ALTERFOR

Deliverable 1.1 – FMM descriptions (in report form)

Project Title	Alternatives models and robust decision-making for future forest management
Project Acronym	ALTERFOR
Project Coordinator	Ljusk Ola Eriksson, Swedish University of Agricultural Sciences (SLU)
Scientific Coordinator	Vilis Brukas, Swedish University of Agricultural Sciences (SLU)
Project Administrator	Giulia Attocchi, Swedish University of Agricultural Sciences (SLU)
Project Duration	1 April 2016 – 30 September 2020
Project Duration in months	54
Authors, organizations (short name)	Main authors: Eric Agestam and Urban Nilsson, SLU Co-authors: local case coordinators
WP No., WPL(s)	WP1, Urban Nilsson and Eric Agestam
Date of delivery by Coordinator	07 June 2017
Date of delivery according to DoA	31 May 2017
Reviewed by	
Project coordinator, scientific coordinator, administrative coordinator	
Type of Deliverable	
Report	X
Demonstration	
Websites, patents, fillings, etc.	
Dissemination level	
Public	X
Confidential, only members of the consortium (including the Commission Services)	
Other	

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

ALTERFOR

III. Technological landscapes

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

Contents

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

List of Tables

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

1. Technological landscapes - overview

1.1. Introduction

The technological landscape is in this report defined as a combination of available technologies and infrastructure for various silvicultural interventions; professional knowhow and practical experience of FMMs; and drivers and barriers, created by legislation, certification rules and markets for forest products. The available technologies may affect implementation of FMMs both in a strictly practical way when a certain technology that are essential is missing in a case study area (CSA), but it may also affect the result when implementing FMMs both with regard to economy and provision of ecosystem services. For example, old harvesting and transporting equipment in thinnings may result low economic result and unnecessary damage soil and retained trees. Lack of knowhow and practical experience among forest owners and forest managers is probably an important restriction for introducing new FMMs. Knowhow can to a certain degree be gained by literature and oral presentations. However, when introducing FMMs to a region, they probably need to be adjusted to the regions biological and socio-economic conditions through practical experience, demonstration sites and local research. This has to be done by both scientific and semi-practical long-term field experiments which most often is time consuming. Legislation and certification rules generate substantial restrictions for implementation of certain FMMs in some CSAs. However, these restrictions may change with time and should therefore not be considered as permanent. The same is true for the market situation which may prevent introduction of some FMMs. However, introducing a new market in a region often need a large amount of raw-material which may be difficult to achieve with forest products because of the long time-horizon between regeneration and harvest.

This chaåter aims to describe the technological landscape of each CSA. Such descriptions will provide background information about possibilities can constrainsts when consider the practical implementation of alternative FMMs.

1.2. Collection of data

The description of the technological landscape was done by a questionnaire and answered by the LCC. The questions was divided in two parts. The first part describing strength, possibilities, weaknesses, problems and economy for important operations connected to forestry. The questions were general for all FMMs but it was possible to give details for FMMs when needed. A second part was about more general information about drivers and barriers for forestry and changes of forestry. Drivers and barriers can be market for forest products, infrastructure, human capital and forest legislation.

1.3. Summary of findings

In general, and not unexpectedly, the technology of each case-study area (CSA) is adapted to the major FMMs used. This will cause a major difficulty when it comes to introducing new FMMs, but more on that later.

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

Almost without exception, equipment and knowledge for regeneration of the most common FMMs in each CSA is considered to be adequate. Problems that are mentioned are foremost browsing by deers and moose. High browsing pressure has been mentioned by Germany, Ireland, The Netherlands, Slovakia, Sweden and Turkey. High browsing pressure restricts the choice of tree-species and in many cases, only Norway spruce can be used. In some countries, e.g. Germany and Slovakia, fences or individual tree protections are used in order to reduce browsing damage and to make it possible to choose desired tree species (oak, beech and Scots pine). However, fencing is an extremely expensive treatment and also requires management of the fences during many years to avoid break-ins by game with subsequent damage to crop-trees. Therefore, fencing is not used in many of the CSAs and this puts a major restriction on which tree-species that can be used.

