ALTERFOR

Deliverable 1.2 – Alternative Forest Management Models for ten Case Study Areas in Europe

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Summary

The project ALTERFOR examines existing and alternative forest management models (FMMs) in ten case study areas (CSAs) in nine European countries, trying to understand how management models would affect provision of different ecosystem services (ES) in a perspective of decades. The work is divided in work-packages (WPs), and the WP1 (providing this deliverable) deals with management/silviculture of forest on stand level.

The analysis of ten CSAs in Europe shows that in most cases biodiversity the most important driver for developing alternative FMMs (aFMM): every case-study area (CSA) has at least one aFMM that has been motivated by a possible increase of biodiversity and the second most important driver for aFMMs is increased volume production for improving economy of land-owners. Increased production for sequestering carbon is almost not mentioned. Protecting and managing regulating ecosystem services (especially water) and increasing the usability of forests for recreational activities are also reported as drivers in some CSA. There is a clear trend that the amount of broadleaved species will increase in Europe if the aFMMs are implemented. The aim of many aFMMs is to increase the proportion of broadleaves in mixed species stands with or without conifers whereas aFMMs for creating monocultures of broadleaves are rare.

Even the processes behind formulating alternative FMMs differed from country to country, experts and scientists had a strong influence as alternative FMMs were intended to be realistic in terms of climate, tree species and more, offering the possibility to do long time forecasts of growth and yield. Nevertheless, stakeholder perspectives shaped the process and in some cases stakeholders fully replaced suggested model, e.g. Sweden.

Most of formulated aFMMs are realistic and their implementation in each CSA requires moderate levels of new research or technical development. From this point the proposed aFMMs may in average be understood as potentially conservative, but some also significantly challenge current FMMs. Most aFMMs can be implemented without violating current laws or certification rules.

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Abbreviations used

aFMMs – alternative Forest Management Models
AFP - Lowland Forest Association (Italy)
AFVS - Vale do Sousa Forest Owners' Association (Portugal)
AWF - Augsburg Western Forest (Germany)
CAB - County Administrative Board (Sweden)
CCF - Continuous Cover Forestry (Turkey)
CSA – Case Study Area
dbh – Diameter at Breast Height
DSS – Decision Support System
ES - Ecosystem Services
FMMs – Forest Management Models
FPM – Freshwater pearl mussel
FRIS - Forest Resource Information System (Turkey)
FSC – Forest Stewardship Council
GEF II - Global Environment Facility Fund (Turkey)
IFM – Integrated Forest Management (The Netherlands)
IFN6 - National Forest Inventory (Portugal)
LCCs – Local Case Coordinators
LSN - Lieberose-Schaubetal-Neuzelle (Germany)
MARA - Minimum Allowable Rotation Age
NGOs - Non Governmental Organizations
PEFC – Programme for the Endorsement of Forest Certification
PCT – Pre-Commercial Thinnings
SC - State Company (Lithuania)
WP – Work package
YC – Yield Class (Ireland)
ZIF Forest Intervention Zones (Zonas de Intervenção Florestal) (Portugal)

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1 Introduction

Forests provide a broad range of Ecosystem Services (ES) that are highly valued and even necessary for mankind. European forests are used since long and management has varied a lot over time and for different regions. The capacity of sustainable producing important ecosystem services are now and then questioned by different actors. Due to uncertainties of climate change, the complex dynamics of evolving global markets, and the pressures for increased use of bioenergy the challenges for managing the forest resources are large.

The project ALTERFOR examines existing and alternative management of forest trying to understand how they affect different ecosystem services in a perspective of decades. The outcome might result in changes in well-established forest management approaches in European forestry.

The work is being carried out in ten case study areas in nine countries, representing different forest management practices and socio-ecological conditions. The partners are Germany (two case study areas), Italy, Ireland, Lithuania, the Netherlands, Portugal, Slovakia, Sweden, and Turkey.

The work is divided in work-packages, WPs, and WP1 deals with management or silviculture of forest and the focus is mainly on stand level. Other WPs work with European analysis, effects of management on landscape level and implementation and knowledge transfer to forest sector (cf. Project structure).

1.1 Forest Management at stand level (WP1)

Forests can be managed in many ways and with different aims. The characteristics of commonly used management or silviculture approaches, in the 10 Case study areas (CSA) in the nine different countries within ALTERFOR project was described and documented in ALTERFOR project documentation D1.1, (Deliverable 1.1 - Description of FMMs).

Beyond describing common forest management, an important part of ALTERFOR is to develop and study effects of alternative FMMs (aFMMs). Work package 1 (WP1) is dealing with management alternatives at the stand level. Especially the local case coordinators (LCCs) have worked with alternatives to existing management and much of the work was done during 2017.

After drafting first alternative FMMs the work in all ten CSA continued. Some alternatives were changed, some excluded and some new included. Also, the possibilities for calculating outcomes in different ES for alternative management were studied. In this report (Deliverable D1.2) the process and the requests behind the selection of aFMMs are described and the finally selected aFMMs are presented.

1.1.1 The process behind aFMMs

The CSAs differ in many ways, not only in growth conditions but also in ownership, forest legislation or influences from stakeholders. Therefore, the processes behind selecting alternative FMMs differ from country to country. The process is described more detailed for each country in chapters 2-10.

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Many scientists working in ALTERFOR where heavily involved in the process of formulating the aFMMs in the CSAs. In some countries, scientists were those suggesting one or more aFMMs. A typical example is Sweden where WP1 scientists suggested three aFMMs they believed were interesting both for stakeholders and from a scientific perspective. In other CSAs the scientists tried to summarize the stakeholder’s requests or wishes and then suggested possible aFMMs. In Ireland three aFMMs where developed by scientists having stakeholders` interest in mind and a fourth was suggested by scientists while aiming to study a special issue of carbon sequestration. In some CSAs the first steps towards aFMMs where taken by scientists together with stakeholders. In Slovakia problems related to forest management where discussed in a seminar to get input to work with aFMMs. In Portugal stakeholders were interviewed and then preliminary aFMMs were suggested by scientists for further discussions. In the Italian CSA the process was open for influences from different stakeholders and the Italian aFMM come as a result of a series of consultation initiatives conducted between local stakeholders, the University of Padova and the non-academic partner ETIFOR.

By obvious reasons experts and scientists had a strong influence in the formulation of aFMMs. An alternative FMMs were intended to be realistic in terms of climate, tree species and more, offering the possibility to do long time forecasts of growth and yield. It is also obvious that stakeholders in some perspective are more tied to traditions than scientists in ALTERFOR. In Lithuania one aFMM is suggested by scientists to understand and demonstrate the effects of changing rotation age. The legislation in Lithuania is then challenged in a way stakeholders normally would not do. In Sweden scientists suggested selection cuttings as one aFMM because they thought it was of interest for stakeholders but also they (scientists) were at the same time interested in the management model. However, stakeholders turned it down and replaced it with another aFMM.

Many CSA got influences and inspiration from other ALTERFOR countries when formulating one or more aFMMs. This is mentioned e.g. by Slovakia, Ireland, Lithuania and Sweden. Some of these models are really new and drastic when applied in other countries. Two examples are given above, adaptive rotation ages in Lithuania, with the ideas from Sweden and other countries, and selection cuttings in Sweden with the inspiration from Germany and Slovakia. A third example is Sitka spruce with birch shelter in Ireland inspired by a silviculture model used in south Sweden.

In all CSAs one or more workshops were held with stakeholders. For this report no information is available about participation (upcoming deliverables of ALTERFOR Work Package 4), but it is already obvious that large forest owners and/or large state organisations dominated the discussions. In some CSAs this is natural, e.g. Turkey where private forest ownership is almost absent - Gölcük State Forest Enterprise and central General Directorate of Forestry have been dominant. Another example is Ireland where the state forest company Coillte is the dominant owner. In Southern Sweden forest owners are organised in the powerful forest owner association Södra that is a member of the ALTERFOR consortium and had a strong influence on the process. Stakeholders other than large forest owners and state organizations obviously had influence but the exact extent is difficult to estimate. Public opinion is mentioned but it is unclear how it influenced the work. NGOs but also some state organisation have mainly been arguing for nature values and care about biodiversity. An uncommon stakeholder is found in Turkey; water bottling plants show the importance of water quality and water protection.

Forest legislation had impact on some of the aFMMs. In Slovakia and Germany some of the aFMMs can be restricted by todays forest act and one aFMM in Lithuania is challenging the existing forest

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act. Some parts of the Italian CSA are classified as Natura 2000 but this has not restricted ongoing management of selection of aFMMs. Certification, FSC and/or PEFC, seems to have small influence on the process, it is only mentioned in reports from CSAs in Italy and Sweden.

Most CSAs report more than one round of workshops or seminars. Most often scientists presented suggestions for aFMMs at the first workshop. In some CSA discussions with stakeholders about aFMMs will continue during the autumn 2018. Most probably the aFMMs will not be changed to any larger extent, the ongoing discussions are where to use the alternative models and to what proportions of the forest area.

1.1.2 Selected aFMMs

The aFMMs suggested by partners are listed in Table 1.

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Table 1. Number of alternative Forest Management Models (aFMMs) from the ten Case study areas (CSA) with the main Ecosystem Services connected to them, Timber production and/or economic outcome, Biodiversity, Cultural values (especially recreation), Water protection, Risk management and Carbon sequestration

Country / CSA	Name of alternative FMM (aFMM)	Ecosystem Services (ESs)						Note
		Timber / Economy	Biodiversity	Cultural values	Water protection	Risk management	Carbon sequestration	
Germany / Brandenburg	Scots pine timber and energy forest	1						
	Biodiversity centered management of pine	1	1	1				
	Oak biodiversity set-aside		1					free development
Germany / Bavaria	Norway spruce timber and energy forest	1						
	Biodiversity centered management of spruce	1	1	1				
	Beech biodiversity set-aside		1					free development
Ireland	Lodgepole pine fibre	1			1			
	Lodgepole pine wilderness		1		1			
	Sitka spruce under birch nurse, on blanket bog						1	
	Bog restoration		1					
Italy	Recreational selective		1	1				
	Uniform shelterwood and coppice	1	1					
Lithuania	Adaptive rotation	1						
	Care for broadleaves	1	1					more broadleaves
	Non-clear cutting							free development

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Country / CSA	Name of alternative FMM (aFMM)	Ecosystem Services (ESs)						Note
		Timber / Economy	Biodiversity	Cultural values	Water protection	Risk management	Carbon sequestration	
The Netherlands	Wood mass forest	1						
	High value timber	1		1				
	Park management			1				
	Climate resilient management							climate adaption
Portugal	Pure maritime pine	1						
	Pure oak forest sawlog	1						
	Oak for cork production		1	1				
Slovakia	Even aged mixed	1	1	1		1		more broadleaves, reducing Norway spruce
	Uneven aged mixed	1	1	1		1		
Sweden	Sitka/Douglas	1						
	Spruce/pine/birch mixture	1						more broadleaves
	Selection		1	1				
	Stand edge management		1					more biodiversity at landscape level
Turkey	CCF	1	1	1	1			

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1.1.3 Characteristics

The two main eco-system services (ES) that have been mentioned as motivation for the selection of alternative aFMMs are biodiversity and volume production (Fig 1). In all ten case-study areas (CSAs) biodiversity was mentioned as the main reason for the choice of one or many aFMM and in eight CSAs volume production was mentioned as the reason. Designing FMMs for increasing biodiversity is often motivated by the detrimental effect on biodiversity of past and current FMMs. However, it is also stated that the positive effect of the proposed aFMMs on biodiversity need to be tested. Many aFMMs that aim at increase biodiversity are based on a hypothesis of their effect on biodiversity but the hypothesis has not been tested in scientific experiments. Increased volume production is motivated by the need for improved economy of private land-owners. Several CSAs mention that the future global market for saw-timber, fibre and fuel-wood can motivate an increased harvest and use of wood. However, it is striking that carbon sequestration is almost not at all the motivation for increased volume production.

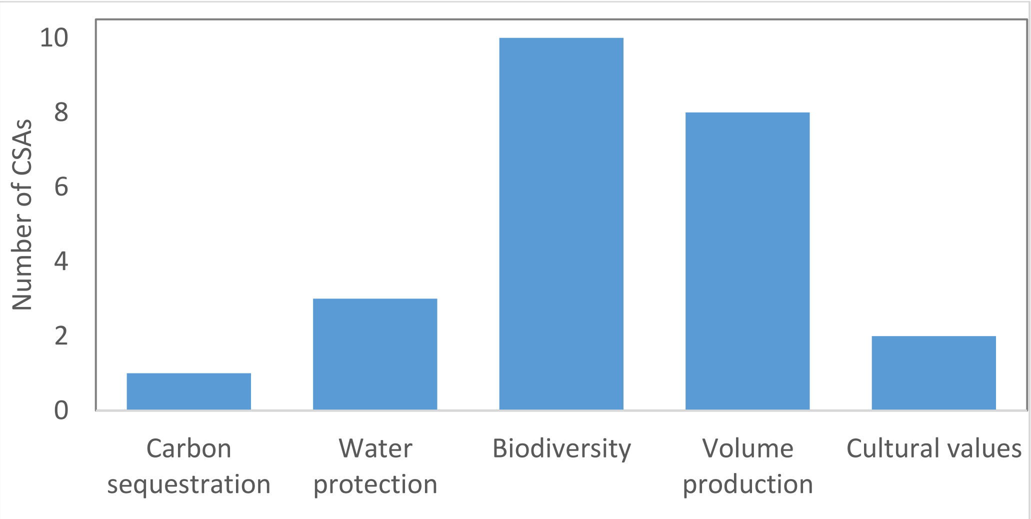

Figure 1. The number of case-study areas (CSA) that have motivated an implementation of alternative forest management models with different ecosystem-services. There were ten CSAs in total.

Different shelterwood systems are common among aFMMs (Fig 2) while clearcutting system are the most common FMM (fig 3). Only 7% of the FMMs was classified as selective cuttings but 19% of the aFMMs, corresponding figures for non uniform shelterwoods are 20 and 35 % respectively.

In Sweden one of the aFMMs are aiming towards more clear-cut free methods, selection systems are motivated by its positive effects on biodiversity and social values. In Turkey, there is a political and legislative support to look for clear-cut free methods. In Lithuania the major question referring to the model of non-clearcutting is whether non-clearcutting actually result in higher non-timber ES. In Germany, the stakeholders are promoting a strong focus on biodiversity and in two of their model's other ES than biodiversity are of low importance, resulting in beech and oak forest to be set aside with no forest management accomplished there.

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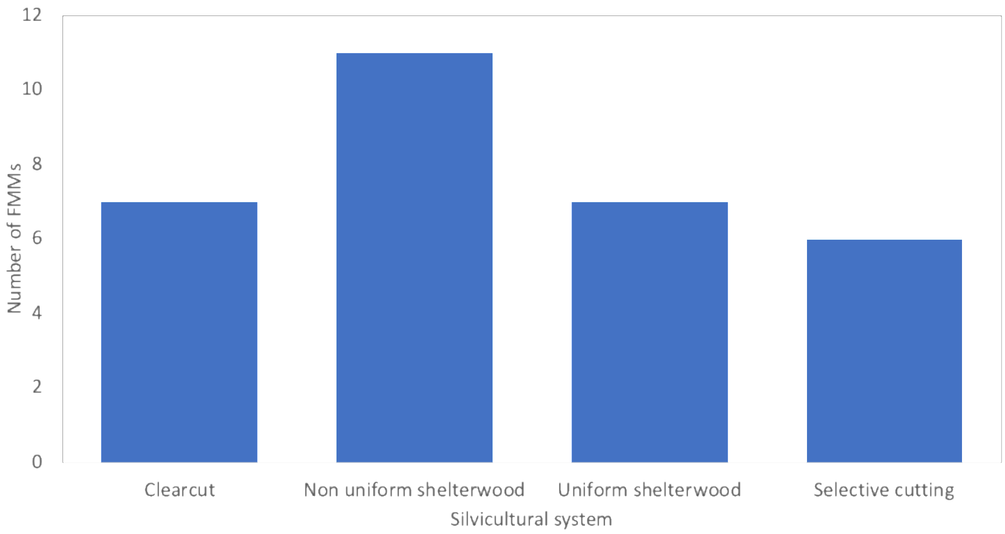

Figure 2. Number of aFMMs that are dominated by different silvicultural systems.

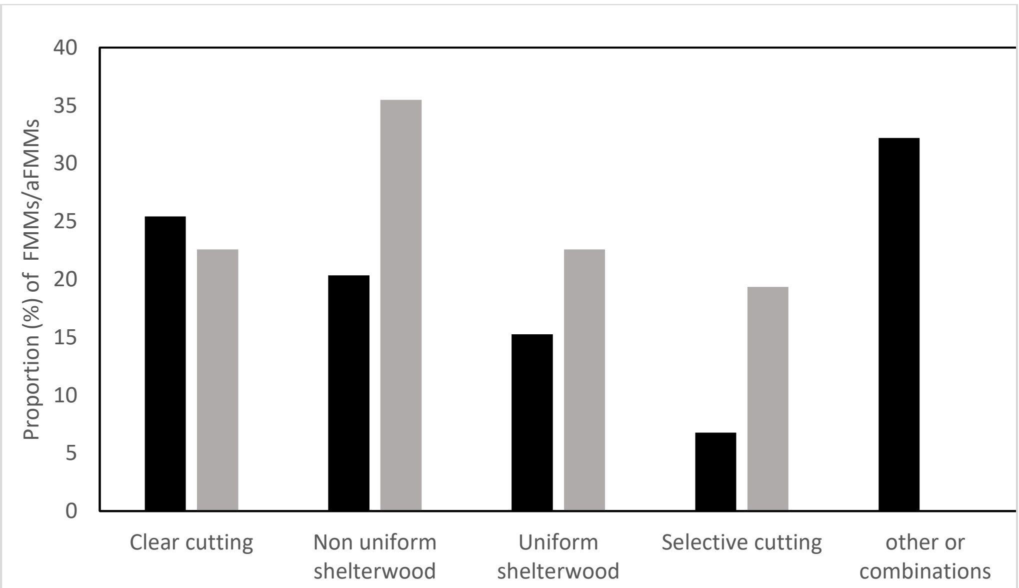

Figure 3. Proportion (%) of dominating silvicultural system; FMM (black) and alternative FMMs (grey).

