according to the target dimensions together with the high presence of conifers in tree species composition lead to increased proportions of roundwood that is favourable for carbon sequestration.

FMM VII Spruce - Timber

Spruce-dominated stands are very productive from biomass point of view. The spruce stands belonging to the described model are twofold: (i) spruce-dominated original stands growing at highest altitudes of the mountain range at relatively less fertile sites, (ii) secondary spruce monocultures out of its natural range growing on fertile sites at low and medium altitudes. The first group of stands has an only average predisposition for biomass production, but the second group is characteristic by high production capacity. Rotation ages are significantly shorter than previous cases (between 70-100 years) which partly dampen the previous positive assessment of C sequestration capacity.

The amount of deadwood and harvest residues left in stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production. The harvest residues are frequently burned on site to prevent random fire risks.

The proportion of roundwood is average, on the one hand, the spruce is fast-growing highly-productive species (especially on fertile sites), on the other hand, shorter rotations prevent to attain large dimensions of harvested trees.

FMM VIII Soil protection

The model cover a broad range of species compositions from lowest altitudes to highest parts of CSA, but generally on bad quality sites with very low to low fertility. Another characteristic feature of forest managed by the model is a very long rotation and slight selective interventions irrespective the tree species compositions to maintain the full cover of soils usually situated on steep slopes. That fact leads to the assessment of average or above average biomass production capacity when a very long rotation periods and almost absence of intentional harvests prevails the poor site quality in the final decision.

The amount of deadwood and harvest residues left in stands is high. All amount of natural deadwood and any harvest residues are left on the stand area to cover soil surface and prevent water or wind soil erosion.

The proportion of assortment classes was not performed, the commercial utilisation of harvested wood is possible only in rare cases due to high harvest and transportation costs and lower quality of wood.

FMM IX Nature Conservation

The model is applied to mixed highly-productive forests at medium or higher altitudes (exceptionally on worse sites) and supports natural, human non-disturbed growth of trees within its

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whole life cycle. The biomass and carbon sequestration capacity are very high. Moreover, all amount of deadwood remain in the ecosystem, and any human intervention is performed due to passive management. No wood products are produced. It follows the almost ideal carbon sequestration capacity of the model.

FMM X Water purification

The model is applied in the narrow protection zone of the water reservoir in artificial spruce monoculture. The production capacity of the site is average. The rotation periods are short (70-90 years) due to the lower ecological stability of nivelised, even-aged mono-specific forests.

No deadwood is allowed, all harvest residues are strictly removed from the stand (to protect water quality against N leak).

The proportion of roundwood on growing stock is lowered/below average in comparison to other models, primarily due to short rotation ages and maintaining the forest in high density negatively affecting the dimension of trees (high number of trees with smaller dimensions characteristic for over-dense stands).

Due to adverse effects of species composition and rotation ages in forest growing on average site quality, the absence of deadwood and relatively low proportion of roundwood on assortment structure the capacity of the model for carbon sequestration was assessed as slightly below average.

2.7.3. Cultural Services assessment

Assessment of cultural ES was based on expert judgement, no DSS or quantitative data has been used in the assessment. Panel of experts was created from ALTERFOR members. Assessment was based on Guidelines for Cultural Services from Marjanke and Geerten. We used the scale from 1 (worst provision of ES) to 7 (best provision of ES). In some cases comparison baseline was used. The baseline was represented by artificial spruce monoculture.

Sense of care – Amount of residue from harvesting and thinning per ha

7 is representing state, where no residue from harvesting and thinning are left in the stand. This state is in FMM IX, where any active human interventions are prohibited and in FMM X where all residue are strictly removed due possible contamination of drinking water by these residue. In FMM I to V are left some residue (branches), but most residue are removed or burned. This is prevention against insect and fungi spread and fire in forest stands.

Alteration – Area of final felling / Frequency of final felling

Clear cuts are not allowed in Slovakia. In FMM VII (spruce) are often disturbances on bigger area and result is similar to clear cuts. Rotation and regeneration periods in most FMMs are long, around 100 years and longer. Only in FMM X is rotation period shorter and also due possible damage due disturbances is the rank lower.

Natural value – Naturalness of forest stands

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According to guidelines FMM I, II, III, IV and V belongs to Semi natural forests. In each FMM could be differences according to site condition and to this related management and species mix. Therefore interval 3 – 5 was used. FMM IX is natural forest, on the other hand FMM X is relatively far from natural forest - artificial spruce monoculture with strict management rules. FMM VIII is used on extreme site condition (soil protection). Forest stands are under management with respect to site condition. But some parts could be without management in regard to high slope, or other conditions that limits management of these forests.

Wilderness – Amount of natural dead wood

In FMM I to VII is most of dead wood removed from forest stands. . This is prevention against insect and fungi spread and fire in forest stands. More dead wood is left in forest stand that are under certification. More dead wood is left in FMM VIII, because remove of this wood is sometimes not economically effective and dead wood (trees) increase stability of soil until new trees grow up. All dead wood is left in FMM IX, and all dead wood has to be removed in FMM X - possible contamination of drinking water.

Intrusion – Naturalness of forest edges / edge effects

Clear cuts are not allowed in Slovakia. Shelterwood management is used in most of FMMs. Linear (not natural) edges are created by roads and in neighbourhood of fields with intensive agricultural management. In higher altitude are more natural edges, due fact, that there is not so intensive human intervention. According to forest management are FMM I to V and VII with lower ranking.

Diversity – tree species diversity within stand

Species mix in forest stands of Slovakia could be rich, with more than tree species. FMM goals and possible species mix was used for assessment. Assessment was in regard to species richness according to Slovak conditions. The goal of FMM X is spruce monoculture without broadleaves. In FMM VII are other species mostly as admixture. In FMM VIII is number of tree species different according to altitude and site conditions.

Variety – Variation in tree size within stand / Age structure

The variety of commercial forest depends on species in forest stand. Oak in FMM I has less tree size variety than beech in FMM III. Higher tree size variety is in FMM IV, V and VI due mixture conifer and broadleaves species. In FMM VI is also high variety in age structure. Variety in FMM VII depends on altitude and site conditions. Highest variety in tree size and age is in FMM IX due prohibition of human activities. On other hand, lowest variation is in FMM X - spruce monoculture.

Spatial pattern – Variation in tree spacing within stand

In FMMs that are closer to natural conditions is spacing irregular. In FMM VIII is irregular spacing due site conditions. Regular spacing is used by artificial regeneration, but this regular spacing is lost through pre-commercial thinning, thinning and felling (FMM I to V). Regular spacing after artificial regeneration in FMM VII and X could be identify for longer time.

Openness – Visual penetration / density of obstruction

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The basic philosophy was how the "play of light and shadow" in forest stands is; leak of the light through crown canopy. Thinning from above is used in forest stands with broadleaves. Canopy is therefore opened. On other hand, in conifers (spruce monoculture) thinning from below is used. In even age oak stands under FMM I is higher uniformity than beech stands under FMM III. Oak is light demander and all gaps in crown canopy are quickly filled. In higher altitude (on hills) forest stands in FMM VII are more opened than in lower altitude. Frequent management actions in FMM VI leads to opening of canopy. Openness in FMM IX depends on altitude and to this related species in stand and growing phase of forest. Goal in FMM X is dense crown canopy. FMMs with mixed main tree species are more opened due different tree size. Forest stands in FMM VIII are more opened due extreme site conditions.

Visibility – Presence of understory in stand

From 1 – dense understory and therefore very low visibility in forest stand; to 7 – no understory in forest stand. Understory is not present in FMM X; shrubs and trees in understory are removed. Lot of trees in understory is in FMM VI – different age classes on small place. Lot of shrubs and trees in understory could be in FMM VIII, depends on altitude and site condition. Similar situation is also in FMM IX.

Historical richness – Age of trees in stands

Assessment was based on situation in Slovakia. Most of forest stands are even aged. Rotation and regeneration periods were used for this assessment. They are long, for some tree species more than 100; especially oak and fir. Rotation period in stands with spruce is from different reasons shortened (bark beetle calamity, damage due different harmful factors). Trees with different age in one forest stand (some more than 200 years) are in stands under FMM IX. Old trees are located also in stands under FMM VIII. Tree size as felling criterion is used in FMM VII. Trees with different age are in forest stands under FMM VII, but there are not over-mature trees.

Historical continuity – Age of current land-use

Historical research has to be done. Our assessment was based on assume, that most of forest land on CSA is longer than one rotation period (rank 7). After WWII began afforestation of agricultural and pasture land. The afforestation was made mostly with spruce – FMM VII. Water reservoir Hriňová was built in 1965. Around this reservoir are forest stands under FMM X.

Seasonal change – Presence of broadleaves

First criterion was presence of broadleaves. FMM X is spruce monoculture. Spruce in forest stands under management FMM VII could be mixed with some broadleaves. Second criterion was also mix of broadleaves and their different time of flowering and defoliation. Better rank is for FMMs with more broadleaves.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Table 36 Cultural Services assessment, Slovakia

ES	Indicator	FMM									
		I – Oak (timber)	II - Oak-Beech (timber)	III – Beech (timber)	IV - Fir-Beech (timber)	V - Spruce-Fir-Beech (timber)	VI - Spruce-Fir-Beech (close-to-nature)	VII - Spruce (timber)	VIII - Soil protection	IX - No intervention	X - Water purification
Cultural	sense of care	5	5	5	5	5	6	5	6	7	7
	alteration	7	7	7	7	7	7	5 - 7	7	7	6
	natural value	3 - 5	3- 5	3 - 5	3 - 5	3 - 5	5 - 6	1 - 7	5 - 7	7	1
	wilderness	2 - 3	2 - 3	2 - 3	2 - 3	2 - 3	2	2 - 3	7	7	1
	intrusion	3 - 5	3- 5	3 - 5	3 - 5	3 - 5	4 - 6	3 - 5	4 - 6	7	2
	diversity	3	3	3	5	5 - 7	5 - 7	1 - 2	3 - 7	5 - 7	1
	variety	3	4	4	5	6	6	2 - 4	5	6 - 7	1
	spatial pattern	4	4	4	4	4	6	2	6	7	2
	openness	5	4	3	4	4	5	2 - 5	3 - 5	3 - 6	1
	visibility	4	5	5	5	5	1	5	1 - 4	2 - 5	7
	historical richness	4 - 6	2 - 4	2 - 4	3 - 5	3 - 5	5	1 - 3	7	7	1
	historical continuity	7	7	7	7	7	7	5 - 7	7	7	5
	seasonal change	5	6	5	5	4	4	1 - 3	5 - 7	3 - 6	1
Overall ranking		4-5	4-5	4-5	4-5	4-5	5	3-4	5-6	6-7	3

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2.7.4. Regulatory Services assessment

Every year the biggest damage to forests is caused by wind. In the winter, coniferous stands under the age of 50 are particularly vulnerable to severe wet snow and frost. Further, the stands are damaged to a greater extent by dryness, insects and fungi. Fire as a disturbance factor in Slovakia is not significant. In the period 1996-2014 wind damage reached 17.3 million. m^3 of wood with a majority share of spruce and beech (with peaks in 2004 and 2014), insect damage in the period 1993-2013 reached 24.7 million. m^3 of wood, in the period 1990-2014 damage caused by fungi was registered 4 mil. m^3 of wood.

Ranking is based on expert judgement of project research team, supported by earlier research from actual CSA. It is based on general characteristics as dominant tree species (root system type), presence of understory (stabilizing element) and forest stand structure (greater height variation). Ranking was in values from 1 to 5. 5 to most vulnerable forest stand on catastrophic event (non-native spruce stands as most vulnerable were used as comparison base).

Wind

The oak-dominated portions (FMM I) are stable with low occurrence of wind throw. On the contrary, in the stands where the dominant beech (FMM II-IV) occurs, the probability of the occurrence of the wind calamity increases. Landscapes with a larger proportion of different tree species (FMM V, VI and IX) and relatively greater height variability act as a stabilizing element. Also resistant are forest stands with soil protection function (FMM VIII), where thanks to the unfavorable natural conditions structure is resistant to wind - they are thinner, with a lower growth, etc. The most vulnerable are spruce stands usually with spruce dominance in the vicinity of water tanks (FMM X) and non-native spruce monocultures, which are at high risk of wind damage, but also include vertebrae relatively resistant to wind.

Snow and icing

Occurrence of damage caused by snow and icing mainly coincide with wind damage occurrence with exceptions in forest stands with beech dominance and higher presence coniferous tree species. In these forest stands occurrence increases. Broadleaves, especially beech (FMM II, III, IV, V, VI) are vulnerable to snow and icing damage in spring and fall when they are foliaged.

Pests

Oak forest stands (FMM I) are often damaged by Lymantria dispar as most important pest in oak forests. As beech dominance rises (FMM II), resistance increases. Spruce (FMM VII) is very often damaged by pests so stands where is present are less resistant with exception with spruce stands on mountain tops (in his production optimum) where is more resistant to disturbances. In stands with no intervention formed by a different mixture of tree species, especially occurrence of spruce, reduce resistance to pests (high damage of natural spruce stands in present protection land area). Stands with soil protection function mainly of deciduous trees, which are not intensely attacked by pests.

Aridity

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Forest stands with applied FMM I-IV are not endangered by drought, tree species composition is more resistant. Due to increased requirements for water content, spruce is especially sensitive to droughts. Nevertheless, in higher locations, lack of available water supply is not a problem. Due to higher precipitation and lower evaporation.

Fungi

Forest stands with intensive management are relatively resistant to fungal diseases, more frequent occurrence only in the case of the weakening of whole stands, where the fungus is occurred secondary. Fungal diseases in case of spruce monocultures are most frequent in non-native spruce stands in lower altitudes and in the vicinity of water tanks are least resistant.

Fire

Fire is not a very damaging factor in our conditions. It occurs especially in the vicinity of settlements, hiking trails and facilities, while working in the stand (burning residue from harvesting and thinning), and burning grass. In recent years there has been an increase in fires. The rating was 2 for FMM X and FMM VII (young conifers are more susceptible). The other FMM was assigned a value of 1.

Table 37 Regulatory services assessment

FMM	Vulnerability to catastrophic events						
	Wind	Snow and icing	Pests	Aridity	Fungi	Fire	Overall ranking
I - oak (timber)	2	2	3	2	2	1	2
II - oak-beech (timber)	3	3	2	2	2	1	2
III - beech (timber)	3	4	1	2	2	1	2
IV - fir-beech (timber)	3	3	1	2	2	1	2
V - spruce-fir-beech (timber)	2	2	2	3	2	1	2
VI - spruce-fir-beech (close-to-nature)	2	2	2	3	2	1	2
VII - spruce (timber)	2-5	3-5	3-5	3-5	2-5	2	3-5
VIII - soil (protection)	2	2-3	2-3	2-4	1-3	1	2-3
IX - no intervention	1-2	2-4	2-4	2-3	1-2	1	2-3
X - water purification	5	5	3-5	5	4-5	2	4-5

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2.7.5. Water related services assessment

In our assessment, we used the recommendations defined in the Guidelines for Water 2 with respect to the assessment of specific/partial ES (water yield, flood protection, water flow maintenance, erosion control, chemical conditions), usable indicators as well as parameters, data and metrics usable for future more detailed assessments using DSS. We emphasized manner of performing the final logging (the potential for clear-cuts creating), the tree species composition of the stands, the age and structure of the stands (age layers existence, brush undergrowth existence, complex stand structure) due felling age/rotation, type of final logging as well as the need for opening-up/road density for management/logging interventions performance. In all cases, we used a 7-degree qualitative scale 1 – for the worst ES performing, 7 – for the best ES performing.

The evaluation is very general with some simplifications, a generalisation of details and based on expert judgment. The values in Table 38 are the result of a multi-expert discussion as a consensus of a relative qualitative comparison with the application of basic assessment on the stand level. At the same time, we have begun consultations with forest hydrology experts to verify the validity of the Guidelines rules for local Slovak conditions, the existence of relevant domestic knowledge, and/or the need to correct the Guidelines recommendations. It can also be noted, that such an interim evaluation has highlighted a number of open questions and lack of precise knowledge in this area and provided interesting suggestions for future CSA stand assessment using DSS, as well as the need to take into account the context of more detailed assessments and/or assessment on landscape level.

Water yield

The logic applied - the forest uses water for transpiration, the older ones, the more, a run-off is higher from the clear-cuts, broadleaves are more water productive than the coniferous, the longer rotation, the water yield will be lower.

FMM I – Oak timber: Oak-dominated broadleaved forest, typical of the long rotation, the frequent occurrence of brush undergrowth, lower biomass production compared to European beech (75%).

FMM II – Oak-beech timber: Taking into account the effect of tree species composition.

FMM III – Beech timber: Beech-dominated broadleaved forest, shorter rotation compared to oak, more biomass than oak vegetation, typically without understory but with the possibility of low layer stand existence.

FMM IV – Fir-beech timber: Taking into account the effect of tree species composition.

FMM V – Spruce-fir-beech timber: Taking into account the effect of tree species composition.

FMM VI – Spruce-fir-beech close to nature: Taking into account the effect of tree species composition and higher management intensity.

FMM VII – Spruce timber: Pure coniferous vegetation, relatively short rotation, the possibility of using a small clear-cuts, a more intensive management.

FMM VIII – Soil protection: Typically the overall higher representation of the broadleaves, the creation of storeys.

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FMM IX – No Intervention: Natural, highly structured forests retain the most water.

FMM X – Water purification: Pure coniferous forest, short rotation, spruce with high water requirements.

Flood protection.

The logic applied - coniferous stands, long rotation and storeys formation were preferred, virgin forests protect the area from floods.

Water flow maintenance.

The logic applied - the more management/logging interventions, the higher run-off fluctuation during the year, Close-to-nature stands are typical of the different age stages that form the pitches/layers, in the stands, No management is similar to CTN but with a larger distribution in the space, for spruce dominant stands are typical clear-cut-like interventions (even as a result of calamities), the natural conditions of Protective Forests do not allow large water retention - they have shallow soils, overheated sites, etc.

Erosion control – corresponding with Flood protection

Chemical conditions

The logic applied - benefits are old trees, deciduous trees, long rotations and few management and logging interventions (risk of oil and fuel pollution, etc.)

FMM I – Oak timber: Oak-dominated broadleaved stands, long rotations.

FMM II – Oak-beech timber: Taking into account the effect of tree species composition.

FMM III – Beech timber: Beech-dominated broadleaved stands, shorter rotations.

FMM IV – Fir-beech timber: Taking into account the effect of tree species composition.

FMM V – Spruce-fir-beech timber: Taking into account the effect of tree species composition.

FMM VI – Spruce-fir-beech close to nature: Frequent management interventions, permanent soil cover.

FMM VII – Spruce timber: Unfavourable chemistry, shorter rotations in the lower vegetation zones.

FMM VIII – Soil protection: Prevailing of deciduous tree species, very long rotations, management interventions are not frequent and intensive.

FMM IX – No intervention: Occurrence of old trees, no management interventions, absolutely without application of chemicals.

FMM X – Water purification: Unfavourable chemistry, short rotations, frequent and intensive management interventions, even if it is forbidden to use mineral oils in a saw.

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Table 38 Water related ES assessment Slovakia

ES	Indicator	FMM									
		I – Oak (timber)	II - Oak-Beech (timber)	III – Beech (timber)	IV - Fir-Beech (timber)	V - Spruce-Fir-Beech (timber)	VI - Spruce-Fir-Beech (close-to-nature)	VII - Spruce (timber)	VIII - Soil protection	IX - No intervention	X - Water purification
Water	water yield	5	4	4	4	3	2	2	3	1	3
	flood protection	3	4	4	4	5	6	4 - 6	5	7	5
	water flow maintenance	3	4	4	4	5	7	2	4	7	2
	erosion control	3	4	4	4	5	6	4 - 6	5	7	5
	chemical condition	6	5	5	5	5	4	1 - 3	6	5 - 7	2
Overall ranking		4	4	4	4	5	5	3-4	5	5-6	3

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2.8. Sweden

2.8.1. Contrasting the relative biological diversity of Sweden's stand level FMMs

We used previously identified biodiversity goals for Sweden (Felton et al., 2016a) to identify positive vs. negative outcomes for three key determinants of habitat availability in production forests: Tree species composition, forest structures, and spatial-temporal disturbance patterns. We then ranked each FMM and in most cases their relevant subcategories, on a 7 point scale with respect to each of the three key determinants of forest habitat availability, with an average of the three scores providing a summary rank (Table 39). The allocated ranking was determined by two researchers with expertise evaluating the biodiversity contribution of different production forest alternatives in Sweden. As there is an unavoidable element of subjectivity in this assessment, the net result should be as an approximate indicator of relative biodiversity value. Inevitably the net biodiversity value of any FMM will vary with biogeographical context, the availability of source populations, and the availability of habitat alternatives in a landscape. See the associated text for motivation, and the summary FMM document for full descriptions of the FMMs assessed.

Clearcutting with intermediate rotation – Norway spruce.

Rotationally clear-cut even-aged stands of Norway spruce dominated stands, though native, are intensively managed, structurally-simplified, single-species dominated, and thus relatively homogenous production forest alternatives (Felton et al., 2010). This FMM is the most dominant form of production forest in this region by volume (SFA, 2014). Whereas this FMM does use a native conifer tree species, the FMM overall provides only limited allowance for broadleaf and other tree species which are largely removed during pre-commercial and commercial thinning (with the exception of those provided by green tree retention). Note that the loss of broadleaves and the widespread structural simplification of forest cover, are two key drivers of biodiversity concerns in this region (Lindbladh et al., 2014a). Due to its homogenous even-aged structure, these stands likewise are generally lacking in adequate deadwood accumulation and structural heterogeneity for support many forest-associated species. Likewise, the use of clearcutting is inconsistent with attempts to better align production forest disturbance regimes with the natural disturbance regimes of this region, which would involve smaller scale disturbances and better allow for natural processes of growth and decay (Kuuluvainen, 2009). The net result is an intensively managed, widely applied, conifer dominated, and greatly simplified forest ecosystem, with therefore relatively limited biodiversity values. Note also that current rotation times are likely to get shorter in the future (Roberge et al., 2016; Felton et al., 2017).

Clearcutting with intermediate rotation – Scots pine.

Whereas Scots pine production forests likewise involve the rotational clearcutting of even-aged stands, this stand type supports distinct floral and fauna communities, and is declining in the landscape primarily as a result of its vulnerability to increased browsing pressure by forest ungulates (Månsson et al., 2007). With respect to biodiversity, pine stands provide different bark and dead wood characteristics, and their more open crowns and branches alters the understorey microclimatic and soil conditions that arise (Kuusinen, 1996; Jonsell et al., 1998; Barbier et al., 2008). As a result Scots pine forests are often found to support distinctive communities of epiphytic lichens (Marmor et al., 2013); macrofungi (Ferris et al., 2000); bryophytes (Augusto et al., 2003);

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and birds (Gjerde and Saetersdal, 1997). In addition, Bilberry (*Vaccinium myrtillus*) is often associated with Pine stands (Miina et al., 2010), which is also important food resource for many species. Pine itself also provides a substantial part of the winter diet for Moose and roe deer. For these reasons we rank Scots pine higher than Norway spruce in terms of habitat provision and associated biodiversity value in this region.

Clearcutting with intermediate rotation – Spruce-birch mixture.