Site-preparation methods used are mainly different variants of soil-scarification. None of the CSAs mention that availability of scarification equipment is a problem for sufficient site-preparation. However, the scarification technology is probably adjusted to the currently dominating FMM. Mounding and patch scarification may be more common when planting whereas continuous systems, like disc-trenching, may be used in natural regeneration. Herbicides have not been mentioned in any of the CSAs and the use of herbicides is often restricted by legislation.

The cost for regeneration varies greatly between CSAs. In Italy, the total cost of regeneration may be as high as 25.000€/ha (planting 5.000€, maintainance 5.000€ and compensate initial loss of revenue by farmers up to15.000€) whereas the cost for regeneration may be as low as 750€ for establishment of eucalypts in Portugal. The difference in regeneration cost is probably due to the need of expensive regeneration methods to establish sensitive species (e.g. protection against browsing) but also to some degree because of tradition and the need to avoid too radical regeneration treatments because of public opinion.

Local problems in regeneration has been mentioned. In Ireland, regeneration of Sitka spruce on low productive sites have traditionally been done with fertilization at the time of planting. Fertilization is now restricted by legislation and many sites cannot be regenerated with Sitka spruce. In Portugal, natural regeneration of maritime pine is decreasing because of wild-fires. This species in now instead regenerated by planting. In Lithuania, planting of Scots pine and Norway spruce is decreasing because of economic reasons.

The use of improved genetic material at planting are common in Ireland, Portugal, Lithuania and Sweden. In Slovakia, it is not allowed to use seed-sources from outside specified seed-regions which restricts the use of genetically improved seeds.

Because regeneration methods are specialized according to the dominant FMM in most of the CSAs, regeneration will be a bottle-neck for introducing new FMMs. It is also possible that previous knowledge is being lost in some countries because of little use of a specific method. E.g. natural regeneration of Scots pine has decreased dramatically in Sweden and many forest managers in the Swedish CSA has limited experience of that method.

In all CSAs except Italy, pre-commercial thinning is used to some degree and manual brush-saws is by far the most dominant method. The goal of pre-commercial thinning is both to control density and to adjust species composition. It is mentioned that one problem is that educated, skilled personnel is needed when the goal is to create a mixed forest of a specified structure. In contrast, when the goal is monocultures of planted conifers, cheaper personnel can be used. In many of the

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

CSAs, a problem is also that PCT is sometimes avoided or are done late because of the high cost and the unclear economic benefit.

The use of harvesting machinery varies greatly between CSAs. Use of mechanical thinnings (harvesters and forwarders) have been mentioned to be dominating in private forests in Germany, in productive forests in Ireland and in all forests in Sweden. In CSAs in Lithuania, Slovakia and Turkey manual chainsaw is most common in thinnings. Sometimes (Slovakia) the use of harvesting machines is restricted by topographical conditions but the main reason for not using harvesting machines is probably that manual harvesting methods are cost-effective.

In most CSAs where thinning is performed it is stated that knowledge of thinning practices and thinning programs is high. Thinning programs have developed over may years and are performed in a cost-effective way. However, it is sometimes problematic to achieve a positive net-income in first thinnings when small trees are harvested. In later thinnings, the economic result is often much better. The situation regarding thinning is somewhat different when it comes to the more unusual FMMs. In many CSAs, for obvious reasons the experience of stand management is much lower for the unusual FMMs than for the dominating FMMs. Some CSAs (Ireland and Slovakia) mentioned that thinning is done to a much lower degree in the unusual FMM because of possible damage to soils or because of unclear economic motivation. Thinning may also be avoided because it is not considered as a necessary part of the stand management program (Eucalypts in Portugal).