Other reasons could be tourism or cultural services as for the model suggested in Italy that both aims at protecting and enhancing biodiversity and also seeks to create suitable conditions for tourism and recreational activities within the area. Cultural services are also mentioned as a reason for the park-forest management in the Netherlands especially in terms of recreational quality and aesthetic beauty. In Lithuania and Sweden, one reason for increasing broadleaves in conifer dominated stands is to improve aesthetic values.

The main reason for choosing the clear-cutting systems with Sitka spruce and Douglas fir as suggested in Sweden is the potentially higher wood production that could be achieved. In Germany the goal of many forest managers responsible for large private forest estates is to maintain or increase the

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overall high forest productivity so the models Scots pine and timber and energy forest and Norway spruce timber and energy forest are mainly designed for this purpose. In Portugal selection of the aFMMs on pure maritime pine forest systems and pedunculated oak have been designed because of a strong internal demand for sawlogs. In the Netherlands, the wood mass forest management is focusing on production of large quantities of wood, mostly biomass together with carbon sequestration while other ES are of less importance. In Slovakia, a continuous income for small land-owners is the reason for frequent thinnings. In Lithuania, adaptive rotation length is proposed for increasing production and economy.

In some of the aFMMs combination of wood production and biodiversity are mentioned as the main reason. For example, on Ireland the low-stocked lodgepole pine aiming for fibre will allow for a crop that can produce fibre over a long rotation period and in the same time allow for regeneration of native shrubs and trees that will positively impact biodiversity. In the Netherlands the production of high quality timber will simultaneously preserve ecological functions providing attractive forests for recreation. In Lithuania, sustainable management of special purposes forests will try to validate if the potential increase of timber supply could be accomplished without harming the main ES. In Italy, the increased demand for timber and biomass might result in that especially the oak and hornbeam forests will be managed for this purpose while part of the coastal forests will be left mainly for the aim of recreational activities.

Protection of water quality was mentioned as the main reason in two CSA. In Ireland, where many of the low productivity sites in the CSA can no longer be fertilised due to eutrophication concerns that threaten the Freshwater pearl mussel (FPM, *Margaritifera margaritifera* L). The other example is Portugal who recently added an additional aFMM to the CSA, riparian system for biodiversity. Cultural values were mentioned as the main reason in the Netherlands, where the park-forest management focuses on the cultural services of the forest, especially in terms of recreational quality and aesthetic beauty.

Alternative FMM for sequestering carbon was mentioned in one CSA (mass wood production in the Netherlands) even though several other CSAs concluded that improving volume production also would lead to increased sequestering of carbon. In three CSAs, the attempt to reduce various risks were the main reason for the choice of aFMMs, for example Portugal and wild fires. In one case only there was a clear relation between risk and future climate change and that came from Slovakia. The aFMM in Slovakia is primarily oriented to improve the ecological stability of unstable Norway spruce stands growing outside its natural range.

An important motivation for aFMMs is public opinion. Most CSAs has at least one aFMM that may be implemented as a response of various stakeholders' perception of the current FMM. One important aFMM as a response to public opinion is the use of various clearcut-free methods instead of using clearcuts (Sweden, Turkey, Germany and Lithuania).

Many of the aFMMs promote broadleaves. Most typical are aFMMs from Germany and Sweden. In Germany two aFMMs actively favor oak and beech and in Sweden increasing amount of birch is the aim of one aFMM. Mixed stands are in those examples used to increase proportion of broadleaves.

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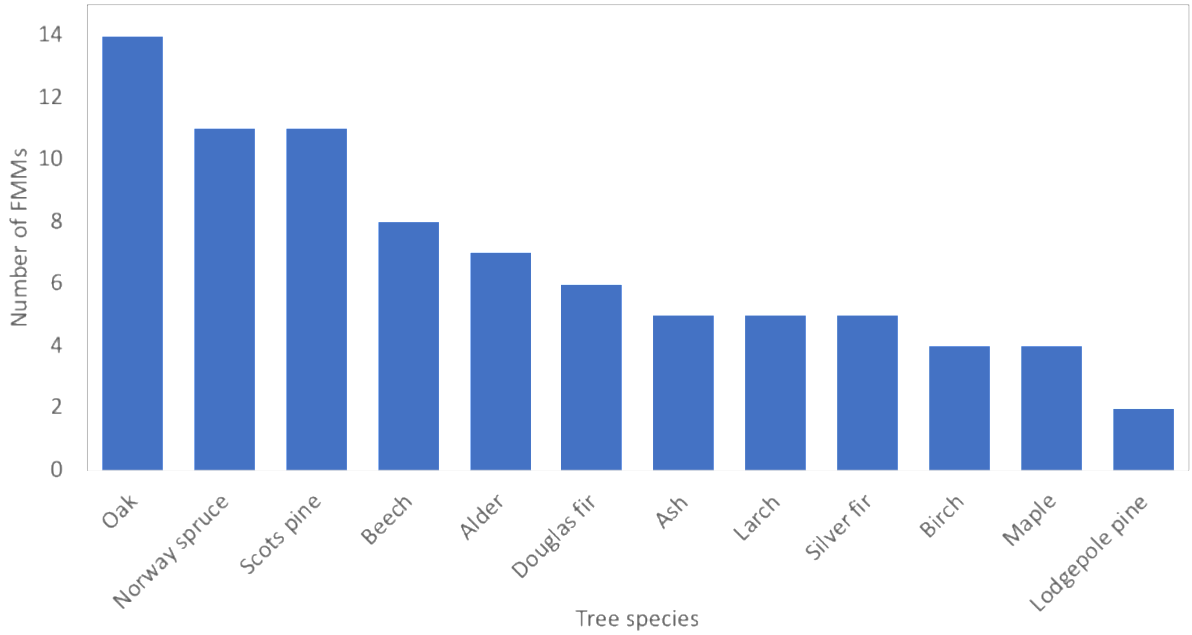

Figure 4. Number of FMMs where different tree species are used

The use of mixed species forests instead of monocultures has also been proposed as a response to stakeholders' opinions. The spruce/pine-birch mixture model from Sweden is motivated by expected positive effects in all sustainability dimensions (economic, social and ecological) and is a pathway of increasing the share of broadleaves without planting. In Germany, Norway spruce and Scots pine stands will be actively transformed into more diverse stands with more deciduous species. In Ireland, the main concern of the model of low stocked lodgepole pine-biodiversity is water quality but it will also allow the forest to be open and allowing for natural regeneration of native trees and shrubs in the area. Wild fire risks and diseases are a main concern for forest owners in Portugal and forest mosaics diversification with pedunculate oak and other broadleaves contribute to reduce these risks. In Slovakia, the main intention of the model of multifunctional management is to ensure the ecological stability of economically important spruce-dominated stands in effort to mitigate climate change. Therefore, the aim is to create even- or uneven-aged mixed stands that will lead to better continuity of harvests and promotion of fulfilment of other ESs.

It is only four CSAs that do not propose an aFMM that includes clearcuts and three CSAs do not include clear-cut free methods in their portfolio of aFMMs.

The significance of legislation when designing aFMMs has been mentioned by four CSAs. In two CSAs, legislation may be a serious hinder for implementing the proposed aFMMs and in two CSAs, the aFMMs are a response to new legislation that have made current FMMs difficult to pursue. Current legislation may hinder implementation of aFMMs in Slovakia and Lithuania and influence implementation of two of the aFMMs in Germany. In Lithuania minimum allowable rotation age is regulated by strict legislation. In order to implement the aFMM adaptive rotation length, politicians and public need to be convinced about the advantages of adapting rotation length to site properties and market situations at the same time as they are convinced that other ES-values are not reduced to unacceptable values.

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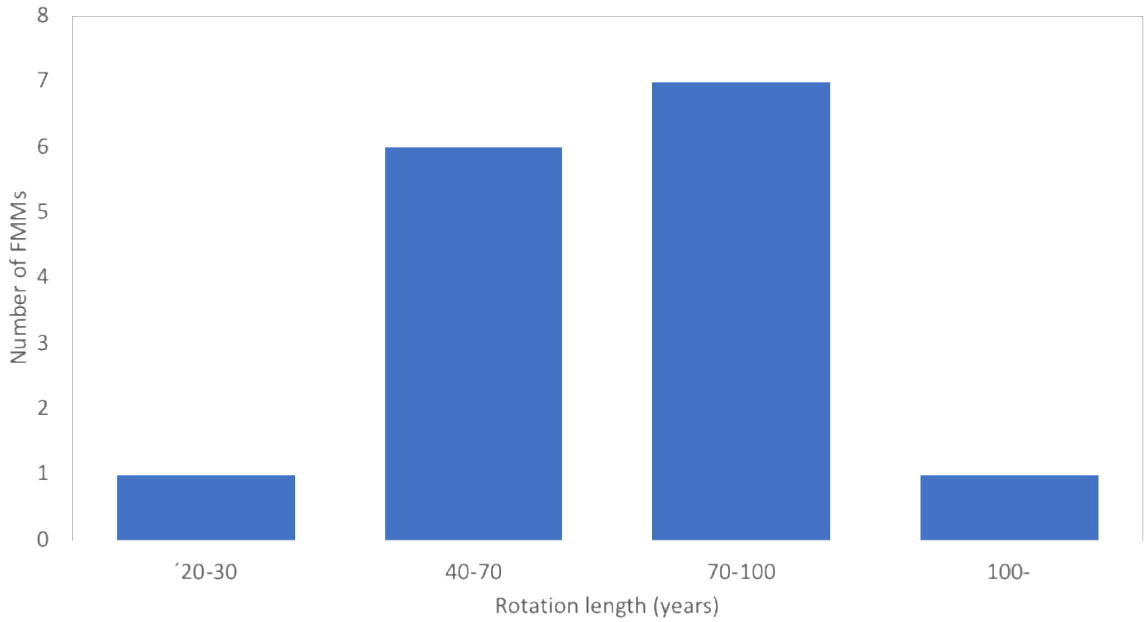

Figure 5. Number of FMMs where different rotation lengths are proposed

In Ireland and Portugal two different relatively new legislations motivated design of aFMMs in the CSAs. In Ireland, new reforestation rules, corporate policies and local government decisions about protecting water quality limits the use of fertilizer, while in Portugal the new more strict legislation on plantation of Eucalyptus contributed to the changes. However, most of the aFMMs are not hindered by current legislation.

Certification rules are mentioned as an important driver for designing aFMMs in two countries, Sweden and Italy, therefore one might draw the conclusion that their importance is lower in the other countries.

Goals of forest owners are often mentioned as motivation for aFMMs and the most common goal is improved economy. In one case, it is important for small forest owners to have a continuous flow of income from a limited land-base (Slovakia). In another, production of fast growing conifers is combined with clear-cut free methods in order to achieve good economy with an FMM that can be acceptable by the public (Germany). Another example of achieving economic goals without jeopardizing other ESs is improving volume production in specific stands while at the same time assigning other forest stands for biodiversity, recreation, etc (Sweden).

For those CSAs that have mentioned volume production as a motivation, the aFMMs are not extremely radical compared to current FMMs. Fertilization, improved genetic material or exotic tree species are almost not used in any of the aFMMs. That is surprising as these are well-known methods to increase wood production and often used in other parts of the world.

Another more overall trend is that if all these aFMM will be applied in all countries the area of broadleaves will increase in Europe. Without exception, there is one or more aFMM in every CSA that will promote broadleaves. Broadleaves will mainly be grown in mixtures but in some cases also in monocultures.

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Most countries present aFMMs with different and opposite aims. Examples are Germany and Sweden who both have aFMMs for higher production of wood and bioenergy and also have aFMMs for biodiversity where volume production is of no or low importance. In the end the outcome will depend on the extent these different stand level models will be used, i.e. what will be their proportions in the future landscapes.

A challenge for implementing aFMMs that is often mentioned is the possibility to achieve a sufficiently good regeneration. Many aFMMs rely on natural regeneration which has an inherent insecurity with respect to the end result. Dry periods, seed availability, browsing pressure and competition from ground vegetation are possible reasons for to low density of seedlings of desired tree-species. Even if a good regeneration is achieved, the success of aFMMs often rely on timely and correct implemented pre-commercial thinnings. Many CSA mention that skilled forest workers that can do the often complicated silvicultural treatments may be a limiting factor for implementation of aFMMs.

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2 Germany

2.1 Background

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

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% of the forest area), 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. Documentation about forest management in private forest is typically kept disclosed from the public.

There are two case study areas in Germany. Augsburg Western Forest (AWF) in the federal state of Bavaria, southern Germany and Lieberose-Schaubetal-Neuzelle (LSN), in the federal state of Brandenburg in North-Eastern Germany. CSA AWF is fertile and moist (900 mm p.a.), and hence highly productive, while CSA LSN as compared to average German conditions is notably dry (550 mm p.a.) and marked by low productivity. Accordingly, both case study areas differ in their dominating tree species: in AWF the most important species are Norway spruce (62%) and beech (11%), while in LSN Scots pine (65% of standing volume) and oak (11%) are the most important and common ones. The state forest concept strives to maintain or established mixed and uneven-aged forests. On the contrary, large private forest owners in general do not intend to reduce the area share 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 most common FMMs in Case study area AWF are shelterwood or clearcutting with Norway spruce, selection systems with Norway spruce and selection or non-uniform shelterwood system with beech. In CSA LSN the most common are selection systems or uniform shelterwood systems with Scots pine, clearcutting g with Scots pine and selection or shelterwood systems with oak.

However, about private forests, there is not as precise information 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.

2.2 Process and motivation

The alternative FMMs in both case study areas are fully based on stakeholder research done by Nataly Jürges. The reason why certain stakeholders want to have certain alternative kinds of forest

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management implemented is what kind of ecosystem services they deem most important and expect to be best provisioned by certain FMMs. E.g. large private forest owners want to maximize yield (income), nature protection NGOs want to have as large set asides as possible (biodiversity), recreationalists want a forest that is managed but does not look like managed etc.

Currently both case study areas are dominated by a mix of two distinctly different landscape level concepts ("production oriented forest" – large private forest owners and "multifunctional forest" – state and municipality forest, and other owners). Most interesting for the stakeholders is what happens if versions of these concepts, and also complete omission of any management are applied to the whole landscape or in certain portions.

The landscape level alternatives that are of interest for the two CSA in Germany are:

- timber and energy providing forest,
- biodiversity oriented forest (strict set aside – no treatment)
- multifunctional forest
- In the CSA Augsburg Western Forests (AWF), there are two combinations of these in addition:
- recreation and biodiversity forest (80% of the area multifunctional, 20% set aside)
- segregated forest (80% timber and energy forest, 20% set aside)

Private forest, wood industry have a motivation for increase wood production for material and energetic use. State forest managers are dependent on general public and the aim is to provide a balanced set of all ES explicitly including wood production *on the same area*

A special part of the general public is recreationalists, hotel sector, service providers. Their aim is to increase cultural services, make the forest as attractive as possible.

Many NGOs and other parts of the general public have one goal with forest management, to increase biodiversity by giving up forest and leave it without management on as large areas as possible

Parts of private forest owners, and some NGOs aim for generally introduce segregated forestry, provide distinct areas e.g. for production, recreation, biodiversity Increase **wood production** (requires more conifers). This would probably increase the **carbon balance** but reduce **safety**, **biodiversity**, and **cultural services**. Increase **biodiversity**, **cultural services**, **safety**, possibly **ground water recharge** by increasing the shares of other species, and uneven-aged mixed stands. This can be expected to reduce **wood production**. Conflicts will probably arise between **biodiversity** and **cultural services**, if large set asides are established for increasing biodiversity.

Stakeholders promoting a strong focus on biodiversity in forest management (often powerful NGOs) argue that natural forests and especially natural beech forests are almost completely lacking in Central Europe, while such forests would be covering almost the whole (Central European) forest area without human interference. Thus, they postulate to take substantial natural forest and beech forests areas out of management. Other ecosystem services than biodiversity (and nature protection) are not relevant from this point of view. This raises the question (hotly debated) if and to what extent such set asides have to be counterbalanced by differently managed forest areas. Simulating different scenarios in that context will be one of our most interesting tasks in ALTERFOR.

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2.3 Description of aFMMs

The ten aFMMs are:

- (Case Study area AWF, Bavaria, spruce dominated with beech admixed),
    - Production oriented Timber and Energy forest GERBa1
    - Multifunctional management GERBa2
    - Set aside GERBa3
    - Multifunctional with set aside 20% GERBa4
    - Production oriented with set aside 20% GerBa5
- (Case Study Area LSN, Brandenburg, pine dominated with oak admixed)
    - Production oriented Timber and Energy forest GERBr1
    - Multifunctional management GERBr2
    - Set aside GERBr3
    - Multifunctional with set aside 20% GERBr4
    - Production oriented with set aside 20% GerBr5

2.3.1 Production oriented Timber and Energy forest

The two production oriented aFMMs, aiming for high production differs mainly in the species, for AWF in Bavaria Norway spruce with admixture of Douglas fir and in Brandenburg (LSN) Scots pine.

The main targets of the aFMM are high production of material, and energy production and Carbon Sequestration.

Common is the increase share of conifers species. Natural regeneration is replaced with planting. The rotation time is shortened compared to traditions in Germany. The silviculture systems are shelter wood systems, uniform and non-uniform. Chemicals are used to control pine weevil in regeneration phase and bark beetles and pine tree lappet in established forests. Fertiliser can be an alternative but areas with fertilisation will be small because on many high production sites fertilization have no or small effects. Conifers are promoted in thinnings and some broadleaved stands replaced with coniferous.

Norway spruce dominated stands are managed with short rotation periods (down to 50-60 years), depending on site conditions in order to maximize wood production per unit area. Planting densities are comparably low in order to keep the number of thinnings low. Natural regeneration is an exception. When regenerating stands, the share of Douglas fir is substantially increased. Clear cut hence is not used in the aFMM, as Douglas fir is susceptible to late frost damage. Therefore, uniform and non-uniform shelterwood systems will be used. Pre-commercial thinnings should be avoided by using comparably low plant densities. Thinnings will be applied about 1-3 times per rotation on 100% of the area.