Spruce-birch mixtures are ranked higher than spruce monocultures, due to the benefits of diversifying tree species composition via the addition of a broadleaf tree species, with the additional implications for understorey conditions. The addition of a broadleaf tree species will likely increase levels of soil insolation and rates of nutrient cycling, raise soil quality in terms of mineral content and carbon:nitrogen ratio, and therefore benefit the diversity of vascular plants and associated taxa (Barbier et al., 2008; Felton et al., 2016c). Stand-scale increases in species richness and abundance may be expected for birds, understory vegetation, saproxylic beetles, and lichens (Felton et al., 2010). Recent reviews and empirical studies thus provide substantial justification for expecting increased biodiversity benefits with the use of this FMM relative to Norway spruce monocultures (Felton et al., 2010; Felton et al., 2011; Felton et al., 2014; Felton et al., 2016c).

Clearcutting with intermediate rotation – Spruce-pine mixture.

Spruce-pine mixtures are ranked higher than spruce monocultures, due to the addition structural complexity of adding pine to the stand and the associated biodiversity benefits linked to this tree species specific characteristics, as outlined above (Felton et al., 2016c).

Clearcutting with short rotation - birch

The advantages of using broadleaf tree species within stands, is that by so doing production forests help to rectify long terms trends in regional land-use change which have generally acted to reduce the percentage cover of broadleaf trees, in favor of conifer trees (Lindbladh et al., 2014a). For this reason, even-aged birch dominated stands are considered more positive for biodiversity than conifer dominated stands. These benefits are however tempered by the relatively short rotations (Felton et al., 2016a). It is important to note however that birch is a pioneer tree species and often has a shorter natural lifespan than other tree species in the region (e.g. pine, oak).

Clearcutting with short rotation – hybrid aspen

Whereas the use of hybrid aspen is consistent with the goal to increase the proportion of broadleaf trees, it requires caveats with respect to the goal to favor native tree species and the associated limitations of short-rotation forestry (Felton et al., 2016a). There are also are concerns regarding the extent of introgression occurring between hybrid aspen and wild populations of European aspen. These are risks that may increase with climate change (Felton et al., 2013). We also note that there are substantial uncertainties regarding whether hybrid aspen has the same epiphytic benefits of European aspen with respect to the bark conditions provided. Furthermore, hybrid aspen's intensive rate of growth enables stands to reach heights in 25 years that are comparable to Norway spruce during normal rotation periods of 60–70 years on similar sites. The associated benefits in terms of tree size must however be balanced by the short time window for establishment, and the need for stable substrates. . Further complexity is added by the need to

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fence these stands and the associated diverse structurally complex understories that result from the absence of ungulate browsing (Lindbladh et al., 2014b). For these reasons hybrid aspen stands have aspects that are both potentially consistent and inconsistent with biodiversity goals addressing forest structures.

Clearcutting with short rotation – hybrid larch

Hybrid larch is a cross between European larch (*Larix decidua*) and Japanese larch (*Larix kaempferi*), and neither are native to Sweden. As such this FMM involves a combination of clearcutting, short rotation, and hybrid exotic conifer, and is thus considered very low in terms of general biodiversity value. However, in relation to understorey biodiversity (Felton et al., 2013), there are some indications that the relatively sparse and deciduous nature of larch canopies, can favor a relatively rich understorey of flora compared to dense canopied conifers (Barbier et al., 2008; Wang et al., 2009).

Clearcutting with long rotation - Oak

Whereas oak production stands are managed using the same intensive prescriptions as other even-aged monocultures, this FMM is managed over relatively extended rotation periods and involves one of the most important broadleaf tree species for biodiversity in Sweden. Oak is associated with a substantial number of species from a wide range of taxa (Jonsell et al., 1998; Thor, 1998; Berg et al., 2002; Götmark and Thorell, 2003; Koch Widerberg et al., 2012; Felton et al., 2016b), many of which are threatened (Gärdenfors, 2015). For this reason oak production stands achieve the highest biodiversity value of the production forest alternatives assessed.

Uniform shelterwood – Scots pine

Unifrom shelterwood involving Scots pine ranks slightly higher than clearcutting with intermediate rotation Scots pine, due to the allowance for some percentage of mature trees to temporarily remain after clearcutting to act as seed trees. As these trees provide larger categories of dead wood when they blow down, they are slightly more consistent with goals for forest structures.

NS – nature conservation with management

Although nature conservation with management can be expected to provide higher biodiversity values than many of the production forest alternatives, these values are like to range widely and thus are provided with a range of scores for the aspects assessed.

N – Voluntary and official set asides

Although voluntary and official set asides can be expected to provide higher biodiversity values than many of the production forest alternatives, these values are like to range widely and thus are provided with a range of scores for the aspects assessed.

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Table 39 Six Swedish FMMs and associated subcategories ranked in terms of their relative capacity to close the gap between the habitat provided in production forests and the habitat requirements of forest dependent flora and fauna. See Felton et al. (2016a)

FMM	FMM subcategory	Tree species composition (Native trees, broadleaf trees, tree species diversity)	Forest structures (older / larger trees coarse woody debris)	Disturbance regime (emulate natural disturbance regimes spatially and temporally	Rank out of 7
Clear cutting with intermediate rotation	Norway spruce (>70% basal area)	2	2	2	2,0
	Scots pine (>70% basal area)	3	3	3	3,0
	Spruce-birch mixture (30%-70% birch)	5,5	3	3	3,8
	Spruce-pine mixture (30%-70% pine)	4,5	3	3	3,5
Clearcutting with short rotation	Birch	5	3	3	3,7
	Hybrid aspen / populous	3	3	1	2,3
	Hybrid larch	1	1	1	1,0
Clearcutting long rotation	Oak	6	5	4	5
Uniform shelterwood Pine	Scots pine shelterwood	3	3,5	3	3,2
NS - Nature conservation with management	Mix of tree species possibilities but, mostly beech, oak, broadleaves	2 to 7	5 to 7	7	4 to 7
NO- Voluntary and official set asides	Mix of species possibilities	2 to 7	5 to 7	7	4 to 7

2.8.2. Contrasting the relative and absolute carbon mitigation value of Sweden's stand level FMMs

We used the Heureka system to compute the figures for stock of C in forest and HWP and the resulting figures on harvest to assess the substitution effect of HWP. The system estimates the C

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content on all fractions of biomass related to trees and has in addition a soil carbon model, thus enabling a rather comprehensive assessment of C stock.

The assessment is based on the same stand input in order to make a comparison possible. It may well be that the different FMM normally find use under different site conditions, but differentiating them would make comparisons rather difficult. Another feature of the assessment is that we made a steady-state analysis, i.e. the assessment answers to the question "What is the stock and flow for a normal forest given the FMM?" One reason for that is that the initial state would have such an impact that comparing different FMM based on them would be rather meaningless. This would not be a problem if all FMM were even aged FMM; however, the continuous cover FMM and the no management FMM cannot reasonably be initiated with the same state as rotation FMM. You may then run the model for a very long time to make the initial state less important; yet this does not work with Heureka where age tends to slow growth for continuous cover FMM and no management forest.

The assessment should be interpreted with great care. The relative ranking of FMM is dependent on the fact that they are based on the same conditions. It may well be that another ranking could result if conditions were different (e.g. less fertile soils) and FMM application adapted to those conditions. The common site conditions assumed correspond to the average conditions in the Kronoberg CSA (Table 40). All FMM were simulated for 400 years. The data for the rotation FMM were taken from the last rotation over the 400 years to have soil carbon to stabilize. The continuous cover FMM were assessed as average over years 100-200 (production tends to decrease for longer periods) and the no management FMM over the years 200-400.

Table 40 Site conditions assumed correspond to average conditions in Kronoberg CSA

Altitude (m)	Latitude (°)	SIS (m at age 100)
178	56.8	27

The assessment follows the minute instructions in "Guidelines for C sequestration DSS" to the extent possible. After the evaluation a few comments on the instructions are given in case an updated C guideline will be made available.

The FMM descriptions below are shortened descriptions of what is found in the document Biodiversity Sweden.

Clearcutting with intermediate rotation – Norway spruce.

Rotationally clear-cut even-aged stands of Norway spruce dominated stands, though native, are intensively managed, structurally-simplified, single-species dominated, and thus relatively homogenous production forest alternatives (Felton et al., 2010). This FMM is the most dominant form of production forest in this region by volume (SFA, 2014). Whereas this FMM does use a native conifer tree species, the FMM overall provides only limited allowance for broadleaf and other tree species which are largely removed during pre-commercial and commercial thinning (with the exception of those provided by greentree retention).

Clearcutting with intermediate rotation – other species.

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/The intermediate rotation is only reported for the spruce monoculture FMM motivated by the rather similar implications for C stock and flow that would result from other combinations. /

Clearcutting with short rotation – larch

It is interesting to evaluate the potential for a fast growing species with short rotation with respect to C stock and flow. Unfortunately, Heureka is not equipped with hybrid species like hybrid aspen or hybrid larch. The best we could do was ordinary larch. Thus, the figures for this FMM represent most certainly an underestimate of what is actually possible for a short rotation FMM.

Clearcutting with short rotation – other species

/The short rotation FMM is only reported for larch because other species would probably show results that are even more an underestimate of the potential of the FMM/

Clearcutting with long rotation – Oak

Whereas oak production stands are managed using the same intensive prescriptions as other even-aged monocultures, this FMM is managed over relatively extended rotation periods and involves one of the most important broadleaf tree species for biodiversity in Sweden.

Uniform shelterwood – Scots pine

/This FMM is not evaluated because it would most likely perform as good as intermediate rotation spruce. Additionally, the FMM is preferred on sites less productive than the one chosen for the comparison. /

NS – nature conservation with management

Management of sites for nature conservation may take many different forms depending on what kind of structures and features should be enhanced. The assumption here is that management is relatively intensive and follows more or less a continuous cover forest kind of management. The simulation is based on oak which is the dominant species in this kind of FMM.

N – Voluntary and official set asides

This FMM assumes no intervention at all. As pointed out above, the growth in Heureka tends to slow down over time. The figures showed something like a stabilization in the last decades of the 400 year simulation. The stand is a pure spruce stand.

Table 41 Stock and flow of C for different FMM (all figures per ha; the same color = the same C impact).

FMM	FMM subcategory	Rotation length (y)	Stock (tC)	Substitution (tC/y)	Rank out of 7 (stock/subst)
Clear cutting with intermediate rotation	Norway spruce (>70% basal area)	75	171	0.235	5/6
	Scots pine (>70% basal area) ~ spruce				
	Spruce-birch mixture (30%-70% birch) ~ spruce				

FMM	FMM subcategory	Rotation length (y)	Stock (tC)	Substitution (tC/y)	Rank out of 7 (stock/subst)
	Spruce-pine mixture (30%-70% pine) ~ spruce				
Clearcutting with short rotation	Birch ~ larch				
	Hybrid aspen / populous ~ larch				
	Larch (not Hybrid larch)	40	80	0.105	2/5
Clearcutting long rotation	Oak	130	155	0.188	4/4
Uniform shelterwood Pine	Scots pine shelterwood ~ spruce intermediate				
NS - Nature conservation with management	Oak for continuous cover forestry	~	122	0.027	3/2
NO- Voluntary and official set asides	Spruce	~	367	0.000	7/1

It appears that set asides give the largest stocks at the expense of no substation. The standard spruce program comes out as a good alternative due to its growth and usability. The short rotation is most likely underestimated as regards stock and handicapped by no substitution effect attributed paper products. The NS FMM is the result of oak being less productive than e.g. spruce. The substitution effect is surprisingly small in this steady state analysis.

Table 42 Stock and flow of C for different FMM under different scenarios (all figures per ha).

FMM	Rotation oak	Rotation larch	Rotation spruce	Cont. cov. for.	No mgm
BAU					
Stock (tC)	155	80	171	122	367
Substitution (tC/y)	0.188	0.105	0.235	0.027	0.000
HFD					
Stock (tC)	155	80	171	122	367
Substitution (tC/y)	0.304	0.301	0.397	0.109	0.000
HSV					
Stock (tC)	168	81	186	122	367

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Substitution (tC/y)	0.236	0.042	0.278	0.000	0.000

The figures in Table 41 is based on what could be termed a BAU scenario. The other required scenarios are High fuelwood demand (HFD) and High substitution value (FHSV) (Table 42). As indicated the stock figures do not change much (as expected) whereas the flow do. The latter are improved by a turn to more energy use of wood.

2.8.3. Assessment of the provision of cultural services by the stand level FMMs in the Swedish case study

The ranking of the FMMs in the Swedish case study have departed from the guidelines provided for cultural services. The concepts, dimensions and attributes used in the ranking are presented in Table 43. Each attribute has been qualitatively ranked 0-1 (0=very bad, 1=very good) based on expert judgment i.e. no DSS or quantitative data has been used in the assessment.

Table 43 Concepts, dimensions, attributes used to rank the aesthetic/recreational

Concepts	Dimension	Attribute	Indicator	Effect
Stewardship	Sense of care	Amount of logging residue	Frequency of thinning/final felling. Very high (0) – No intervention (1).	-
Naturalness/ disturbances	Alternation/ impact	Frequency of final fellings	Frequency of final felling. Very high (0) – No intervention (1).	-
Complexity	Diversity	Tree species diversity within stands	Monculture (0)- Higly Mixed (1)	+
Complexity	Variety	Variation in tree size within stands	Even aged (0)- Uneven aged (1)	+
Visual scale	Openess	Visual penetration	Extremly dense (0)- Open (1)	+
Historicity/ imageability	Historical richness	Age of trees in stands	Relative age/size* at final-felling. Very low (0) - Similar to “natural” conditions (1)	+
Ephemera	Seasonal change	Presence of broadleaves	Totally absent (0)- 100 % broadleaves (1)	+

**Relative to the species lifespan and growth pattern, because a fast growing species will reach the size associated with higher aesthetical/recreational values faster.*

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Table 44 Qualitative assessment of the recreational/ aesthetical values associated with FMMs in the Swedish case study.

FMM/Concept*	S	N	C	V	H	E	Average
Clearcutting intermediate							
Norway spruce (>70% basal area)	0.5	0.5	0.1	0.25	0.25	0.1	0.28
Scots pine (>70% basal area)	0.6	0.7	0.1	0.5	0.4	0.1	0.4
Spruce-pine mixture (30%-70% pine)	0.5	0.6	0.3	0.375	0.3	0.1	0.36
Spruce-birch* mixture (30%-70% birch)	0.5	0.5	0.35	0.375	0.25	0.5	0.41
Clearcutting short							
Birch	0.4	0.4	0.1	0.5	0.25	1	0.44
Hybrid aspen/populous	0.25	0.25	0.1	0.35	0.25	1	0.37
Hybrid larch	0.4	0.4	0.1	0.3	0.25	0.1	0.26
Clearcutting long- oak	0.5	0.8	0.5	0.6	0.75	1	0.69
Uniform shelterwood system – Pine	0.6	0.75	0.15	0.5	0.45	0.1	0.43
NS - Mix of tree species possibilities but mostly beech, oak, broadleaves	0.75	1	0.25-0.875	0.75	0.75	0.75	0.71-0.81
NO - Mix of species possibilities	1	1	0.25-0.875	0.25-0.75	1	0.25-0.75	0.62-0.89

**s= Stewardship, N= Naturalness/disturbances, c= Complexity, v= Visual scale, h= Historicity/imageability, e= Ephemera*

Clearcutting intermediate

The range in this FMM is explained by the variability in dominating species. Scots pine scores higher than Norway spruce due to increased visual penetration and longer rotations. The birch admixture increases the recreational/aesthetical value.

Clearcutting short

This FMM involves establishing plantations of fast growing pioneers. For birch and Hybrid aspen/populus the economic performance (expressed as NPV) is highly dependent on a short rotation period, thereby partly compensating for the high establishment cost. The positive effect due to the broadleaved component is therefore partly neutralized by the intensive management regime (in addition the negative effect due to fencing, which often is required, has not been considered). As an intensively managed exotic conifer, clearcutting short with Hybrid larch has the lowest ranking of all FMMs.

Clearcutting long with Oak

This FMM is ranked highest among the FMMs oriented for wood production. Oak is a broadleaved species managed with long rotations to obtain a large target diameter. The open canopy implies good visibility and the possibility of admixture with other broadleaved species. All these are factors that gives this FMM a high aesthetical/recreational value.

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Uniform Shelterwood system with pine

Similar to clearcutting with Scots pine. The higher score is due to a little bit longer rotation and aesthetical qualities associated with the seed trees.

NS- Nature conservation with management

The range is explained by the fact that this FMM is applied in different stand types. However, among private forest owners in Kronoberg it is almost exclusively used in broadleaved stands, situated close to houses/farmland/lakes. Aesthetical/recreational goals are generally overlapping with nature conservation goals. The high score is explained by the management regime, which is oriented towards favoring/maintaining large broadleaved trees.

NO- Nature conservation without management

This FMM is used in very different stand types and the big range is explained by variability in complexity, openness and the proportion of broadleaves. The lack of cutting gives it a high score.

2.8.4. Regulatory services- Assessment of the risk of storm felling for the FMMs in the Swedish case study

Storm damage has been the most significant disturbance factor to the forests of southern Sweden over the past decades. This is especially valid for Kronoberg County, which is situated in the core of the area affected by the devastating winter storms of 2005 and 2007, felling 75 and 15-20 million m^3 in southern Sweden respectively. Beyond such catastrophic events, minor winter storms are more or less annually occurring. Due to its magnitude in terms of damage, as well as its potential detrimental effects on the economic outcome of forest management, we focus our regulatory service assessment on the FMMs relative susceptibility to storm felling.

The ranking of the FMMs is based on expert judgement, supported by earlier research and information regarding the local forest management practices, the later obtained from qualitative interviews with forest consultants/wood buyers currently working in the County. This ranking is based on general characteristics of the different FMMs. The risk associated with an FMM at a particular site and time, will be influenced by factors such as local exposure (e.g. edges, neighboring stands, topography) and seasonal factors (e.g. leaves or not, frozen ground). Below are some comments for each indicator that have been influential for the ranking of the FMMs.

Indicators[3]:

Species – Norway spruce has a lower mechanical stability than both Scots pine and Birch (Peltola, 2000), the other common species in Kronoberg. The relative susceptibility of different species to storm damage is also influenced by season, since broadleaves (and Hybrid larch) are leafless during the winter. This ranking is based on storms in the winter, the peak season in southern Sweden for devastating storms. An analysis of the damages inflicted by the winter storm Gudrun revealed that

[3] It is quite difficult to provide an assessment of the different individual indicators because they are hard to asses in isolation e.g. stand height/species affect the risk associated with thinning. This implies that the total average score provides the most just assessment.

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the damages were positively correlated with the proportion of spruce (Valinger & Fridman, 2011). Mixing spruce with Scots pine and birch reduced the risk of damage. This was especially evident for birch, where an admixture of 30 % reduced the risk with 50 %.

Height at final felling - The risk of storm felling increases with increasing stand height. When comparing height development curves of different species at sites where they typically are grown, it is evident that the height of Norway spruce overall tend to be higher at the age of final felling i.e. on average relatively more stands of spruce will grow to a higher height. In this regard it is also important to remember that the site index (defined as dominant height after 50/100 years) of spruce generally is higher than all other native species regardless of site productivity (Ekö et al., 2008). According to the forest consultants/wood buyers rotations have been reduced due to the lessons learned after the Gudrun storm, where large areas of over mature (from a silvicultural perspective) forests were damaged. The strongest actor in the county, the forest owners association Södra, has also reduced their recommended rotation periods. The reduced rotation periods invoked by the increased risk awareness implies that no FMM reach the highest score for this indicator.

Standing volume – In general, a forested landscape consisting of stands with a higher standing stock will suffer more storm damage in absolute numbers. The average standing stock during a rotation depends on the growth and the rotation i.e. a FMM used for a productive species (high MAI) with long rotation (often later MAI culmination) will have a higher average standing stock during a rotation compared with other FMMs. Also here spruce scores high.

Thinning program – The risk of storm felling is increased after thinning. Thinnings at a high height, and especially late and heavy interventions in previously unthinned stands are associated with a high risk. However, due to the lessons learned in the Gudrun storm the thinning practices in Kronoberg County have changed over the last decade. Thinning in mature stands of Norway spruce has largely been abandoned, and a widely acknowledge guideline is to not perform any thinnings in stands higher than 20-22 m. Due to the increased risk awareness the thinning programs of all FMMs are ranked medium in risk, with two exceptions. The uniform shelter wood system scores high due to the seed tree cutting, where approximately 50-150 seed trees of Scots pine are retained, thus left heavily exposed and suffering a high risk of storm felling. According to the consultants/wood buyers many private forest owners interest in this method has dropped due to the frequent fellings of the seed trees. Thinning in NS (nature conservation with management) stands scores below average since it is oriented towards favoring broadleaves at the expense of spruce.

2.8.5. Water - Assessment of the effect of different FMMs on the chemical and ecological status of streams and lakes in the Swedish case study

In the guidelines for ES water five different subcategories are listed in Table 46. Our assessment has focused mainly on the fifth category; chemical conditions of freshwater. In addition, some FMM characteristics that can be related to ecological processes in streams have also been included in our assessment.

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Table 45 Assessment of the risk of storm felling (1-5) of the FMMs in Kronoberg County.

FMM	FMM subcategory	Tree species	Height at final felling	Standing volume	Thinning program	Average
Clearcutting intermediate	Norway spruce (>70% basal area)	5	4	5	3	4.25
	Scots pine (>70% basal area)	3	3	4	3	3.25
	Spruce-pine mixture (30%-70% pine)	4	3	4	3	3.5
	Spruce-birch mixture (30%-70% birch)	3	3	3-4	3	3.13
Clearcutting short	Birch	1	2	2	3	2
	Hybrid aspen/populus	2	3	3	3	2.75
	Hybrid larch	2	4	4	3	3.25
Clearcutting long	Oak	1	2	2	3	2
Uniform shelterwood pine	Pine	3	3	4	5	3.75
NS- nature conservation with management	Mix of tree species possibilities but. mostly beech. oak. broadleaves	1-3	3-5	3-5	2	2.25-3.75
NO- nature conservation	Mix of species possibilities	1-5	3-5	3-5	0	1.75-3.75

The effects of forest management on freshwater goes beyond the differences associated with the FMMs. General considerations in harvesting such as retaining buffer zones along streams and lakes, measures to minimize the soil damage inflicted by machinery and the use of temporary bridges when crossing streams are all crucial. The following ranking assumes that such considerations, which are stipulated in the forestry act and certification standards, are taken for all FMMs. In addition, it is important to remember that this assessment has been conducted at a general level. For example, the tree species that are possible to utilize at a specific site depends on the site conditions e.g. in reality you cannot contrast oak with Scots pine on a very poor site.

Below are some comments regarding the two FMM characteristics, tree species and harvest intensity, which have guided our ranking of the FMMs. They were both among the suggested DSS outputs relevant for an assessment on the chemical conditions of freshwater in the guidelines. Among other relevant factors, fertilization and burning has been disregarded. No fertilization is

conducted in Kronoberg due to the limited growth response and/or requirements in the certification standards and the forestry act. Prescribed burning is only conducted by certified forest companies, and with 80 % share of small private forest ownership in Kronoberg the activity in prescribed burning is negligible.

Tree species: Regarding water quality there is strong support to suggest that FMMs with broadleaves are superior to conifer FMMs (Felton et al. 2016). Conifer litter produce higher concentrations of dissolved organic carbon (DOC), and subsequently higher levels of leakage and brownification. In broadleaves stands favorable light conditions, as well as the leaf litter, has positive effects on the ecological processes in streams, this includes favoring the development of heterotrophic biofilms, which retain stream nutrients and thereby reduce leakage of inorganic carbon. In contrast, a spruce forest will support less broadleaves and understory vegetation producing high quality litter due to the low light availability. The relative ranking within the conifers and broadleaves are based on light availability e.g. Scots pine and Hybrid larch (open at least at the end of the rotation) scores higher than spruce.