Thinning is in most cases directed towards stand management with the aim to increase average growth and quality of retained trees. However, in some cases individual tree management is the focus. In the CSA in The Netherlands, targeted selection of “future-trees” is a common thinning strategy. Also in the state forest of the CSAs in Germany, future crop trees are in focus during the thinning operations. A more individual tree approach to thinning probably requires personnel with much more education and skill than thinning for stand-level development. It is not mentioned in the questionnaire, but it is possible that trees to be removed in thinnings are marked beforehand by forest managers which of course increase the cost for thinning compared to selection by the thinning crew.

As for thinnings, the harvesting techniques in final felling varies between CSAs. Manual chain-saw methods in final felling have been mentioned in the CSAs in Turkey, Maritime pine in Portugal, Lithuania and Slovakia. In Slovakia, cable systems are sometimes used because of steep slopes. In the Netherlands, Sweden, Ireland and private forests in Germany mechanized systems with harvesters and forwarders dominates. However, final felling is not part of the selective cutting silvicultural systems. In state forests in Germany, the stands are thinned a number of times with the aim to create a heterogeneous stand structure. When this is achieved, target diameter cutting will follow. Because large trees are harvested among trees that will be retained, mechanized systems may not be used in order to avoid damage to retained trees. This has also been mentioned in the Swedish CSA and it will of-course increase the cost of harvest as compared to final felling on clear-cuts.

In all CSAs, except Italy, the market for the dominating assortment is good. In most cases this is pulp- and timber from conifers. In Italy, wood is primarily used for fire-wood and are not used in the industry. The market situation for high-quality broadleaves is more variable. In Ireland there is a need for high-quality broadleaves but the supply is low. In Germany, there is a growing market for saw-logs from beech which is the largest broadleaved species in that CSA. Markets for broad-leave

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

timber in Sweden is very poor and are currently restricting the development of forest management in broadleaved species. In Turkey, there is a market both for high quality veneer and for fuel-wood from broadleaves. However, the market for chestnut and oak in Turkey is poor which reduces interest for this uncommon FMM. It is also mentioned that clear-felling of mixed stands may results in a high variability of assortments which puts a pressure on transport logistics. Sometimes one assortment from a clear-cut site may not make up to one truck-load.

The market for recreation was mentioned in The Netherlands but a problem is to find a system where the forest owner get a share of the economic value of this ecosystem service. In Italy, market for truffle and pine nuts are probably more important than traditional timber market. In Portugal, it is possible that a future market for biodiversity and recreation will develop and include economic compensation to forest owners. But on the whole, traditional markets for pulp-wood and timber seem to be the most important source for income.

As mentioned before, the level of mechanization in harvesting during thinning, selective cutting and final felling varies between the CSAs. In Germany, Ireland, The Netherlands, Portugal and Sweden, both harvesting and transport is mechanized to a high degree. However, in the Netherlands, the harvesting infrastructure is weak. In other CSAs, harvests are often done by chain-saw whereas transport is done with forwarders or other equipment. Horses are only mentioned for the CSA in Slovakia. In the Italian CSA, there is no developed harvesting organization because forest management in the area is new. Harvest is done mainly with chain-saws and transport to roadside either by tractors or manually depending on the size of the logs. In most other CSAs, harvesting is done by contractors. In some cases (Slovakia) it is mentioned that the equipment is sometimes old and outdated. In other places like Sweden, equipment in very modern and the efficiency of harvesting is constantly improving.

However, for less common FMMs the situation is sometimes different. The mechanization is even less than for dominating FMMs and sometimes special problems do occur. E.g. in water protection areas in Slovakia, contamination from oil from machinery must be avoided. Furthermore, tradition and knowledge restricts the use of other silvicultural systems than clear-cutting in many CSAs, but the situation seem to be slowly improving in many countries. It will also be possible to study techniques used in other countries when trying to implement a more diversified forestry.