Scots Pine dominated stands are managed with short rotation periods (target diameter 25-35 cm, this is equal to about 60 years rotation period), depending on site conditions in order to maximize wood production per unit area. Planting densities are comparably low in order to keep the number of thinnings low. Natural regeneration is an exception. When regenerating stands, clear cut is not a good option; uniform and non-uniform shelterwood systems would be the option of choice. Pre-

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commercial thinnings should be avoided by using comparably low plant densities. Thinning will be done on 100% of the area, number of thinnings bout 1-3 times per rotation period.

2.3.2 Multifunctional management

Two alternative FMMs, one in Bavaria and one in Brandenburg aiming for multifunctional silviculture. Their target is to provide all ES on one and the same forest stand (production, recreation, biodiversity).

The two aFMMs are characterised by a decrease of the share of conifer species, especially in monospecific stands. Management aims to create and maintain uneven-aged mixed forests with conifers and broadleaves. Even-aged stands will be transformed into continuous cover stands and volumes kept on an appropriate level for continuous cover forestry. The stand is thought to produce comparably large target diameters. The conversion of stands will be done smoothly and gradually with no abrupt transformation of existing stands. Conversion will thus be done carefully and slowly in old stands due to risks for wind damages.

In both systems thinnings broadleaved species will be favoured. Natural regeneration will be used wherever feasible, steering species shares in regeneration by main stand canopy opening.

The two aFMMs can be characterized as non-uniform and selective cutting systems. There are no clearcuttings but the systems will be used on areas, or stands, with size from 1 up to 50 ha. Gaps size varying from 50-150m^2 diameter 8-14m, depending on size of old trees.

The whole silvicultural concept is intended to be active nature protection. In addition, there will be detailed biotope mapping going along with tailored forest management (with special regard to preserving hollow trees and the like).

In Bavaria the aFMM mainly deals with Norway spruce stand. Monospecific spruce stands and stands dominated by spruce are being actively transformed in uneven-aged forests dominated by broadleaved species, most importantly European beech. In old and middle aged stands Norway spruce will be harvested as single trees or gap-wise; creating diverse stand structures. High yield of Norway spruce is not important. Natural regeneration is used wherever possible (which requires consequent reduction of game densities), but if the desired species do not turn up in sufficient numbers, they will be underplanted. If deemed favorable for biodiversity, this kind of harvest will also take place in economically pre-mature stands. Gaps might even be cut and planted in young spruce stands. Pre-commercial and commercial thinnings are done on all areas.

After successful transformation, stands will be managed in a target diameter concept in order to maintain high structure or taken out of management. Typical target tree size for Norway spruce would be a dbh of 40 cm in the transformation phase. After successful transformation, broadleaved tree target diameters would be higher (about 60 cm) if still actively managed. Important tree species expected after transferring are*, Fagus sylvatica, Quercus robur, Acer pseudoplatanus, Tilia cordata.*

In Brandenburg, (LSN) monospecific Scots pine stands and stands dominated by Scots pine are being actively transformed into uneven-aged forests dominated by broadleaved species (most importantly oak). In old and middle aged stands Scots pine is harvested as single trees or gap-wise; creating diverse stand structures is more important than yield-oriented considerations. Natural regeneration is used wherever possible (which requires consequent reduction of game densities), but if the desired

species do not turn up in sufficient numbers, they will be underplanted. Tree species are mainly *Pinus sylvestris, Quercus sp., Picea abies, Larix decidua, Pseudotsuga menzisiesii, Abies alba, Fagus sylvatic*a.

If deemed favorable for biodiversity, this kind of harvest will also take place in economically pre-mature stands. After successful transformation, stands will be managed in a target diameter concept in order to maintain high structure or taken out of management. Typical target tree size for Scots pine would be a dbh of 40 cm.

The whole silvicultural concept for the two aFMMs is intended to link forest production to active nature protection and to foster stand resilience. In addition, there will be detailed biotope mapping going along with tailored forest management (with special regard to preserving hollow trees and the like).

2.3.3 Set aside

That silvicultural concept stops all silvicultural management and leads to stand dynamics that are governed by natural regeneration and mortality. This alternative is the same for the two CSA in Germany.

2.3.4 Multifunctional with set aside 20%, Augsburg/Bavaria

There are various presumptions possible about the kind of stands being selected as set asides. Such stands might e.g. be marked by low productivity or main tree species that are typical for the PNV. Therefore, the set aside scenarios do not favour a particular type of forest for being set aside, but exclusively presume the share of the forest area that would be excluded from managed forest. That area share is a large one of 20% in order to underpin the effect that set asides would have on ecosystem provision by the whole CSA. In GERBa4 and GERBr4 the remaining managed forest area is treated with the multifunctional concept of GERBa2 resp. GERBr2.

2.3.5 Production oriented with set aside 20%, Augsburg/Bavaria

These scenarios correspond to GERBa4 resp. GERBr4 with the exception that the managed forest area is treated with the production oriented concept of GERBa1 resp. GERBr1.

2.4 Challenges and opportunities

The silvicultural radicalism applied in the ten alternative FMMs takes place less on stand level, but on landscape level. Different stakeholder groups (from timber industry to recreationalists) have very contrasting views of how the forest landscapes should be managed. The corresponding stand level concepts they have in mind are partly extreme, but they are not genuinely new.

2.4.1 Production oriented Timber and Energy forest

The two FMMs for high timber production within the whole landscape reflect the goals of many forest managers who are responsible for large private forest estates. The primary ecosystem service to be maximized is the monetary yield which is intended to be obtained from producing large amounts of coniferous wood for energetic and industrial use. Norway spruce but also Scots pine

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however are species coming along with many risks. Production oriented management aims at mitigating risks through shorter rotation periods and admixture of other species, mainly Douglas fir. Possibly, future forest management in large private forest estates will converge towards that type of FMM.

Other forest managers and stakeholders will criticize its mere economic focus. Applying this concept in the state forest would require drastic – albeit not unthinkable - changes in legislation. Moreover, first effects on yield and income will show up rapidly: during the first 30 years a dramatic decrease of the stocking volume is to be expected, because the shorter rotation period leads to the situation that most mature stands exceed the new rotation age. However, a large amount of carbon from timber will concomitantly be immobilized in durable wooden commodities. A strong argument in favour of the production oriented timber and energy forest is hence its strong effect on carbon sequestration. Moreover, biodiversity is not exclusively an effect of structure on the stand level but also of forest type heterogeneity on the landscape scale level. Stakeholders who advocate production oriented forest may thus point out, that a certain amount of production oriented forest within a landscape being considered is not detrimental to biodiversity but rather an essential prerequisite.

2.4.2 Multifunctional management

State forestry that is a strong stakeholder and owns about 50% of the forest area in both CSAs would favour a forest management with a balanced provision of ecosystem services, ranging from timber production through recreation to groundwater recharge within one and the same forest stand. That multifunctional management aims at increasing the proportion of broadleaved tree species and at fostering the heterogeneity of age classes on stand level.

In CSA AWF and CSA LSN the share Norway spruce resp. Scots pine will be gradually reduced in favour of broadleaved tree species. Promoters argue that this strategy will reduce risk as they consider more diverse ecosystems as the more stable ones. Whether multifunctional management will be adopted by private forest owners certainly depends on whether the provision of non-commercial services will be rewarded through financial incentives. From the current point of view possible trends are diverse. If economy runs well, society could be very "eco-friendly" which, in the end, could lead to a forest legislation fostering FMMs like the one described here. Under economic strains, society - and consequently legislation - might tend to force the state forest to increase profit rather than to offer financial incentives to private forest owners.

2.4.3 Biodiversity oak and beech

Stakeholders promoting a strong focus on biodiversity in forest management, such as powerful NGOs, argue that natural forests are almost completely lacking in Central Europe. Thus, they postulate to take substantial natural forest areas out of management. Other ecosystem services than biodiversity (and nature protection) are not relevant from this point of view. This raises the question (hotly debated) if and to what extent such set asides have to be counterbalanced by differently managed forest areas. Simulating different scenarios in that context will be one of our most interesting tasks in ALTERFOR.

The question who could be convinced is quite complex. Actually, finding this out is one of the most important questions of the whole project. Currently, our view is as follows: The stakeholders in favour

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of this FMM (strong NGOs) do not own forest themselves (or only negligible shares). However, they try to influence politics in a way that forest managers are forced by legislation to adopt their ideas. Only a certain share of small private owners, for whom their forest is a mere hobby, could be *convinced* to adopt this strategy.

Changes in legislation would be required which enforce such set asides.

3 Ireland

3.1 Background

Following periods of heavy reforestation and deforestation from the 1600s to 1900s, forest cover in Ireland was about 1% in the early 1900s. The government therefore 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. In 2012, about 10.5% (732 000 ha) was covered with forests and the goal is to bring the forest cover to 18% by 2046.

Today, ecological and social benefits of forests are recognized 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.

In the CSA the way forward is to establish native woodland sites, plant lodgepole pine on sites where fertilization is restricted 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.

Irish forestry is dominating by silvicultural systems or models characterized by clear-felling. Approximately 85% of forest land is managed with clear-felling systems. For nature conservation and biodiversity protection other management systems are used.

3.2 Process and motivations

When the Irish afforestation program was formed in the early 20th century it was decided that only land that does not compete with agriculture should be afforested. Afforestation was largely driven by the need for national timber supply and the social aspect to create jobs in disadvantaged areas. Thus, large areas of blanket bog were afforested using drainage methods and extensive fertiliser application, resulting in over 30% of Irish forests being located on blanket bogs.

Today, the viability of blanket bog forestry is seen in a different light: forest managers question the economics and timber quality from these forests, environmental NGOs would rather see natural blanket bog than exotic conifer plantations, anglers and water quality stakeholders are concerned about eutrophication and siltation in watersheds dominated by bog forests.

Thus, the main objective when developing aFMM were to find less intensive management systems, to avoid using fertilisers, and to focus more on the environmental aspects of forestry. Today, tourism, angling and hillwalking are important social values that were taken into consideration when developing these aFMM.

The aFMMs were developed with certain stakeholder interests in mind. The decision process behind each aFMM is described below.

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- To have less intensively managed blanket bog forest, by planting lodgepole pine in low stocking densities
- To increase sawlog output, timber quality, and broadleaves in the landscape by planting Sitka spruce with downy birch (*Betula pubescens* Erhr.), the birch acting as a nurse species
- To restore blanket bogs to natural condition

The low stocked lodgepole pine aFMM came about from non-academic partner Coillte (the Irish state forestry board) as a potential way to manage bog forests. Their motivation for looking into this alternative was that lodgepole pine assortments are only utilised for bioenergy and wood-panel boards. The main interest is high stand volume, not stem straightness and stem diameter. Thus, commercial thinnings are not done.

The lodgepole pine aFMMs are planted at even lower densities and left to be unmanaged is a way of avoiding negative net present value associated with future harvest and reforestation of low productivity stands with low-value assortments and high transportation costs. Leaving the forest unmanaged increases the biodiversity value through old growth forests, reduces environmental impacts associated with forestry operations, and avoids the administrative application process of deforesting a site. Coillte suggested initial density of 1600 stems/ha for fibre production and 1100 stems/ha for biodiversity. The 600 stems/ha and 300 stems/ha were included after the ALTERFOR meeting in Galway, October 2017, aiming for testing something more extreme. Wild Nephin is a large wilderness area on similar soil type in a nearby county. The forest was recently heavily thinned down to 300-600 stems/ha and taken out of commercial management, so this aFMM has been tried in a pilot study.

The Sitka spruce under birch nurse was suggested by Dr. Kevin Black (ALTERFOR carbon ES expert). The idea for this aFMM came during the ALTERFOR meeting in Galway 2017, when we saw some productive Sitka spruce stands during the field day. Dr. Black has evaluated the potential of Sitka spruce-birch mixtures established under the BOGFOR programme. Mixtures on cutaway peat have shown higher volume production and higher crop survival, compared to monocultures on the same sites. Although these mixtures were established on cutaway peats (raised bogs) there may be a potential to try this silvicultural system on blanket bog. This aFMM and its test sites in the BOGFOR program is heavily influenced by the Swedish "Kronoberg system" with the main difference being that the birch is planted as the natural seed source of birch is rather limited in many parts of Ireland.

Restoring blanket bog is the aFMM strongly favoured by the environmental NGOs and it has been on the agenda of Irish forestry for a long time. For these reasons, it was natural to include it. There was a EU LIFE project that restored around 2,000 ha of blanket bog in Ireland, half of it previously forested. Coillte is not opposed to expanding bog restoration on suitable sites. However, special permission is needed to deforest a site, and it costs more to restore bog than it is to plant lodgepole pine in low densities and taking it out of commercial forestry.

During the last two newsletter mailouts the stakeholder consortium has been asked if they are interested in providing aFMMs. Although no suggestions were received later, the interviews (held in autumn/winter 2016) revealed that environmental and social stakeholders are generally interested in bog restoration, low impact forestry, more native species, and fewer exotic conifers. In summary, these aFMM were developed with stakeholder preferences in mind, and for what is realistically possible to grow on the blanket bogs of western Ireland.

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The lodgepole pine fibre production and lodgepole-biodiversity are suitable models for sites on low productivity sites that can no longer be fertilised due to eutrophication concerns that threaten the Freshwater pearl mussel (FPM, *Margaritifera margaritifera* L). The first model will be able to provide fibre over a long rotation period.

The model promoting biodiversity is suitable for sites far away from roads with very low intensive management and still ensuring minimum criteria of tree cover on these sites. Both models will additionally create more open forests, potentially allowing for a long term natural regeneration of native trees and shrub species that will positively impact recreation and biodiversity.

The model Sitka spruce under Birch nurse on blanket bog was created due to a decline in sawlog volume under current FMM scenarios with the potential to produce sawlog timber. The inclusion of birch for part of the rotation may also gain some support with other stakeholders that are not interested in the provision of sawlogs. Thus, it is a combination of increasing sawlog production and the share of broadleaves, not only in the stand but also as a potential seed source to encourage natural birch regeneration in the landscape. In current scenarios lodgepole pine will dominate the future landscape, and this aFMM can act as a good counterbalance to that.

Naturally, much of the forested land was blanket peat and the model bog restoration addresses concerns about afforesting peatland, restoring valuable ecosystems that have been degraded due to peat harvesting and forestry. Bog restoration means that no future timber will be harvested, but it will improve recreation and biodiversity ESs.

3.3 Descriptions

3.3.1 Lodgepole pine fibre production

This FMM is meant to replace heavily fertilised Sitka spruce (*Picea sitchensis* (Bong.) Carr.) stands and lodgepole pine (*Pinus contorta* Douglas) stands planted at 2,500 stems/ha for the last rotation. Sitka Spruce is being replaced because Coillte no longer practices commercial forestry on sites with yield class (YC) lower than 12 and because heavy applications of rock phosphatic fertiliser are no longer allowed for the intention of increasing YC, but are permitted on poor sites for the intention of crop establishment. However, the standard fertiliser application of 250-350kg/ha during spruce establishment is no longer permitted on sites within a 6km hydrological distance of sites where are thought to contain viable populations of FPM.

For this FMM, lodgepole pine is replaced with a lower stocking because it is not economically viable to thin this species lodgepole pine responds with crookedness and generally poor form when thinned, resulting in excessive snags or self-thinning. Self-thinned trees will be avoided by planting at densities between 1,600 - 1,800 stems/ha for fibre production. Tree form is not the main concern as lodgepole pine is mainly used for wood panel products and biofuel.

Management interventions will be minimal. Stands will be established and clearfelled with rotations of about 65-80 years.

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3.3.2 Lodgepole pine wilderness/biodiversity

This aFMM was initially planned to be planted by 1100 seedlings per ha but has now been expanded to include options with initial stocking of 600 and 300 stems/ha. This inclusion was to try something more bold and experimental.

The model is meant to replace heavily fertilised Sitka spruce stands and lodgepole pine stands planted with normal densities (2,500 stems/ha). Sitka Spruce is being replaced because Coillte no longer practice commercial forestry on sites with yield class (YC) lower than 12 and because heavy applications of rock phosphatic fertiliser is no longer allowed to increase the YC.

The option to establish a fully stocked lodgepole pine is being foregone with a lower stocking at 1100, 600 or 300 stems/ha to fulfil the reforestation rules and a minimum forest cover. The aim is to change the management objective from commercial forestry to biodiversity protection. Management interventions are expected to be minimal including only planting, it is unknown if any future interventions are necessary to enhance biodiversity further.

3.3.3 Sitka spruce under birch nurse, on blanket bog

The stand is planted with 50:50 mix of Sitka spruce and downy birch in alternating rows on better blanket bog sites (YC > 16).

Stands are thinned when birch trees are ca 15m in height. Every 3rd row of birch is harvested and negative selection (i.e. selection of large diameter birch trees to reduce competition) leaves 500-700 stems per ha of birch and 1200-1400 stem per ha of Sitka spruce.

Stands are thinned again when the stand is around 25-30 years old. All birch is removed, and stocking of spruce is adjusted to 1000 stems per ha by removing smaller diameter trees. Stands are thinned for a 3rd time when it is possible to select ca 500 final crop trees. Final harvesting of all Sitka spruce at the age of ca 40 years.

3.3.4 Bog restoration

The aFMM is intended to restore blanket peat ecosystems that were degraded due to peat harvesting and/or afforestation. Peat formation returns when drains are blocked. This causes the area to become waterlogged.

3.4 Challenges and opportunities

3.4.1 Challenges

There is a defined uncertainty in how the low density stand of lodgepole pine will develop in real life: Coillte has planted lodgepole pine for decades, but in a slightly higher stocking. Uncertainties with implementing the low density models might be in how the stand develops since these densities have not been tried before. It is possible that the lower density can cause the lodgepole to become branchier, which can cause more expensive harvesting and misjudge the proportion of harvest assortments.

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For the low density planted lodgepole pine promoting biodiversity there is uncertainty if native species will establish in the open space between the trees and what species will occupy the site after the lodgepole pine dies from fire, windthrown or old age, important factors for cultural and biodiversity ESs.

One consideration might be that the model for fibre production might not be bringing anything new to the ES. Replacing the current lodgepole pine FMM to a similar aFMM with lower stocking might not change the ES drastically. There will be slight changes in harvest volume and the establishment costs will be lower, but it will probably not have a huge impact on the landscape ES basket.

Roads are always useful to reduce planting costs, but will likely not be built for the sites where the goal is not commercial forestry.