Harvest intensity: Clear-felling increase the runoff of nitrogen, phosphorus, metyl mercury, DOC (dissolved organic carbon) (Eriksson et al. 2011). Hence, the annual area of final felling in a catchment is linked to the quality of ground and stream water. The annual area cut depends on the rotation, and the FMMS have therefore been ranked based on their relative rotation length.

In summary, an ideal FMM for the ecological and chemical status of freshwater at both smaller (the individual stream crossing a stand) and larger spatial scales (the catchment) would consists of a broadleaved species managed with CCF. In contrast, an intensively managed conifer monoculture with short rotation and dense canopy would get the lowest score.

Table 46 Assessment of relative suitability (1-5) of different FMMs for the chemical and ecological status of streams and lakes (1= very bad, 5=very good).

FMM	FMM subcategory	Tree species	Harvest intensity	Average
Clearcutting intermediate	Norway spruce (>70% basal area)	1	3	2
	Scots pine (>70% basal area)	2	3.5	2.8
	Spruce-pine mixture (30%-70% pine)	1.5	3.25	2.4
	Spruce-birch* mixture (30%-70% birch)	3	3	3
Clearcutting short	Birch	4	2	3
	Hybrid aspen/populus	4	1	2.5
	Hybrid larch	2	2	2
Clearcutting long	Oak	5	4	4.5
Uniform shelterwood pine	Pine	2	3.75	2.9
NS- nature conservation with management	Mix of tree species possibilities but, mostly beech, oak, broadleaves	3-5	5	4-5
NO- nature conservation	Mix of species possibilities	1-5	5	3-5

**For this FMM we assume that the birch component is clustered along streams, in line with the guidelines of the major forestry actors (e.g. Sveaskog, Södra) in Kronoberg.*

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2.8.6. References

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2.9. Turkey

2.9.1. Assessments of FMM in terms of Biodiversity at stand level

Clearcutting with intermediate rotation – Calabrian pine.

This FMM is based on clearcutting and then planting of Pinus brutia, because other species generally have understorey problems and covered by a great deal of different species such as Rhododendron, smilax or berries that prevent regeneration. This FMM is applied in timber production not in other forest values such as soil conservation, water conservation or aesthetics. Rotation age was used to be 60 years. Maximum regeneration areas are restricted with 25 ha. There are also some standards to contribute to the nature protection in the stand-level management such as dead wood thresholds. In clear CC FMM all other individual native trees or plants not threatening the natural regenerations are recommended to leave over. For these reasons Calabrian pine stands have some aspects that are both potentially consistent and inconsistent with biodiversity goals addressing forest structures.

Clearcutting with short rotation – Maritime pine.

Maritime pine is a fast growing exotic tree in the region, its regeneration is based on clearcutting and then planting. This FMM is applied in timber production not in other forest values such as soil conservation, water conservation or aesthetics. Rotation age was used to be around 50 years. As in Calabrian pine stands, maximum regeneration areas are restricted with 25 ha and other native trees or plants not threatening the natural regenerations are left over. However there are not many other species in the site. For these reasons Maritime pine stands have very little aspects that would both contribute to the biodiversity goals. Thus the score was low.

Big area/uniform shelter-wood method (Very Long Rotation) – Oriental beech, Anatolian pine and Oak spp.

This FMM is based on retention of overstory trees as seed-source and buffer the detrimental effects of a wide range of factors. Forests classified for ecological and socio-cultural values are potentially subject to this FMM in even-aged management systems. Stands composed of especially beech, oak, chestnut and hornbeam species are covered by a great deal of different understorey species such as Rhododendron, smilax or berries in Turkey. This FMM prevents direct sun light and assists saplings. Big area shelterwood system is applied to forests with Fagus orientalis, Castanea sativa, Quercus spp., Pinus nigra, Pinus sylvestris, etc. species. Conservation forests focusing on soil and water conservation are subject to this FMM in the CSA. The rotation age is around 200 years. There are also some standards to integrate nature protection in the stand-level management such as dead wood thresholds. Thus, this FMM ranks quite higher than clearcutting FMM.

Uniform/long rotation shelter-wood method (Long rotation) – Oriental beech, Anatolian pine and Oak spp.

Similar to very-long rotation shelterwood method. Stands composed of especially beech, oak, chestnut and hornbeam species are covered by a great deal of different understorey species such as Rhododendron, smilax or berries in Turkey. The rotation age is around 140 years. The contribution to the amount of deadwood is a bit lower than the very long rotation shelterwood system. Thus this FMM has a bit lower score.

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NS – nature conservation with management

The nature conservation with management may provide higher biodiversity values than many of the production forest alternatives due to the fact that conservation is the dominant/main purpose of this FMM

Nature conservation / NS without management

The nature conservation without management is expected to provide much higher biodiversity values than many of the other FMMs due to the fact that conservation is the solo purpose of this FMM

Conversion of coppice

None of the above FMMs resembles this FMM. Regeneration is not permitted until the conversion of high forests in this FMM. However, thinning for the maintenance of stands is applicable. Currently, a nominal rotation period is determined as 80 years. This FMM is based on all Oak species In Turkey. Thus, there is a certain biodiversity value as the coppicing is abandoning and is expected that in the future the FMM will provide better value for biodiversity.

Medium rotation coppice

FMM is based on clearing all shoots after reaching 20 years and providing new shoots. Timber production (pole woods or construction board) is set as management goal in this FMM. This FMM is suitable for oak species and chestnut, however, chestnut is preferred in the CSA. Thus, there is a low level of biodiversity value as the coppicing is the main actions of this FMM.

Short rotation coppice

This FMM is based on cutting the shoots after reaching 4 years and providing new shoots. Four-year shoots of the chestnuts is used in the production of hand-made chairs. This FMM is suitable for oak species and chestnut, however, chestnut is preferred in the CSA. Thus, there is a very low level of biodiversity value as the intensive coppicing is the main actions of this FMM.

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Table 47. Eight Turkish FMMs and associated subcategories ranked in terms of their relative capacity to close the gap between the habitat provided in production forests and the habitat requirements of forest dependent flora and fauna.

FMM	FMM subcategory	Tree species composition (Native trees, broadleaf trees, tree species diversity)	Forest structures (older / larger trees coarse woody debris)	Disturbance regime (emulate natural disturbance regimes spatially and temporally	Rank out of 7
Uniform shelter-wood method (FMM1)	Fagus orientalis. Pinus nigra, Oak spp. shelterwood	5	4	5	4.66
Big area/uniform shelter-wood method (long rotation) (FMM2)	Fagus orientalis, Pinus nigra, Oak spp. shelterwood	6	5	6	5.66
NS - Nature conservation with management (FMM3)	Mix of tree specie; mostly beech, oak, chestnut broadleafs and the pines	6	6	7	6.33
Nature Conservation (FMM4)	Mix of all native tree species existing in the area	7	7	7	7.00
Conversion of coppice (FMM5)	All Oak species	5	4	4	4.3
Medium rotation coppice (FMM6)	All Oak and chestnut species	4	2	2	2.66
Short rotation coppice (FMM7)	All Oak species	3	1	1	1.66
Clear cuttings systems (FMM8)	Calabrian pine (>70% basal area)	3	3	3	3
	Maritime pine (>70% basal area)	2	3	3	2.66

Reference list

The information is based on the view and interpretation of wildlife biologists and the literature of

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Felton, A., Gustafsson, L., Roberge, J.M., Ranius, T., Hjältén, J., Rudolphi, J., Lindbladh, M., Weslien, J., Rist, L., Brunet, J., Felton, A.M., 2016. How climate change adaptation and mitigation strategies can threaten or enhance the biodiversity of production forests: Insights from Sweden. Biological Conservation 194, 11-20.

2.9.2. Stand level assessment of Carbon sequestration value of Turkey's stand level FMMs

The stand level assessment is conducted at a stand level using a simple spreadsheet programme for C stock in forest and HWP as well as the substitution. A quick assessment is based on the same stand input in order to make a comparison possible. The relative ranking of FMM is dependent on the fact that they are based on the same conditions. The site conditions is assumed to be average conditions in the Gölcük CSA.

The FMM descriptions below are brief descriptions of Carbon stock and flow.

FMM1: Uniform shelterwood system (Oriental beech)

The assumption here is that management is relatively intensive and follows more or less a clear cut kind of management with slow clearance of final felling. The simulation is based on beech which is the dominant species in this kind of FMM.

FMM2: Uniform/long rotation shelter-wood method (Long rotation) – Oriental beech)

/similar expectations with FMM1/

FMM3 – nature conservation with management

The assumption here is that management is relatively less intensive and follows more or less a continuous cover forest kind of management.

FMM4: Nature conservation

This FMM assumes no intervention at all. As pointed out above, the growth tends to slow down over time. The figures showed something like a stabilization in the last decades over the simulation. The stand is a Beech dominated stand.

FMM5: Conversion of coppice

We do not have much info about the conversion. Thus, it is left out

FMM6: Medium rotation coppice

/similar to FMM7/

FMM7: Short rotation coppice

This is similar to CC yet with a short rotation of Oak stands

FMM8: Clearcutting with intermediate rotation – Calabrian pine.

Calabrian pine is the only species allowed for CC FMM. The Calabrian pine stands are natural stands intensively managed, structurally-simplified, single-species dominated, and thus relatively homogenous production forest alternatives.

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Table 48 Stock and flow of C for different FMM (all figures per ha; the same colour = the same C impact).

FMM	FMM subcategory	Rotation length (y)	Stock (tC)	Substitution (tC/y)	Rank out of 7 (stock/subst)
Uniform shelter-wood method (FMM1)	Fagus orientalis, Pinus nigra, Oak spp. shelterwood	120	204	0,1611	5/4
Big area/uniform shelter-wood method (long rotation) (FMM2)	Fagus orientalis, Pinus nigra, Oak spp. shelterwood				
NS - Nature conservation with management (FMM3)	Mix of tree specie; mostly beech, oak, chestnut broadleafs and the pines	240	240	0,27	6/5
Nature Conservation (FMM4)	Mix of all native tree species existing in the area	240	244	0,00	7/1
Conversion of coppice (FMM5)	All Oak species				
Medium rotation coppice (FMM6)	All Oak and chestnut species				
Short rotation coppice (FMM7)	All Oak species	20	15,89	0,014	1 / 2
Clear cuttings systems (FMM8)	Calabrian pine (>70% basal area)	60	93,43	0.05713	4/3
	Maritime pine (>70% basal area)				

The BAU global strategy was used to relatively compare some FMM with respect to C stock and substitution. It appears that forest conservation with a relatively longer rotation gives the largest stocks at the expense of no substation (Table 49). The common use of shelterwood programme seems as a good alternative due to its growth and usability. Clear cut management model with Pine stands produces relatively enough amount of carbon stock with a medium level of substitution. The short rotation of Oak used in coppice FMM provides the lowest amount of carbon stock as expected.

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Table 49 Stock and flow of C for different FMM under BAU scenario (all figures per ha).

FMM	Beech Shelterwood	Pine ClearCut	Oak Coppice	Conservation	
Stock (tC)	204	93,43	15,89	244	
Substitution (tC/y)	0,161	0.057	0.014	0.000	

2.9.3. Cultural

Ranking of FMM 1-8 in terms of cultural values shows that FMM 5-8 have lower ranking than FMM1-4, in all attributes except visual scale, Figure 39 Cultural Services FMM 1- 8, Turkey. FMM5 to 7 are characterised by coppice, conversion of coppice, medium rotation and short rotation coppice respectively and FMM8 is clearfelling model.

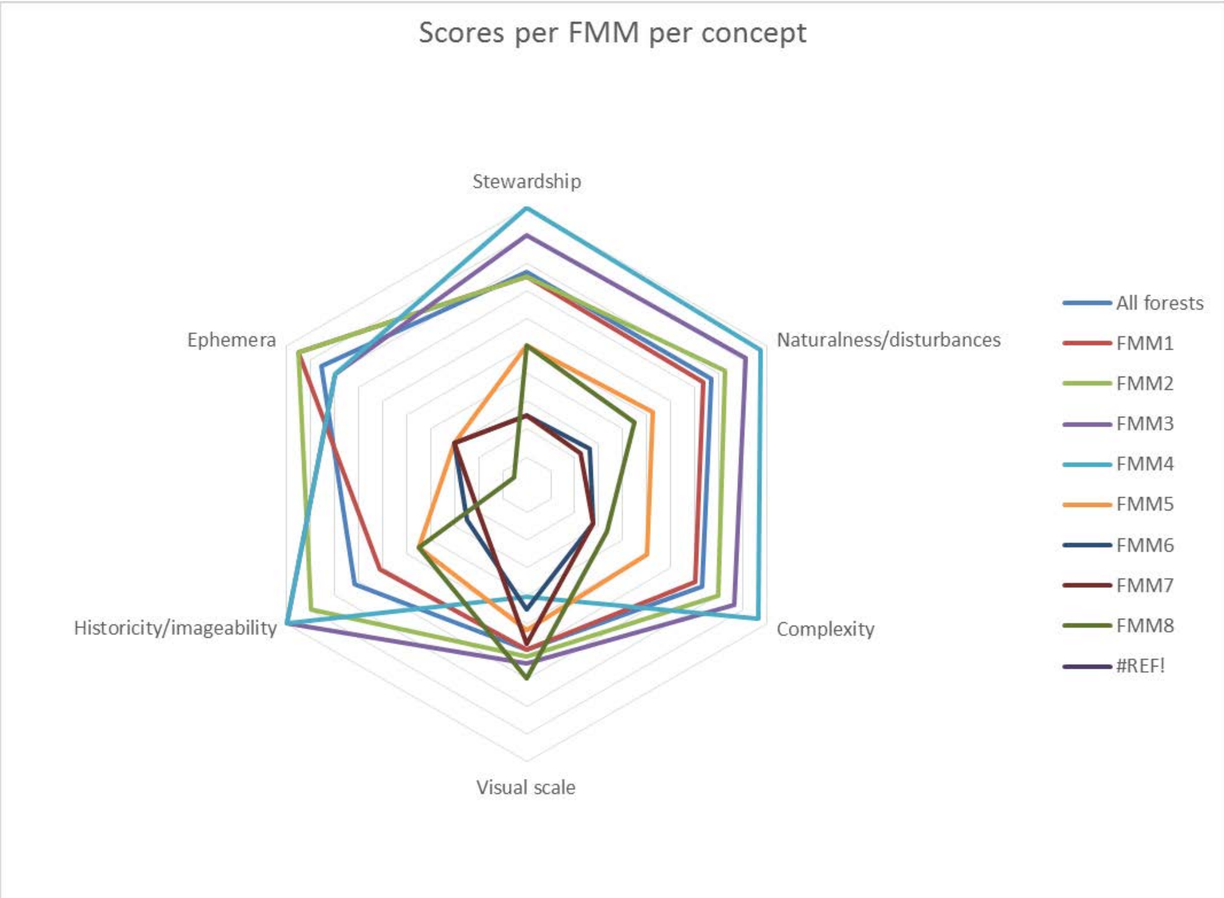

Figure 39 Cultural Services FMM 1- 8, Turkey

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2.9.4. Assessment of the contribution of FMMs to mitigate impacts of catastrophic events Gölcük CSA

We will prepare a non-model based forest fire vulnerability assessment of GÖLCÜK CSA. The vulnerability classes will be characterized according to a number of stand based **biometric and spatial** metrics. These include species type, basal area, number of trees, development stages, age, topography and shape of patches. The scale of the Fire Sensitivity Index (FSI) is between 0, no fire danger, and 10, extremely sensitive to fire. Here is the list of dendrometric and topographic criteria and their associated fire sensitivity indices.

Basal area (m2/ha)

Number of trees (n/ha).

Quadratic mean diameter (cm)

Dominant height (m)

Understory biomass (Mg/ha)

Age (years) in the case of even-aged stands

Distribution of tree sizes (% of Vol/ha of each size class)

Species composition (% of Vol of each species/ha)

Table 50 Fire Sensitivity Index (FSI) for some combinations, age and tree species (top), age and mixture (second), basal area (third), no of trees per ha (fourth), slope (second from bottom) and patch figuration (bottom).

Species (Fuel Type)	Fir Spruce			All Hardwood Trees			Pine (Calabrian pine, Anatolian pine)			Pine (others)		
Age	<4	80	>80	<40	80	>80	<30	50	>50	<30	50	>50
FSI	1	2	3	1	3	2	10	7	5	9	5	4

Species (Fuel Type)	Coppice	Mixed (Hardwood+Softwood)			Mixed (Softwood+Hardwood)		
Age	<40	<40	80	>80	<	50	>50
FSI	1	3	4	3	7	5	4

Basal Area	80	70	60	50	40	30	20	10	0
FSI	1	2	3	4	5	6	7	2	0

#trees	>50	400	300	200	100	500	250	50	20
FSI	4	8	10	7	5	3	2	1	0

Slope		**Aspect**		**Elevation**		**Canopy**		**Development stages**	
%	**FSI**		**FSI**	**M**	**FSI**	**%**	**FSI**	**DBH class**	**FSI**
<5	2	N	2	<200	10	<10	1	a (0-19,9cm)	4
15	4	NE	4	500	7	10	2	b (20-	10

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Slope		Aspect		Elevation		Canopy		Development stages	
30	6	E	4	1000	5	40	5	c 36-	6
50	8	SE	6	>1000	3	70	8	d (>52cm)	2
>50	10	S	10			>70	10		
		SW	8						
		W	4						
		NW	2						

Patch Config	Near Circle			Regular			Irregular			Meandering		
$\frac{(2\sqrt{\pi}\sqrt{Area})}{Perimeter}$	1	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1		
FSI	10	9	8	7	6	5	4	3	2	1		

When producing the fire vulnerability map of the CSA we will use the ***combined value*** of the various parameters of forest fires listed above. Then, we will slice the area into five major vulnerability categories-VU **(5 - very high vulnerability, 4- high vulnerability, 3 - average vulnerability, 2- low vulnerability and 1 - very low or no vulnerability)** in terms of ***combined*** VU classes. We caution that the combined values are literally/quantitatively used here, no qualitative differences were sought for the sake of clarity and simplicity.

The following sample table shows the simple implementation of above indicators for a 40 year old Calibrian pine stand with 20m2 basal area, 500 trees, 30%slope, SE aspect, 1000m elevation, 30% canopy, 30cm dbh and Irregular shape. This stand is scored to be ***"average vulnerability***" for both FMM4 and FMM8 (other FMMs are not applicable for this stand). However, as the stand changes over time with respect to the FMM, thus some of the parameters such as basal area, age, #of trees will change, than the effects of different FMMs will emerge.

Table 51 implementation of above indicators for a 40 year old Calibrian pine stand

FMMs	Age Species composition	Basal area	# of trees	Slope	Aspect	Elevation	Canopy	Development stages	Patch Config	Score out of 5 (VU)
Uniform shelter-wood method (FMM1)	N/A									
Big area/uniform shelter-wood method (long rotation) (FMM2)	N/A N/A									
NS - Nature conservation with management (FMM3)	N/A									
Nature Conservation (FMM4)	7	7	3	6	6	5	2	10	3	2.7 (Average)

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FMMs	Species composition Age	Basal area	# of trees	Slope	Aspect	Elevation	Canopy	Development stages	Patch Config	Score out of 5 (VU)
Conversion of coppice (FMM5)	N/A									
Medium rotation coppice (FMM6)	N/A									
Short rotation coppice (FMM7)	N/A									
Clear cuttings systems (FMM8)	7	7	3	6	6	5	2	10	3	2.7 (Average)

2.9.5. Evaluation of water related ecosystem services – CSA Gölcük

In Gölcük case study area, water yield (ground run-off water) and erosion control are the most relevant ES to evaluate changes. As the topography is not harsh, heavy erosion and landslides do not prevail in the CSA. Besides, chemical conditions of the area is unknown.

Soil loss and amount of ground run-off water (not water quality) are estimated by our DSS based on a typical regression models using basal area, developed in similar other forest conditions.

Our DSS ETÇAP does not estimate all outputs listed inof the guideline document, see appendix. Our DSS provides information regarding forest cover type, area distribution, treatment areas, treatment period, amount of estimated ground run-off water yield and amount of soil loss in each planning period and yet we have no model nor expert knowledge to estimate and evaluate the development of other water related indicators (run-off time, water distribution, chemical conditions and water quality) either at the stand and the landscape-scale (Table 52, Table 53). Additional effort may be done with GIS routines to compute road and stream crossing. Nevertheless, again we have no models or expert knowledge that might link those variables to the rest of the quantified water related ES. Thus, regarding the basic level, changes in several variables (Table 52, possible related DSS Output) can be **identified** through our DSS. On the other hand, we are not able to model the three advanced level of ES evaluation suggested in your water services guidelines as no data is available for that purpose.

Stand-scale: Basic level

At the basic level, our CSA can report the variation of the raw DSS outputs (Table 52), but the net contribution to the indicators is not provided as no model or expert knowledge is available for that purpose.

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Table 52 Basic Stand-level – indicators related with ETÇAP DSS outputs

ES	Indicators	Possible Related SADfLOR Output
water yield	Total supply of water per forest area	Harvesting (%) – harvested or not harvested stand in each planning period Age – stand age Species – type of forest specie evergreen or deciduous Amount of water yield: The amount of ground run-off water for each stand per period
Flood protection	Runnoff time	Harvesting (%) - harvesting or not harvesting in each planning period
Water flow maintenance	Water distribution along the year – flow regime	Harvesting (%) - harvesting or not harvesting in each planning period Change of water: The development of run-off water over time
Erosion control	Erosion protection	Harvesting (%) – harvesting or not harvesting in susceptible area. Additional GIS routine to overlay stand clear cuts in steep areas Soil loss: The amount of soil lost over time
Chemical conditions	Water quality	Harvesting (%) - harvesting in each planning period Species – Type of forest specie broadleaves or conifers Age – stand age

Landscape-scale

At the landscape-scale, our CSA can report the variation of the raw DSS outputs (Table 53), but the net contribution to the indicators is not provided as no model or expert knowledge is available for that purpose (except run-off water and soil loss)

Table 53. Landscape scale – indicators related with ETÇAP outputs

ES	Indicators	Possible Related SADfLOR Output
1. Water yield	Total supply of water per forest area	**Harvesting (% of cover removed)** – sum of areas of harvested stands in each planning period **Stand age distribution** – stand age distribution in each planning period **Species** – Distribution of forest species per area in each planning period (evergreen or deciduous) **Amount of water yield:** The total amount of ground run-off water per period

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ES	Indicators	Possible Related SADfLOR Output
2. Flood protection	Runnoff time	**Harvesting (% of cover removed) -** sum of areas of harvested stands in each planning period **Road density** (density) - additional GIS routine to compute road and stream crossing
3. Water flow maintenance	Water distribution along the year – flow regime	**Harvesting** (% of cover removed) - sum of areas of harvested stands in each planning period
4. Erosion control	Erosion protection	**Harvesting** (% of cover removed) **in susceptible area**. Additional GIS routine to overlay clear cuts in steep areas. **Road density** (density) - additional GIS routine may be needed to compute road and stream crossing through the entire study area **Soil loss:** The total amount of soil lost over time
5. Chemical conditions	Water quality	**Harvesting** (% of cover removed) sum of areas of harvested stands in each planning period **Species** – Distribution of type of forest species (broadleaves or conifers) per area in each planning period **Stand age distribution –** % and area of various developmental stages (regen, young, mature, over mature) across the entire area

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III. Technological landscapes

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1. Technological landscapes - overview

1.1. Introduction

The technological landscape is in this report defined as a combination of available technologies and infrastructure for various silvicultural interventions; professional knowhow and practical experience of FMMs; and drivers and barriers, created by legislation, certification rules and markets for forest products. The available technologies may affect implementation of FMMs both in a strictly practical way when a certain technology that are essential is missing in a case study area (CSA), but it may also affect the result when implementing FMMs both with regard to economy and provision of ecosystem services. For example, old harvesting and transporting equipment in thinnings may result low economic result and unnecessary damage soil and retained trees. Lack of knowhow and practical experience among forest owners and forest managers is probably an important restriction for introducing new FMMs. Knowhow can to a certain degree be gained by literature and oral presentations. However, when introducing FMMs to a region, they probably need to be adjusted to the regions biological and socio-economic conditions through practical experience, demonstration sites and local research. This has to be done by both scientific and semi-practical long-term field experiments which most often is time consuming. Legislation and certification rules generate substantial restrictions for implementation of certain FMMs in some CSAs. However, these restrictions may change with time and should therefore not be considered as permanent. The same is true for the market situation which may prevent introduction of some FMMs. However, introducing a new market in a region often need a large amount of raw-material which may be difficult to achieve with forest products because of the long time-horizon between regeneration and harvest.