Forest legislation is highly variable between the CSAs. In one extreme is private forestry in Germany and forestry in The Netherlands where very little restrictions is put on forest management through legislation. The opposite is true for Slovakia and Lithuania where forest management is strongly regulated by legislation. In Slovakia, forest management plans are required and has to be followed within certain limits. Any major deviation from the plan requires a new forest management plan which has to be done on the expense of the forest owner. Sweden, Portugal and Ireland has some legislative demands on forest management but the freedom for the forest owner to choose FMMs is still quite large. In Ireland, the law against fertilization has made regeneration of Sitka spruce difficult on low-productive land. In Sweden, the age of clear-felling is regulated in Norway spruce and Scots pine, regeneration after clearcutting is legislatively controlled and it is not allowed to change tree species from Noble broadleaves to other tree-species. In Turkey, forest management plans are mandatory but they do probably not regulate forest management as much as in Slovakia. On state forests in Germany, the aim is multifunctional forests producing several eco-system services such as biodiversity, recreation and biomass production. This is done via a conversion to het-

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

erogeneous mixed species forests without clear-felling. This is probably not a legislative demand but the way it is implemented is as if it was regulated in legislation.

Future development of FMMs are for most CSAs forecasted to be developments and adjustments of current dominating FMMs. In Germany, state forest will most probably be continuously managed according to the close-to-nature paradigm allowing for production of several eco-system services while private forests are managed according to economical optimization. However, management in the private forests may change depending on future markets, damage and climate change. In Lithuania and Slovakia, where current forest management is strictly regulated by legislation, a future with less restrictions on forest management is foreseen, but the time-schedule for this change in legislation is difficult to estimate. Certification rules may play an important role in future forest management development. In Sweden, FSC is currently under revision and a substantial increase on the demand for set-asides for nature conservations may be the outcome of this process. In Slovakia, an increased willingness to manage forests according to certifications schemes may increase the use of continuous cover methods. Future forest management will probably also be driven by technological improvements both with regards to harvesting techniques and with regards to new methods for planning, including remote sensing methods. However, in most CSAs, economy and market development will probably be important drivers for shaping future forest management models.

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

2. Country reports

2.1. Germany

Table 1 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSAs Lieberose Brandenburg and Augsburg, Bavaria, Germany

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
Regeneration, *state forest FMMs* Remark: Among our alternative FMMs there is nothing really uncommon. Under "common" we will always describe state forest management, and "large private forest" under "uncommon"	State forest strongly prefers natural regeneration considered the best way to achieve uneven-aged mixed forests, and to have the locally best adapted trees. High biodiversity already in regeneration.	Natural regeneration only works sufficiently with low game densities. If desired species are not available in sufficient numbers, natural regeneration has to be augmented by planting/seeding.	With low game densities, natural regeneration is economically highly efficient. Foresters can steer regeneration virtually only by the way the harvest the previous stand generation. In practice, often fences are required (that hold for long periods due to the intended diversity of the regeneration).
Regeneration, *large private forest FMMs*	Large private forests usually plant. Procedures are easy to follow, well known and optimized including weed control and mechanization.	Game densities are not really relevant (protection is part of the standard system). Biodiversity is low, energy input is high.	Can be done with cheap personnel. As protection against browsing (fence, single-tree protection) is standard, and as fences do not need to last long, protection is not as expensive as with state forest management