One of Irelands largest sawmill sources a lot of their sawlogs from the area, increasing the area of lodgepole pine could negatively impact their sourcing capabilities in the area.

One important challenge for Sitka spruce under Birch nurse, on blanket bog is probably finding the suitable sites. Previous experience shows difficulty with establishing broadleaves if sheep and deer get through the fences. Wet, organic soils, near the coast on hills/mountains are always susceptible to windthrow so the risk remains that some of the trees will be windthrown before the time of final felling.

Both technical capacity (small harvesting machinery with minimal soil damage) and proper forest management planning (thinning the right trees at the right time, locating suitable sites) will have to be performed exceptionally if this aFMM is to be successful.

For Bog restoration it may be difficult to determine the appropriate type of sites for implementation as it is practiced only on a case-by-case basis, according to forest policy. There is an uncertainty in how long it takes restored bog to grow peat again. Field observations indicate that previous trees often regenerate. It could negatively affect timber availability for local sawmills and wood supply to Coillte’s wood panel mills. Dependent on heavy machinery for blocking/removing drains and roads to bring machinery to the sites.

The main bottleneck is the cost of performing bog restoration.

3.4.2 Opportunities

Lodgepole pine is tolerant of exposed, wet conditions and low-productivity soils, making it suitable for a wide range of sites. The planting with less seedlings will be cheaper than planting fully stocked stands. No pre-commercial or commercial thinnings will lower the costs. Members of Coillte have expressed interest in withdrawing from practicing commercial forestry on low productivity sites, there is already knowledge about managing lodgepole pine and industries to utilise the harvested assortments. The production of fibre will contribute to produce biomass without using fertilizers.

“Wild Nephin” is a wilderness area in Co. Mayo where lodgepole pine stands were commercially thinned and was then left to develop into a natural parkland, with the aim to intervene and leave minimum stocking behind and let the site “return to wilderness”. The biodiversity model ultimately resembles “Wild Nephin” and alternatively a similar FMM can be achieved by doing a heavy thinning, rather than clearfell and low-stocking planting.

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Market (provision of more sawlogs) is likely to be the largest driver for implementing the model of Sitka spruce under birch nurse, based on how lodgepole will dominate the landscape. Nurse species could improve crop survival and increase growth and also increase stem quality, reduce competition and promote the selection of crop trees

The bog restoration that has already been done in Ireland was done with a long term goal in mind, so it is likely going to be the case wait and see until natural bog is established.

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4 Italy

4.1 Background

In Veneto, which is a very densely populated and highly urbanized region, today lowland forests are spread on a very small area, with a patchy distribution. After the First and the Second World War, reforestation was carried out in some sites along the coast (using stone pine (*Pinus pinea*), maritime pine (*Pinus pinaster*) and black pine (*Pinus nigra*)). However, from the ’60s onwards a strong process of urbanization reduced the dynamism of these woodlands.

From the ‘80s to the ‘90s, thanks to the work carried out by the regional and local administrations within the framework of the Common Agricultural Policy, some hundreds ha of new forests were planted in Veneto lowland. However, many of these forests were not subjected to a proper management and some of them were even abandoned. Today there is a growing demand for forest management and planning activities targeting these forests (both the last patches of relic forests and the recently planted stands), driven by a bunch of different stakeholders, including local institutions, forest experts and local stakeholders.

Many stakeholders (forest managers, citizens, tourists, and tourism operators) particularly ask for forest areas where to conduct activities such as hiking, jogging, shadowing and restoration. Others, such as environmental non-governmental organizations (NGOs), public administrations, naturalists and large part of the civil society ask for the maintenance and the restoration of forest ecosystems. The conservation of biodiversity is also a goal pursued by the European, national and regional legislation, and this is particularly relevant for the about 70ha of the case-study area (CSA) that are included within the Natura 2000 network (some of them being also part of the Sile River Regional Park). Although the belonging to such a network per se does not exclude active forest management it affects the intensity of management regimes.

The CSA consists of lowland forests, 60-70-year-old planted forests (mostly planted pine forests) and semi-natural lowland forest remnants but also some, max 20 years old, afforested and reforested areas. The total area is around 350ha.

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).

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 recreation), 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.

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Part of the area has recently been certified according to FSC standards and is the first FSC-certified forest area specifically targeting ecosystem services (ES) in Veneto. Management operation will aim to ensure an adequate ecosystem service flow while dealing with some limiting factors like forest fragmentation and discontinuity, as well as human pressure by both locals and tourists.

All stands in the CSA are managed with selection systems. The most common tree species are *Pinus pinea, Quercus robur* and *Ulmus campestris.* Despite some potentialities, timber production is not regarded as one of the main outputs of forest management within the CSA. Timber market dynamics as well as other factors (e.g. easy connections with central and eastern European countries that provide timber and biomass at lower prices), together with the fact that CSA forests are fragmented, and relatively small and young, discourage to design forest management practices targeting timber production as the main ES.

4.2 Process and motivations

The process of the definition of the aFMM1 started in consultation with the managers of the area and the Lowland Forest Association (AFP) members. The aFMM1 does not come from a top down initiative rather it comes as a result of a series of consultation initiatives conducted between local stakeholders, the University of Padova and the non-academic partner ETIFOR. The aFMM1 is in line with the recommendations of the recently developed forest management plan for the CSA, and it foresees further specifications aimed at improving the provision of the selected ES.

The main reasons that brought to the development of aFMM1 (recreational and habitat selective management model) are i) it is in line with the existing prescriptions defined by the regional administration, as well as with the national and EU prescriptions, including Natura2000 prescriptions/requirements ii) it includes the lessons learned and the results of the researches performed during the latest 20 years, iii) it is feasible and cost-effective, in the framework of the market trends and iv) it is line with the preferences of the stakeholders.

A significant part of the local population has indeed reported that they would prefer not to see in these forests neither logging activities nor forestry residues. Despite these premises, the aFMM2 (Uniform shelterwood and coppice) was designed aiming at managing a part of the CSA area primarily for timber production. According to the model, a prevalent productive function could be implemented in the oak hornbeam forests and in part of the coastal forests, however leaving most of the latter mainly for the aim of recreational activities. In some other areas, instead, the main aim would remain habitat protection and flood prevention/control.

Both aFMM1 and aFMM2 were presented and discussed during the first and the second Italian stakeholder workshop. During these events, it has emerged that stakeholders mostly prefer aFMM1, since it aims at fulfilling the functions that are primarily desired by most of them.

The aFMM1 (recreational and habitat selective management model) primarily aims at creating suitable conditions for tourism and recreational activities within (part of) the area and meanwhile protecting and enhancing biodiversity, favoring forest progress towards more natural conditions. The aFMM1 was developed taking into account the economic, social and environmental context, also in the light of future scenarios provided by IASA. In coastal forests the aFMM1 is also aimed to ensure an appropriate protection against wind and marine aerosol. In some areas aFMM1 will help to reduce the hydrogeological risk.

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The aFMM2 (Uniform shelterwood and coppice) was developed thinking to a future scenario with a strong increase in the demand for timber and biomass. This FMM was developed even if it is unlikely that the demand for timber will be addressed using timber sourced from the CSA forests. Timber production is much more concentrated in alpine and pre-alpine areas or, to some extent, in industrial poplar plantations in the lowland areas. Moreover, as already highlighted, aFMM2 is not supported by all stakeholders and does not fully meet their interests and expectations.

4.3 Descriptions

4.3.1 Uniform shelterwood and coppice

Aiming at producing timber, the alternative FMM (aFMM1) would be declined in the different forest types as follows:

i. Oak hornbeam forests: uniform shelterwood;
ii. Coastal forests: will be partly and gradually converted to holm oak forests, to be then managed through coppicing, and partly managed under current management solutions to maintain pines, mostly to support recreational activities;
iii. Riparian forests: will be managed with selective cutting, not for the primary aim of timber production.

In the **oak hornbeam forest** the terrain is plain and no roughness are present. Forests surface is likely to increase due to new plantations and become relatively wide. In this context, uniform shelterwood can be implemented. The canopy in the whole management unit will be uniformly opened in order to facilitate regeneration. Some oaks will be left for the purpose of seedling and for nature protection. It would be useful to limit the duration of the nitrophilous plants' phase by conducting a superficial work on soil (which could be also guaranteed just by the dragging of logs). This would help in making the soil more "primitive" and therefore favoring oak seeds which, compared to the hornbeam seeds, are more efficient in the water use, thanks to their capacity of closings stoma in presence of high water potential. Hornbeam will be maintained, in order to prevent oak producing epicormic branches. Once regeneration will be secured, the old stand will be uniformly harvested, in several logging events, resulting in an even aged forest. When in presence of an insufficient natural oak renovation, it may be useful to help it with seeds, maybe deriving from nearby stands.

Part of the **coastal forest** will be left for recreational purposes, leaving pines for shadowing and camping. Within the remaining part of costal forest, holm oak will be favored until the forest will be dominantly composed by this species. Once this point will be reached, the holm oak forest will be managed as a coppice forest. Despite today the law does not allow the conversion from a stand forest to a coppice, it is likely that, if in the future the demand for timber, firewood and biomass will increase, current legislation/guideline will be modified accordingly. Furthermore coppicing won't be very intensive since the holm oak coppice will be managed with a rotation period of 35 years as a coppice with standards. Standards will be left as seed source.

In both forest types, a buffer area close to the roads or open areas will be created in order to avoid a negative visive impacts linked to management solutions. In Natura 2000 sites or in presence of protected species, the management will be defined in accordance with the most recent applicable prescriptions.

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In general, nature protection and conservation is not the main aim of this aFMM in the oak hornbeam forest and in the holm oak forest. However, some trees will be left for nature protection. Other areas will be managed for this purpose, such as riparian forests and some areas within the two forest types. Moreover FSC requirements for areas to be left as representative of local ecological conditions will be met as long as FSC certification will be in place.

4.3.2 Recreational and habitat selective management model, aFMM2

In a close-to-nature perspective, the recreational and habitat selective cutting, aFMM2, aims at improving:

i. the environmental and ecological features of the forest and at
ii. the recreational and social/cultural functions.

To these aims, fellings of single trees or small groups of trees will be done all over the management unit at intervals between five and ten years, for creating and maintaining multi-layered and heterogeneous forest stands. The operations will not be performed uniformly but they will respect the potential vegetation of each forest type, and management actions will be defined in the forest stands case by case. The FMM's activities will slightly differ in relation with the forest types to which they apply.

In the **lowland oak hornbeam forests**, the selection of trees for felling will be based, besides the age distribution, on tree vigor and diseased trees will be eliminated. The forest will be progressively brought to the typical oak hornbeam forests, accompanying the species that are naturally dominant. A part of dead wood will be left for saprofilic invertebrates. Plants will be chosen both between standing and fallen big size trees.

In the **riparian forests**, wooden material that can obstruct the water outflow will be eliminated. However, in the areas not close to the rivers, big standing detached dead trees will be left for saprofilic insects.

In the **coastal forests** the specific diversity within the populations will be increased. Interventions will also seek at increasing the mechanical stability of the population to abiotic disorders (wind thrown). When in presence of even-aged planted domestic pine formations, which show serious dieback problems due to biotic and abiotic causes, moderate but frequent thinning will allow the entrance of the holm oak and the earwig. A part of the coastal forest will be brought to a holm oak forest formation. In the Mediterranean maquis, mosaic cut on the shrub-tree component will favor the differentiation of vertical structure and microhabitat. Some dead wood will be left. At microscale this recommendation could be modified for fire prevention. When in presence of species such as *Pelobates fuscus insubricus* and *Emys orbicularis,* prohibition to pass near ponds and the obligation of using light forestry means will be posed.

In all the areas, invasive species such as false indigo-bush, *Amorpha fruticosa*, bramble and nitrogen demanding plants will be removed for favoring the natural regeneration and avoiding the risk of fires.

In all forest types, ecological restoration actions will be conducted, in line with the guidelines of recent studies and researches and following the phases of planning, management, implementation and aftercare. Actions will include the creation and maintenance of gaps and little patches of

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grassland, digging holes and artificially creating nests and managing water in order to create humid areas for improving the presence of deadwood.

The forest area will also be increased through the planting of new trees in areas previously managed as intensive agriculture crop (maize and soy) or degraded grasslands. Reforestation will take place by planting carefully selected species, with seedlings from Veneto, using at least 5 tree species per site.

Despite the biodiversity level of a plantation is not comparable with the one of a natural forest, the careful design of the planted forests will aim at quickly establishing a higher biodiversity level compared to the one of intensively managed crops. These new forests will then be managed with the selective management model.

For improving the recreational and social/cultural functions, interventions will aim at;

i. improving the fruition of the forests by people, and
ii. controlling and canalizing people in some areas for preserving the more relevant natural spots.

Non-forestry interventions such as fencing of some areas, new informative panels in multiple languages, realization of birdwatching sheds, waste baskets, benches, creation and maintenance of paths, bike routes, etc., will be coupled with forestry and landscape interventions. Among the latter, undergrowth that hinder areas with touristic interest will be reduced and removed (after evaluating its naturalistic importance) and plants potentially dangerous for visitors/users will be pruned.

Nature protection and conservation is one of the primary aim of the FMM at stand level. The FMM aims at diversifying forest structure and bringing the current composition to the ecologically coherent native tree species composition based on forest type's functional characteristics, competition relationships and ecological features of the place.

4.4 Challenges and opportunities

Local communities are not familiar with/used to forest management operations and might be concerned especially about the aFMM1, while the operations of aFMM2 will be conducted at a lower intensity.

The application of aFMM2 is considered feasible in a short-term, as some actions have already started, including the planting of new areas with native species. Moreover, the CSA has also been recently certified according to the FSC standards and, within this framework, specific High Conservation Values (HVC) have been identified. The CSA forests have also been chosen as one of the pilot test areas for certification of ES according to the FSC standards.

The aFMM1 aims to favour natural regeneration, although in some cases existing stands have been artificially generated. Favouring 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 favour the expansion of alien species already present in the area (e.g. *Ailanthus altissima*). Particular attention will be posed toward limiting the regeneration of alien species.

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As for oak-hornbeam forests, oak is to be supported through appropriate forest management choices aiming to facilitate natural regeneration and growth.

Currently just a minor proportion of the forest area (less than 30%) is thinned. The cost of thinning operations might not be covered by revenues from firewood sales.

If not properly conducted/managed thinning operations might favour some invasive species.

Little is known about the management of lowland oak-hornbeam forests (aFMM1) for productive uses; however, some previous experiences conducted in similar areas show that, when relying only on natural regeneration, the oak share is likely to decrease. Artificial regeneration could instead be effective in supporting the abundance of oak. Given the lack of consolidated data, the share will be defined by learning from the first experiences on the site. New forest areas will instead be artificially planted.

As for the applicability, the aFMM1 model is not immediately implementable, since neither the context nor the stakeholder preferences will be much in favor of this management solution in the short term. However, it could be seen as an option in the medium/long term, when also stakeholders could recover some familiarity with active forest management and harvesting operations. It has also to be noticed that the aFMM1 is constrained by existing legislation that at the moment does not allow the conversion from high forests to coppice.

It is difficult to define whether aFMM1 is fully realistic, nonetheless it cannot be totally neglected/excluded at this stage and it deserves to be explored.

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5 Lithuania

5.1 Background

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 Lithuanians educated in Russia and Germany that were influenced by respective forestry schools; (ii) a land reform during which most forests were nationalized, resulting in domination of State forests and (iii) the economy of a poor agrarian country, where forests were an important natural resource both for rural population (fuel, timber of building) and for the national economy through incomes 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 use of the forest resource.

During Soviet occupation (1940, 1944-1990) planned economy relied on strict managerial hierarchies in general and so also in forestry. Planners had a heavy say on operational forest management by state the forestry enterprises. 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 a relatively long rotation could deliver as much timber of sawlog dimensions as possible. In addition, forest management was set up with strict rotation ages and area control of age classes. Important additional features were the introduction of forestland zoning by forest functions and the attempt by the Lithuanian authorities to save the domestic resources and instead import timber from the Russian Federation.

The restoration of independence in 1990 that brought radical economic, ideological, and institutional changes at multiple levels inevitably challenging the forestry subsystem. 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 a reduction of forest regulation and planning. Contrary, the regulations were enlarged due to a significant increase of environmental consideration. The latter was caused by changing public preferences, international influences and powerful national patrons of environmental cause. This lead to considerable expansion and refinement of forestland zoning resulting in four 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%).

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In the commercial forests, additional environmental stipulations were introduced, e.g. concerning biodiversity trees and seasonal harvesting restrictions. Further restrictions of different degrees was prescribed for groups I-III.

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 Nature protection and Forest Department of the Ministry of Environment and the state forestry coordinating State Company (SC) State Forest Enterprise. State forests (1 million ha) are managed by 42 regional branches of SC State forest enterprise with an average forest area of 25,000 ha. Private forests (0.83 million ha) are managed by 250.000 owners. The area of private forests is on average 3.3 ha. Forest-related legislation treats state forests and private forest owners largely identically despite important differences in aims and management conditions. SC State forest enterprise has by far superior prerequisites for following the legislated forest management paradigm. Private forest owners largely comply with the legislative requirements (such as minimum allowable rotation ages) but the actual approaches to forest management are highly diverse due to the diversity of ownership objectives. Following the traditional forest management paradigm, a vast majority of forest stands are under even-aged management system with long rotations and relatively small-sized clear cuts, averaging about 2 ha. Preferred tree-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 lower than prescribed, especially in private forests.

5.2 Process and motivations

The choice of aFMMs in Lithuania was based on several reasons, however the main one was related to the limitations of existing FMMs. First of all, Lithuanian forestry has its ideological base in the classical theory of normal forests, in principle originating from the 19th century with forest management aiming at achieving an even age-class distribution to ensure the evenness of timber flow. It is predicted, that the demand for timber, especially firewood, will increase significantly worldwide and in Lithuania. The timber prices may also go up. However, only about 52% of annual gross increment is cut and made available for the market. Nearly 15% of annual increment is lost in mortality. Even though these losses could be interpreted as having potential positive influence on biodiversity-related ESs, much of them occur in commercial forest because of non-efficient thinning and final felling approaches. Recently the final felling amount in state forests for the period 2019-2023 was increased by 6% by the Government. However, even the decision was based on official statistics, there was no scientific analysis except statements from State forest service experts. Shortly, the adopted final felling amount was based on the same forest management principles which shaped Lithuanian forestry during the last several decades. It is obvious, there is an urgent need to discuss alternative approaches because of national and international challenges due to e.g. climate change and market globalization. And it is also obvious, that such discussion needs to be based on scientific estimations, including building forest policy and forest management scenarios, testing the influences of very specific forest management decisions.