This chaåter aims to describe the technological landscape of each CSA. Such descriptions will provide background information about possibilities can constrainsts when consider the practical implementation of alternative FMMs.

1.2. Collection of data

The description of the technological landscape was done by a questionnaire and answered by the LCC. The questions was divided in two parts. The first part describing strength, possibilities, weaknesses, problems and economy for important operations connected to forestry. The questions were general for all FMMs but it was possible to give details for FMMs when needed. A second part was about more general information about drivers and barriers for forestry and changes of forestry. Drivers and barriers can be market for forest products, infrastructure, human capital and forest legislation.

1.3. Summary of findings

In general, and not unexpectedly, the technology of each case-study area (CSA) is adapted to the major FMMs used. This will cause a major difficulty when it comes to introducing new FMMs, but more on that later.

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Almost without exception, equipment and knowledge for regeneration of the most common FMMs in each CSA is considered to be adequate. Problems that are mentioned are foremost browsing by deers and moose. High browsing pressure has been mentioned by Germany, Ireland, The Netherlands, Slovakia, Sweden and Turkey. High browsing pressure restricts the choice of tree-species and in many cases, only Norway spruce can be used. In some countries, e.g. Germany and Slovakia, fences or individual tree protections are used in order to reduce browsing damage and to make it possible to choose desired tree species (oak, beech and Scots pine). However, fencing is an extremely expensive treatment and also requires management of the fences during many years to avoid break-ins by game with subsequent damage to crop-trees. Therefore, fencing is not used in many of the CSAs and this puts a major restriction on which tree-species that can be used.

Site-preparation methods used are mainly different variants of soil-scarification. None of the CSAs mention that availability of scarification equipment is a problem for sufficient site-preparation. However, the scarification technology is probably adjusted to the currently dominating FMM. Mounding and patch scarification may be more common when planting whereas continuous systems, like disc-trenching, may be used in natural regeneration. Herbicides have not been mentioned in any of the CSAs and the use of herbicides is often restricted by legislation.

The cost for regeneration varies greatly between CSAs. In Italy, the total cost of regeneration may be as high as 25.000€/ha (planting 5.000€, maintainance 5.000€ and compensate initial loss of revenue by farmers up to15.000€) whereas the cost for regeneration may be as low as 750€ for establishment of eucalypts in Portugal. The difference in regeneration cost is probably due to the need of expensive regeneration methods to establish sensitive species (e.g. protection against browsing) but also to some degree because of tradition and the need to avoid too radical regeneration treatments because of public opinion.

Local problems in regeneration has been mentioned. In Ireland, regeneration of Sitka spruce on low productive sites have traditionally been done with fertilization at the time of planting. Fertilization is now restricted by legislation and many sites cannot be regenerated with Sitka spruce. In Portugal, natural regeneration of maritime pine is decreasing because of wild-fires. This species in now instead regenerated by planting. In Lithuania, planting of Scots pine and Norway spruce is decreasing because of economic reasons.

The use of improved genetic material at planting are common in Ireland, Portugal, Lithuania and Sweden. In Slovakia, it is not allowed to use seed-sources from outside specified seed-regions which restricts the use of genetically improved seeds.

Because regeneration methods are specialized according to the dominant FMM in most of the CSAs, regeneration will be a bottle-neck for introducing new FMMs. It is also possible that previous knowledge is being lost in some countries because of little use of a specific method. E.g. natural regeneration of Scots pine has decreased dramatically in Sweden and many forest managers in the Swedish CSA has limited experience of that method.

In all CSAs except Italy, pre-commercial thinning is used to some degree and manual brush-saws is by far the most dominant method. The goal of pre-commercial thinning is both to control density and to adjust species composition. It is mentioned that one problem is that educated, skilled personnel is needed when the goal is to create a mixed forest of a specified structure. In contrast, when the goal is monocultures of planted conifers, cheaper personnel can be used. In many of the

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CSAs, a problem is also that PCT is sometimes avoided or are done late because of the high cost and the unclear economic benefit.

The use of harvesting machinery varies greatly between CSAs. Use of mechanical thinnings (harvesters and forwarders) have been mentioned to be dominating in private forests in Germany, in productive forests in Ireland and in all forests in Sweden. In CSAs in Lithuania, Slovakia and Turkey manual chainsaw is most common in thinnings. Sometimes (Slovakia) the use of harvesting machines is restricted by topographical conditions but the main reason for not using harvesting machines is probably that manual harvesting methods are cost-effective.

In most CSAs where thinning is performed it is stated that knowledge of thinning practices and thinning programs is high. Thinning programs have developed over may years and are performed in a cost-effective way. However, it is sometimes problematic to achieve a positive net-income in first thinnings when small trees are harvested. In later thinnings, the economic result is often much better. The situation regarding thinning is somewhat different when it comes to the more unusual FMMs. In many CSAs, for obvious reasons the experience of stand management is much lower for the unusual FMMs than for the dominating FMMs. Some CSAs (Ireland and Slovakia) mentioned that thinning is done to a much lower degree in the unusual FMM because of possible damage to soils or because of unclear economic motivation. Thinning may also be avoided because it is not considered as a necessary part of the stand management program (Eucalypts in Portugal).

Thinning is in most cases directed towards stand management with the aim to increase average growth and quality of retained trees. However, in some cases individual tree management is the focus. In the CSA in The Netherlands, targeted selection of “future-trees” is a common thinning strategy. Also in the state forest of the CSAs in Germany, future crop trees are in focus during the thinning operations. A more individual tree approach to thinning probably requires personnel with much more education and skill than thinning for stand-level development. It is not mentioned in the questionnaire, but it is possible that trees to be removed in thinnings are marked beforehand by forest managers which of course increase the cost for thinning compared to selection by the thinning crew.

As for thinnings, the harvesting techniques in final felling varies between CSAs. Manual chain-saw methods in final felling have been mentioned in the CSAs in Turkey, Maritime pine in Portugal, Lithuania and Slovakia. In Slovakia, cable systems are sometimes used because of steep slopes. In the Netherlands, Sweden, Ireland and private forests in Germany mechanized systems with harvesters and forwarders dominates. However, final felling is not part of the selective cutting silvicultural systems. In state forests in Germany, the stands are thinned a number of times with the aim to create a heterogeneous stand structure. When this is achieved, target diameter cutting will follow. Because large trees are harvested among trees that will be retained, mechanized systems may not be used in order to avoid damage to retained trees. This has also been mentioned in the Swedish CSA and it will of-course increase the cost of harvest as compared to final felling on clear-cuts.

In all CSAs, except Italy, the market for the dominating assortment is good. In most cases this is pulp- and timber from conifers. In Italy, wood is primarily used for fire-wood and are not used in the industry. The market situation for high-quality broadleaves is more variable. In Ireland there is a need for high-quality broadleaves but the supply is low. In Germany, there is a growing market for saw-logs from beech which is the largest broadleaved species in that CSA. Markets for broad-leave

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timber in Sweden is very poor and are currently restricting the development of forest management in broadleaved species. In Turkey, there is a market both for high quality veneer and for fuel-wood from broadleaves. However, the market for chestnut and oak in Turkey is poor which reduces interest for this uncommon FMM. It is also mentioned that clear-felling of mixed stands may results in a high variability of assortments which puts a pressure on transport logistics. Sometimes one assortment from a clear-cut site may not make up to one truck-load.

The market for recreation was mentioned in The Netherlands but a problem is to find a system where the forest owner get a share of the economic value of this ecosystem service. In Italy, market for truffle and pine nuts are probably more important than traditional timber market. In Portugal, it is possible that a future market for biodiversity and recreation will develop and include economic compensation to forest owners. But on the whole, traditional markets for pulp-wood and timber seem to be the most important source for income.

As mentioned before, the level of mechanization in harvesting during thinning, selective cutting and final felling varies between the CSAs. In Germany, Ireland, The Netherlands, Portugal and Sweden, both harvesting and transport is mechanized to a high degree. However, in the Netherlands, the harvesting infrastructure is weak. In other CSAs, harvests are often done by chain-saw whereas transport is done with forwarders or other equipment. Horses are only mentioned for the CSA in Slovakia. In the Italian CSA, there is no developed harvesting organization because forest management in the area is new. Harvest is done mainly with chain-saws and transport to roadside either by tractors or manually depending on the size of the logs. In most other CSAs, harvesting is done by contractors. In some cases (Slovakia) it is mentioned that the equipment is sometimes old and outdated. In other places like Sweden, equipment in very modern and the efficiency of harvesting is constantly improving.

However, for less common FMMs the situation is sometimes different. The mechanization is even less than for dominating FMMs and sometimes special problems do occur. E.g. in water protection areas in Slovakia, contamination from oil from machinery must be avoided. Furthermore, tradition and knowledge restricts the use of other silvicultural systems than clear-cutting in many CSAs, but the situation seem to be slowly improving in many countries. It will also be possible to study techniques used in other countries when trying to implement a more diversified forestry.

Forest legislation is highly variable between the CSAs. In one extreme is private forestry in Germany and forestry in The Netherlands where very little restrictions is put on forest management through legislation. The opposite is true for Slovakia and Lithuania where forest management is strongly regulated by legislation. In Slovakia, forest management plans are required and has to be followed within certain limits. Any major deviation from the plan requires a new forest management plan which has to be done on the expense of the forest owner. Sweden, Portugal and Ireland has some legislative demands on forest management but the freedom for the forest owner to choose FMMs is still quite large. In Ireland, the law against fertilization has made regeneration of Sitka spruce difficult on low-productive land. In Sweden, the age of clear-felling is regulated in Norway spruce and Scots pine, regeneration after clearcutting is legislatively controlled and it is not allowed to change tree species from Noble broadleaves to other tree-species. In Turkey, forest management plans are mandatory but they do probably not regulate forest management as much as in Slovakia. On state forests in Germany, the aim is multifunctional forests producing several eco-system services such as biodiversity, recreation and biomass production. This is done via a conversion to het-

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erogeneous mixed species forests without clear-felling. This is probably not a legislative demand but the way it is implemented is as if it was regulated in legislation.

Future development of FMMs are for most CSAs forecasted to be developments and adjustments of current dominating FMMs. In Germany, state forest will most probably be continuously managed according to the close-to-nature paradigm allowing for production of several eco-system services while private forests are managed according to economical optimization. However, management in the private forests may change depending on future markets, damage and climate change. In Lithuania and Slovakia, where current forest management is strictly regulated by legislation, a future with less restrictions on forest management is foreseen, but the time-schedule for this change in legislation is difficult to estimate. Certification rules may play an important role in future forest management development. In Sweden, FSC is currently under revision and a substantial increase on the demand for set-asides for nature conservations may be the outcome of this process. In Slovakia, an increased willingness to manage forests according to certifications schemes may increase the use of continuous cover methods. Future forest management will probably also be driven by technological improvements both with regards to harvesting techniques and with regards to new methods for planning, including remote sensing methods. However, in most CSAs, economy and market development will probably be important drivers for shaping future forest management models.

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2. Country reports

2.1. Germany

Table 1 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSAs Lieberose Brandenburg and Augsburg, Bavaria, Germany

Operation	**General (strengths possibilities)**	**Comments (+ weaknesses & threats)**	**Economy**
Regeneration, *state forest FMMs* Remark: Among our alternative FMMs there is nothing really uncommon. Under "common" we will always describe state forest management, and "large private forest" under "uncommon"	State forest strongly prefers natural regeneration considered the best way to achieve uneven-aged mixed forests, and to have the locally best adapted trees. High biodiversity already in regeneration.	Natural regeneration only works sufficiently with low game densities. If desired species are not available in sufficient numbers, natural regeneration has to be augmented by planting/seeding.	With low game densities, natural regeneration is economically highly efficient. Foresters can steer regeneration virtually only by the way the harvest the previous stand generation. In practice, often fences are required (that hold for long periods due to the intended diversity of the regeneration).
Regeneration, *large private forest FMMs*	Large private forests usually plant. Procedures are easy to follow, well known and optimized including weed control and mechanization.	Game densities are not really relevant (protection is part of the standard system). Biodiversity is low, energy input is high.	Can be done with cheap personnel. As protection against browsing (fence, single-tree protection) is standard, and as fences do not need to last long, protection is not as expensive as with state forest management

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Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
			(in case it's required there).
Stand management, *Pre-commercial thinning (PCT) state forest*	Species mixing regulation is the most important measure. Also important is negative selection (removing bad quality trees). Rare species are promoted.	Requires educated, skilled personnel (both, foresters and loggers).	Personnel input is higher. However a broader, more balanced range of ES is produced on the same area than in the large private forests.
Pre-commercial, *large private forest FMMs*	As monocultures dominate, mixture regulation is not a topic. Negative selection is done, but as these FMMs are usually focused on conifers, the workload is comparably low.	Low biodiversity	Can be done with cheap personnel.
Stand Management, *thinning state forest FMMs*	Selective cutting and advancement of future crop trees. Higher share of quality timber production. Fostering tree and stand stability is important in order to open a broad range of future silvicultural options.	Requires educated, skilled personnel (both, foresters and loggers).	See above (personnel input is higher. However a broader, more balanced range of ecosystem services is produced on the same area than in the large private forest concept).
Stand management *large private forest FMMs*	Often thinning from below, high stand increment, more mass timber assortments. Easy procedure. Large machinery can be easily used.	Risks increase (bark beetles, snow and storm break).	Can be done with cheap e personnel.
Harvest/final felling *state forest FMMs*	Target diameter harvest is very prominent. This is not only a final harvest but also important for steering growth and species compostition of the regeneration. If target diameter harvesting is not an option, variations of	High biodiversity, soil and water protection. High stability.	Higher personnel input, in average higher wood quality, possibly somewhat lower volume production. High range of eco-

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Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
	shelter cuts are applied. The goal is to obtain a smooth transition of forest generations into uneven-aged structured forests. General risk is lower as in the classic large private forest system. Deadwood accumulation is promoted to a certain extent.		system services provided.
Harvest/final felling, *uncommon FMMs*	Clearcuts, and seam-cuts are most promi-nent. Easy to mechanize.	Low diversity, often low stability, low range of silvicultural options. Often damaging agents (storms, bark beetles) dictate what to harvest when.	Can be done with cheap person-nel. High volume production, more mass sortiments (average quality).

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Table 2 Drivers and barriers for implementing common versus uncommon FMMs, CSAs Lieberose and Augsburg, Germany

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/state forest FMMs*** The market requires a large amount of coniferous wood like pine and spruce. Assortments must be homogeneous enough (in size, quality) for industrial processing (from pulping to modern industrial sawmilling). However, we observe an ongoing change increasing the demand for European beech, our (by far) most important hardwood species. Technological research programs for exploring novel applications of hardwoods are supported/conducted by state-funded organizations. This is due to the state increasing the share of hardwoods in its own forests, and implementing policies intended to trigger similar developments in private forests. High quality wood (species independent) is always very well paid, but can never be produced in amounts like industrially usable wood.
	Large private forest FMMs/ remarks Private forest owners can choose freely what kind of management they implement. The only real restriction is that transforming forest areas into other forms of land use is strictly regulated. The large private forest FMMs reflect the situation that most large private owners prefer to serve the traditional market, whose dynamics are well known to them.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, etc.	***General/state forest and large private forest FMMs*** Mostly there are no such restrictions. The normal situation is the possibility of free decision making (reasonably) within the boundaries given by the environmental conditions (choice of tree species, goal of management, and the according silvicultural concepts and technical processes). There is no lack of well-educated forestry personnel and enterprises which offer forestry-related services including the usage of modern machinery. Due to a dense road network and good forest accessibility there is also no transport- induced bottleneck.

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Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/state forest FMMs*** Legislation requires state forest management that is closer to nature. Hence, the share of hardwoods shall be increased, mixed and uneven-aged forests are promoted. The reasoning behind is that the multitude of forest ecosystem services the state forest must provide to society is best produced with these kinds of for-ests.
	large private forest FMMs/ remarks As said above, policy in Germany keeps the level of restrictions for private forest owners very low. Mostly the behavior of private forest owners is (tried to be) influenced by offering support if policy-conform forest management is performed. But the forest owners are totally free to decide what to do.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarizing remarks?	***General/state forest FMMs*** The most important trend is the development towards closer to nature forests and therefore the increment of broadleaf proportions. Besides the multiple ES production state forest managers also expect this kind of forest to be the least risky option in the face of the ongoing climate change.
	Large private forest FMMs/ remarks Probably, large private forest owners will continue their current management, unless climate change makes it to costly and/or too risky. If new large markets for hardwoods emerge, this might also be an important incentive to move more towards mixed conifer/hardwood stands.

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2.2. Ireland

Table 3 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Western Peatlands

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
Regeneration, *FMM1 clearcutting conifer and FMM2 clearcutting lodgepole pine*	Planting spruce and pine is well-known and all necessary infrastructure, equipment for site preparation etc., seedlings and knowledge are available	One challenge at establishment stage is browsing from deer and protection of the 10% broadleaf sub-FMM may be required in particularly vulnerable zones. Another challenge is reforestation of these FMMs post harvesting. Many of the forests in the CSA were established with the use of artificial fertiliser. The quantities required may not be permitted under current policy or forest certification measures.	Cost for regeneration (planting) is very roughly 1800 €/ha. Including site preparation, seedlings and planting. This is true for plantation of FMM1 and FMM2 of approx. 2500 seedlings.
Regeneration FMM3 Nature conservation and biodiversity protection (*uncommon FMMs*)		The net result of this FMM is reducing the area of timber production. However, it is important for achieving the non-production-based objectives of stakeholder organisations with this viewpoint. Openspace reduces the overall productive area for the timber	Openspace is open area where plants have not successfully re-established. Other than the cost of planting these trees initially, there is little further economic impact. Bufferzone establishment. There is a higher cost of establishing broadleaves in Ireland and some

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Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
		production focus in Ireland. Bufferzone establishment is where native broadleaf species are planted with open space to protect watercourses and road corridors. Bog restoration is where a forest is clearfelled and timber is either extracted or left on site. The drains that were put in place for site preparation are blocked and the area is allowed to revert to its previous bog land-use.	form of protection from deer is often prescribed at a cost of approximately €4 extra per tree although this cost depends on scale. Approximately €849 ha^{-1} without deer protection. Bog restoration. There is an economic cost of approximately 2000 €/ha to block drainage infrastructure.
Stand Management, *FMM 1 clearcutting conifer*	Thinning FMM 1 is very common, but not carried out where it is not considered to be economically viable (typically if GYC is <= 12 $m^3ha^{-1}yr^{-1}$). There is a lot of experience and knowledge about thinning, e.g. thinning guidelines. Harvesters are almost always used.		Cost depends very much on size of trees (small trees - high cost) while income (pulpwood, timber) increases with trees size. In productive areas, thinnings typically give a positive result.
Stand Management, *FMM 2 clearcutting lodgepole pine* and FMM3 Nature conserva-	Thinning FMM2 does not take place. The knowledge and experience is present; however, the lodgepole pine produces heavy branches reducing stem quality and value.		N/A

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Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
tion and biodiversity protection (*uncommon FMMs*)	Once established, no operations take place in FMM3		
Harvest/final felling *FMM 1 clearcutting conifer*	Harvesters are almost always used. Infra-structure such as forest roads, market and more are well developed.		Harvest cost is low for final felling, and there is a large mar-ket for pulpwood and timber that is produced from harvesting these species.
Harvest/final felling *FMM 2 clearcutting lodgepole pine*	Harvesters are almost always used. Infra-structure such as forest roads, market and more are well developed. This FMM is the main wood supply for co-firing fossil fuel power plants and material for producing fibre and particle board, an expanding industry in Ireland.		Harvest cost is low for final felling, and there is a large mar-ket for pulpwood (only) pro-duced from harvesting.
Harvest/final felling, FMM3 Nature conserva-tion and biodiversity protection (*uncommon FMMs*)	There is no final felling. There is minimal tim-ber production benefit for harvesting to es-tablish bufferzones and bog restoration. The stands are often harvested motor manually before commercial maturity and sometimes harvested material is left on site.	Harvesting using motor manual method is slower and expensive compared to conventional har-vesters.	Harvesting for bog restoration can break even or make a small profit but it depends on the maturity of the stands harvest-ed.

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Table 4 Drivers and barriers for implementing common versus uncommon FMMs, CSA Western Peatlands , Ireland

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for pulpwood from FMM1 and FMM2 and timber from FMM1. The heavy production oriented beginnings of the Irish forest sector is still very much reflected in current management, especially on Coillte (the Irish State forest company) land which dominates the CSA. Demand from existing sawmills reflect the wood supplied by the now mature first rotation stands. The knowledge in production oriented forest management and sawmill demand has in turn shaped the private forests. Most sawmills and panel processing plants rely on conifer wood. The sawmills prefer dimensions smaller than 35 cm, since they are not designed to handle larger logs. This means that forest stands rarely achieve their full volume-based growing potential and final felling is suited to the assortments desired by the processing sector, i.e. financial return. Intensively managed conifer plantations (mainly Sitka spruce and lodgepole pine) remain the norm in Irish forestry, but many stakeholders have expressed dissatisfaction with exotic conifer monocultures (especially when established on blanket peat).
	Uncommon FMMs/ remarks There is demand for Irish broadleaf timber for furniture production, but Irish broadleaf timber is rarely managed to produce this standard and is typically firewood. Most processing industries rely on conifer wood smaller than 35cm diameter and although there are a few small wood processors that will accept larger logs, most of the CSA is not suitable for production of large diameter wood due to susceptibility to windthrow and soil fertility.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capaci-	***General/common FMMs*** The forest sector is well organised and optimised to produce conifer timber and pulpwood through the clearcutting system. In the barony of Moycullen, and Ireland as a whole, Coillte is the most powerful actor. Originally afforestation was carried out to promote jobs in disadvantaged rural areas, but in recent times the focus has shifted on making the forest industry more profitable, mainly by technological advancements and mechanisation which reduce personnel costs.

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ty? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	The Forest Service issue road construction grants to mobilise timber from private forests. There is now more emphasis on distance to roads before approving a grant application. Mechanisation means expensive machinery and "economies of scale" favour large concentrated removals (e.g. clearcutting rather than continuous cover forestry). To some extent, this scale is limited due to the presence of Freshwater Pearl Mussel (FPM) where limits on the maximum contiguous harvest area and the cumulative harvest area within a catchment exist in an effort to limit nutrient leaching and erosion.
	Uncommon FMMs/ remarks Tradition and knowledge reduce the interest for other management models than clearcutting systems with Sitka spruce, lodgepole pine and other conifers. However, many actors, including the Irish state, have expressed an interest in a more diverse species and more broadleaves in the forest landscape and more protected areas.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The requirements for suitable site conditions have increased for afforestation in recent years. This has resulted in a reforestation challenge for many forest areas. The establishment of the current rotation was through the heavy use of fertiliser, levels which are not permitted under current legislation. Under Irish legislation, harvested areas must be replanted. These forest stands, found on blanket peat, are very common in the CSA and are thus likely to undergo a change in FMM. Due to technological advancements and rationalisations, Coillte forests are managed by a small number of staff, this makes site descriptions crucial so that the right yield tables are used and that timber forecasts are accurate to ensure proper management of the stands. Private afforestation is something that is done mainly for the afforestation grants. Forest consultants are only responsible for the first 4 years of a stand's rotation and landowners often show little interest in managing their forest stand; with lack of forest management knowledge as a main reason. This leads to many private forests being poorly managed, often lacking thinnings and thus fail to produce a high volume of sawlog assortment. There are many regulations about establishing forests, but not so many about the consecutive management.