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

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
			(in case it's required there).
Stand management, *Pre-commercial thinning (PCT) state forest*	Species mixing regulation is the most important measure. Also important is negative selection (removing bad quality trees). Rare species are promoted.	Requires educated, skilled personnel (both, foresters and loggers).	Personnel input is higher. However a broader, more balanced range of ES is produced on the same area than in the large private forests.
Pre-commercial, *large private forest FMMs*	As monocultures dominate, mixture regulation is not a topic. Negative selection is done, but as these FMMs are usually focused on conifers, the workload is comparably low.	Low biodiversity	Can be done with cheap personnel.
Stand Management, *thinning state forest FMMs*	Selective cutting and advancement of future crop trees. Higher share of quality timber production. Fostering tree and stand stability is important in order to open a broad range of future silvicultural options.	Requires educated, skilled personnel (both, foresters and loggers).	See above (personnel input is higher. However a broader, more balanced range of ecosystem services is produced on the same area than in the large private forest concept).
Stand management *large private forest FMMs*	Often thinning from below, high stand increment, more mass timber assortments. Easy procedure. Large machinery can be easily used.	Risks increase (bark beetles, snow and storm break).	Can be done with cheap e personnel.
Harvest/final felling *state forest FMMs*	Target diameter harvest is very prominent. This is not only a final harvest but also important for steering growth and species compostition of the regeneration. If target diameter harvesting is not an option, variations of	High biodiversity, soil and water protection. High stability.	Higher personnel input, in average higher wood quality, possibly somewhat lower volume production. High range of eco-

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

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
	shelter cuts are applied. The goal is to obtain a smooth transition of forest generations into uneven-aged structured forests. General risk is lower as in the classic large private forest system. Deadwood accumulation is promoted to a certain extent.		system services provided.
Harvest/final felling, *uncommon FMMs*	Clearcuts, and seam-cuts are most prominent. Easy to mechanize.	Low diversity, often low stability, low range of silvicultural options. Often damaging agents (storms, bark beetles) dictate what to harvest when.	Can be done with cheap personnel. High volume production, more mass sortiments (average quality).

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

Table 2 Drivers and barriers for implementing common versus uncommon FMMs, CSAs Lieberose and Augsburg, Germany

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/state forest FMMs*** The market requires a large amount of coniferous wood like pine and spruce. Assortments must be homogeneous enough (in size, quality) for industrial processing (from pulping to modern industrial sawmilling). However, we observe an ongoing change increasing the demand for European beech, our (by far) most important hardwood species. Technological research programs for exploring novel applications of hardwoods are supported/conducted by state-funded organizations. This is due to the state increasing the share of hardwoods in its own forests, and implementing policies intended to trigger similar developments in private forests. High quality wood (species independent) is always very well paid, but can never be produced in amounts like industrially usable wood.
	Large private forest FMMs/ remarks Private forest owners can choose freely what kind of management they implement. The only real restriction is that transforming forest areas into other forms of land use is strictly regulated. The large private forest FMMs reflect the situation that most large private owners prefer to serve the traditional market, whose dynamics are well known to them.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, etc.	***General/state forest and large private forest FMMs*** Mostly there are no such restrictions. The normal situation is the possibility of free decision making (reasonably) within the boundaries given by the environmental conditions (choice of tree species, goal of management, and the according silvicultural concepts and technical processes). There is no lack of well-educated forestry personnel and enterprises which offer forestry-related services including the usage of modern machinery. Due to a dense road network and good forest accessibility there is also no transport- induced bottleneck.

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

Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/state forest FMMs*** Legislation requires state forest management that is closer to nature. Hence, the share of hardwoods shall be increased, mixed and uneven-aged forests are promoted. The reasoning behind is that the multitude of forest ecosystem services the state forest must provide to society is best produced with these kinds of forests.
	large private forest FMMs/ remarks As said above, policy in Germany keeps the level of restrictions for private forest owners very low. Mostly the behavior of private forest owners is (tried to be) influenced by offering support if policy-conform forest management is performed. But the forest owners are totally free to decide what to do.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarizing remarks?	***General/state forest FMMs*** The most important trend is the development towards closer to nature forests and therefore the increment of broadleaf proportions. Besides the multiple ES production state forest managers also expect this kind of forest to be the least risky option in the face of the ongoing climate change.
	Large private forest FMMs/ remarks Probably, large private forest owners will continue their current management, unless climate change makes it to costly and/or too risky. If new large markets for hardwoods emerge, this might also be an important incentive to move more towards mixed conifer/hardwood stands.