There are many experts in the country suggesting, that one of major resources to increase timber production without violating provision of other ESs and even without significant modifications of all other forestry principles and implementations, is to examine adaptive rotation ages. Final forest felling in Lithuania is strongly regulated by the minimal final cutting ages which are supposed to be

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estimated based on stand technical maturity. The minimal final felling ages are inflexible with respect to the market demands for specific assortments, do not consider costs of silvicultural and harvesting activities and do not incorporate the value of time. In addition, minimum final felling ages are not differentiated according to forest growing conditions. Minimal final felling ages are usually relatively high, resulting in reduced timber production and increased risks of damage. In some occasions, it can also indirectly lead to decreased biodiversity and cultural ESs. There has been some attempts by some individual researchers to address this issue (e.g. studies by V. Brukas or R. Deltuvas (done 1-2 decades ago). However, they did not elaborate more than addressing the problem and proposing alternative rotation ages. Therefore, these publications did not receive much attention by forestry authorities and decision makers.

Analysis within ALTERFOR could be a good opportunity to return to the issue of adaptiveness of rotation ages. Now there are tools available for detailed calculations using real data on the outcomes of both current and adaptive rotation ages, including evaluation of several ecosystem services. In addition, the need to discuss the current rotation ages are brought up by various stakeholders but without scientific analysis. With this background, the suggestion to thoroughly evaluate aFMM "Adaptive rotation ages" was generated inside the ALTERFOR team. Thereafter, it was strongly supported by our non-academic partner and did not receive any negative opinion during subsequent discussions with other relevant stakeholders, including the 1st WP4 workshop.

The aFMM2 "Care for deciduous" was chosen due to several reasons. It was not assumed during the initial stages of discussions on the aFMMs and was suggested just before the 1st WP4 workshop with the stakeholders. So, Lithuanian forestry has long been focused on growing coniferous forests: The reasons – site and climatic conditions, economic considerations, available know-how and traditions. The simulations of forest development under existing FMMs revealed, that profits from forestry activities (basically, due to timber supply because of increasing yields and raising timber prices) were expected to increase no matter the scenario. However, current forest management models may have some negative impact on some ES (biodiversity, cultural) in a long run, mostly due to decreased species diversity, dropping the share of broadleaves and jumping the volumes of spruce. The question raised by ALTERFOR team and some relevant stakeholders was whether is it possible to keep the share of deciduous stable or increasing during one or more rotations without significant economic issues. Even though since recently the tolerance to deciduous species in operational forestry has increased, however, nobody has attempted to predict the impacts of the "care for deciduous" on the full basket of ecosystem services. The shares of deciduous trees in young stands are found to increase during last decade, but whether this increase is due to issues in regeneration and pre-commercial thinning, shall the deciduous "survive" through the whole rotation? Such questions were found to be requiring special research focus, relatively easy to implement in ALTERFOR. Combining aFMM1 and aFMM2 was also expected to be very useful to compensate potential deficiencies of other than timber supply ESs due to potential reducing rotation ages.

The aFMM3: "Non-clear cutting in protective forests" was much inspired by various ENGOs suggesting "prohibition" of clear cutting system in all forests of Lithuania, or only Group III forests, or in all state-owned forests, etc. Usually, such suggestions are not followed by any substantiation (nor about the reasons – sometimes, just because the clear cut does not look nice, nor about the outcomes). This aFMM is expected to reduce the timber supplies, but the key question is to test whether the non-clear cutting does always result in higher non-timber ESs. The idea to test this

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aFMM was generated inside the ALTERFOR team, it has been somehow addressed also in another research project. Finally, it was strongly supported by many stakeholders at the 1st WP4 meeting, which motivated it to be included as an alternative FMM for analysis in ALTERFOR.

5.3 Descriptions

5.3.1 Adaptive rotation ages

This alternative FMM, (aFMM1), aim at differentiating the minimal final cutting age depending on main tree species, site productivity, or other factors. Economic and financial maturity ages (2% interest rate) will be estimated for major tree species in the CSA, taking soil type into account. The maturity ages will be estimated dynamically, for each simulation decade, also accounting for the conditions assumed in IIASA scenarios (like, timber prices). Minimal cutting ages identified in previous studies will be also analysed to consider current economic, technological, and environmental conditions. Some expert judgement may be introduced to adjust the new final cutting ages, e.g. due to increasing damage risks in aging spruce forests or special cultural values of oak forests. Target diameters, number of years until the stand is most efficient to be harvested or other indicators of final cutting starting point may also be used and validated in our study.

Changed minimal final cutting ages will influence the annual cutting amount at estate levels. In state forests this is estimated using the age class method, while stands are allocated for final cutting when they reach the minimal final cutting age in private forests.

Modified final cutting ages may influence the timing of thinnings. Since the last thinning should not be done later than 10 years before final felling, the thinning program may need to be adjusted both with respect to timing and frequency. This aFMM will be used for many other current FMMs and other silvicultural activities than thinning remain as under current forest management models. Therefore, it will be analysed for all major tree species in Lithuania and for clearcuts with planting and shelterwoods with natural regeneration. Most of the planted seedlings will be genetically improved with seeds collected in seed orchards. Pre-commercial thinnings will be done according to normal practices for respective tree-species.

5.3.2 Care for deciduous trees

A common feature of Lithuanian forestry is a lack of adaptiveness in many practical aspects with a great number of regulations. Forest regeneration is planned and performed by assigning list of target tree species to be regenerated to each soil type, depending on forest group. The lists are usually long with up to 10 tree-species. Deciduous tree species usually are in the lists, except grey alder, willows, poplars and similar tree species. Forest regeneration and afforestation rules also recommend numerous tree species compositions, initial densities and planting schemes. Lithuanian DSS Kupolis has a functionality for user to define forest regeneration details, including species compositions and proportions of each species composition by soil types. So, alternative regeneration specifications will be elaborated based on current regeneration principles but increasing the share of deciduous trees in the species composition of the plantations and increasing the proportions of admixtures with deciduous.

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The principles of thinning cuttings in Lithuania are focused on removing softwood deciduous and retain coniferous tree species. The thinnings are requested when the target tree species are overtopped by other tree species, starting from 8 years in coniferous dominated stands and 6 years in deciduous dominated stands. The thinnings are later planned based on the relative stocking index by tree species and stand age, i.e. the cutting is conducted when the relative stocking index reaches a defined value and the intensity of thinning is to be reduced by some stocking degrees. To have the thinning cuttings positive influence on the increasing the shares of deciduous trees somewhat lower relative stocking indices at maturity will be targeted, about 0.8 and 0.7 in coniferous forests and deciduous forests, respectively. In this alternative, aFMM2) more frequent thinning cuttings will be done compared to current FMMs and the intensity of cuttings will be relatively. This approach was tested in INTEGRAL project and was reported to increase the amount of dead wood and create more favorable conditions for tree species diversity. Clear final felling will be prioritized using FMMs but shorter rotations may be used in the future due to changed dominant tree species. All other silvicultural activities remain as under current forest management models.

5.3.3 Non clear-cutting

This alternative FMM model (aFMM3) would assume that clear cuttings are avoided in some forests (first of all – protective Group 3 forests), which used to be harvested by clear cutting under current FMMs. Clear cutting is replaced by non-uniform and uniform shelter-wood systems.

The shelterwood systems automatically involve larger share of natural regeneration, with some soil scarification and some planting where the natural regeneration is not sufficient. The choice of tree species for regeneration is rather limited, main tree-species are Norway spruce, Scots pine, silver and downy birch and grey alder. Thinnings are done as under current FMMs with non-clear final cuttings.

Non-clear final cutting may result in reduced stand resistance to the wind. The protective potential of some stands may also be reduced, as natural in-growth of low quality tree species and brushes may occur. Some alternatives of this aFMM are assumed, e.g. no clear cuttings at all, except the stands on wet sites. This FMM may be also combined with adaptive rotation ages. Then the “Adaptive rotation ages” FMM specification does also apply.

The aFMM is typically done in relatively small stands of about one ha. In non-uniform shelterwoods, gaps should not exceed 0.3 ha and the regeneration should be completed within 20 years. Several alternatives of rotation length will be tested. Firstly, the same rotation length as in the aFMM adaptive rotation ages but also an additional 10 years to comply with the current approach to have 10 year longer rotation in group 3 compared to group 4. Scarification may be used to improve germination and establishment of naturally regenerated seedlings, especially in Scots pine stands but sometimes also in Norway spruce, birch and black alder.

Pre-commercial thinning is done 1-2 time and follows current recommendations. Except for short rotation deciduous species, 1-2 commercial thinnings are done during the rotation and thinnings are done in the same way as in current FMMs.

Since this is a new method for Lithuania, both knowledge transfer and new research is needed for successful implementation.

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Currently, motor-manual methods with chain-saw are used for harvest but future development with harvesters is possible. All transportation in the stand is done with forwarders.

5.4 Challenges and opportunities

For all three aFMMs and especially for aFMM 2-3, natural regeneration will be used relatively frequently. Natural regeneration is more unpredictable than planting with occasional failures in the whole stand or in parts of a stand. Natural regeneration may also result in a dominance of unwanted tree species. If the natural regeneration does not work according to plan, the future development of the stand may be jeopardized or expensive additional planting may need to be used. However, the hypothesis is that natural regeneration will be one important way to improve biodiversity values.

For aFMM 2-3, pre-commercial thinning will be especially important in order to regulate both density and tree-species composition. Since both FMMs are new to Lithuania, there exist little knowledge and tradition in how to perform PCT in these stands. Therefore, professional forest workers and private land owners need to be educated in new PCT-principles. In addition, it will probably be important to time PCT relatively exact in both FMMs in order to avoid overtopping and reduced vitality of desired individual trees of desired tree-species. This may be difficult to achieve, especially for private forest owners, since it requires frequent surveillance of forest stands approaching PCT.

For the clear-cut free and care for deciduous (aFMM2 and 3), the principles of commercial thinnings may need to be reconsidered. In the latter FMM, a larger share of deciduous trees should be retained after thinning which need a new mind-set of forest workers and forest planners. For the adaptive rotation age FMM, there is a possibility to improve economy by better timing of commercial thinnings.

The elimination of clear-cuts in the clear-cut free aFMM may potentially improve biodiversity values. But it comes at the cost of more complicated and expensive harvests. The use of shelterwoods also increase the risk for wind-throw. For the adaptive rotation length aFMM, reduced rotation may lead to reduced damage by wind-throw, root-rot and insects. However, the trees will be smaller at harvest which marginally will increase harvest-cost. Shorter rotations will increase the amount of clear-cuts on the landscape scale and this may potentially be negative for the public opinion of forest management in Lithuania.

In order to implement the adaptive rotation length aFMM, current legislation in Lithuania need to be changed. Currently, rotation length is highly regulated in legislation that is a heritance from the past era of planning for even age class distribution and aim for producing large trees for saw-timber. To make the necessary changes of legislation, politicians and the public need to be convinced about the advantages of adapting rotation length to site properties and market situations at the same time as they are convinced that other ES-values are not reduced to unacceptable values.

The care for deciduous FMM may decrease production slightly compared to coniferous monocultures which may be negative for economy. However, productions of other ES may be enhanced and it is also possible that future market development will value deciduous trees at higher prices which will improve economy. High quality deciduous wood may be a limited resource in the future which will improve the price.

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6 The Netherlands

6.1 Background

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. After 1970, more emphasis was placed on the role of forests in the protection of nature, and natural processes received more attention. 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. 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 natural 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. 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 (IFM). IFM is related to concepts such as "nature oriented" and "pro silva" management and the basic underlying conditions that are often considered, are:

- 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.

Despite all the discussions on what the concept entails, most forest managers, when asked, would indicate to follow the ideas of Integrated Forest Management. 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.

6.2 Process and motivations

Based on the analysis that the existing dominant FMMs have a focus on either nature conservation, or production of timber (at moderate intensity), three alternative FMMs were proposed that focus stronger on either production of specific assortments or on recreation. By choosing these FMMs, with all FMMs described (existing and alternative) they cover the three main ES of Dutch forest management (timber/wood; nature/biodiversity; recreation), in different variations/levels. Other ES are also considered to be important, but are implicitly taken into account in the multifunctional character of all FMMs.

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Two of these aFMMs focuses on production, either on large quantities of wood mostly for biomass or production of high quality timber. The wood mass forest management model intend to increase the production of more renewable energy together with lower CO2 emissions through replacement (HWP), while other ES are of less importance. This model is also closely linked to a segregation of functions as several forest management organizations have recently introduced and/or plan to introduce.

The aim of the other aFMM (high value timber forest management) is to achieve the cost-efficient production of high quality timber while preserving ecological functions and stability of the stand, providing an attractive forest for recreation. This aFMM was created to increase focus on the ability to provide ES other than timber (such as recreation and biodiversity, which are important to Dutch society) on a relatively high level.

The third aFMM, Park forest management, focuses on the cultural services of the forest, especially in terms of recreational quality and aesthetic beauty. Dutch forests fulfill an important function in terms of recreational use (walking, cycling, hiking, etc.). This is rather important in a country with a high population density. It is expected that the demand for recreational use of the forest will further increase in the future and that the pressure of recreational use on Dutch forest will become very high.

These aFMM concepts were discussed during a workshop with forest managers and policy makers (July 5 2018). Within this workshop the need was recognized for more segregated FMM definitions. However, some additional focus was asked towards climate resilient forests. This focus mainly followed the shared notion that, although climate change will happen, the direction, speed and endpoint of this change are uncertain. Thus, there is need for a refinement of the current multifunctional FMM to further increase species and structural diversity and increase the share of broadleaved species. This aFMM should be characterized by the current small scale harvesting. These measures are expected to reduce the risks imposed by possible drought and other climate extremes, increase flexibility of the forests to yearly variation in weather conditions and improve soil conditions.

Given the large area in the CSA (the whole of the Netherlands) and the great diversity of growth conditions, the aFMMs are formulated in generic terms. Within the simulations with EIFSCENspace species specific management will be defined and site specific growth and competition will be calculated. No long term scientific trials exist to validate the simulations of the aFMMs at stand level. Expert judgement of tree, stand and landscape level projections is used for validation purposes.

6.3 Descriptions

6.3.1 Wood mass forest management

The aim of this FMM is to increase the production of (low quality) wood. Instead of a by-product, in this FMM wood mass is the main objective. A combination of: a) short rotation plantations (e.g. coppice system), an even-aged and size crop, with early maximum growth rate and short rotation periods, and no regeneration costs once the stand has been established, b) a conventional forest management system, including relatively short rotations in comparison to the other FMMs, larger stand sizes with larger sizes of harvesting areas, above the commonly accepted maximum of 2 ha, no precommercial thinnings, removal of (most of the) wood from the stand.

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6.3.2 High value timber forest management

This aFMM strives for the production of premium quality wood by managing for knotless boles of thick trees with strong, solid branches that form large crowns. The forest includes a variety of species to ensure diversity and make use of natural competition between species in shaping the individual stems. Young trees are planted or germinate naturally in the first stage. The second stage focuses on the best trees; natural pruning of lower branches can take place due to the natural dynamics within the forest. Operations in this stage are only justified in case of possible loss of or damage or a negative influence to these best trees, or when specific species need to be supported. In the third phase, management is strictly limited to the removal of those trees that inhibit the growth of the best trees (i.e. single tree oriented) and are based on large distances between the best trees to ensure the development of large crowns. Trees can be harvested from the point that they qualify as "quality timber". Pruning may take place during the rotation to increase the quality of the timber. Dead wood (both standing and lying) remains in the stand. (Description of FMM inspired by the QD approach).

6.3.3 Park management

This FMM focuses on the production of an attractive forest, especially in terms of recreation. Management is proactive, and includes activities such as cutting back overgrown paths, carry out thinnings and in some cases high pruning (to open up the canopy and create views out onto the surrounding landscape), remove (part of the) dead wood in order to promote a sense of active management, etc. The forest includes a variety of species, and old and big trees. An understory may be present but not too dense to inhibit views through the forest stand. Trees are only harvested to create a more attractive forest.

6.3.4 Climate-resilient management

By actively increasing the tree species and structural diversity of the forest at stand level, the ES targeted by current multifunctional management are bolstered against possible negative effect of climate change. This FMM is characterized by small scale interventions (gap creation), both planting and natural regeneration and the active promotion of soil-forming broadleaved species.

6.4 Challenges and opportunities

For public and specific stakeholder to support the implicit inclusion of a wide range of ES within forest management is of high value. The wood mass production is focusing mainly on one ESs, renewable energy, which might decrease stakeholders support. However, emphasizing the value of storage of CO2 makes the model more interesting. During the workshop forests managers were interested in options for partially replacing management-oriented subsidies with carbon-oriented subsidies as an explicit payment for this ES.

The most defined challenge mentioned for the high quality timber model which also strives for preserving ecological values is the demand of relatively much knowledge on silvicultural practices. This can be a challenge given the large number of private owners with small (< 5ha) forest. Other aFMMs are however less demanding if it comes to silvicultural knowledge.

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The upcoming markets for wood mass and high valuable timber makes those models focusing on the related ES financially interesting for forest owners. The model aiming mainly at recreation has no substantive production of wood that will gain an income but the increasing demand for cultural services, and lower income dependence of some forest owners, might compensate for this.

The use of natural regeneration, especially while promoting broadleaved species can be hampered by the high browsing pressure. More intensive game control, or fencing should be considered.

The main legislative bounds on forest management practices are related to the demand that forest is rejuvenated after clear felling and the prevailing Natura2000 habitat and species directives. Felling operations do demand approval from regional government. Further public and governmental demands, with respect to harvest intensity, species selection and public access, are not legally enforced but encouraged through subsidy and certification schemes. This creates space, possibly at the cost of the loss of subsidy, for implementation of more extreme FMMs.