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	Uncommon FMMs/ remarks In recent years, there have been major changes to Irish forestry, mainly through the implementation of the EU Habitats and Birds directives and to comply with sustainable forest management. These changes include larger protected forest areas, afforestation grants for broadleaf stands, national goals on broadleaf areas, more sensitive operations in forests and species diversification of conifer monocultures. One aspect of forest management policy that will reduce the conifer FMM area in favour of minor FMMs is the implementation of buffer zones, which several older stands lack. This area will mainly be open space with natural vegetation and provides important habitat for natural vegetation and wildlife species within the forest.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General all FMMs*** A combination of market and forest management planning and policy is mainly responsible for the development of the FMMs where fast-growing, exotic conifers are used. Technology and human capacities have assisted in intensifying management of these FMMs and favours the amount of knowledge about conifer clearcutting systems. The timber processing market is predominantly for exotic conifers since this is what all wood processing plants are designed to process. However, recent changes in forest management policy favours the establishment of other FMMs, especially for broadleaves, native species and more protected areas. One expected trend in FMM change is from FMM 1 to FMM 2, i.e. Sitka spruce will change to lodgepole pine plantations. This is because there are large areas of poor quality land (blanket peat) where Sitka spruce cannot be established without the use of fertiliser. However, on the landscape level the combined area of FMM 1 and FMM 2 is expected to slightly decline and FMM3 to slightly increase. The infrastructure, both technical and human resource based is currently in place to accommodate current requirements. There is a shift from largely human-based forest management planning to one aiming to leverage advancements in computer technology. This is new and it will take time for this decision to be considered a valid and acceptable approach amongst stakeholders for forest management purposes. These new approaches are currently considered innovative and sufficient refinements of these methods are essential toward acceptance that they will be sophisticated enough to accommodate more restrictive legislation into the future. The alternative being a reversion, to some extent, toward the human resource-based approach to address these, sometimes complex, challenges faced by the forest industry. The main challenge now and in the future is finding a balance between the requirement to supply a growing market

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	from a landscape where there is currently a divergence in stakeholder opinion with regard to the management practices required to produce timber for industry. The move by Coillte to become FSC and PEFC certified is one of the biggest changes in forest management in the last two decades (Clarke, 2017, Business Area Unit 2 Team Leader, Coillte Forest *Pers. Comm.* to Lundholm, A.). This has introduced a level of stakeholder consultation, recreational facilities and environmental management considerations. The minor FMMs are likely to become more common from this perspective also. EU habitat and birds' directives enforced through National level policy (and Irish forest policy itself) is in-line with forest certification and also outlines the fundamental requirements for forest management in Ireland. The human factor has played a role in realising these changes on the ground and spreading awareness about the importance of preserving natural environment and lobbying for increased species diversification of the forest estate. In the CSA there are large areas of forest either upland and/or on blanket peat. Both site factors are unsuitable for growing broadleaves or conifers other than Sitka spruce and lodgepole pine. However, some of these sites are inherently so infertile that transforming them to either natural bog habitat, scrubland or protected open space might be the only alternative option. This may prove congruent with the financial, even if not productive, goal. The challenge in future will be whether these policy and certification requirements, which often reduce productive area and productive capacity, can be balanced with industry supply requirements.

References

Clarke, T., 2017, Business Area Unit 2 Team Leader, Coillte Forest *Pers. Comm.* to Lundholm, A.

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2.3. Italy

Table 5 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Lowland Forest Association (Italy)

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most common FMMs***	The FMM aims to favor natural regeneration, although in some cases existing stands have been artificially generated. Artificial regeneration through planting of shrubs Interest by some private investors to invest in new forest generation by planting trees (improved image/reputation, green marketing, etc.).	Favoring natural regeneration might produce negative effects in some cases. In the coastal pine stands, for example, while support to holm-oak regeneration (in principle) helps the shift towards more natural forest conditions/composition, it might also favor the expansion of alien species already present in the area (e.g. *Ailanthus altissima*). As for oak-hornbeam forests, oak to be supported through appropriate forest management choices aiming to facilitate natural regeneration and growth.	Reforestation costs of agriculture lands or abandoned lands with mixed broadleaved species with 10% species for truffle production: 5.000 €/ha for planting 5.000 €/ha maintenance costs over a period of 10 years 10-15.000 € to compensate initial loss of revenue by farmers. Enrichment planting with truffle seedlings with 100 trees/ha has a cost of 2.800 € including maintenance costs for 3 years.
Regeneration, *uncommon FMMs*			
Stand management, ***Pre-commercial thinning (PCT)***	In principle same as for thinning, please see below.	Pre-commercial thinning is not implemented on regular basis because forest management activities do not aim to	As mentioned, pre-commercial thinning is not implemented on regular basis. In general terms,

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
		maximize wood production, favoring the most productive species, rather to support evolution towards more natural forest ecosystems and multiple functions/services.	thinning is costly and often performed with the support of rural development funds (see below). Cost of pre-commercial thinning is of 5000 €/ha. This is based on use of rural development funds for selective logging. The Lowland Forest Association is now finding opportunities to establish contracts with private doing thinning and getting in change only the thinned wood material (mostly firewood)
Pre-commercial, ***uncommon FMMs***		Pre-commercial thinning is not implemented on regular basis because forest management activities do not aim to maximize wood production, favoring the most productive species, rather to support evolution towards more natural forest ecosystems and multiple functions/services.	
Stand Management, *thinning common FMMs*	Thinning can favor: - increased future value of wood assortments, although this is not the main objective of the current management activities. The production of limited	The cost of thinning operations might not be covered by revenues from firewood sales. Currently just a minor proportion of the	Thinning is costly and often performed with the support of rural development funds Cost of commercial thinning is of

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	quantities of high quality assortments from oak-hornbeam forests remains possible but very hardly predictable at the current stage since it might be influenced by a number of factors; - firewood and chipwood production; - improved truffle production in coastal and oak-hornbeam forests; - improved pine nuts and wild asparagus production in coastal forests; - improved natural features (composition, structure, etc.) including support to regeneration; - increased carbon sequestration capacity; - increased accessibility by tourists/visitors; - reduced fire risk. Thinning is strongly encouraged by the newly developed forest management plan with a target of 100% forest area thinned/naturalized by 2025.	forest area (less than 30%) is thinned. If not properly conducted/managed thinning operations might favor some invasive species. Local communities are not familiar with/used to forest management operations and might be concerned	5000 €/ha. This is based on use of rural development funds for selective logging. The Association is now finding opportunities to establish contracts with private doing thinning and getting in change only the thinned wood material (mostly firewood). Firewood: 60 €/m^3 (piled, cut to size at road-side) Chipwood: 1-2 €/Mkg (i.e. ton) Conifer wood for packaging, diameter 13-30 cm, length 2-2.4m: 45 €/m^3 Truffle: 150-300 €/ha/year. Use/collection fee: 20-30% Brown truffle production in coastal pine stands: 0.2 to 1.9 Kg/ha/anno. Since in some areas stands are still young and not dense productivity can increase up to 4 to 16 Kg/ha/year if appropriate silvicultural techniques are

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
			implemented. For holm-oak stands values are slightly lower, but normally the production period is longer. Pine nuts: 400-600 €/ha/anno. Collection fee: 20-30% 1 Kg pine nuts need collection/processing of some 25-30 Kg pine cones. Market price for cones ranges between 0.65-0.9 €/Kg; for unpeeled pine nuts 3.9-5.9 €/Kg; wholesale price 14-25 €/Kg. Carbon price (as from monitoring of the Italian voluntary carbon market): 7-10 €/tCO2e. Afforestation/Reforestation = 3.000 €/ha. Improved forest management = 1.000 €/ha
Harvest/final felling *common FMMs*	Firewood and chipwood retrieved from harvesting operations can help to financially support forest management thus	Wood production only limited to firewood and chipwood. More valuable assortments might be retrieved in the	No data.

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	enhancing other ecosystem services. In recent past firewood has been made available to locals in order to make them more familiar with the idea of active forest management.	future, nonetheless this opportunity remains uncertain. Local communities are not familiar with/used to forest management oper-ations and might be concerned	

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Table 6 Drivers and barriers for implementing common versus uncommon FMMs, Lowland Forest Association (Italy)

Market What is the overall market situation and trends? What kind of assortments (size, species) are favored due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** Since forest management operations and FMMs are not primarily intended for wood production, reference to wood market is not very much relevant. The market for firewood however remains quite active. ***Uncommon FMMs/ remarks*** Truffle and pine nuts have relevant market potentials and could provide excellent income sources for forest managers, however –especially for truffle- there are no dedicated FMMs in place. Markets remain quite informal. As regards other services (e.g. biodiversity, tourism/recreation, carbon sequestration, etc.) some potential market opportunities exist, however this mostly depend on isolated initiatives and are currently not structured/organized. Forest certification according to FSC standards and the possibility to pilot-test certified ecosystem services and their marketing, as well as the networking/bundling in cooperation with other forest areas might contribute to more visibility and market opportunities. Some private investors have already started to invest in afforestation/reforestation activities in the area for several reasons, including diversification strategies, offsetting/compensations, better reputation and green marketing, etc.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the	***General/common FMMs*** There are no standardized and well-defined FMMs for the management of forest types present in the area. This is even more emphasized by the fact that some of the stands are still quite young (about 20 years old) and have not been appropriately studied yet. This implies management operations are to be defined case-by-case by the forest manager(s). Mechanization level is limited: harvesting is normally performed manually through chain-saw. Wood extrac-

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choice of FMMs, etc.	tion is normally performed with tractors and trailers, while full mechanization (forwarder) is very limited. Loading operations can be either manual or mechanized, depending on the size and nature of different assortments. Limited mechanization is due to several factors, including forest fragmentation (and consequent limited size of single forest areas), limited relevance od wood production, constraints by proximity to urban/peri-urban areas (use of machinery might create concerns on local population that is not familiar with it) and lack of specific expertise/competences by most of local enterprises.
	Uncommon FMMs/ remarks As regards non-timber forest products and ecosystem services, FMMs are still being developed and, despite an increasing interest, are poorly implemented or not implemented at all in the area.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The case study area is fully covered by a recently approved forest management plan that while addressing all applicable normative requirements also includes innovative issues, such as a tentative focus on ecosystem services. This is not a normative requirement, rather is needed to meet forest certification requirements against FSC standards. At the moment there is still a normative gap in terms of specific legislation regulating delivering and marketing of ecosystem services. Given the specificity and dynamicity of forests within the case study area and the lack of consolidated FMMs and silvicultural approaches for them, the forest management plan defines specific management directions and objectives, but at the same time remains flexible, leaving to the manager the possibility to choose the best solution case-by-case. In line with this approach, criteria for selecting trees to be harvested are not only based on age distribution, but again take into account multiple issues, including health status, present and future potential forest structure, presence of deadwood, presence and status of natural regeneration, accessibility and risk for visitors, etc.
	Uncommon FMMs/ remarks Same remarks and comments as for the general/common FMMs. The case study area presents good potentialities for wild forest product production that is regulated by specific norms (at least with reference to collection activities). As for management planning, there are no spe-

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	cific FMMs for wild forest products implemented in the area, however -as commented above- the forest manager is given the chance to choose the most appropriate management solutions within the general normative framework.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General/common FMMs*** The most relevant factors (valid for both general/common and uncommon FMMs) are: - lack of standardized and well-defined FMMs due to limited extension of coastal and lowland forests - potentialities but also uncertainties linked to emerging markets for products and services different from wood - huge anthropic pressure on forest resources (tourism and recreation, fragmentation due to agriculture, presence of important infrastructures (highway, railway…), etc.) - visibility of forest areas and potential concerns by local communities (who miss/have lost forest culture) - diversity of stakeholders and multiple interests mirrored by the number of actors directly or indirectly in-volved in forest management operations
	Uncommon FMMs/ remarks Same as above.

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2.4. Lithuania

All FMMs identified in the CSA were divided into two groups:

General (or most common) – incorporating the models first of all aimed at timber production and experiencing default management restrictions which apply for all forests and forestry operations in Lithuania. This group includes FMMs with clear final cutting systems allowed, however non-clear cutting may be prioritized due to silvicultural considerations.

Special – in principle, are the FMMs with no clear final cutting allowed. This group includes the FMMs with non-clear final cutting mandatory due to silvicultural or legal considerations or even with no active forest management.

Table 7 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Telšiai, Lithuania

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most common FMMs***	Artificial regeneration is prioritized in pine and spruce dominating forests no matter the ownership, aiming to regenerate the same species with some share of deciduous tree species. Some natural regeneration is also possible on wet soils (up to 30% of FMM area). Natural regeneration dominates in deciduous forests, with some black alder planted on drained peatlands. Soil scarification is always done if artificial regeneration is applied. Seeds are collected locally, as well as seedlings are grown in local nurseries (only local trees are used for artificial regeneration). Some pine plantations in state forests are fenced. Repellents are used in areas with pine and spruce planted	Natural regeneration in private forests is at relatively significant level or even dominating. Usually, there should be more artificial regeneration used in private forests, but it is avoided due to cost saving by private owners. Natural regeneration in combination with non-clear final cutting is much dependent on the competence and professionalism of forestry specialists, this becomes an issue in private forests. Combination of non-clear cutting and natural regeneration sometimes is not economically reasonable, especially in spruce dominated forests.	Relatively high costs of artificial regeneration (around 1000 €/ha for pine, spruce and birch, up to 3000 €/ha for oak). Typically, higher costs of protection against browsing comparing to natural regeneration. Higher expected quality and value of future stands, if seedlings originated from seed plantation are used.
Regeneration, *spe-*	Non-clear cutting requirement is usually	Increasing the share of natural regenera-	Lower costs of regeneration and

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
cial FMMs	associated with the increased importance of natural regeneration, assuming lower regeneration costs and naturalness of forest development. Natural regeneration dominates in private forests, but basically aiming for cost saving. Soil scarification is applied in forests with non-clear final cutting.	tion (except the no intervention forests) should be considered as a long-term forestry objective, however, this can hardly be reached. Artificial regeneration dominates in state forests. The non-clear cutting requirement sometimes is due to legal acts and the geographic location of forests (inside the National parks or near the roads). So, in principle due to natural conditions and importance of recreational and aesthetic values, the natural regeneration should not dominate. Soil scarification is not welcome in Žemaitija NP, leading to decreased regeneration quality.	protection, but higher risk of failure. High costs if natural regeneration is not successful. Lower productivity of stands and expected value of timber.
Stand management, ***Pre-commercial thinning (PCT)***	Lithuanian forestry principles require all stands to be pre-commercially thinned at least once. Depending on site, species and densities, some stands are thinned 2-3 times. Pre-commercial thinning is done manually, using brush saws. Cut timber is usually left in the forest for natural decay.	State forests are thinned practically following the thinning standards, while private forests are significantly underthinned, most likely due to avoiding extra costs and undervaluing the importance of pre-commercial thinning on the structure and growth of future stand.	One of major issues affecting the precommercial thinning is relatively high thinning cost, 130 – 200 €/ha, depending on the volume of brush. In 2013 – 2020, precommercial thinning are supported by Rural Development Program (197 €/ha).
Pre-commercial, ***special FMMs***	Depends on specifics of FMM. Except the no intervention forests, the pre-commercial thinning need to be used in the way in all forests. Mixed pine stands	Private forests are practically not pre-commercially thinned. Assuming specific purpose of forests under these FMMs, pre-commercial thinning requires extra	Costs of PCT in special cases might be higher comparing with common FFM. Support by Rural Development Program can be

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	regenerated after non-clear cutting are thinned to minimize snow damage risks.	costs and high professionalism in forestry. Sometimes the issue becomes avoiding additional forestry activities in protected areas.	applied (197 €/ha), which in most cases is sufficient to cover expenses of PCT.
Stand Management, ***commercial thinning, common FMMs***	Usually 2 commercial thinning are recommended in Lithuanian forests. The 1st commercial thinning in mixed forests is aimed reduce the amount of deciduous trees in the stand. Deciduous trees which are in groups and do not disturb the coniferous, are not removed. Usually weak or so called “wolf” trees are removed; noble deciduous and pine and spruce, if present, are preserved. Pure stands are thinned to reach required number of stems per ha. The 2nd commercial thinning follow the same principles as the 1st commercial thinning, however, the thinning intensity is less, the commercial value of assortments is higher.	In principle, the aim of commercial thinning in Lithuania is declared to be the development of optimal growing conditions for the most productive trees, removing damaged, low productivity, stem form trees, i.e. increasing future potential rather than generating extra incomes currently. The 1st and 2nd commercial thinning are usually under optimal level in state forests, however they are much less applied in private forests. The share of thinned stands in private forests tends to increase with the stand age – i.e. the relatively largest share of thinned stands belongs to the 2nd commercial thinning, when the output of commercially more valuable timber is higher. The 1st commercial thinning in private forests is often avoided.	The 1st commercial thinning operations usually start with minimal, zero, or even negative net profit. The profitability increases with stand age, dimensions and volume of assortments. Depending on logging conditions, the costs of assortments production are 1.5 – 2.3 €/m³ higher comparing to final clearcuts.
Stand management, commercial thinning	Except no intervention forests, the same as for commercial thinning in common FMMs	The same as for common FMMs. There is some seasonal limitation on cutting in forests of protected areas	Depending on FMM, volume, dimensions and value of cut timber might be smaller comparing to common FMMs

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
special FMMs			
Harvest/final felling *common FMMs*	Chain saws are preferred under shelter-wood cutting systems. Chain saws dominate in private forests - harvesters are used in private forests less than 50% of cases. If clear cutting in state forests is applied, then the harvester may be used. Extraction is fully mechanized. Road infra-structure is well developed	The use of harvester may result in loses of timber due to mistreating the stump part of the log and trees with large branches. The last becomes an issue with aspen, oak and birch trees on fertile soils. Also, the use of harvester is associated with more soil damages, however it is more cost efficient and nowadays the harvesting contractors are lacking. Work load for harvesters is relatively low reducing the timber harvesting profitability. Telsiai SFE extracts ~90% of timber using own equipment	Lower logging and extraction costs in clearcuts. Easier organization of production, comparing with special FMMs. Operational costs of logging in final clear cuts is around 13 €/m^3
Harvest/final felling, *special FMMs*	Chain saws are prioritized. Extraction is fully mechanized. Horses are also used for timber extraction in special purpose forests and Žemaitija National park	The issue is that non-clear final cutting is mandatory on some fertile wet spruce stands, resulting in increased wind damage risk and regeneration of low value tree species and dense brush layer.	Costs of timber assortments production in non-clear felling are higher by around 1.5 €/m^3. Costs of extraction to the road-side are higher as well because smaller volume of timber in area.
Other: (what)	Not less than 3-7 trees per ha with the age over MARA and the diameter over the average value for the compartment are left in the stand during clear cutting	Stand level restrictions are introduced due to woodland key habitats, presence of nests of some birds, potential habitats of EU importance.	

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Table 8 Drivers and barriers for implementing common versus special FMMs, CSA Telšiai, Lithuania

Market What is the overall market situation and trends? What kind of assortments (size, species) are favored due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** During last decades, large scale sawmilling industry started to dominate in Lithuania. The industry favors larger timber sellers, especially of pine, spruce and birch sawlogs. Common FMMs, when large final cutting areas are allowed, have an advantage in such a situation. Timber trade is strongly influenced by third parties and sometimes non-transparent round timber coming from state forests auctioning and interests on local timber industries.
	Special FMMs/ remarks The composition of timber assortments and organization of timber sales might be ineffective, if small amounts of each assortment are produced in a cutting area, sometimes even below single truck load. In some low intensity non-clear-cut areas with big number of tree species, the number of assortments can exceed 10 – 12, and organization of sales could become really problematic.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	***General/common FMMs*** The main actor in the CSA is the Telšiai SFE managing majority of state owned forests – they cut around half of timber using harvesters. Majority of timber is extracted using own forwarders. Private forest owners usually must rely on services of contractors to perform forest harvesting and transportation. The efficiency of using harvesters is sometimes low – the cutting involves combination of using chain saws and harvesters (e.g. chain saws are used before the harvester to come to the cutting area and after).
	Special FMMs/ remarks Use of harvesters in non-clear cutting has not been proved to be efficient. So, using the chain saws should be considered as the dominating harvesting technique. Increased harvesting complexity and relatively lower profitability may have negative influences on forest management under specific FMMs, especially in private forests and using services of contractors. In principle, this does not introduce the change of FMM (as the FMMs are much predetermined by strict regulations, segregative forest management and natural conditions), however, the implementation of some forestry operations may be affected (e.g. choice of final cutting method, regeneration type, pre-commercial thinning).

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Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** Forest management system in Lithuania has its ideological base in the classical theory of normal forests. The silvicultural ideal is to grow productive stands which by the end of the (sufficiently long) rotation can deliver the highest possible amount of timber of sawlog dimensions. Therefore, the forest management is aimed at achieving an even forest age class distribution to ensure the evenness of timber flow. This forestry paradigm is followed in relevant legislation and operational implementation of forestry planning. Forest management planning principles in Lithuania and the CSA are based on strict rotation ages and area control of age classes. Forest management plans are mandatory for forest holdings of more than 3 ha of forest area. The compulsory parts of the forest management plan are the 10-year final cutting norm, forest regeneration, and environmental requirements. For estates of more than 150 ha, the final cutting norm needs to be estimated using age class method – this yields in different approaches for planning the final cutting in state and private forests (the lasts never exceeding estate area over 150 ha). E.g. all mature stands can be included in the 10-year cutting norm in private estate. This has some influence on the implementation of the same FMMs in state and private forests, e.g. resulting in larger ages of stands cut by final cutting. In principle, forest management planning can actively influence choice of FMM, but more likely it will act inside the FMMs defined using higher level legal requirements and practices.
	Special FMMs/ remarks The same forest management planning principles apply here as under common FMMs, however, the planner must consider additional planning conditions due to environmental requirements, planning in protected areas. There are two types of forest management planning in Lithuania: development of internal forest management project for an estate and building forest management scheme for a county. The last option also includes development of proposals for changing forest grouping, what may lead to changing of FMMs. Such changes are relatively small, nevertheless, they usually are leading towards increasing the share of special FFMs.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the	***General/common FMMs*** The forest management paradigm itself is one of key factors having the impact on current FMMs, including the potential for alternative solutions. Normal forest is the forest management ideal with the aim to obtain even maximized timber flow of sawlog dimensions, believing that other ESs are automatically best provided in most indus-

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most significant role? What trends can be expected? Any important summarizing re-marks?	trial timber productive forests. Private and state forest legally are required to be managed in largely the same way. However, actual management under the same forest conditions differs often in state and private forests. The command&control approach in forest management is much inherited from the soviet times and changes that have taken place since restoration of independence have not lead to relaxation of forest regulation and forestry. Rather on the contrary, the regulatory clout was enlarged. However, it becomes obvious, that following national and international challenges due climate change, market globalization, etc. alternative approaches are coming. In principle, introduction of close to the current FMMs but substantially more flexibility in choosing rotation lengths, thinning regimes and other silvicultural measures at stand level or advanced solutions for allowable cut calculations at landscape level are very relevant even under current political forestry environment. Potential reform of state forestry announced by new Lithuanian government (basically assuming delegating the functions of 42 state forest enterprises to one large state forest enterprise) may introduce some modifications in forestry administration, changed legislation and redistribution of current forest management functions, potentially without much influence on operational forestry. However, we have not enough materials to discuss the influence of state forestry reform on the FMMs much.
	Special FMMs/ remarks Special FMMs became increasingly important due to substantial increase of environmental considerations. This was caused much by changing public preferences, international influences (Rio 1992, signing international agreements, joining the EU in 2004) and powerful national patrons of environmental cause. Nevertheless, forest management under special FMMs is in a large extent based on segregative forest management approaches. Namely, forestry is much based on forestland zoning by forest functions (practices applied in the whole USSR) aimed by the Lithuanian authorities to save the (previously depleted) domestic resources due to the possibilities of timber shipments from the Russian Federation. Slightly upgraded grouping was included in Forest act in 1994, hurrying to start forest ownership restitution processes. Forest grouping principles were weakly scientifically supported. The system of protected areas and spatial planning has evolved later and sometimes overlaps with forest groups. However, majority of forestry regulations (well, definitions of FMMs in Lithuania up to some level, too) are built referring to the forest groups. Expected trends can be that forest management regimes are adjusted for each group aiming to obtain max deliveries of targeted ES at a landscape level. Another option – canceling the forest grouping at all, as today there are special conditions for land and forest use used in spatial planning and they incorporate most of restrictions which are duplicated by the forest grouping system. This would require revision of

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	numerous acts regulating current Lithuanian forestry (and, hopefully, optimization the extent and contents of such acts). One could expect, that the assumed state forest management reform mentioned above, could potentially have larger influence on special FMMS rather than on the common ones. Seeking for more economically efficient forestry, operational approaches under less economically attractive FMMs may result some abandonment of current practices or turning to other ones (e.g. avoiding non-clear cutting and natural regeneration where they are not the most efficient ones but used much due to political will), especially in the areas currently managed by Telšiai SFE.