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

2.2. Ireland

Table 3 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Western Peatlands

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
Regeneration, ***FMM1 clearcutting conifer and FMM2 clearcutting lodgepole pine***	Planting spruce and pine is well-known and all necessary infrastructure, equipment for site preparation etc., seedlings and knowledge are available	One challenge at establishment stage is browsing from deer and protection of the 10% broadleaf sub-FMM may be required in particularly vulnerable zones. Another challenge is reforestation of these FMMs post harvesting. Many of the forests in the CSA were established with the use of artificial fertiliser. The quantities required may not be permitted under current policy or forest certification measures.	Cost for regeneration (planting) is very roughly 1800 €/ha. Including site preparation, seedlings and planting. This is true for plantation of FMM1 and FMM2 of approx. 2500 seedlings.
Regeneration FMM3 Nature conservation and biodiversity protection (*uncommon FMMs*)		The net result of this FMM is reducing the area of timber production. However, it is important for achieving the non-production-based objectives of stakeholder organisations with this viewpoint. Openspace reduces the overall productive area for the timber	Openspace is open area where plants have not successfully re-established. Other than the cost of planting these trees initially, there is little further economic impact. Bufferzone establishment. There is a higher cost of establishing broadleaves in Ireland and some

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

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
		production focus in Ireland. Bufferzone establishment is where native broadleaf species are planted with open space to protect watercourses and road corridors. Bog restoration is where a forest is clearfelled and timber is either extracted or left on site. The drains that were put in place for site preparation are blocked and the area is allowed to revert to its previous bog land-use.	form of protection from deer is often prescribed at a cost of approximately €4 extra per tree although this cost depends on scale. Approximately €849 ha $^{-1}$ without deer protection. Bog restoration. There is an economic cost of approximately 2000 €/ha to block drainage infrastructure.
Stand Management, ***FMM 1 clearcutting conifer***	Thinning FMM 1 is very common, but not carried out where it is not considered to be economically viable (typically if GYC is <= 12 $m^3ha^{-1}yr^{-1}$). There is a lot of experience and knowledge about thinning, e.g. thinning guidelines. Harvesters are almost always used.		Cost depends very much on size of trees (small trees - high cost) while income (pulpwood, timber) increases with trees size. In productive areas, thinnings typically give a positive result.
Stand Management, ***FMM 2 clearcutting lodgepole pine*** **and FMM3 Nature conserva-**	Thinning FMM2 does not take place. The knowledge and experience is present; however, the lodgepole pine produces heavy branches reducing stem quality and value.		N/A

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

Operation	General (strengths possibilities)	Comments (+ weaknesses & threats)	Economy
tion and biodiversity protection (*uncommon FMMs*)	Once established, no operations take place in FMM3		
Harvest/final felling *FMM 1 clearcutting conifer*	Harvesters are almost always used. Infrastructure such as forest roads, market and more are well developed.		Harvest cost is low for final felling, and there is a large market for pulpwood and timber that is produced from harvesting these species.
Harvest/final felling *FMM 2 clearcutting lodgepole pine*	Harvesters are almost always used. Infrastructure such as forest roads, market and more are well developed. This FMM is the main wood supply for co-firing fossil fuel power plants and material for producing fibre and particle board, an expanding industry in Ireland.		Harvest cost is low for final felling, and there is a large market for pulpwood (only) produced from harvesting.
Harvest/final felling, FMM3 Nature conservation and biodiversity protection (*uncommon FMMs*)	There is no final felling. There is minimal timber production benefit for harvesting to establish bufferzones and bog restoration. The stands are often harvested motor manually before commercial maturity and sometimes harvested material is left on site.	Harvesting using motor manual method is slower and expensive compared to conventional harvesters.	Harvesting for bog restoration can break even or make a small profit but it depends on the maturity of the stands harvested.