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7 Portugal

7.1 Background

Three major forest species cover Portugal forest lands, eucalypt (*Eucalyptus globulus* Labill), maritime pine (*Pinus pinaster* Aiton), and cork oak (*Quercus suber* L.) encompassing 25.8% (8.12 × 10^3 ha), 23.7% (7.37 × 10^3 ha), and 23.4% (7.14 × 10^3 ha), respectively. The remaining area is occupied by holm oak (*Quercus ilex*) (10.5%), stone pine (*Pinus pinea*, 6%) and other broadleaved tree species and conifer species (17%). These forests encompass a wide variety of ecosystems ranging from intensive silviculture plantations for wood production to plantations for coastal dune protection and agroforestry systems. The dominance of eucalypts stands is a result of twentieth century afforestation to stimulate a national based timber-processing sector. The decrease of maritime pine and the expansion of eucalypt plantations were the most significant trends in the last decades. However, according to the latest National Forest Inventory (IFN6), there was a considerable increase in forest stands with stone pine (+54%) and chestnut (+48%). Most Portuguese forests are primarily intended for production functions, not only for roundwood but also for pulpwood, cork and other non-wood forest products. 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.

Private ownership accounts for 85% of forest land (mostly by small non-industrial private forest owners) and 70% of it has less than 4 ha, while only 1% of it has 100 ha or more. The state ownership represents only 2% of the Portuguese forest land and communal land 13% of the total forest area. In the North and Central regions of mainland Portugal, forest has often low profitability and tenure is highly fragmented. Under these conditions, effective intervention to protect forests and increase its profitability is made possible through cooperation within forest owners associations (e.g. the Vale do Sousa Forest Owners' Association – AFVS in our case study area) and through the establishment of partnerships under the ZIFs (Forest Intervention Zones), that 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. About 47% of the non-industrial forest owners (small properties) are 70 years old or more and only undertake few types of silviculture practices. Larger private owners usually live in the city and lease out their lands to tenants or leave them under-used.

The Vale de Sousa CSA 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 current 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. 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. Indeed, 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 favours its application in practice. Nevertheless, there is a trend for increasing diversity and providing additional forest products and services in the CSA. In addition, the supply of native hardwood volumes and of other ecosystem services (e.g. biodiversity) is perceived and interesting by stakeholders and can increase with the success of policy or market payments for ecosystem services as well as the ZIFs eligibility for additional support by forest policies and may further contribute to increase the importance of alternative FMMs.

The losses caused by wildfires are one of the major sources of uncertainty when projecting timber supply in the CSA. Yet after every fire, more landowners switch to eucalyptus, hoping that a shorter production cycle can allow them to recoup their losses faster and to harvest their trees before the next fire erupts. Nevertheless, following the catastrophic wildfires of 2017, the National Forest Policy was prompted to address prevention and control to the eucalyptus plantations. There are now stronger planting restrictions on eucalyptus, and thus the forest owners are looking for alternative species for timber production. In addition, Management planning must comply with silvicultural rules in the Tâmega Regional Forest Plan (PROF-T), approved in 2007 by the Minister of Agriculture. For example, there are regulations on the rotation length for broadleaved trees in the CSA, which defines the minimum rotation of chestnut at 40 years. In addition, the legislation implies that clearcut not exceed 50 contiguous hectares to address environmental concerns with impacts of harvests. 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.

7.2 Process and motivations

The selection process of alternative FMMs began in the summer - early autumn of 2017. The results of the interviews (conducted in June 2017) were an instrumental baseline for the description of preliminary alternative FMMs in MS3. As a follow up, two proposed alternative FMMs and their contribution to the provision of ecosystems services were presented in Galway (October 2017); aFMM 5 *(Pure Pinus pinaster)* and aFMM6 *(Quercus robur).*

As part of the processes for the assessment of FMM alternatives, the actor analysis (interviews - June 2017) was discussed with the non-academic partner AFVS and was communicated by the research team to the stakeholders at the 1st workshop that took place on the 22nd and 23rd November 2017 in the city of Porto at the Portuguese Catholic University. The research team provided a description and preliminary findings on the current FMMs (referring to the situation prior to the wildfires of 2017), included and referred to recent changes in the forest policy and social context. Therefore, the 1st Workshop focused on stand-level Forest Management Models (FMM), it also focused on obtaining some preliminary information on landscape-level objectives and alternative FMMs.

The two aFMMs listed above were in line with stakeholders' concerns regarding the context situation related to:

- the perception regarding eucalyptus plantations;
- forest fires and lack of forest management;

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- and that more attention should be given to other native wooded areas (forest stands) to develop a landscape mosaic that may better address the demand of hardwood sawlogs and positive trends for biodiversity indicators and cultural services.

Furthermore, a proposal for the possible inclusion of one more native species as cork oak (*Quercus suber* L.) has been suggested as a new alternative FMM. Existence of several spots with spontaneous regeneration of the two climax oak species (*Q. robur and Q. suber*), suggesting that with proper guidance they could succeed and gradually replace mixed stands with pine and eucalyptus.

As outlined above, wildfires in the summer of 2017 impacted the case study area inventory. The research team was challenged during the winter /spring of 2018 by the need to update the inventory to reflect the current forest conditions (e.g. identify forest cover; validate stand ages; natural regeneration, define initialization of aFMM) and to further redefine the management units. After completing this task, the research team felt the importance of introducing a riparian system (FMM8) in Vale de Sousa CSA. The diversity of community types and hydrology within wetland forests may have large-scale implications for the conservation and management of these ecosystems. Thus, the main objective when developing aFMM8 was focused more on the environmental aspects of riparian systems, while on the supply of wood production. It involves considerable interest in alluvial ecosystems, where nature conservation and watershed management are more important.

In this sense, three native alternative forest management models that involve the cooperation of all categories of stakeholders namely forest owners, pulp and paper industry, municipalities and forest authorities were considered for implementation in Vale de Sousa:

- FMM5 To have less intensively managed pure maritime pine (*Pinus pinaster*) stands in low densities (1111 trees per ha instead of 2222 trees/ha as current FMM1 and 2) with a pre-commercial thinning at 15 years and focus on resin production (pine trees with dbh> 20 cm);
- FMM6 To increase sawlog production, timber quality, and native broadleaves in the landscape by planting where the soils are fertile and deep with good water availability pure pedunculate oak (*Quercus robur*) (1600 trees/ ha) with rotation lengths of 40, 50 and 60 years for fire hazard precautions;
- FMM7To increase cork production and contribute/help to reduce fire and diseases risks by planting forest mosaics with cork oak, a native species (*Quercus suber* - planting 1600 trees /ha). The debarking to get the valuable cork starts at 30 years of age, the second debarking at 40 years of age and then debarking could be done every 9th years.

A fourth aFMM (FMM8) were included by the research team reflecting the provision of biodiversity values, which constitutes a milestone target to the national environmental quality objectives: To restore wetland natural condition by watershed sustainable management in the alluvial ecosystems of 60 management units with the main riparian species of *Alnus glutinosa, Salix atrocinera, Salix alba, Fraxinus angustifolia* and *Populus nigra*.

7.2.1 Further development of new aFMM

Taking into consideration all the suggestions of stakeholders, the list of alternative FMMs described in MS3 (September 2017) was slightly modified:

- an adjustment of prescriptions within FMM5 - Maritime pine (e.g., silvicultural schedule);

- an adjustment of prescriptions within FMM6 - Pedunculate oak by changing rotation lengths to 40, 50 and 60 years instead of 120 years as suggested in MS3 and presented at the 1st workshop (November 2017).

The changes that have been made reflect an adaptation to management for timber production by single native species plantations such as pedunculate oak and maritime pine harvested under patch clearcutting on short rotations lengths (< 55 years) for intended to minimize fire hazard. Also changed final cutting ages may influence the growth and development of understory layers.

Two new aFMMs have been developed as see "description"; Pure cork oak forest system for cork production and riparian systems for biodiversity conservation

Summary of the decision-making process:

- Initial selection of two aFMMs (FMM5, FMM6) by the researchers in the Portuguese CSA team based on the actor analysis (interviews). Further, described in the MS3 and presented at meeting in Galway (October 2017).
- The 1 st workshop (November 2017) focused on stand-level Forest Management Models with the CSA stakeholders. Interest of stakeholders in implementing the aFMMs chosen by the research team, however reducing the rotation lengths for maritime pine and pedunculate oak. Cork oak for cork production - *Quercus suber* (FMM7) emerging as a new aFMM.
- Regarding key stakeholders' concerns on nature conservation in the CSA and the additional work of the research team to update the inventory conditions, a new aFMM focus on the environmental aspects of riparian systems (FMM8) has been developed.

7.3 Descriptions

7.3.1 Pure maritime pine and pure pedunculate oak forest system for sawlogs production

These two aFMM targets the supply of pine sawlogs. It provides 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 researched. The rotation age for both systems is ranging from 40-60 years.

For maritime, plantation will be done with density of ca 1100 trees per ha. The seedlings are in a container with clod. Fuel treatments may take place every 5 years, pruning at 10-15 and 15-20 years, with precommercial thinning at 15 years of age, commercial thinning occurring in the period from 25 to 55 years of age based on a spacing factor.

For oak, plantation will be done with spacing of 1600 trees per ha. One pre-commercial thinning that should take place when the trees have 10 meters height (approximately 18-22 years) to remove dead trees, diseased and poorly shaped trees in order to reduce stand density. Intensive commercial thinning to favor the crown development and diameter growth, is based on the dominant height of the trees and should take place between 13 meters height (about 25-29 years of age) and then every ten year before the final cut at 40-60 years. Fuel treatments may take place every 5 years.

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7.3.2 Pure cork oak forest system for cork production

Cork oak is considered a native alternative FMM by the existence of several spots with spontaneous regeneration of the two climax oak species (*Q. ilex* and *Q. suber*), suggesting feasibility for practical implementation with a proper guidance cork oak could succeed and gradually replace mixed stands with pine and eucalyptus. Due to the recent changes on the Forest Policy, there are now stronger planting restrictions on eucalyptus, and thus the forest owners are looking for native alternative species for cork production and risk reduction.

Suitable sites are planted with 1600 trees per ha and after ca 15 years a pre-commercial thinning is conducted. Usually four commercial thinnings are performed at 30, 40, 58 and 76 years. The debarking in order to get the valuable cork starts at 30 years of age, the second debarking at 40 years of age and then debarking could be done every 9th years. The target for ES services is to promote native vegetation, produce cork, promote biodiversity and to achieve resistance to wildfire with this tree species.

7.3.3 Riparian system for biodiversity

The reason for including this new FMM is because species such as *Alnus glutinosa, Salix atrocinera, Salix alba, Fraxinus angustifolia* and *Populus nigra* contributes particularly to riverine ecosystems and to the services they provide. It contributes to biodiversity by providing habitats for a specific flora and fauna both on the tree itself and in the flooded root system. Moreover, it assists with water filtration and purification in waterlogged soils, and the root system helps to control floods and stabilize riverbanks. This FMM will contribute to biodiversity by providing habitats for a specific flora and fauna both on the tree itself and in the flooded root system. Moreover, it will assist with water filtration and purification in waterlogged soils, and the root system helps to control floods and stabilize riverbanks. It provides carbon stock storage and may contribute to the supply of other ecosystem services (cultural services and resistance to wildfires).

It is mainly a lentic system located in the low areas of CSA, on soils subject to frequent flooding and saturation or with markedly impeded drainage with different levels of connectivity with the fluvial network. The area is ca 10 ha and the methodology is to create buffer zones in the area, 10 m from non-navigable waters and 30 m from navigable waters.

7.4 Challenges and opportunities

7.4.1 Challenges

In the models with maritime pine and pedunculate oak there is a risk of soil erosion in the thinning lines. Damage to remaining trees might occur within thinning operations as well as damage to already occurring natural regeneration. For the natural regenerated pedunculate oak planting it is necessary to densify the stand in case of insufficient trees from natural regeneration. Predation of acorns by animals (e.g. mouse, wild boar) can make natural regeneration impossible.

Main demanded assortment for both models are logs greater than 20 cm diameter for sawmills. There is also a market demand for wood logs under 20 cm, for energy use (firewood, pellets and biomass based power plants), normally sourced from thinning's. However, there is some pressure

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for anticipated final cuts before the stands reach maturity. This may also deplete the capability of natural regeneration and undermines the potential for older stands with potentially greater income.

Small-scale forest areas play the most significant role on the implementation of all FMM in the CSA. A minimal economical scale is often not achieved which also makes it difficult to implement wild fire prevention operations. Small-scale private property can be a limitation for management intensity due to financial concerns. Some operations are not profitable, because stand areas are too small.

7.4.2 Opportunities

The maritime pine and pedunculate oak models will benefit the reduction of fuel density within the thinning operations, which is an important wildfire risk reduction factor. Commercial thinning also improves conditions for good quality timber production and is an intermediate profitable operation. Market is demand driven, currently there are not enough saw wood logs available for the internal industrial demand. There is no infrastructure, technical or human capacity limitations for the clear-cut system. Appropriate machinery and human experience are available in the CSA.

7.4.3 Ability to model aFMMs in available decision support systems

The aFMMs described above are well motivated and realistic. The possibilities to estimate output on landscape- level for different ES are appreciable. The landscape-level simulations, with all the decision space of aFMMs will be presented at the stakeholders in November 2018, in the 2nd workshop at Porto. The visualization of the trade-offs possibilities is an easier way of understanding the impacts of the multiple management options that can be displayed in the form of a Pareto Frontier. This technique encapsulated in the SADfLOR DSS, allows for a visual perception of the aFMMs trade-offs between ecosystem services facilitating the setting and negotiation of management planning targets (Borges et al 2017). Our DSS provides direct output related to wood production, however, difficulties to implement and evaluate aFMM, essentially refer to lack of information on process-based models to check the impact of climate change on growth, tree mortality and species suitability. While the standing volume and the volume harvested values do reflect the climate change impacts assumptions, the interpretation of the other biometric variables values should be cautious. Moreover, it was not feasible to assess the impact of climate change on mortality. The use of process-based growth and yield models might provide more accurate projections of timber yield under climate change, yet this would require data acquisition and modeling research not supported by ALTERFOR. Thus, to overcome this issue we adjusted linearly a percentage in yield under climate change scenarios over the planning horizon. In this context, our timber supply projections (standing volume) are made with empirical growth and yield models. Adjustments to accommodate temperature changes over 90-years of simulation were made on the corresponding values of standing volume and volume harvested (as well as on biometric variables such as stand dominant height, diameter at breast height, standing basal area) to reflect the WP2 climate scenarios. Based on information (averages for the region) from the SIAM national study about the effects of climate change on forest growth in the Northern part of Portugal, we adjusted linearly a 10% increase in yield over the planning horizon in the severe climate change scenario "REF" - "Reference", and by interpolation 6.76% in "BIO - EU Bioenergy"" scenario and 4% in scenario "GLOB". In addition, a "no change" scenario (herein named "BAU") considers that there is no climate change and conditions will remain the same.

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8 Slovakia

8.1 Background

Before 1990, forest management in Slovakia was highly influenced by the socialist era. All forest land was owned by the state and were managed by the State Forest Enterprise. A strict top-down management hierarchy was applied with national economic targets transferred into forest management plans. Although the economic environment was completely changed after 1990, the management of forests through forest management plans remains obligatory for all forest owners. In addition, main paradigms of forest management at stand levels and at ownership unit level (forestland zoning) remain intact. Forest management plants are considered as the main political tool of the state for regulation and control of forest management in order to assure provision of ecosystem services demanded by society. At the same time, strict rotation ages limit the risk of overharvesting of forest estates.

Three management zones of forests are distinguished: commercial, protection, and special-purpose forests. Forest stands for protection are set by site properties and borders are determined by the planning authority. Similarly, some special-purpose forests are set aside independent of the owner's goals, 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 are considered as commercial unless the owner changes their orientation for some preferred cultural service.

The Forest Management Plans sets the amount of allowable cuts and profits for the forest owners through three mechanisms: forestland zoning, thinning volume determination, prescription of silviculture system and rotation and regeneration period length. Moreover, it is mandatory to regenerate final cutting areas within 2 years. However, the many other regulations and prescribed actions in the Forest Management Plans have lost their obligatory nature, now they are more recommendations than prescriptions.

Although production-oriented paradigm still prevails in contemporary forest management in Slovakia, a trend of more ecological forestry has emerged. Wood and biomass are the primary source of financial outcome for the forest owners, but today there is a need to fulfil a broader, more balanced variety of ecosystem services already at stand level. This trend is clearly related to the growing demands of broader public and environmental agencies on forest biodiversity and ecological stability in changing climate. An increased public pressure has resulted in many forest owners joining certification. Today, silviculture systems linked to natural regeneration of stands are applied as standard and clearcuts are fully excluded from planning and practice. Also, close-to-nature approaches based on selection systems are tested and promoted.

In the case study area most of the forest management is classified as non-uniform shelterwood systems. Shelterwoods are used with broadleaves such as oak, beech or in spruce dominated stands. Selection systems are used on small areas with spruce-fir-beech. As Norway spruce is the most common tree species in the CSA, the most common FMM is non-uniform shelterwood with spruce that is used on 65% - 70% of the area. On 18% of the area managed is focused on soil protection,

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nature conservation or watershed management. In the protection areas, free development is combined with selection cuttings or small-area non-uniform shelterwoods.

8.2 Process and motivations

The process that resulted in two alternative FMMs for the Slovakian CSA can be divided into six different steps:

1. A kick-off seminar for relevant stakeholders was organized in June 2016. At the seminar, stakeholders had the possibility to discuss problems related to forest management in the CSA or in Slovakia
2. Analysis of Slovak Travel Lab discussions and WP4 actor descriptions and interviews with stakeholders such as the main planning authorities of State forest enterprise, National Forest Centre and important forest managers for small private owners and communities, provided us with in-depth information about the hot topics in contemporary forest management practice.
3. Several attempts were made by the researchers in the Slovak TUZVO team in order to formulate aFMMs for specific stakeholder needs.
4. The D1.1 Report on current FMMs in Europe in combination with the guidelines about the aFMM formulation provided by consortium and the simulation results with cFMM provided inspiration for formulation of aFMMs.
5. The above information and inspiration resulted in a decision to formulate two general aFMM concepts that respond to a wide array of stakeholders demands
6. The main concepts, underlying ideas and the most important features of aFMM was presented on a stakeholder workshop to validate the preliminary proposals and obtain a new impulses and suggestions.