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2.5. The Netherlands

Table 9 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Dutch case

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most FMMs***	Choices for a forest managers as regards regeneration (OBN, 2017): - natural or artificial regeneration - large-scale (stand-level/ shelterwood or not), in groups, or individual regeneration - with or without site preparation *Natural versus artificial regeneration* Traditionally, silvicultural systems using natural regeneration did not receive much attention in the Netherlands. However, in the 1970s, after the heavy storms in 1972 and 1973, it was not possible to immediately clear and reforest all of the affected areas, and in many of these areas a good natural regeneration took place. This proved that natural regeneration was silviculturally possible. Moreover, at that time also the subsidy scheme for replanting trees disappeared, which made artificial regeneration too costly. As a consequence, many Dutch forest owners focused on natural regeneration (Mohren and Vodde, 2006). During the last years, this has changed somewhat. With an increased attention for wood production,	Natural regeneration: more cost efficient, but not always providing the right species and good quality/quantity (not only negative for wood production, but on some soils also from an ecological point of view) (OBN, 2017) Artificial regeneration: more costly in comparison with natural regeneration. For both types of regeneration: problem of high game population	Cost of regeneration, depending on: - type of regeneration (natural or artificial) - in case of artificial regeneration: type of species, number of species planted, way of planting - site preparation or not - depreciation of land or not (in case of new forest areas) - etc.

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	species composition and the quality and volume of regeneration have become more important, which was/is not always the best in stands that were naturally regenerated. Hence, more forest owners nowadays make use of articificial regeneration. *Size of regeneration* The size of regeneration (stand, group, individual) depends, a.o., on the objectives of the forest owner (e.g. efficiency for wood production versus other functions), historical background of the forest stand (even-aged or not), species (light demanding species or not), direction towards lights, etc. (OBN, 2017) *Site preparation or not* In some cases, no site preparation takes place. In other situations site preparation takes place, varying from superficial to intensive.		
Stand management, *Pre-commercial thinning (PCT) and thinning*	(Pre-commercial) Thinning is probably one of the most importants operations for a Dutch forest manager to guide the development of the forest (OBN, 2017). An often-used approach of thinning is a targeted selection of so-called "future trees". These are the trees of the wanted tree species that have (potentially) the best quality (this might be for wood	One of the threaths mentioned of thinning is that regular thinnings can lead to too homogeneous and too light forest stands, disturbing natural developments too much (OBN, 2017.)	

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	production, but can, in some cases, also be from a different point of view, e.g. a good tree from a biodiversity point of view or for recreation). These future trees are "set free" by thinning.		
Harvest/final felling *common FMMs*	Until the 1990's, most of the harvesting in Dutch forests was done with a chainsaw in combination with with a tractor/horse. Nowadays, most harvesting is done with machines; in many cases this is a combination of a harvester with a forwarder (boswachtersblog.nl, 2016).	Problems in harvesting encountered are, a.o.: - in general, soil damage by machines - the necessity to harvest (partly) in the (wet) autumn/winter/early spring time due to rules set up in the frame of the Flora and Fauna Act (a.o., inaccessibility, damage to the soil) - Inefficient communication during the harvesting process (leading to a.o., damage to flora and fauna, damage to roads) - harvesting-infrastructure weak	

Table 10 Drivers and barriers for implementing common versus uncommon FMMs, The Netherlands

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due	Marketing of forest products in the Netherlands relate mostly to wood/timber and recreation/tourism. In the following, we will briefly describe these two markets.

to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	<u>Wood/timber</u> Dutch timber is mostly used domestically (there are no specific regional markets), but supplies only a small percentage of the annual timber needs of Dutch society. The self-sufficiency rate is about 8.5%, which means that most of the timber needed is imported. Next to import to satisfy domestic demand for timber, the Netherlands import timber for export (7,7 M m^3 per year). In total, 20,3 M m^3 is imported per year to the Netherlands (Probos, 2017). As stated in the sixth Dutch National Forest Inventory (Schelhaas et al., 2014): there is an increasing imbalance between the demand for and the supply of wood coming from Dutch forests. Despite the fact that the demand for Dutch wood has increased, and harvest amounts also increased, the Inventory shows that over the last 10 years in almost half of the Dutch forests no wood has been harvested and the gap between demand and supply seems to be widening. Next to the mismatch between quantities, there is also a mismatch between types of species. While two-third of the demand for wood for industrial applications is for coniferious wood, most of the trees planted nowadays are deciduous trees. One development that might have a profound impact on Dutch forest management in the future (but is still unclear) is the market for woody biomass. The Dutch government aims at increased used of biomass (including woody biomass), but at this moment the supply is still low. Main reasons are the relatively low prices for biomass, uncertainties about the development of the biomass market, the high transport cost, the negative environmental effects (removal of dead wood from the forests), preferences of forest owners for other products. Several forest owners, however, expect to sell (more) biomass in the (nearby) future. <u>Recreation/tourism</u> In a highly urbanized society such as The Netherlands, the need for green areas in the vicinity of cities for recreation and leisure is high. Most forests (73%) in the Netherlands are open to the public. Some forests are closed for several reasons: military, hunting, or nature protection (Probos, 2017). Accessibility is rather high, 37% may be reached by car, indicating that many forests are accessible by a network of local roads (Hoogstra et al., 2013). Despite the fact that the economic value of recreation of forests is high, only part of this is a financial revenue for the forest owner. Revenue models in recreation/tourism for forest owners include campings, bare foot walks, sight seeing tours, paid parking places, etc.

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Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	Harvesting-infrastructure weak Dutch wood market strongly internationally oriented Decreased knowledge on (traditional) forestry (including silviculture) Large number of hobby forest owners Large number of small forest owners Large diversity in motivations of forest owners
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	The relatively liberal Dutch Forest Law supports an individualistic attitude of forest owners and forest owning organizations. To realize public interests, the government prefers financial policy instruments as the main tools of public intervention (Schanz and Ottitsch, 2004), such as the Subsidy System for Nature and Landscape Management. Forest owners and provincial authorities make agreements about so-called "management types", i.e. a type of natural area, which requires a particular form of management (CBS et al., 2015). Forest owners/organizations are only subsidized if they meet the criteria required by the regulations of the specific management types, which include aspects such as accessibility for recreation, natural value (e.g. % of exotic tree species allowed, number of dead trees, and the presence of certain species), and the level of harvesting allowed (Hoogstra et al., in prep.). In order to receive subsidies in frame of the SNL scheme, forest owners/organization need to be certified following the certification rules of the SNL system. This means, a.o. that forest owners/organizations have to be able to show they have management plans for all their forests, and have a system of regular evaluation (including monitoring). In total, about 45% of the Dutch forest (168.179 ha) is FSC certified (Probos, 2017). Since 2016, it is also possible for forest owners to get certified within the PEFC system. Forest owners certified (either FSC or PEFC) have to follow the criteria set by the certifying bodies in their forest management.

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Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	Combination of factors: - social developments (such as demographic developments (e.g. demand for recreation), forest ownership) - scientific/technological developments (e.g. new forest management models, technical innovations) - economic developments ((inter)national economics, but also forest markets (e.g. demand for biomass, timber prices)) - environmental aspects and changes (e.g. storms, climate change, drought, frost, pests, diseases) - political rules and regulations (e.g. forest management subsidies, new nature law, flora and fauna act)

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2.6. Portugal

Table 11 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Vale de Sousa CSA, Portugal

Operation	General (strengths possibilities)	Comments (+ weaknesses and threats)	Economy
Regeneration, ***general and most common FMMs***	The experience, equipment for preparation, and seedlings for the most common FMMs (involving either eucalypt or a mix of eucalypt and maritime pine) are available. The forest owners association (AFVS) provides guidance to forest owners.	Due to the frequency of wildfires in the CSA the natural regeneration of the maritime pine is becoming scarce in the area, forest owners choose to plant this species. On the other hand, the *Gonipterus platensis* disease constitutes a major problem for the eucalypt forest that is currently circumvented by the application of pesticides.	The regeneration costs (including preparation and plantation) average is 753€ for eucalypt (and 1317€ for maritime pine in the typical stand-level prescription.
Regeneration, *uncommon FMMs*	The experience, equipment for preparation, and seedlings for chestnut forest systems is available. The forest owners association (AFVS) provides guidance to forest owners.	Wildfires may impact the success of the regeneration.	The average regeneration costs (including preparation and plantation) is 1554.73€ for 1250 seedlings /ha in the typical stand-level prescription.
Stand management, ***Pre-commercial thinning (PCT)***	The experience and knowledge about pre-commercial thinning (PCT) in maritime pine areas in the mixed stands is available. The forest owners association (AFVS) provides guidance to forest owners. There is no need for PCT	In some pine areas the (recommended) PCT may be performed irregularly as a consequence of incipient forest management by some owners.	The costs for PCT is around 1381€ per ha, but varies depending especially on tree height. If forest owners do it when tree height is high, this increases the cost for thinning.

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Operation	General (strengths possibilities)	Comments (+ weaknesses and threats)	Economy
	in eucalypt areas /stands.		
Pre-commercial, ***uncommon FMMs***	Chestnut trees are typically planted at final spacing. Thus, there is no need for pre-commercial thinning.		
Stand Management, ***thinning common FMMs***	The experience and knowledge about thinning in eucalypt x maritime pine stands is available. The forest owners association (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the thinning. There is no need for thinning in eucalypt areas.	In some maritime pine areas thinning may be done irregularly as a consequence of incipient forest management by some owners.	Maritime pine timber is typically sold before harvesting and stumpage prices are a function of age. The cost is variable and depends on the size of trees. Stool thinning cost In the case of eucalypt coppice stands are around 187.85€/h.
Stand management ***uncommon FMMs***	The experience and knowledge about thinning in chestnut stands is available. The forest owners association (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the thinning.	In some chestnut areas thinning may be done irregularly as a consequence of a) the high mortality of trees in mature stands, caused by *Phytophthora cinnamomi*, responsible for the ink disease, and by *Endothia parasitica* And & And., responsible for the chestnut cancer and b) incipient forest management by forest owners.	The chestnut timber is typically sold before harvesting and stumpage prices are a function of age. The cost is variable and depends on the size of trees.
Harvest/final felling ***common FMMs***	The experience and knowledge about both final harvest and coppice harvests in mixed pine x eucalypt stands is available. The forest owners associ-	In the mixed forest, the harvests of eucalypt and maritime pine are performed independently, when the species reach the harvest age (e.g. euca-	Both pine and eucalypt timber are sold before harvesting.

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Operation	General (strengths possibilities)	Comments (+ weaknesses and threats)	Economy
	ation (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the harvests. The maritime pine areas are typically harvested using chain saws. A harvester is used only in the case of the eucalypt share of area that is managed by the industry. Extraction is fully mechanized (100%): skidder in areas managed by the industry and tractor with winch in the remaining areas,	lypt may be harvested thrice, during one rotation of maritime pine). Nevertheless, there is no information available on the impact of the harvests in the eucalypt areas over the growth of pine and vice versa.	
Harvest/final felling, *uncommon FMMs*	The experience and knowledge about both final harvest of chestnut stands is available. The forest owners association (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the harvests. Chestnut stands are typical harvested with chainsaw. Extraction is done with tractor equipped with winch.		Chestnut timber is sold before harvesting.

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Table 12 Drivers and barriers for implementing common versus uncommon FMMs, Vale de Sousa CSA, Portugal

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** The case study is situated in an area where supply of raw material to the forest based industry, mainly sawmills and pulp and paper industries is of primary interest. Indeed, three FMM target the supply of eucalypt pulpwood and two of them maritime pine fuelwood and sawlogs in the list of ecosystem services provided by Vale de Sousa CSA. The area further provides hardwood volume and carbon storage. At present pure eucalypt stands extend over approx. 66% of the area, as expected most ownership types in the 'Economic' class focus on the supply of wood products, thus confirming the importance of economic factors as drivers to forest management. However, the supply of hardwood (chestnut) volume and of forest services (e.g. biodiversity) is perceived and interesting by stakeholders and may increase with the success of policy or market payments for ecosystem services as well as the ZIFs (Forest Intervention Zones) eligibility to further support by forest policies. Paper companies and forest organizations that are dependent on a continuous supply of pulpwood and timber assortments provide information and advice regarding forest management to private forest owners.
	Uncommon FMMs/ remarks A considerable increase in wooded areas (forest stands) with chestnut (+48%) has been suggested by stakeholders to develop a landscape mosaic that may better address the demand of hardwood sawlogs and of other ecosystem services.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management in-	***General/common FMMs*** The Vale do Sousa Forest Owners' Association (AFVS) is the only forest owners' association in the case study area. Therefore, it is the only voice representing the forest owners (360 landowners who are members of the ZIF - Forest Intervention Zones) in the dialogue with public authorities and other stakeholders. It is, also the most important organization providing technical support to forest owners, and the only one having forest sapper brigades to carry on preventive silvicultural works for reducing the risk of forest fires. Thus , AFVS constitutes the most powerful actor, together with the paper industry , and several local sawmills. The level of self-employment among private forest owners in harvesting has dropped substantially over the last

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tensity, the choice of FMMs, etc.	decades and the forestry owners contract entrepreneurs for thinning and final felling. The ZIF was designed to overcome the main bottlenecks to the implementation of the FMMs, namely at landscape/level management planning: property fragmentation and incipient management by some forest owners)
	Uncommon FMMs/ remarks The traditional dominance of market actors in forest management planning promotes the dominant FMM (clearcutting with eucalypt/ pine), since it is associated with a large market demand reducing the interest for other management models. Nevertheless, there is a trend for increasing diversity and providing additional forest products and services and there is knowledge and experience for the implementation of the chestnut FMM.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The Vale do Sousa Forest Owners' Association (AFVS, Associação Florestal do Vale do Sousa) is the major actor that produces forest management plans to private forest owners under the ZIFs (Zonas de Intervenção Florestal, DL 127/2005, 5 de Agosto DR 150).The ZIFs are joint management areas that must encompass at least 1,000 ha and 50 forest owners and that promote the integration of multiple owners' forest management plans to address wildfire prevention goals. ZIFs have a management board that may consist of a forest owner's association. This management board is responsible for developing the ZIFs forest management plans. Typically, the management board holds meetings with representatives from each ownership type as well as with representatives from other stakeholders e. g., other non-governmental organizations (NGOs), forest service, to engage them in the development of the forest plan. The forest owners with forest stands within the perimeter of a ZIF are compelled to follow the forest management plan after its approval by the general assembly of the ZIF and by the National Forest Authority. Forest management plans are not mandatory but required to obtain certification. The Vale de Sousa CSA extends over an area of 14,840 ha of ZIF: Entre-Douro-e-Sousa (north of the Douro river) and Paiva (south of the Douro river). The landscape-level FMM results thus from the spatial distribution of stand-level FMM agreed by the ZIF's forest owners. Management planning has to comply with silvicultural rules in the Tâmega Regional Forest Plan (PROF-T), approved in 2007 by Minister of Agriculture (www.icnf.pt/portal/florestas/profs/tamega). It specifies, for example, that in areas without a Forest Management Plan (PGF), contiguous clearcut areas should not exceed 10 ha. Typically, in the CSA, harvest areas in properties with Forest Management Plans do not exceed 50 contiguous hectares to address

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	environmental concerns with impacts of harvests. Also, the minimum rotation period is defined in the Tâmega Regional Forest Plan (PROF-T), that prescribes eucalypt coppice cycles ranging from 9 to 14 years, in practice rotation range is slightly lower, 10 to 12 years. Besides that, there is a stipulation stating that an authorization is needed from the National Forest Authority (ICNF) for premature cuts in maritime pine in areas greater than 2 ha and in eucalypt in areas greater than 1 ha (Decree-Law No. 173/88 of 17 May).
	Uncommon FMMs/ remarks In practice the optimal stand-level rotation depends on the site index and on financial considerations, At the same time the preservation of biodiversity is prioritised by legislation as well as by local stakeholders. There are regulations about rotation length for broadleaved trees in the CSA. This complies with sylvicultural rules in the Tâmega Regional Forest Plan (PROF-T) that sets the minimum rotation of chesnut at 40 years. In addition, the legislation implies that clearcut not exceed 50 contiguous hectares to address environmental concerns with impacts of harvests.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General/common FMMs*** The combined effect of market, technical and human capacities play the largest role in maintaining the current almost total dominance of the production system with the eucalypt and maritime pine. Forest owners as well as wood-buyers/planners are uncertain regarding the performance/management and future market demand for alternative species. Reflecting the stability of current forest management practices, the level of experiential knowledge and practical know-how is much more advanced for clearcutting with eucalypt and maritime pine which favors its application in practice. The losses caused by wildfires are one of the major sources of uncertainty when projecting timber supply in the CSA. The decrease of maritime pine and the expansion of eucalypt plantations were the most significant trends in the last decades. Wildfires are a severe threat also to eucalypt plantations, which provide key raw material for the pulp and paper industry. However, eucalypt grows fast compared to other species growing in the CSA. Dominant height after 10 year are in the same magnitude as after 45-50 years for maritime pine and chestnut. Community ownership (local parish) accounts for 35% of the ZIF_Vale Soua area. Medium and large private properties (area greater than 5 ha) extend over 60% of the ZIF_VS area. The remaining 5% are owned by small or very small forest owners. The Vale do Sousa Forest Owners' Association plays an important role in those small properties. Under these tenure conditions, effective intervention to protect forests and increase its profitability is made possible through cooperation within forest owners associations and through the establishment of partnerships (e.g.

	ZIFs). Ownership of forests might influence forest management, environmental performance, the production of timber and other forest products and services, e.g. on the global level private forests provide more market based goods such as timber, while public lands produce proportionally more fuel wood and multiple-use goods and services. Those active and representative institutions support active management and protection of private and communal forests.
	Uncommon FMMs/ remarks The framework described above applies too to the least represented FMM. At present chestnut management model cover approx. 1 % of the area. Nevertheless, as suggested recently by stakeholders the area of mixed eucalyptus – maritime pine stands) may be converted to pure (even-aged) chestnut stands to increase the supply of hardwood saw logs and other ecosystem services. Scenario outlined above - the success of policy or market payments for ecosystem services as well as the ZIFs (Forest Intervention Zones) eligibility to further support by forest policies – may further contribute to increase the importance of this FMM.

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2.7. Slovakia

The tables below briefly describe the "technological landscape" in the **CSA Podpoľanie, Slovakia**.

The FMMs in the Slovakia are mainly about timber production under consideration of the current legislation and FMPs that are mandatory. Furthermore, the management with the special focus mainly either on cultural, recreation or nature values could be described as "uncommon FMMs" (no-management, soil management, or water management FMMs).

Table 13 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Podpoľanie

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most commonFMMs***	More than 60% of the area of all FMM is established through natural regeneration. Artificial regeneration is well known, decades of experiences. All equipment and seedlings are available.	Mainly artificial regeneration should be fenced to avoid browsing damage. It should be up to 1% for full-area fencing and individual protection up to 10 % of the CSA (expert judgement). Individual tree protection is applied on 1 - 5% of the CSA, based on available data. It is only possible to use seeds from the same seed region and the same altitudinal vegetation zone (defined in a seed law Act No. 138/2010). It is not allowed to transport seeds between forest seeds regions. On the CSA, there are many seed sources which are utilised for production of seeds. Genetically improved or modified trees and also hybrids are not used due conservation of local tree species and original ecosystems.	The average cost for artificial regeneration in Slovakia is 1 878 €/ha. The number of seedlings per ha for artificial regeneration depends on tree species. The number varies from 1000 to 8000 seedlings per ha. Plantation cost of one seedling with all necessary works varies from 0.20 to 0.50 € (approx. - expert judgement). The average cost for young plantation care in Slovakia is 167 €/ha. The average cost for the protection of young forest stands in Slovakia is 152 €/ha.

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
		Artificial regeneration is at present done through outsourcing (supplying private companies or persons).	
Regeneration, *un-common FMMs*	More than 80% of the area of all FMM is established through natural regeneration. Artificial regeneration is well known, decades of experiences. All equipment and seedlings are available. In Natural protected areas for nature conservation is 100% of the area established through natural regeneration.	Protection against browsing damage is not allowed in Natural protected areas for nature conservation. Protection against browsing on other areas is similar as with common FMMs. Artificial regeneration on extreme sites and high slopes is difficult and not always successful and needs to be repeated. Applications of chemicals (herbicides, pesticides, fertilisers, etc.) is not allowed in Natural protected areas for nature conservation and near to drinking water reservoir. It is only possible to use seeds from the same seed region and the same altitudinal vegetation zone (defined in a seed law Act No. 138/2010). Genetically improved or modified trees and also hybrids are not used due conservation of local tree species and original ecosystems. Artificial regeneration is at present done	The average cost for artificial regeneration in Slovakia is 1 878 €/ha. The cost for artificial regeneration on extreme sites and high slopes is higher than the average cost in Slovakia. The average cost for young plantation care in Slovakia is 167 €/ha. The average cost for the protection of young forest stands in Slovakia is 152 €/ha.