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

Table 4 Drivers and barriers for implementing common versus uncommon FMMs, CSA Western Peatlands , Ireland

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for pulpwood from FMM1 and FMM2 and timber from FMM1. The heavy production oriented beginnings of the Irish forest sector is still very much reflected in current management, especially on Coillte (the Irish State forest company) land which dominates the CSA. Demand from existing sawmills reflect the wood supplied by the now mature first rotation stands. The knowledge in production oriented forest management and sawmill demand has in turn shaped the private forests. Most sawmills and panel processing plants rely on conifer wood. The sawmills prefer dimensions smaller than 35 cm, since they are not designed to handle larger logs. This means that forest stands rarely achieve their full volume-based growing potential and final felling is suited to the assortments desired by the processing sector, i.e. financial return. Intensively managed conifer plantations (mainly Sitka spruce and lodgepole pine) remain the norm in Irish forestry, but many stakeholders have expressed dissatisfaction with exotic conifer monocultures (especially when established on blanket peat).
	Uncommon FMMs/ remarks There is demand for Irish broadleaf timber for furniture production, but Irish broadleaf timber is rarely managed to produce this standard and is typically firewood. Most processing industries rely on conifer wood smaller than 35cm diameter and although there are a few small wood processors that will accept larger logs, most of the CSA is not suitable for production of large diameter wood due to susceptibility to windthrow and soil fertility.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capaci-	***General/common FMMs*** The forest sector is well organised and optimised to produce conifer timber and pulpwood through the clearcutting system. In the barony of Moycullen, and Ireland as a whole, Coillte is the most powerful actor. Originally afforestation was carried out to promote jobs in disadvantaged rural areas, but in recent times the focus has shifted on making the forest industry more profitable, mainly by technological advancements and mechanisation which reduce personnel costs.

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

ty? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	The Forest Service issue road construction grants to mobilise timber from private forests. There is now more emphasis on distance to roads before approving a grant application. Mechanisation means expensive machinery and "economies of scale" favour large concentrated removals (e.g. clearcutting rather than continuous cover forestry). To some extent, this scale is limited due to the presence of Freshwater Pearl Mussel (FPM) where limits on the maximum contiguous harvest area and the cumulative harvest area within a catchment exist in an effort to limit nutrient leaching and erosion.
	Uncommon FMMs/ remarks Tradition and knowledge reduce the interest for other management models than clearcutting systems with Sitka spruce, lodgepole pine and other conifers. However, many actors, including the Irish state, have expressed an interest in a more diverse species and more broadleaves in the forest landscape and more protected areas.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The requirements for suitable site conditions have increased for afforestation in recent years. This has resulted in a reforestation challenge for many forest areas. The establishment of the current rotation was through the heavy use of fertiliser, levels which are not permitted under current legislation. Under Irish legislation, harvested areas must be replanted. These forest stands, found on blanket peat, are very common in the CSA and are thus likely to undergo a change in FMM. Due to technological advancements and rationalisations, Coillte forests are managed by a small number of staff, this makes site descriptions crucial so that the right yield tables are used and that timber forecasts are accurate to ensure proper management of the stands. Private afforestation is something that is done mainly for the afforestation grants. Forest consultants are only responsible for the first 4 years of a stand's rotation and landowners often show little interest in managing their forest stand; with lack of forest management knowledge as a main reason. This leads to many private forests being poorly managed, often lacking thinnings and thus fail to produce a high volume of sawlog assortment. There are many regulations about establishing forests, but not so many about the consecutive management.