Slovakian Travel Lab discussions, WP4 interviews and actor analysis and frequent contacts with different kinds of stakeholders interested in forest management on CSA revealed an increasing needs for: (i) promotion of nature conservation and biodiversity, (ii) the ecosystem stability and future economy of spruce-dominated stands, (iii) the sustainability of forest facing the drying the landscape, (iv) climate change mitigation and carbon sequestration, (v) regulation of natural hazards, risks, water and climate, (vi) fuelwood and biomass, (vii) even-flow of harvests and improved cash-flow from wood, (viii) more balanced forest management at stand level, (ix) enlarged decision-making freedom in forest management and planning.

In summary, the general demand was an improvement of ecosystem stability, provision of regulating services and wood production, but also some more specific demands appeared (related to specific stakeholder group):

- Better harvest flow and wood-related incomes (small owners)
- Promotion of multifunctional management in small areas (foresters and state administration)
- Enlarged freedom of decision making within planning and management (forest managers, owners)
- The people in Slovakia also call for a more flexible forest management that can respond to changing climatic, economic and social environment.

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The first idea was to propose separate aFMMs for each demand, but that would have resulted a large number of very specific aFMMs. Instead it was decided to create two models that will aim at solving as many as problems as possible and are not linked to specific age, species, site or ecosystem services.

At the same time, the aFMMs should be inspired by other countries and should not be restricted by the current forest management frameworks or current highly prescriptive legislation in Slovakia. Different groups of stakeholders should be addressed but the aFMMs are not tailored to specific needs of individual stakeholders.

Two aFMMs were proposed:

- Sustainable multifunctional management in partly uneven-aged mixed stands – based on the idea of innovative mix of the elements of even- and uneven aged forestry concepts,
- Model for a sustainable timber production in even-aged mixed species stands – based on the idea of flexible rotation-length and regeneration time.

Both proposed models can be regarded more as two families of FMMs than as two individual FMMs. Both FMMs can be developed into more specific subvariants if needed. The planning procedures should be more flexible to improve adaptiveness of forest management, promote the forest sustainability and improve the economy of forest owners.

Both new management options have several common features and respond to same challenges stated by responded actors:

- Sustainability is attained by more close-to-nature thinking
- Natural regeneration of the stands promotes biodiversity
- The aFMMs increase production of several eco-system services simultaneously
- More freedom for forest managers in decision-making results in greater flexibility in forest management planning
- The aFMMs are focused on contemporary commercial stands
- The aFMMs are original for Slovakia but are inspired by ALTERFOR and related to several models from several countries (e.g. Germany, Sweden, Lithuania and Portugal).

The first aFMM is primarily motivated by concern about the sustainability and economic future of spruce-dominated stands under climate change combined with increased amount of wood from small forest areas. At the same time, the model reflects the public opinion for more close-to-nature principles. The model is applicable under current legislation, it does not violate main forestry paradigms and its implementation is supported by almost all actors types. On the other side, the first model is more challenging for operational implementation and the need for investments in infrastructure, technology and education can seriously limit its implementation.

The second model was designed to improve cash-flow within highly regulated age-class forestry in combination with an effort to avoid decrease of timber value in over-mature stands. In addition, growing demand for green energy and biomass combined with promoted forest variability at the landscape level is targeted. The model allows applying the principles of adaptive forest management under climate change to meet the ecological stability demands. The model is not in line with the current legislation and current forestry paradigms. It may also be harder to accept by nature-oriented persons. The model requires the change in current forest goals and instead manage forest stands for

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production of high-quality timber. It is possible that forest managers will have to resist the pressure of different wood processing lobbies and irresponsible owners for overharvesting.

The two aFMMs were not limited by DSS features, the models are fully compatible with DSS capabilities and quantification of ES production under different climate/economic/ behavioural scenarios is possible. The practical implementation of the aFMMs are highly demanded and does not require an intensive research effort. The aFMMs are realistic, and although they are not applied actively in Slovak forestry, many examples of successful applications can be founded in Germany and northern or north-eastern Europe.

8.3 Description

8.3.1 Sustainable timber production in even-aged mixed species stands

This aFMM is based on age-class forestry principles combined with more flexible rotation-length and regeneration time in comparison to present state. It is intended for mixtures of naturally occurring tree-species and rotation length will be shorter than normal forest management in the area. The aFMM aims at (i) producing maximal amount of wood and biomass in shorter rotations, (ii) prevent the reduction of wood quality over-mature stands (iii) minimize the environmental risks associated with harmful factors and disturbances (iv) improve biodiversity of the forests through utilization of natural regeneration of native tree species and (v) improving the continuity of financial incomes from smaller areas.

A minimum allowable rotation length will be defined based on site index and tree species in order to maximize total stem volume production. Pre-commercial thinning and commercial thinnings are similar to classical even aged management with one PCT and up to eight commercial thinnings. The regeneration cutting can be done by shelterwood cutting on the whole area, by cutting in strips or gaps or by selection of individual trees.

A prolonged regeneration period enables natural regeneration of different tree resulting in a more natural tree species composition. This may reduce the ecological risks and mitigate the drying effects of climate change. Norway spruce outside its natural range will probably still be a significant part of future stands which is a potential future risk. In addition browsing by deer, regeneration failure due to prolonged drought periods at spring, high risk of weed pressure on medium and high-quality sites need to be considered when regenerating stands. A clear advantage is that the natural regeneration almost comes without any cost and the large number of seedlings may reduce the negative impact of browsing.

Pre-commercial thinning (PCT) aims at reducing the high density of naturally regenerated stand and make sure that high-quality individuals of desired tree-species are given enough space growth. As for aFMM no 1, PCT requires skilled and qualified workers. PCT can be considered as long-term investment significantly improving future growth and quality of the stand by the reduction in density and by selecting vital individuals of desired tree-species.

Commercial thinning applied differently by tree species can improve growth of the best quality trees, improve the average quality of the stand and significantly improve quality of target trees. Therefore, commercial thinnings is important for increasing the value in later phases of stand development. Moreover, the ecological and mechanical stability of the stand is improved by thinnings. The trees

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that are retained after the thinnings can be damaged by the harvest and soil erosion may be increased after thinnings. After thinnings, the recreation values is temporarily reduced but the long-term effects of thinnings on recreational values are often positive. Commercial thinnings are an important source of financial incomes, especially for small owners unable to achieve continuity of revenues from larger areas of forests.

The final felling has shelterwood nature and due to the application of the prolonged period of stand regeneration, the probability of successful natural regeneration with natural species composition is much higher. The diversified stand structure and species composition promote biodiversity, the ecological stability of the forests and production of various regulating and cultural services. Thus, a wide basket of eco-system services can be fulfilled. The shorter rotation periods compared to traditional forest management in the area will lead to improvement of continuity and evenness of financial incomes for small owners. Because the regeneration phase can be initiated within a wide range, this system gives forest managers high flexibility in decision making when, where, how much and how to harvest. This flexibility may be used to adjust to market- and owner-demands. The shelterwood natural regeneration of stands favor shade-tolerant species and on good quality sites, competition from ground vegetation may be considerable. In cases when natural regeneration will not be successful, artificially planted seedlings threatened by high browsing pressure. The final felling is the most important source of financial revenues that serve for covering of all other silviculture and harvests costs. Incomes from final felling are also the main source of resources for long-term infrastructure and technological investments.

The application of the new FMM does not require big changes in infrastructure or completely new technologies for harvest, skidding or transportation. Long-term experiences with natural regeneration of stands by shelterwood cuttings in different natural conditions and species compositions are available. However, the outdated harvest and skidding technologies used in current practice and poor transportation infrastructure may severely limit the implementation of the FMM.

Small and larger owners will be interested in improved continuity, quality and volume of final harvests. The professional conservationists will support the enhancement of biodiversity by natural regeneration of mixed forests. With high probability, the FMM implementation will be also supported by broader public and local inhabitants which demand sustainable provision of regulation services like is water flow and quality, air and climate regulation that is more probable due to limiting off large-scale disturbances. Lastly, professional forest managers will like the greater flexibility of operational planning.

8.3.2 Sustainable multifunctional management in partly uneven-aged mixed stands

This aFMM is based on the idea of mixing even-aged silviculture in early developmental stages with selection and harvest of individual trees that have reached target dimensions in later stand development. The aFMM consists of one precommercial thinning and up to 7-8 commercial thinnings. Commercial thinnings are done about every 10:th year. Thinnings will gradually become a selection system where trees that has reached a target diameter will be removed. At this stage, natural regeneration will start and at the late development stage, the stand will consist of seed trees. The regeneration period is relatively long, up to 60 years. During the entire rotation, several tree species will make up the production stand. Main tree species are Norway spruce, European beech, silver fir, Sycamore maple, Common ash and European larch.

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The natural regeneration of different tree species is achieved during a long regeneration period leading to mixed species composition which may reduce the ecological risks and mitigate the drying effects of climate change. However, Norway spruce outside its natural range will probably still be retained. Pre-commercial thinning is important for regulating stand density but an important aspect is also to regulate tree-species composition by retaining desirable tree-species. Because PCT involves decision about density of retained trees and selection of tree species and individuals within species, it requires skilled and qualified workers. PCT can be considered as long-term investment significantly improving future growth and quality of the stand by the reduction in density and by selecting vital individuals of desired tree-species. PCT can be considered as long-term investment significantly improving future growth and quality of the stand by the reduction in density and by selecting vital individuals of desired tree-species. The relatively frequent commercial thinnings with out-of-date technology may lead to damage of retained trees with subsequent damage by insects and fungi. The transition from even-aged forest to partly-uneven aged structure is done by target-diameter-harvests, prolongation of the rotation length and regeneration period. However, selective harvest of trees that have reached the target-diameter is costlier and more demanding from technology, organization and qualification of workers and foresters compared to clear-felling. Damage and partial destruction of existing natural regeneration are almost inevitable. The target-diameter cutting is the main source of financial incomes. The continuity of income is secured by frequent cuttings and the possibility to react to changing markets may improve income from the cuttings.

The new FMM is primarily oriented to improve the ecological stability of unstable Norway spruce stands growing outside its natural range. Such stands were planted in the past mainly to achieve maximal economic profits from this highly productive tree. The replacement with mixed species stands with a significant proportion of broadleaves can partly decrease the economic profitability. However, frequent cuttings will result in a better distribution of incomes and the possibility to respond to changing markets is advantageous. Spruce and fir will provide raw-material for construction wood, pulp and paper wood whereas valuable broadleaves will be used for furniture, construction and fuelwood assortments.

The application of this aFMM need investments in infrastructure, especially road construction to make stands accessible for harvest and harvest machines. The aFMM need forest managers with knowledge of uneven-aged management for planning of harvests but educated personnel is also needed on the ground doing actual harvests.

8.4 Challenges and opportunities

8.4.1 Challenges

For implementing both aFMMs, forest managers with good knowledge of management of uneven-aged stands and mixed species stands are needed. Pre-commercial thinning, commercial thinnings and shelterwood cuttings are the most important tools for influencing future stand development. Therefore, skilled forest workers are needed to select future crop trees during harvest operations. Because frequent thinnings are done in both FMMs, great care must be taken at thinnings to avoid damage to retained trees that could potentially reduce future value of the stand. For this reason, investment in harvesting equipment that are more adapted to thinnings in dense stands than what is currently available might be necessary.

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Both systems rely on natural regeneration and the aim is to achieve mixed species stands. A prerequisite is of course seed-trees that are close enough for seeds to be transported by wind or animals to the regeneration area. If regeneration fails, planting is needed but planted seedlings are usually heavily damaged by browsing from deer and might need to be protected. Protection against browsing will add extra costs to already high cost for planting.

The stands will be harvested in thinnings or selection felling about every 10:th year. For this to be commercially viable, the stands need to be easily accessible from roads. Therefore, expensive investments in road-construction might be needed.

The concept if minimum allowable rotation age (MARA) is almost unknown for a Slovak public, foresters, owners and politicians. Currently, it is practically not allowed due to a fear that private owners will over-exploit its forest properties if it was possible. At the same, increased harvests after the introduction of FMMs into practice may be badly perceived by nature oriented and the broader public. Therefore, the practical application of the FMMs must be done sensitively and advantages must carefully be communicated with politicians, conservationists and the broader public.

8.4.2 Opportunities

Both aFMMs aim at achieving a continuous output of harvestable wood in a sustainable way but at the same time secure production of other eco-system services such as biodiversity, recreational values and water protection. The use of natural regeneration and the aim for mixed species stands will increase the stands biodiversity values compared to the previous monoculture of Norway spruce. Use of mixed species stands may secure long-term production given a future with climate change and possible dry periods.

Both aFMMs gives a higher degree of freedom for planning of forest operations compared to current FMMs. Because of this, it will be possible to react to changing markets and cut stands when prices of a certain wood-quality is high. Both aFMMs also include frequent cuttings which will secure a steady and continuous economic output, which is especially important for small forest owners.

Both aFMMs is directed to commercial stands that are readily available in the case study area. Thus, a relatively large scale transformation of current FMMs to these new ones is both possible and realistic.

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9 Sweden

9.1 Background

Forest have for centuries been important in Sweden. During the end of 19th century Sweden increased utilization of forest resources for sawmill industry and for export. 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 labor costs. In line with overall production-orientation, the very dominant FMM since the 1950s is the clear-cutting system, primarily of conifer monocultures.

The production-oriented paradigm aiming for increased supply of timber for industrial use remained intact into the late part of 20th century. 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 increasing 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.

The ownership structure in Sweden shows distinct regional differences, a high proportion o the forest in the north are owned by big companies whereas small-scale private forest ownership dominates in the 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. The current liberal policies, guided by the principle "Freedom with responsibility" give industrial actors (private, public and cooperatives) a big influence in shaping forest management practices and promoting production-oriented ideals among private forest owners.

9.2 Process and motivation

The selection process for alternative aFMMs started in late summer-early autumn 2017. The alternative FMM "Shelterwood pine" "mixed forest (birch-spruce/pine mixture)" and "selection system with Norway spruce" were early discussed. These three alternatives represent potential solutions to well-known, and rather accepted problem formulations in contemporary Swedish forest

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management, namely the need to increase the consideration to other ES than timber production by an increased variation in forest management. This is also reflected in “A more varied forestry”, which constitutes a milestone target to national Swedish environmental quality objectives, where it is stipulated that an increased use of clearcut free methods, broadleaves and mixed forest are needed. Due to limited time this initial selection of aFMMs was only made by scientists within ALTERFOR.

Autumn 2017 aFMMs was discussed with non-academic partner Södra. The initial alternative FMMs did not attract much interests. At this stage the initially discussed aFMMs did not strongly reflected the interests of our non-academic partner Södra i.e. maintaining or increasing wood production, nor the increased demand for wood in the IIASA scenarios. Therefore one, or two exotic conifers were suggested as aFMMs. During a meeting with Södra it was decided to have an aFMM with Douglas fir and Sitka spruce, while Abies grandies was turned down.

In the ongoing revision of the Swedish FSC standard, the current proposal suggests that additional requirements on + 5 % nature conservation or management with increased consideration (e.g. clearcut free methods) will be included in the new standard. In a discussion with Anders Ekstrand, Södras representative in ALTERFOR, it was therefore decided to include the selection system as an aFMM in one simulation, thereby investigating the consequences of implementing this requirement in practice.

The first workshop was organized together with County Administrative Board (CAB) Kronoberg 8 May 2018, and focused on the nature values of the production forests in the Helgeå river basin and CAB Kronobergs ongoing work with the project “Green infrastructure”. A first planning meeting were held in October 2017, where it was decided to base the new landscape level simulations (with aFMMs) on the results of the simulations with current management practices. These results were presented in March 2018, where together with Mårten Västerdal at the CAB also decided which strategies that would be investigated and presented at the workshop. The simulation results showed positive trends for some biodiversity indicators related to the native conifers (area of old forest, volumes of larger trees, deadwood). This can be explained by the “ageing” of the areas set-aside for nature conservation in the simulations, combined with a build-up of standing volume (since the growth exceeded the demand in the selected IIASA scenario).

The CAB were therefore not particularly interested in “selection system with spruce” and “shelterwood pine” (which would increase the nature values in the conifer forests) and instead wanted to focus on investigating different strategies to enhance the nature values by promoting broadleaves. Mixed stands with spruce and birch will increase amount of broadleaves. Border zones with/without management towards water and other land-uses (e.g. agriculture land) is a common measure. The idea is to retain a border zone of approximately 15 m at final felling and in addition to favour broadleaves in these border zones by thinning operations.

Finally, “mixed stands with spruce and birch” and “boarder-zones” was included as aFMMs. As result of the discussions, the following four aFMMs were chosen:

1) Sitka spruce-and/or Douglas fir
2) Spruce-Birch admixture (one of our alternative FMMs)
3) Border zones with/without management towards water and other land-uses (e.g. agriculture land).
4) Selection systems

To summarize, the decision process was initially driven solely by the ALTERFOR researchers and highly influenced by contemporary ideas about suitable alternative forest management practices in Sweden. The changes that been made reflect an adaptation to simulation results that have been produced within the project, as well as an ambition to better tailor the aFMMs to the interests of the stakeholder we collaborate with in the workshop preparations.

The motivations for alternative FMMs varies from increased biodiversity to high production potential.

Exotic species as Sitka spruce (*Pices sitchensis)* and Douglas fir (*Pseudotsuga menziesii)* are of interest due to the high production and valuable timber (Douglas fir). This is to meet the increased demand in the IIASA Global Bioenergy scenario. This is also a way to efficient utilization of the forest primary used for wood production to maintain/increase the consideration to other ecosystem services in other areas. Finally, other species is a method for risk-spreading; wind damages and in a longer perspective climate change.

The motivations for mixed stands of spruce and birch are mainly to get a more varied forest, which would reduce the risks that are associated with the current strong dominance of monocultures of Norway spruce (e.g. wind damage, climate change). In addition to risk-spreading, this aFMM is positive for biodiversity and cultural values.

Border zones is a way to increase biodiversity. Zones are believed to have many advantages. They can act as corridors in the landscape and thereby increase the connectivity between valuable habitats. Edges between water-forests, agriculture lands-forests are especially valuable because they often have a higher share of broadleaves, or alternatively have site characteristics which made them suitable for broadleaves. Depending on tree species they can increase amount of broadleaves. They also often give other structures as they often includes bushes.