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
		through outsourcing (supplying private companies or persons).	
Stand management, *Pre-commercial thinning (PCT)*	Science-based guidelines are available. The intensity and type of the thinning depend on the species composition and whether the stand was established by planting or by natural regeneration. Thinnings are usually done once per decade and are prescribed in the forest management plans (so the forest owner is obliged to carry out them). It mainly includes modification of species composition and reducing stand density.	Pre-commercial thinning are at present done through outsourcing (supplying private companies or persons) and the quality of thinning (e.g. damage to standing trees) decreased since the change of the system (from own employees to outsourcing). Due to relatively high costs and no income, pre-commercial thinning are often not carried out leading to increased stand density and reduced the static stability of the stands in the future.	Pre-commercial thinnings are costly (100 – 300 €/ha), and no income is generated in general. Costs are higher for the stands established by natural regeneration as these are much denser than the forests from planting. However, pre-commercial thinnings are considered important to increase the quality of wood and so increase the potential income from the future commercial thinning and final fellings. Timely and intensive thinnings lead to an increased volume increment and may thus reduce the rotation period necessary to reach desired assortments.
Pre-commercial, ***uncommon FMMs***	Pre-commercial thinning are either not applied at all (no-management FMM) or are done with very small intensity (soil protection and water management FMMs)	Pre-commercial thinnings are required in some soil protection FMMs to keep the forest structure diversified. However, in many cases, the pre-commercial thinnings are not done at all.	Minimum (soil protection FMM) or no (no-management FMM) costs for thinning and no income generated. Other than timber production functions are preferred and ensured.
Stand Manage-	Knowledge background on the intensity	Due to increasing frequency and intensity	Both the costs and income de-

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
ment, ***thinning common FMMs***	and timing of the commercial thinning is good and science-based. It should be done three or four times (each five years). Depending on the current forest state (stand age, site index, species composition and stand density) the thinning intensity ranges between 5% and 80% of the standing volume (merchantable volume).	of catastrophic events (windstorm and bark beetle attacks) the commercial thinnings are not carried out.	pend on many factors – site index, tree size, species composition, assortment structure. Usually, thinnings give positive results, but the older and larger-sized is the stand the higher the income can be generated. However, this is the situation when there is demand for all assortments produced by thinning. In case, all the timber cut in thinning would be sold as pulpwood or fuelwood; the net income would be smaller. On average, the costs for thinning ranges between 15 and 25 €/m3. The average income can reach 30-50 €/m3 (mainly pulpwood).
Stand management ***uncommon FMMs***	As in the case of pre-commercial thinning, commercial thinnings are done at less intensity (soil protection FMM) or no thinnings are done at all (no-management FMM). Some exceptions might apply to water management FMM.	The same holds true for commercial thinning as for pre-commercial thinning (in soil protection FMM). No thinnings are allowed in no-management FMM.	Minor costs for thinning in soil protection FMM and no costs for no-management FMM.
Harvest/final felling ***common FMMs***	Manual workers with a chainsaw in combination with skidder are predominant due to the dominance of broadleaves.	Skidding machines used in forest stands are often outdated due to the contractor's way of carrying out harvest opera-	Costs for final felling in the case of using manual workers with chainsaw ranges from 10 to 18

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	Harvesters are used for thinning where conifers are dominant, but they are not used often. The selection of the harvesting technology also depends on the terrain conditions.	tions. Because of low harvest prices, contractors are unable to buy new skidding or harvest machines. Despite the increasing rate of natural regeneration, there are relatively high costs of cultivation (protection against weeds, animals) except the close-to-nature FMM	€/m^3 and for using harvesters are relatively higher with an average of 20 €/m^3. Cost is higher when performing harvesting in areas with high slopes and extreme sites (lower tree volumes).
Harvest/final felling, ***uncommon FMMs***	Biodegradable lubricants produced from natural oils and fats are used in skidders; cable system is used in forest stands with soil protection function.	Relatively high cost of cable system technology and the use of biodegradable lubricants and lubricants. In the case of no management FMM, no final felling is allowed.	Costs for using cable system starts on 18 €/m^3 up to 30 €/m^3. It depends on skidding and pulling distance.

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Table 14 Drivers and barriers for implementing common versus uncommon FMMs, CSA Podpoľanie Slovakia

Market	***General/common FMMs***
What is the overall market situation and trends? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, regarding management intensity, the choice of FMMs, etc.?	There is a large market for round wood– spruce, pulpwood and fuelwood in Slovakia. The round wood is largely processed by the large but also many small sawmills. Although the large proportion of broadleaved forests in Slovakia in general and in the CSA particularly (including the future developments towards broadleaved species), present are rather processing capacities and also demand for coniferous round wood– mainly spruce. In contrast, processing capacities for high-quality assortments, especially in the case of broadleaves species (e.g., production of veneers) are absent in Slovakia. Often, these assortments are exported. This situation is even more pronounced in the CSA for which are typical long rotation periods, large and/or long logs among others. Broadleaved pulpwood and other industrial round wood are mainly processed by the pulp and paper industry for the production of pulp. Significantly lower volumes are utilised by the producers of particleboards. The importance and demand for fuelwood in Slovakia and particularly in the CSA grew considerably. Not only it is used for energy production by the heating plants or CHP plants, but also households increasingly use fuelwood as a source of production of heat energy. The situation in the timber processing industry is important to forestry in general and the forest owners in particular. This is mainly because the sale of timber provides approximately 80% of their revenue. Additionally, recent developments concerning the promotion of energy from renewable resources, lack of processing capacities of high-value assortments or enlarged protected areas among others, are all triggering a significant shift from the traditional utilisation of timber as a material for the production of wood products towards being a main renewable energy source. As a consequence, these trends influence wood utilisation patterns and thus the competition between material and energy production. They also influence the competition between different forest uses as the forestry in Slovakia is traditionally focused on the production of high-quality assortments. Largely, most of the FMM are thus oriented towards timber production under current legislation and rules concerning FMM and FMP. In other words, timber production is based on available resources as a result of FMP, but also by the increased proportion of salvage felling. Nevertheless, timber production follows also developments on the markets and situation in the wood processing sector, which tries to steer forestry in general and forest owners in particular towards increased management intensity.

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	Uncommon FMMs/ remarks In the case of uncommon FMMs, the special focus is placed on supporting, regulating or cultural ES. Few FMMs (e.g., water management) also provide marginal timber output. The market for other than provisioning ES as an output of these FMMs is almost non-existing in Slovakia. An exception could be found in the CSA, which has a well-developed market for some non-provisioning ES, especially associated with game management (e.g., deer game, the harvest of trophy deer, the infrastructure of huts for hunters, protection of deer population, research on deer population biology and large beast). Delivery of supporting, regulating or cultural services is commonly associated with costs for which forest managers and especially forest owners do not have available resources— unless they are covered by the provisioning of timber or by the subsidies (e.g. via EU Rural Development policies).
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks that impact the management intensity, the choice of FMMs, etc.	***General/common FMMs*** The level of mechanisation on forest stand establishment and afforestation is currently very low, focusing mainly on soil preparation in support of natural regeneration and planting of seedlings during artificial forest regeneration. The engineering of these works significantly reduces field and soil conditions. Therefore, it is only to a limited extent. Despite the significant increase in the recent period and general preferences and support, the proportion of natural forest regeneration still does not correspond to natural conditions, which increases the need for artificial afforestation and increases costs. In the case of artificial afforestation, mainly bare-root seedlings are used, with losses after afforestation being high. Natural restoration is complicated by forest stands instabilities, early recovery after accidental fellings, failure to comply with management and recovery plans, weather extremes and harmful factors impact. The production of seedlings for artificial reforestation has been strongly concentrated in a few specialised nurseries, which has led to the maintenance of personnel professionalism and an adequate level of specific equipment and mechanisation of the most activities. However, production cycle is too long, and it does not take full advantage of the possibility of growing the planting material under controlled conditions - foil plants, greenhouses and high production substrates. Pre-commercial thinnings and commercial thinnings up to 50 years are performed exclusively moto manually. The share of harvesters in thinnings over 50 years and in final fellings is also very low, and their usability is limited also objectively

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	due to the high proportion of the broadleaves in the stands and the high share of broken terrains with a slope of 50%. Long timber - stem technology is predominant with the production of assortments at the hauling place (forest yard) or expeditionary (central) yard. Nearly 70% of the timber extraction is performed by tractors and horses. The total length of the forest road network in Slovakia is about 37,000 km with a density of about 18.5 m/ha and dominance of non-paved roads, which is inadequate. The distribution of the roads is very uneven, especially in the higher mountainous areas roads are significantly missing. The length, structure and distribution of roads mostly adversely affect the application of logging and transportation technology. This builds on the applicability of forest regeneration practices and the use of biomass production potential for energy purposes. Significant impact on the application of logging technologies also has a high rate of accidental fellings, mainly as a result of wind calamities and other abiotic pests influence. The volume of investment into the technological equipment and road construction is insufficient. The level and knowledge and personal professionality of the whole forestry profile are reasonable and sufficient. Developed, structured and sufficiently functional is forestry specialised education and research. However, the process of innovation and the transfer of the latest knowledge and research results into practice is stagnant. The innovation cycle is too long; there is a lack of productive collaboration between research and development institutions, manufacturers and users of the results. Investments into the research, particularly from the private sector, are rare. There are no investments in forest opening-up and infrastructure development. A particular problem is the maintenance of existing forest roads, in particular as a result of reprivatisation. In the majority of forestry holdings, the level of equipment of machinery for the mechanisation of harvesting, manufacturing and transportation does not correspond to still increasing demands for the reduction of negative environmental impacts. By the majority of forest managers, the lack of financial sources is perceived as a main barrier in the innovation process. Many forestry holdings implement the realisation of forest management activities by contracts (outsourcing). Since the contracts are short-term, there is a problem for forest operation enterprises to realise renovation of technology park through a loan, leasing, etc. It has finally an impact on the quality of realised works, obsoleteness of technical equipment working in the forests and a negative effect on the environment.

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	Uncommon FMMs/ remarks In the case of uncommon FMMs, the special focus is placed on supporting, regulating or cultural ES. Forest opening in high slopes and Natural protected areas is low in comparison to common FMMs. Well-developed is a network of hiking paths and cycle routes. In water management, FMM is necessary to use biodegradable oils in chain saws and avoid contamination of the environment by oil from machinery. Supporting of cultural ES is under development.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** Forest management planning in Slovakia is governed by the Act on Forests (Act No 326/2005 Coll. on Forests) through the state financed forest management plan. The state will obtain information about the state of the forest lands, which is updated throughout the ten years period in the whole territory of Slovakia. The forest management plan prescribes the exact framework governing the owner. The forest manager must not exceed planned felling in forest stand over 50 years of age about 15 percent, and the planned felling in the forest management plan must not be exceeded for the whole area of forest management plan creating. In the case of adjusting the level of the felling, it is necessary to make a change to the plan, which is financed by the forest owner. The law imposes an obligation to the owner to afforest the unstocked area for the age of two years. In the case of pre-commercial thinning, the emphasis is placed on the area of thinning. The forest manager enters to the planning process of forest management plan creating as an actor. Management planning is based on the particular state of forest stands and their stability while minimising the potential risk. The restoration of the forests begins with a precisely defined age set according to rotation and regeneration period determined by stand maturity, which makes provision for the maximisation of the production but also the representation of the highest quality assortments. Forest owners and wood processors do not enter directly into the planning process.
	Uncommon FMMs/ remarks Planning of management in forests with a dominant non-production forest function is carried out through a forest management plan, where the support of a specific forest function in practice is implemented through the adjustment of indicators (especially it is a reduction or complete exclusion of felling, modification of the tree species composition, support of uneven forest structure, etc.). FMM with no management is applied in nature reserves, and the owner is financially

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	compensated by compensations. There is a 100-meter buffer zone around each of no management area, where the management is adjusted to minimise of damages in the conservation area. Compensation is not paid to the owner in practice, even though it is covered by Act No. 543/2002 Coll. On Nature and Landscape Protection. There is a high proportion of protected areas in Slovakia, and there are frequent conflicts between conservation and forestry sector, which in the case of the territory of Polana does not apply.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General/common FMMs*** Slovak forestry is commercially oriented forestry aiming for high and “even-flow” timber yields. Similarly to many CEE countries, it still shared some of a socialist legacy of strong technical forestry, long rotations (based on a concept of ‘production maturity’ rather than ‘economic maturity’), shelterwood cuts, and annual allowable cut below mean annual increment. The provision of other ecosystem services on the landscape level is achieved through spatially segregating management zonation (some parts of the forest are managed to fulfil other services than wood production primarily). The selection of management and application of FMM’s is firstly guided by **policy and legislation** (eg. Act no. 326/2005 of the Coll. on Forests or Act no. 543/2002 of the Coll. on The Nature and Land Protection) incorporating the sustainability and maximal wood production paradigm, secondly by the **environment properties and forest state** assessed by forestry planning specialists and thirdly, by **wood and biomass market** situation. The provisions of regulative and cultural services are regarded as external benefits of proper wood-oriented management usually. **Policy and legislation** together with **site and forest state** play a dominant role in FMM selection. All forests are managed according to mandatory plans (elaboration financed and regulated by the state). The plan is the instrument by which the state define and regulate the allowable profit from wood for owners to secure the forest sustainability and provision of non-profitable regulative and cultural/social services. The ownership rights are highly restricted, and their application is strictly controlled. Selection of current FMMs is made by planning authority almost independent of the owner will – the site properties, current species composition and ecological stability of the forest combined with paradigms of full utilisation of site production capacity and continual existence of forest on given area almost fully predetermine the application of FMM. Changes in such settings are not expected shortly, although some initiatives of non-state forest owners exist. The forestry section within Ministry of Agriculture has a minor influence and only limited possibilities effectively affect the major political decisions in this sector. The dominant opinion of state administration is that financially profitable forestry (in

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	comparison to problematic agriculture) need not be reformed for that setting. The distribution of political power in the current system is clearly biased toward the state administration (unfortunately frequently affected by various lobbies groups) what is considered as satisfying. The additional payments for non-provisioning ecosystem services or other dramatic changes in forestry financing schemes in such situation are almost surely excluded. The main source of financial incomes for forest owners is likely to remain the wood sales, even for more distant future, although the clear tendency for a higher proportion of incomes from biomass can be forecasted. Selection of FMM is markedly affected by **tree species composition and health and ecological status of the managed forests**. Negative impacts of climate change on Slovak forests are especially severe, and they are visible everywhere. Large-scale disturbances and a high proportion of random fellings on the total annual cut (from 50-70 %) highly impacted the wood market. Wood supply is irregular and wood quality supplied on the market is frequently worsened. Moreover, the ecological stability of many stands has been decreased, and provision of regulative and cultural services in many areas was lowered. Climate change is also reflected in changed growth abilities of main tree species. Growth deterioration of spruce at lower altitudes and outside of the natural range, regeneration of growth depressed fir and improved production of beech and spruce at higher elevations are registered across the all Slovak territory. At the same time, positive growth trends at higher elevations are dampened by negative effects of increased weather variability resulting in increased occurrence of extreme events (droughts, frost, icing, ...) Growing fears about the growing stocks raise the pressure to reduce the length of rotation periods that are likely to be reduced. The expectation of increased broadleaves proportions on species composition also exist. Although at least somewhat increased growth productivity of broadleaves and their extended distribution in Slovak forests are expected, still, the regeneration of Norway spruce stands is supported by a majority of practitioners due to its great economic importance. Therefore the spruce is preserved wherever possible, partly due to missing wood processing facilities for broadleaved assortments, despite the demands for nature-mimicking management in response to fears about the ecological stability of forests in Slovakia. Orientation to the wood production of common FMMs predetermines an important role of **trends in wood-related industries** (wood processing, furniture, construction, housing market, energy sector, local wood consumptions, ...) within their selection (and far more within their operational implementation). A significant shift from the traditional utilisation of timber as a material towards being a main renewable energy source is expected. As a consequence, these trends in-

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	fluence wood utilisation patterns and causes the competition between different forest uses as the forestry in Slovakia is traditionally focused on the production of high-quality assortments. The pressure on forests as a source of renewable energy can enlarge the demands for management intensification in the future, that means, demands for a better utilisation of mean annual volume increment can be more pronounced. However, overall, the orientation on shelterwood natural regeneration and certified management regarding biodiversity in response to public pressure for close-to-nature management will probably prevent the intensification of forest harvests, especially until the negative effects of disturbances on ecological stability of the forest will not be diminished. The application of common FMM is relatively less affected by **infrastructure, technical and human capacity**. The infrastructure and the technical situation are relatively bad due to long-term absence of sufficient investments into financially undermined, highly regulated forestry sector. The level of equipment of machinery for the mechanisation of harvesting, manufacturing and transportation does not correspond to still increasing demands for the reduction of negative environmental impacts. By the majority of forest managers, the lack of financial sources is perceived as a main barrier in the innovation process. On the opposite side, the human capacity is high due to the historically high level of forestry specialised education and research. The forestry professionals have profound knowledge about the forest ecosystem processes, ecology and economics of forest production and they are willing for reasonable innovations. Moreover, due to legislative regulations, they fully govern the strategic forest management aside from the forest owner opinions. However, the process of innovation and the transfer of the latest knowledge and research results into practice is stagnant (low investments into the research), and the low salaries reduce the willingness of young people work in the sector that can endangered human capacity in the future.
	Uncommon FMMs/ remarks The bad ecological situation of the spruce stands outside its natural distribution, negative effects of pronounced droughts and the occurrence of large-scale wind and bark beetle disturbances in combination with improved environmental education and the increased activity of nature protection NGOs triggered fears of the public about the existence of the forest. Subsequently, changing public opinion on forestry also greatly affected the applied management approaches. Over the last 25 years, the pressure of public opinion towards the more close-to-nature management and biodiversity protection

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	was manifested in a shift away from the clearcutting systems linked to the artificial forest regeneration to the shelter-wood management with an increased share of natural regeneration. Clear cuts were completely prohibited. At the same time, the forest owners and managers are more willing to manage its forest according to certification schemes (FSC or PEFC certification are most widespread). CCF principles are educated and promoted by PRO-SILVA initiative and are actively tested in various Slovak regions. Moreover, the CCF ideas becoming very attractive also for small forest owners whereas they enable to harvest the wood resources continually and allow to meet demands for wood assortments on markets better. Within the elaboration of FMP, some uncommon FMM (e.g., water purification, soil protection, nature conservation) are supported by management zonation (called categorization) based on the idea of multi-functional forestry which is obligatory implemented into FMP. Once again, public interests for water, environment protection or nature heritage or biodiversity take precedence over private interests without the compensation, what is secured by legislation. The application of uncommon FMM for cultural services (e.g., recreation or biodiversity promotion) stemming from the owner decision is very rare due to the restriction of financial incomes from the wood production. On the other side, as it was already mentioned, the introduction of the payments for non-marketable, common-pools, non-rivalry utilised ecosystem services from the state initiative are almost excludable because the current situation and idea of superiority of the public interests over the private ones is considered as unchangeable status quo.

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2.8. Sweden

Table 15 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Kronoberg, Sweden

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most common FMMs***	Planting spruce and pine is a well-known and there are equipment for site preparation, seedlings available and knowledge.	Natural regeneration of pine becomes more and more uncommon due to high browsing pressure	Cost for regeneration (planting) very roughly 1500€/ha. Including site preparation, seedlings and planting. This is true for plantation of spruce approx. 2500 seedlings /ha
Regeneration, *"special" and uncommon FMMs*		Planting broadleaves are costly, sometimes need fencing	
Stand management, ***Pre-commercial thinning (PCT)***	There is a lot of experience and knowledge about Pre-commercial thinning PCT is done by manually, (brush saw). Most common is regulating tree species mixture, cutting.	Many forest owners don't perform PCT or do it when tree height is high, this increase the cost for thinning	Average cost 2500 sek (260€/ha), but varies depending on tree height
Pre-commercial, ***uncommon FMMs***		There is a lack of knowledge about stand management in broadleaved stand and in stands for nature conservation	
Stand Management, ***thinning common FMMs***	There is a lot of experience and knowledge about thinning, e.g. thinning guidelines Harvesters are almost always used.		Cost depends very much on size of trees (small trees high cost) while income (pulpwood, timber) increase with trees size. Normally all thinnings give a positive result also 1st thinning,

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Stand management ***uncommon FMMs***	There is technology about thinning that can be used in almost all kind of stands	The experience and knowledge about stand management of mixed stands and broadleaved stands are limited	Thinning is sometimes costly as there is no market for pulpwood for some species
Harvest/final felling ***common FMMs***	Harvesters are almost always used		Harvest cost is low for final felling,
Harvest/final felling, ***uncommon FMMs***	Most often harvesters and forwarders can be used, reducing the cost for felling	Harvesting technology in Sweden is developed for clearcuttings and alter-natives, e.g in selective cuttings are expensive if they exist. Manual work-ers with chainsaw is expensive	

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Table 16 Market and Legislation that can be drivers and barriers for development of FMMs, CSA Kronoberg, Sweden

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for pulpwood and timber of spruce and pine, and a good situation for pulpwood of many broadleaved species. Forest companies and organizations that are dependent on a continuous supply of conifer assortments provide information and advice regarding forest management to private forest owners. Reflecting the interest of these organizations, as well as an uncertainty and lack of knowledge regrading suitable alternatives among their staff, spruce and pine are consequently favored when forest owners select species in reforestation. In addition, these industrial actors steers forest owners towards increased management intensity.	***Uncommon FMMs/ remarks*** The market situation for broadleaves in southern Sweden is bad. There is now only one sawmill buying broadleaved timber, that is Kährs flooring industry that buy oak and ash. This reduces the interest for uncommon species and uncommon management models.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	***General/common FMMs*** The forest sector is well organized and optimized for the production of conifer timber and pulpwood through the clearcutting system. In Kronoberg County, the forest owner association Södra constitutes the most powerful actor, together with the Stora Enso affiliate Sydved, and various sawmills. The level of self-employment among private forest owners in harvesting has dropped substantially over the last decades and the forestry actors' therefore contract entrepreneurs for thinning and final felling. Large and expensive harvest machinery, sometimes coupled with the investment in the maintenance or construction of forest roads implies that the fixed cost associated with harvesting is substantial. Consequently, an "economies of scale" favor large concentrated removals (e.g. clearcutting rather than continuous cover forestry). Reflecting the stability of current forest management practices, the level of experiential knowledge and practical know-how is much more advanced for clearcutting with Scots pine and Norway spruce which favors its application in practice.	