There is an increasing interest in a "more varied forestry" (clearcut free methods, mixed forest, more broadleaves) in Sweden that motivates the alternative FMM "selection systems". This aFMM constitutes a good alternative for private forest owners that are interested in revenues from harvesting, but at the same time want to maintain the visual qualities of the mature forests. This desire might be especially important on certain areas on their forest holding e.g. avoid clear-cuts close to their houses. Hunting and other activities are very popular and might also influence forest management, favoring less intensive management methods, such as various types of selection systems.

9.3 Descriptions

9.3.1 Clearcutting system with Sitka spruce/Douglas fir

This FMM includes the management of two exotic species through the clearcutting system. However, the management objectives are quite different between the two species. In southern Sweden, Sitka spruce constitutes an alternative for forest owners interested in effective production of wood. The wood production is higher and rotation shorter than Norway spruce, with a similar, or lower, wood quality. In contrast, the management of Douglas fir is more complicated and demanding, and has traditionally been oriented towards producing highly payed quality timber.

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Regeneration: The soil is scarified to increase the growth and early survival of the planted seedlings. Both Sitka spruce and Douglas firs are planted with a seedling density 2000 -2500 seedlings/ha. A slightly higher density is recommended if the goal is to produce spruce timber. Proper site selection is crucial for the performance of these species in southern Sweden. Due to the drier climatic conditions, Sitka spruce should be avoided in the eastern parts of the CSA, and should only be planted on sites with good water availability. Douglas fir is sensitive to frost and should therefore be planted on slopes.

Pre-commercial and commercial thinning: The precommercial thinning program is similar to the normal management of the native conifers. 1-3 precommercial thinnings depending on the degree of competition from the naturally regenerated trees. Sitka spruce can be managed with a conventional thinning program for spruce (normally two commercial thinnings), or alternatively with no thinnings at all. The thinning program for Douglas fir is more intensive, oriented towards favouring the diameter development of selected high quality trees. These trees should be artificially pruned if the goal is to reach the highest timber qualities.

Final felling: As with all exotic species, there is no minimum allowable rotation period for these two species. Due to its faster growth Sitka spruce can be managed with a shorter rotation period compared with Norway spruce. High quality Douglas fir is often grown to large diameters (+ 60 cm). However, it is also possible to produce normal timber of Douglas fir (30-40 cm) within a shorter rotation period.

With the current level of browsing it can be difficult to establish Douglas fir in the CSA without fencing. However, fencing is a costly measure, involving costs for establishment, maintenance and removal. This cannot be economically justified.

Herbicides and pesticides should not be used. Mechanical protection is gradually replacing the use of pesticides to protect from pine weevils, and this development will be completed in the near future. Protection against browsing may be used depending on the browsing pressure.

9.3.2 Spruce/birch mixture

Naturally regenerated birch can generally establish and survive despite the high browsing pressure. Birch has a very good seed dispersal and can regenerate on most site independent on earlier tree species. During the first phase (0-15 years) this FMM closely resemble the clearcutting system with the native conifers. The visual effects, and the associated benefits for recreation, of this FMM will become evident when the stands enter the thinning phase through a substantially higher share of birch than normal. The positive effects for biodiversity will most likely come with a greater time lag, because the biodiversity values are mainly associated with older/larger broadleaves trees.

Establishment: Approximately 1000 seedlings ha^{-1} of either pure Scots pine/Norway spruce or a spruce-pine admixture is planted after scarification. Disc-trenching is preferred over mounding, because the goal is to expose as much mineral soil as possible to facilitate natural regeneration of birch. On sites with low fertility and low soil moisture establishment of birch often is poor and mixtures with birch a less attractive alternative.

Pre-commercial and commercial thinning: The goal with this FMM is to maintain a 25-50 % admixture of birch until final felling, and that these birches should reach timber dimensions. To

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achieve a rapid diameter growth of birch it is crucial to stimulate the crown development by releasing the crowns from competition. Compared with pure conifer stands this FMM is therefore characterized by a higher frequency precommercial and commercial thinning. As a rule of thumb three precommercial and three commercial thinnings should be conducted, were the removal intensity is adjusted based on the competitive status of the birches.

An alternative approach is to remove the birches in the last thinnings, but maintain some birches as future retention trees.

Final-felling: Mature birches can develop brown heart that reduces the quality of the timber, and it is therefore wise to harvest the birches without delay. In addition, keeping the rotations as short as possible is generally positive for the internal rate of return. Rotation age 50-60 years for spruce-birch mixtures and 60-70 years for pine-birch mixtures. Birches should be retained as conservation trees due to their higher conservation value. These trees can also facilitate the establishment of sufficient natural regeneration of birch in the next rotation. If the birches are removed in the last thinning the rotation period can be similar to a pure conifer plantation.

Herbicides and pesticides should not be used. Mechanical protection is gradually replacing the use of pesticides to protect from pine weevils, and this development will be completed in the near future. Protection against browsing may be used depending on the browsing pressure.

9.3.3 Boarder zones

Border zones of approximately 15 m width are retained towards streams, river, lakes, populated areas, recreational facilities and agriculture land at final felling. In the border zones without management these areas are left untouched. In the border zones with management the borders are managed with various treatments that aims to promote the conservation values, where the treatments will vary depending on the conditions of the specific sites (e.g. promoting broadleaves, creating various types of deadwood). The CSA is dominated by conifers, and especially the shade tolerant and highly competitive Norway spruce. The most common silviculture treatment in the border zones will therefore be removal of Norway spruce, thereby favoring light demanding broadleaves.

Border zones without management is most suitable on sites where conifers are totally dominant. Border zones with management is most suitable when the forest has a substantial share of broadleaves.

This FMM is not tied to any particular species, but to a specific locations in the landscape. All species will therefore be included in this FMM, but the most common species i.e. Norway spruce, Scots pine and Betula spp., will dominate when looking into the share of the standing volume. However, the long term goal of border zones with management is to promote broadleaves at the expense of conifers, resulting in an increasing proportion of both trivial (e.g. aspen, rowan, birch, alder) and noble broadleaves (e.g. Oak and Beech).

Border zones with management is most suitable when the forest have a substantial share of broadleaves, mixed with the shade tolerant Norway spruce. Border zones without management is most suitable when the forest is totally dominated by conifers.

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Boarder zones is more a model for landscape level than on stand level but they are present at stand level. They use of boarder zones are especially important considering the results of the simulations with cFMMs, showing that the production forest matrix in the future will be denser and darker, with an even higher share of Norway spruce.

9.3.4 Selection systems

This FMM constitutes a tool to avoid clear-felling's. It therefore constitutes a good alternative for private forest owners that are interested in revenues from harvesting, but at the same time want to maintain the visual qualities of the mature forests. It also constitutes a suitable tool for municipalities that manage forests close to cities and villages.

The clearcutting system with the native conifers is very dominant within the CSA. An increased use of this FMM within the CSA would therefore put the forest landscape as a whole closer to the natural conditions, and by providing a richer variety of habitats this would be positive for survival of forest dependent species.

The wider use of this FMM is also in line with the current forest policy, where the Swedish forest agency recently highlighted that an increased use of clearcutting free methods are needed. Moreover, requirements to promote the use of continuous cover forestry are currently discussed in the revision of the Swedish FSC standard. Considering the high share of certification in Sweden, this could play a decisive role in promoting the spread of this FMM in the future.

The goal with this FMM is to maintain a multi-layered forest with trees in all dimensions. When this state has been reached, the only silvicultural treatment involves harvesting mature trees with a cutting interval of approximately 20 years. Transforming even-aged spruce plantations by thinning operations to the desired multi-layered structure takes a lot of time. Considering the strong dominance of even-aged management in the CSA, this long transformation period will often be required. However, it is of course wise to prioritize this FMM in stands that already have some vertical heterogeneity.

Normal management in a multi-layered forest: The cutting operations are conducted from permanent strip roads (20 m distance) i.e. in the first cutting a large share of the removal comes from the strip roads. The only treatment involves cutting mature spruce trees (20-30 % of the volume) every 10-20 years. If the regeneration and ingrowth (when trees pass a predefined diameter threshold) of smaller trees is sufficient, this management scheme maintains an inverted j-diameter distribution.

9.4 Challenges and opportunities

9.4.1 Challenges

Sitka spruce and Douglas fir are not very common today in the CSA. Forest owners in Kronoberg are a bit traditional in choice of tree species and the experience of introduced species are limited. Management of Sitka spruce and Douglas fir are based on experience in other parts of Sweden, the adjacent counties Skåne and Halland. There is no reason why it should not work also in Kronoberg, even if recommendations for establishment, management, and rotation periods will be adjusted with more knowledge.

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Since some decades interest for birch in mixture with spruce have become more and more common in Kronoberg. Normally birch is removed at early thinnings. It is a challenge to keep birch for longer rotations.

In practice border zones are accepted and most often retained after final-felling. However, full retention of functional border zones implies that substantial areas of forestland are excluded from normal management. In the Heureka simulations border zones with a width of 12,5 m were retained towards agricultural fields, meadows, grazing land, other open land, exploited land (e.g. for various human use), recreation facilities, freshwater. In total, this corresponds to approx. 9 % of the productive forestland. In one simulation the border zones where left as set-asides. In the other simulation the border zones were managed with thinning every 20 years, where the tree selection favored broadleaves at the expense of conifers. The ambition regarding border zones in our simulations (i.e. 9 % of the productive forestland), is higher than current legal requirements, and most likely more ambitious than what is common practice in the forestry sector today. Full implementation will therefore depend on forest owners' willingness to promote biodiversity on a voluntary basis.

There is a lot of discussions about alternatives to clearcutting. Many forest owners and especially other actors discuss different silviculture methods. Often, they are merged together and called clearcutting free methods. It is of large interest to include this and the aFMM to be used are selection cuttings. As forests in Sweden and Kronoberg for more or less a century have been managed with clearcuttings a lot of knowledge and experience is missing.

9.4.2 Opportunities

The four selected aFMMs have different goals. Using introduced species will most probably increase wood production and Douglas fir also produce more valuable timber than spruce. Mixed stands will increase share of broadleaves, board zones give possibilities for increased biodiversity.

The clearcutting system with the native conifers is very dominant within the CSA. There is a strong opinion, especially from stake holders not themselves forest owners to avoid clear cutted areas. This alternative FMM "selection cuttings" mimics the small-scale disturbances (e.g. mortality of single trees or groups of trees due to wind damages/pathogens/insects) that historically were important in shaping the ecosystem and produced forests with higher structural diversity than are provided by today's production forests. An increased use of this aFMM within the CSA would therefore put the forest landscape as a whole closer to the natural conditions, and by providing a richer variety of habitats this would be positive for survival of forest dependent species. Selection cutting systems give other forest structures most probably also be appreciated for recreation.

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10 Turkey

10.1 Background

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 managed 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 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 prepared for every 10 years based on management guidelines. Area, increment, and growing stocks of each stand type are measured in forest inventories. 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

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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.

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.

10.2 Process and motivations

Although 8 different FMMs are existing within the Gölcük CSA, stands for suffering from above mentioned problems necessitates a new FMM especially for the created uneven structure beech dominated stands. Therefore, the main objective when developing aFMM were to improve or regulate those stand structure without damaging ecological integrity.

Moreover, the forest service gets difficulty in regenerating uneven like structure of beech-dominated forests in addition to providing primarily ecological and socio-cultural forest values to the society in the same area. Private forest ownership is quite low within the CSA and generally subject for Chestnut stands. On the other hand, as a local forest service, Gölcük State Forest Enterprise has the influence on the management of beech forests. Therefore, the ALTERFOR team and forest service including both local Gölcük State Forest Enterprise and central General Directorate of Forestry had the influence during the decision-process. Other stakeholders put forth a less effective attitude and agreed on the decisions taken. From their side, this was a result of accepting the issue as a technical problem and focusing more on the outputs.

Forestry guidelines shaped the road map during the determination of aFMM, since forest management planning and silvicultural regulations limits forest management methods or silvicultural treatments to be applied in relation to subject tree species. For instance, according to silvicultural guidelines, clearcutting, selection methods or coppicing could not be applied to beech stands (GDF, 2014a). In this case, shelterwood or continuous cover forestry were the two choices for the mentioned tree species. Additionally, beech and spruce dominated stands for ecological and socio-cultural values are also subject to CCF according to technical guideline no:299 (GDF, 2014b).

In Gölcük CSA, firstly water and soil conservation, biodiversity and then timber are the main target ES when considering the location and site parameters of the beech stands. Here, steep topographic conditions and the demands/reservations of water bottling plants were considered, since there are four different water bottling plants constructed in recent years and there are thirteen of them operating within the CSA. The fresh water supply of the residences within the CSA comes from the water bottling plants established nearly 10 km away from the forests and is bottled within the Gölcük city center. As a result, these conditions naturally caused the Continuous Cover Forestry (CCF) to come to the forefront.

One important problem in the CSA is the difficulty to regenerate uneven like structure of beech dominated forests in addition to providing primarily ecological and socio-cultural forest values to the society in the same area. Since there are apparently beech dominated stands with various aged/sized trees created as part of either mismanagement or social conflicts, an uneven structure has been

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created. As well, the ecological requests of beech trees coincide with the practices of CCF. Such conditions have necessitated the use of different FMM like CCF. There is also a political and legislative support to look for clear-cut free methods.

In fact, CCF has already been implemented in similar other forest areas, yet a big debate among the foresters has forwarded towards the feasibility of CCF. The doubt about CCF primarily may result from the requirements for intensive management, fear of instability of technical foresters and management policy, and lack of knowledge, technical equipment and technical know-how. However, the state forest organization is willing to apply CCF but they want to do it with caution.

There are no legal obstacles for implementing CCF methods. In fact, the current forest management guidelines (rescript No: 299) encourage foresters to apply CCF in beech and spruce dominated forests identified for ecological and socio-cultural purposes. As well, the state forest agency has for many years (1987-2005) promoted the use of CCF in similar other forest conditions.

10.3 Descriptions

In principle, the aFMM "Continuous Cover Forestry" (CCF) is designed to maintain the level of current growing stock that can facilitate a combination of high quality wood production, biodiversity enhancement and reduce the adverse visual impact of clear-cuts in the landscape. Various types of management actions such as regeneration in small groups, cohorts and gaps, thinning, plantation and pruning may be implemented within the forest managed under CCF FMM. Some of the prevailing features of the CCF FMM are:

- Mixed size class and multi-layered stand structure is created with regeneration in small areas from almost one hectare down to a single tree size,
- All harvesting (regeneration, thinning) types take place at the same time,
- Natural regeneration is promoted unless plantation is necessary where seed trees are absent,
- Various cutting may be described such as cutting to improve the health of trees, cutting to improve natural seedlings, thinning and final felling,
- Close to uneven-aged management; yet regeneration on small areas (0,05 – 0,5 ha),
- The silvicultural treatments are applied at stand level,
- Certain level of target growing stock is to be retained, such as 450 m^3/ha in fertile beech stands,
- Other ecosystem services are believed to be provided at most,
- Cutting targets certain sizes of trees, such as over 60 cm DBH,
- Skidding, hauling and other tertiary roads/paths are to be built and maintained continuously as all forest operations happen continuously,
- In treatment cutting target- or future-trees are marked to maintain till final felling.

It is possible to successfully regenerate small areas with partially degraded beech stands considering the local conditions. The greatest threat is the experienced foresters and the maintenance of infrastructure for intensive management. Expected to be expensive as smaller area are targeted for regeneration.

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Pre-commercial thinning in CCF may only be used in dense regenerated and immature stands to create good conditions for production of high quality timber and speed up the growth. Skilled workers are required to find appropriate areas/stands to apply pre-commercial thinning. In dense stands PCT may need to be done more than once.

Commercial thinning in CCF is applied for promoting target/future trees towards the high quality timber. A good combination of skilled foresters and workers is necessary to implement the right level if commercial thinning will be applied in beech stands. Otherwise, degraded beech stand structure may be created in the future. There is a high chance for a successful regeneration as final felling is conducted in small areas. Skidding may cause damages to the new seedlings as most often regeneration is conducted in gaps and small areas. There is also a fear that stands in remote locations or hard terrain conditions requiring treatment may be omitted or left without treatment in due time. That poses a risk for a sustainable management. Final felling in large areas contributes to most of the economy because of low harvesting costs and valuable trees. Yet it may be a bit costly in areas where a single tree selection is to applied.

10.4 Challenges and opportunities

There is an apparent limitation for CCF. A good road network needs to be established in the CSA wherever the CCF system is to be applied and experienced foresters need to be appointed to the CSA, as the system requires intensive management capacity.

One of the risks involved is the possible halt of the system by new decision makers down in the future. Another problem is that the CCF requires continuous support with experienced foresters in the CSA.

By the current legislation, the CCF system can only be applied on beech and spruce stands designated for mainly ecological and socio-cultural purposes. It is recommended to apply in good and medium site, not bad sites. Hufnagl's formula is suggested by the forest management guidelines in the calculation of allowable cut for CCF stands. However, this equation considers the number of trees in the diameter classes and is not guarantee the optimal structure and regulated forest for the selected aFMM. Moreover, the growth and yield of stands managed under CCF has not introduced yet to project the future outputs. Besides, information about optimal distribution of trees/volumes/basal area like regulated forests is needed to clarify target stand/forest structure. However, based on some assumptions, optimal parameters for the CCF can be generated using even aged normal yield tables. The modified empirical yield table adapted from even aged beech stands (Carus, 1998) was used to produce required outputs for the CCF FMM.

The forest management planners are to be trained and supported by the forest headquarters with the requirements of CCF system to prepare the appropriate forest management plans where CCF is involved. This is crucial for a successful implementation of the system in CSA.

The CCF system was implemented during 1990s in the country as part of a German-Turkish cooperation project. There was a relative success of the method. Yet, the system was abandoned because of a lack of technical and managerial support, inappropriate implementation and force to implement it in all forests without justification of the system. For it to be used on a larger scale than today, the target/optimal stand structure needs to be quantified, intensive forest management infrastructure is to be provided, a continuous political and managerial support is needed and a continuous training of local foresters and planners is conducted. Unless these requirements are

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considered, there is no future implementation of the system in either CSA or elsewhere in the country.