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	Uncommon FMMs/ remarks Tradition and knowledge reduce the interest for other management models than clearcutting systems with pine and spruce. But there is a clear trend for more diversity, more nature conservation, and other species and mixed forest than spruce.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** Overall, the liberal Swedish forest policy, guided by the principle “Freedom with responsibility” gives private forest owners almost a total freedom in the selection of FMMs. Forest management plans are not mandatory but re-quired to obtain certification. Industrial actors are the major actors that produces forest management plans to private forest owners, while the activity of the Swedish forest agency has been reduced due to budgetary cuts. The dominance of market actors in forest management planning thus promotes the dominant FMM (clearcutting with pine/spruce), since it is associated with a large market demand.
	Uncommon FMMs/ remarks The management of the areas dominated by noble broadleaves (mainly Oak, Beech) is regulated in the noble forest act. The legislation implies that reforestation with noble broadleaves is mandatory after final felling. The govern-ment can formally protect forests with high conservation value (currently approximately 2 % of the productive forestland in Kronoberg), this involves financially compensating the private forest owners for their economic loss-es. These areas are assigned no intervention or nature conservation oriented management depending on the con-servation objective. Restrictions in the certification standards influence the distribution of FMMs at the level of the single private property. The certification standards require a minimum level of nature conservation (≥5 % of the productive forestland) and broadleaved dominated stands (≥5 % of the productive forestland on mesic/moist soils). In addition, there are restrictions regarding the use of exotic species (≤ 5 % FSC/≤ 25 % PEFC of the produc-tive forestland).
Concluding remarks Concerning the impact on FMMs, which of the above fac-tors (markets, etc.) play the	***General/common FMMs*** Lacking both prescriptive legislation and forest management planning procedures (with the exception of the few requirements in the certification standards), the combined effect of market, technical and human capacities play the largest role in maintaining the current almost total dominance of the clearcutting system with the native coni-

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most significant role? What trends can be expected? Any important summarising remarks?	fers. Forest owners as well as wood-buyers/planners are uncertain regarding the performance/management and future market demand for alternative species. Hence, the different factors are highly interlinked, and the continuation of the current dominant practices is strongly connected to a reliance on experiential knowledge obtained, and institutionalized, through experiences in the past. When it comes to alternatives to clearcutting, higher harvesting costs and a fear of storm felling, the later explained by massive storm fellings in the near past, constitute great barriers towards implementing different continuous cover approaches. The stability of the current dominant practices despite major challenges can be exemplified by the reforestation efforts in the aftermath to the Gudrun storm in 2005. Despite a generous system of subsidies that compensated for the higher establishment cost of broadleaves, > 90 % of the reforestation area after the storm was regenerated with Norway spruce, a species that suffered disproportionally high damages. Looking into the future it is therefore most likely that future challenges will be tackled within the current dominant management approaches, rather than inducing large-scale changes to other systems (CCF) or species (broadleaves). One such trend, that is already evident, is changes induced by an increased awareness of the risk of storm felling, the development towards fewer thinning's and shorter rotation periods will therefore most likely continue. Another challenge for the future is to uphold a decent level of profitability, because the increased cost for labor has not been coupled with associated increases in the prices of timber/pulpwood. Reducing the planted seedling density and increasing the share of naturally regenerated broadleaves in conifer plantations is therefore a possible alternative for the future. This also overlaps with goals associated with risk reduction and nature conservation. Finally, the current high browsing pressure constitutes a major challenge that needs to be tackled to uphold forest management programs for Scots pine. As a final remark, it is important to consider that a massive shift to broadleaves not only is constrained by the anthropocentric factors covered here, but also by the characteristics of the ecosystem. The performance of these species generally requires fertile soils, which at least in the short and medium term constrains the possibilities for its large-scale application (because in the long run climate change might of course induce major changes). Consequently, the current dominant forest management practices will most likely prevail on the land managed for wood production also in the future.
	Uncommon FMMs/ remarks The barriers that currently constrain the use of alternative FMMs have already been covered in the previous section. But to summarize, the current production oriented forest management paradigm, combined with a long period where the forest sector has been optimized for the production of a narrow set of assortments (pulpwood and

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	timber of the native conifers), with one dominant methods (clearcutting), altogether constitute a major obstacle for wider application of other FMMs. However, alongside the stability of the practices oriented to wood production, the importance of nature conservation in the forest sector has increased over the last decades. A development that has been induced by new policies and legislation (the forest act in 1993, environmental objectives in 1999) and market instruments (certification). Considering the policy goals related to biodiversity conservation the share of set-asides will increase in the future if current policies remain intact. In addition, the Swedish FSC standard is currently under revision, and the preliminary proposals include higher requirements regarding nature conservation. All in all, the areas left unmanaged (NO) or managed actively for nature conservation purposes (NS) will most likely increase in the future, and relative to the current low proportion, probably quite substantially. Climate change, increased demands to supply a growing bio economy, and discussions regarding risk spreading are all discourses in the forest sector that have the potential to increase the utilization of alternative species. Despite the constraints connected with the current ecosystem conditions, a possible increased use of broadleaves on fertile sites is therefore a likely development in the future. In a possible future where increased production is emphasized, a wider use of Hybrid larch could be a possible alternative, a species that not are restricted by the soil conditions to the same extent and overall shows a good performance in Kronoberg.

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2.9. Turkey

Table 17 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Gölcük Case Study Area

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, *general and most FMMs*	Both natural and artificial regeneration of pine and beech are established well and all necessary infrastructure, equipment for site preparation etc., seedlings and knowledge are available	Natural regeneration is a bit difficult in beech stands due to the difficulty to capture the appropriate seeding year and high social pressure like grazing.	Cost for regeneration (planting) very roughly 886€/ha. Including site preparation, seedlings and planting. This is true for plantation of beech and oak approx. 3500 seedlings /ha. However, cost for natural regeneration is nearly 425 €/ha.
Regeneration, *uncommon FMMs*		Where the objective of management is nature conservation, regeneration is uncommon. Thus no well-designed method is used.	No economic return is calculated
Stand management, *Pre-commercial thinning (PCT)*	There are technical experiences and knowledge about Pre-commercial thinning (PCT). PCT is conducted manually, (brush saw). Most common aim of PCT is to manage the density of stands (i.e., reducing density).	There are lots of stands where PCT was not applied due to managerial and operational problems. Most of the practitioners (Foresters) don't perform PCT due to insufficient workforce or budget allocated.	Average cost for PCT is (98€/ha)
Pre-commercial thinning, *uncommon FMMs*	PCT can be a tool to control the density of fire-prone stands and increase nature values.	There is a lack of experience and partly knowledge about stand management allocated for values other than stand and in timber production	

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Stand Management, *thinning common FMMs*	Thinning beech and pine are very common forest operations. There is a lot of practical experience and knowledge about thinning, e.g. thinning guidelines for beech and pine. Manual chain saw is common.	The level, intensity and time interval of thinning for all commercial tree species are not quantitatively described to put them in the guidelines. Yet, some practical and qualitative description of thinning is mentioned in the guidelines. There exist conventional/poor stand management practices. Furthermore, the thinning response (post-thinning performance) is not modelled. Lack of stand density management.	The average cost per ha for thinning is 65 Euro. Normally all thinning give a positive result.
Stand management, ***uncommon FMMs***	There are technologies for thinning that can be used in almost all kind of stands.	Same problems exits. Plus, there is a lack of experience and technical knowledge about stand management for other forest values or ES. For example, the thinning level, intensity and interval are unknown for water production or mushroom production oriented stands.	Thinning cost is unknown. Foresters often hesitate to actively manage forest with e.g. nature values
Harvest/final felling *common FMMs*	Harvesters are rarely used. However, chainsaw is commonly used in harvesting operation. Animals and tractors are used for hauling. Infrastructure as forest roads, market and more are relatively developed.	Manual harvesting is cumbersome and costly. Manual workers with chainsaw increase the cost. Occasional unavailability of workers often create problem. The maintenance of roads is poor.	Harvest cost is low for final felling, and there is a large market for saw timber, particle board (chip production) and timber. High cost for shelterwood FMM
Harvest/final felling, *uncommon FMMs*	Harvesters are rarely used. However, chainsaw is commonly used in harvesting operation. Animals and tractors are	Harvesting other than CC is expensive. Manual workers with chainsaw increase the cost. Providing incentives to coopera-	

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Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	used for hauling. Infrastructure as forest roads, market and more are relatively well developed.	tives provides problems.	

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Table 18 Drivers and barriers for implementing common versus uncommon FMMs, Gölcük Case study area.

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for particle board (wood chip) and timber industries for almost all species, and a good situation for furniture and veneer of oak and beech tree species. Fast developing private forest companies and organizations that are dependent on a continuous supply of wood assortments provide information and advice regarding harvesting material to state forest organizations, not much on forest management in general. In addition, these private actors have recently started to steer state forest institutions towards increased management intensity. Due to higher costs, requirement for location specific knowledge and practices and intensive management, practitioners do not favor continuous cover FMM.	
	Uncommon FMMs/ remarks The particle board industry does not commonly favor or buy Oak and Chestnut. Yet, the state forest organizations put pressure on the companies to buy them too. Other companies buy oak and chestnut. This reduces the interest for uncommon species and uncommon management models.	
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the	***General/common FMMs*** The state forest institutions are well organized to carry out the forest management operations. In the meantime, Kastamonu Entegre in Gölcük area constitutes the most powerful private actor, together with the local cooperatives and various other small sawmills. The level of forest workers in harvesting has dropped substantially over the last decades and the state forest organizations therefore contract entrepreneurs for thinning and final felling. The rough topography prevents to use various harvesting machineries and increases the maintenance or construction of forest roads and limits the use of certain FMM. Due to regular management practices, the level of experiential knowledge and practical know-how, clearcutting and shelterwood are still a favorable FMM.	

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choice of FMMs, etc.	***Uncommon FMMs/ remarks*** Tradition and knowledge reduce the interest for other management models than clearcutting and shelterwood systems. But there is a clear trend for more diversity, more nature conservation, and other species and the maintenance of mixed stands than pure stands.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The Turkish forest policy and management guidelines do not usually give a total freedom to select and practice various FMMs. Forest management plans are primarily mandatory, yet not required to obtain certification. State forest industries are the major actors that develop and prepare forest management plans while some forest management plans are prepared by some small and relatively new private forest companies. Pine and fir are preferred by market actors in forest management planning. In fact, almost all FMMs are described how and what stand to apply in silvicultural guidelines developed in association with forest management planning guidelines.
	Uncommon FMMs/ remarks The management of the areas dominated by mainly Oak, Chestnut, Poplar and other broadleaved trees is also regulated in the silvicultural principles in the guidelines. The legislation implies that any artificial regeneration must keep the same/previous species mix after final felling regardless of FMM used. New regulations were developed to manage areas for NWFP The state formally protects forests with conservation of forest for other regulatory services. No intervention is assigned to “nature conservation areas”. No green certification is in place in the case study area.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising re-	***General/common FMMs*** The legislation and forest management planning and silvicultural procedures play the most significant role in maintaining the current FMMs. There is a little impact of market, technical and human capacities on the use of various FMMs in the case study area. Since the solo owner of the forest resources is state, the centralized approach towards the use of FMMs in forest management planning dominates the other approaches. For instance, “continuous cover forest FMM” has been implemented over nearly two decades in the past, yet the management authority in the state almost abandoned the FMM leaving less room for the practitioner to try and implement any FMMs. Clearcutting is only implemented in pine stands (primarily on Calabrian pine) and not implemented in other spe-

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marks?	cies. Shelterwood FMM seem to the primary FMM implemented in most of the stands in the case study area, except some Oak stands where coppicing is exercised. No management interventions is required or implemented in conservation areas. The major driving factor is the state forest policy and regulations that almost always dominate the implementation of FMM in any state forest areas. The major challenge is to describe the appropriate FMM for a forest management unit designated or managed for ES other than timber, such as water production. Forest management areas where timber production is the leading objective, FMMs is well-established in terms of market, knowledge, technical and legislative infrastructure. Another major challenge is the rehabilitation of degraded areas (areas with trees sparsely distributed <10% crown closure). Appropriate FMM using planting is to be developed for multiple use forest management approach. Another challenge for the future is the accountability of SFM using certification process where the Turkish forestry principally accepts to go through on an incremental basis. Due mainly to state forest management, accounting for a decent level of profitability in terms of market values has been one of the important challenges in forest management planning. The increased cost for labor coupled with the increases in the prices of timber/particle board and severe competition in international forest market necessitate to uphold the economy of forest management interventions. Using appropriate stand management practices, site preparation, improved seedlings seem to be a possible alternative for the future. Finally, the discussion and the pressure between the conservation of forests and economic use constitutes a major challenge that needs to be tackled to uphold forest management planning approaches/models. As a final remark, although ecosystem based multiple use forest management approach has been accepted as a leading/dominant forest management policy and regulations, wood production will most likely prevail in forested landscape in the future.
	Uncommon FMMs/ remarks There is not any important barrier in forest management legislation to implement appropriate forest management model for ES other than timber production. Yet, lack of technical and experimental knowledge constitutes a major obstacle for wider application of other FMMs. There is a widespread use/implementation of ecosystem based multiple use forest management approach that paves the way for all forest values to account for in the preparation of forest management plans. Biodiversity and nature conservation areas are increasing, NWFPs are gradually taken into account, recreational areas are set aside. Yet, the challenge is to scientifically come up with the appropriate forest management models for the management of other ES. In addition, green certification in Turkish for-

	estry will probably effect the forest management practices in the future as it started in other forested areas. Modelling the risk management, economy of ES and the effects of climate change will likely be the focus of future forest management planning approach in Turkish forestry.

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Appendix 1 FMMs Questionnaire

Part 1 background

Stand level forest management models (FMMs)

ALTERFOR WP1 Questionnaire

The objective of this survey is to provide documentation of current FMMs that are implemented in the case study (CS) areas and hence give information to the ontology of FMMs and FMMs descriptions. These are among the deliverables of ALTERFOR, to be reported on Wikipedia. The documentation of the CS-specific FMM will support the communication of FMM to other CS in a later stage when new FMMs are implemented and assessed. Furthermore, the survey addresses issues that are suitable for scientific publications. Expectedly several such publications can be produced by multi-author research teams of ALTERFOR. The questionnaire is divided into two parts. The first part aims at giving a broad overview of FMMs, followed by more detailed information for specific FMMs in the second part.

List of content:

- Part 1: Overview of FMMs in CS
- Part 2: FMM details (separate files to be filled in for each FMM)
- Annex 1: FMM definitions
- Examples of Part 1 and 2 from Lithuania (Annex 2) and Sweden (Annex 3)

Instruction

- Read through all the documents, including the definitions and examples, before starting.
- The questionnaire consists of two parts. The objective of Part 1 is to give an overview of the CS area and it´s FMMs.
- In Part 2 each specific FMM, together covering ≥90 % of the forest area, is to be described.
- Save the descriptions in separate files (one FMM = one copy of Part 2) named by the CS and FMM and list the file-names in Part 1.
- The division into FMMs should be done firstly according to the definitions of silvicultural systems in Annex 1.
- If tree species that are significantly different in biology but management are according to the same silvicultural system, these should be described as separate FMMs (e.g. species with very short (e.g. 20-40 years) and very long (e.g. >100 years) rotation periods managed by clearcutting).
- Each CS should not give detailed descriptions of more than 10 FMMs.
- More FMMs can be described briefly at the end of Part 1.

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- In Part 2 some questions are divided in to two parts. One describing an ideal situation and one describing how things are done in the reality. The ideal situation should be according to your expertise. It should describe how the FMMs are to be implemented to deliver the target output ESs and balance between different ESs. In many cases, it can correspond to the "textbook silviculture" as promoted in your country.
- When a question refers to regulation of certain management, please indicate how this is regulated, e.g. legislation, certification schemes etc.
- Supply answers within the textboxes that follows the questions.

PART 1: Overview of FMMS

1. Briefly describe what is the historical background to the current forest management orientation and dominant FMMs in your country. Consider such general aspects as societal developments, main ideas around forest management, and forest policy development. In what context (main stakeholders, ownership structure, governance model) is current FMMs applied in your country? (Max 1 page)

Answer:

2. What is the tree species distribution in the case study area (+ region, country). List the species by decreasing proportion.

Species (Latin name)	CSA	Region/province	Country

Comments: [1]

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3. According to the best available knowledge and your expert judgment, indicate how are the edaphic conditions (site productivity, soil moisture) are distributed within the case study area. Provide the percentage of the forestland that belongs to each unique combination in the grid, the sum should be 100 %. Please also indicate what high, medium and low site productivity corresponds to (in m^3 ha^{-1} yr^{-1}) in the case study area.

Productivity/soil moisture	Dry	Mesic	Moist	Wet
High				
Medium				
Low				

Comments:

4. Describe the most dominant FMMs in the case study area (together covering ≥90 % of the forest area) in the table below. Indicate, according to the best available knowledge and your expert judgment, how large area of the CS and the country the FMM covers, and in which file the detailed description is to be found.

   The division into FMMs should be done firstly according to the definitions of silvicultural systems in Annex 1. If tree species that are majorly different in biology and management are managed by the same silvicultural system, these should be described as separate FMMs (e.g. species with very short (e.g. 20-40 years) and very long (e.g. >100 years) rotation periods managed by clearcutting). In case of smaller but still significant difference, they can be expediently described in comments under relevant questions. Each CS should not, however, describe more than 10 FMMs.

Domestic name in English	Corresponding FMM (appendix 1)	Coverage CSA (% forestland)	Coverage country (% forestland)	File name

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Comments:

5. If there is a substantial difference between the case study and the entire country regarding the coverage of FMMs? What is the major reason(s) behind this divergence?

Answer:

6. Which additional minor FMMs exists within the case study areas? Provide a short description of these FMMs (max 400 words per FMM)

Answer:

7. Describe main preconditions for managing forests (such as forest cover, ownerships structure and protected areas in forests), compare between CSA and the whole country, region. Indicate any feature that you consider to be of high importance.

	CSA	Region/province	Country
Total area (ha)			
Forestland (ha)			
Forestland cover (%)			
Productive forestland (ha)			
Productive forestland cover (%)			
Average volume (m^3ha^{-1})[2]			
Site productivity ($m^3ha^{-1}year^{-1}$)[2]			
MAI 2011-2015 ($m^3ha^{-1}year^{-1}$)[2]			
<u>Ownership forestland (%)</u> Companies Private			

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Stand level forest management models (FMMs)

ALTERFOR WP1 Questionnaire

PART 2: FMM details

Stand level forest management model (one file per FMM)

General questions

1. What's the name of the FMM in the local language and English translation?

Local language:

English:

2. According to your expert judgment, how large share (%) of the forest area in the CS **should** be covered by this FMM? Please motivate your answer.

Answer:

3. How large share (%) of the forest area in the CS **is** actually covered by this FMM?

Answer:

4. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

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Answer:

5. Which is the target ecosystem service(s) of the FMM within the case study area (including wood)? If more than one, please rank them by decreasing importance (most important first).

Answer:

6. Which of the following management systems (see definitions in Annex 1) does the FMM resemble most?
   A. Clear cutting systems
   B. Uniform shelterwood systems
   C. Non-uniform shelterwood systems
   D. Selection systems
   E. Coppice systems
   F. No intervention

   Answer:

7. How does the FMM differ in practice from the definition of the management system you have chosen?

Answer:

8. Which main tree species are managed by this FMM within the CSA? List the scientific names by decreasing importance (share of standing volume within FMM).

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Answer:

Size of stand or management unit

9. Is the size of area harvested at one time-point (e.g. clearcut area or area with shelterwood) regulated? No/Yes, in what way?

Answer:

10. What is the size (ha) of individual harvested areas at one time-point in the CSA?

Minimum:

Maximum:

Mean:

11. What is the normal size (m^2) of gaps (only system 3)? Answer with an area interval. Explain the reasons behind the interval of area.

Answer:

Rotation period

12. Is the rotation period (systems 1-3, 5)/target tree age (system 4) regulated?

Yes/No:

Comments:

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13. According to your expert judgement, which is the **optimal** rotation period (systems 1-3, 5)/target tree age (system 4) of this FMM in relation to the output of ES? Answer with an interval of years. Explain the reasons behind the interval of years.

Answer:

14. What is in **practice** the rotation period (systems 1-3, 5)/target tree age (system 4) of this FMM? Answer with an interval of years. Explain the reasons behind the interval of years.

Answer:

15. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

16. Are standards (overwood, large trees) used (only system 5)? If yes, how many per ha?

Answer:

Distribution over edaphic conditions

17. According to your expert judgement, under which edaphic conditions **should** this FMM be applied (tick as many boxes as needed)?

Productivity/soil moisture	Dry	Mesic	Moist	Wet
High				
Medium				
Low				

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18. Under which edaphic conditions **is** this FMM applied in practice (tick as many boxes as needed)?

Productivity/soil moisture	Dry	Mesic	Moist	Wet
High				
Medium				
Low				

19. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

Tree species composition

20. According to your expert judgement, how dominant **should** the most abundant tree species be (pole stage and larger)? Indicate how large share of the standing volume on the stand level that should be allocated to the most abundant species and if this varies within the FMM (e.g. only monoculture 95+ = 100%)

Share of the most abundant tree species on stand level	Share of area within FMM and CSA
% of standing volume	% of FMM area
95+	
75-94	
50-74	
25-49	
0-24	
Sum	100

Comments:

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21. How large a share of the standing volume on the stand level **is** allocated to the most abundant tree species (pole stage and larger)?

Share of the most common tree species on stand level	Share of area within FMM and CSA
% of standing volume	% of FMM area
95+	
75-94	
50-74	
25-49	
0-24	
Sum	100

Comments:

22. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

23. According to your expert judgement, in this FMM, which tree species should be used and how **should** the standing volume on the stand level be distributed under the (pole stage and larger) conditions that are most typical for the CSA?

Answer:

24. Which tree species **is** used and how **is** the standing volume on the stand level distributed under the (pole stage and larger) conditions that are most typical for the CSA?

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Answer:

25. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

Forest regeneration

26. According to your expert judgement, how large share (%) of the trees reaching the pole stage **should** be established through natural regeneration?

Answer:

27. How large share (%) of the trees reaching the pole stage **is** established through natural regeneration?

Answer:

28. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

29. According to your expert judgement, to what extent **should** soil scarification be done to facilitate regeneration? I.e. how large share (%) of the area should be scarified?

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Answer:

30. To what extent **is** soil scarification done in practice? I.e. how large share (%) of the area is scarified?

Answer:

31. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

32. According to your expert judgement, how large share (%) of the area under regeneration **should** be fenced to prevent browsing by game?

Answer:

33. How large share (%) of the area under regeneration **is** in practice fenced to prevent browsing by game?

Answer:

34. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

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Answer:

35. To what extent are tree species non-native to Europe used?

Percent of the seedlings:

If not at all, what is the reason for this:

36. To what extent are European tree species non-native to the CS country used?

Percent of the seedlings:

If not at all, what is the reason for this:

37. To what extent are non-local seed sources used (more than 100 km distance)?

Percent of the seedlings:

If not at all, what is the reason for this:

If seeds are moved, what is the reason for this:

38. To what extent are **genetically improved** trees used?

Percent of the seedlings:

If not at all, what is the reason for this:

39. To what extent are **genetically modified** trees used?

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Percent of the seedlings:

If not at all, what is the reason for this:

40. To what extent are **hybrid** trees used?

Percent of the seedlings:

If not at all, what is the reason for this:

41. Are herbicides and/or pesticides) applied at any stage of management? If yes, by which cause? This question does not apply to use in nurseries and timber yards. Seedlings treated at nurseries to protect against pests in the forest should be included.

Yes, which:

No, why not:

42. Are fertilizers applied at any stage of management? This question does not apply to use in nurseries. If not at all, what is the reason for this? If yes, in which type of forests (species, age) and to what extent (as a share of CSA forests)?

Yes/No:

Comment:

Stand management

43. According to your expert judgement, to what extent **should** pre-commercial thinnings be done? How large share (%) of the area where this FMM is applied should be pre-commercially thinned at least once during a rotation period?

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Answer:

44. To what extent **are** pre-commercial thinnings done in practice? How large share (%) of the area where this FMM is applied is pre-commercially thinned at least once during a rotation period?

Answer:

45. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

46. According to your expert judgement, to what extent **should** commercial thinnings be done? How large share (%) of the area where this FMM is applied should be thinned at least once during a rotation period?

Answer:

47. To what extent **are** commercial thinnings done in practice? How large share (%) of the area where this FMM is applied is thinned at least once during a rotation period?

Answer:

48. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

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Answer:

49. According to your expert judgement, to what extent **should** pruning or other similar tending of trees be done? How large share (%) of the area where this FMM is applied should be treated at least once during a rotation period?

Answer:

50. To what extent **is** pruning or other similar tending of trees done? How large share (%) of the area where this FMM is applied is treated at least once during a rotation period?

Answer:

51. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

Harvesting

52. How large share (%) of the wood harvest is fully mechanized (harvester)?

Answer:

53. How large share (%) of the wood extraction is fully mechanized (forwarder or skidder)?

Answer:

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54. How large share (%) of the logging residues (branches >5cm) is extracted?

Answer:

55. Is nature protection integrated in the stand-level management? If yes, how? If no, why not?

Answer:

The primary sources

56. What have been the primary sources in answering the questionnaire? Including both the team of the participating or consulted experts and primary written sources for describing both the ideal and the actual forest management.

Answer:

FMM summary

57. Short summary summarizing key features of the FMM

Answer:

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