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

	Uncommon FMMs/ remarks In recent years, there have been major changes to Irish forestry, mainly through the implementation of the EU Habitats and Birds directives and to comply with sustainable forest management. These changes include larger protected forest areas, afforestation grants for broadleaf stands, national goals on broadleaf areas, more sensitive operations in forests and species diversification of conifer monocultures. One aspect of forest management policy that will reduce the conifer FMM area in favour of minor FMMs is the implementation of buffer zones, which several older stands lack. This area will mainly be open space with natural vegetation and provides important habitat for natural vegetation and wildlife species within the forest.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General all FMMs*** A combination of market and forest management planning and policy is mainly responsible for the development of the FMMs where fast-growing, exotic conifers are used. Technology and human capacities have assisted in intensifying management of these FMMs and favours the amount of knowledge about conifer clearcutting systems. The timber processing market is predominantly for exotic conifers since this is what all wood processing plants are designed to process. However, recent changes in forest management policy favours the establishment of other FMMs, especially for broadleaves, native species and more protected areas. One expected trend in FMM change is from FMM 1 to FMM 2, i.e. Sitka spruce will change to lodgepole pine plantations. This is because there are large areas of poor quality land (blanket peat) where Sitka spruce cannot be established without the use of fertiliser. However, on the landscape level the combined area of FMM 1 and FMM 2 is expected to slightly decline and FMM3 to slightly increase. The infrastructure, both technical and human resource based is currently in place to accommodate current requirements. There is a shift from largely human-based forest management planning to one aiming to leverage advancements in computer technology. This is new and it will take time for this decision to be considered a valid and acceptable approach amongst stakeholders for forest management purposes. These new approaches are currently considered innovative and sufficient refinements of these methods are essential toward acceptance that they will be sophisticated enough to accommodate more restrictive legislation into the future. The alternative being a reversion, to some extent, toward the human resource-based approach to address these, sometimes complex, challenges faced by the forest industry. The main challenge now and in the future is finding a balance between the requirement to supply a growing market

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

	from a landscape where there is currently a divergence in stakeholder opinion with regard to the management practices required to produce timber for industry. The move by Coillte to become FSC and PEFC certified is one of the biggest changes in forest management in the last two decades (Clarke, 2017, Business Area Unit 2 Team Leader, Coillte Forest *Pers. Comm.* to Lundholm, A.). This has introduced a level of stakeholder consultation, recreational facilities and environmental management considerations. The minor FMMs are likely to become more common from this perspective also. EU habitat and birds' directives enforced through National level policy (and Irish forest policy itself) is in-line with forest certification and also outlines the fundamental requirements for forest management in Ireland. The human factor has played a role in realising these changes on the ground and spreading awareness about the importance of preserving natural environment and lobbying for increased species diversification of the forest estate. In the CSA there are large areas of forest either upland and/or on blanket peat. Both site factors are unsuitable for growing broadleaves or conifers other than Sitka spruce and lodgepole pine. However, some of these sites are inherently so infertile that transforming them to either natural bog habitat, scrubland or protected open space might be the only alternative option. This may prove congruent with the financial, even if not productive, goal. The challenge in future will be whether these policy and certification requirements, which often reduce productive area and productive capacity, can be balanced with industry supply requirements.

References

Clarke, T., 2017, Business Area Unit 2 Team Leader, Coillte Forest *Pers. Comm.* to Lundholm, A.

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

2.3. Italy

Table 5 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Lowland Forest Association (Italy)

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most common FMMs***	The FMM aims to favor natural regeneration, although in some cases existing stands have been artificially generated. Artificial regeneration through planting of shrubs Interest by some private investors to invest in new forest generation by planting trees (improved image/reputation, green marketing, etc.).	Favoring natural regeneration might produce negative effects in some cases. In the coastal pine stands, for example, while support to holm-oak regeneration (in principle) helps the shift towards more natural forest conditions/composition, it might also favor the expansion of alien species already present in the area (e.g. *Ailanthus altissima*). As for oak-hornbeam forests, oak to be supported through appropriate forest management choices aiming to facilitate natural regeneration and growth.	Reforestation costs of agriculture lands or abandoned lands with mixed broadleaved species with 10% species for truffle production: 5.000 €/ha for planting 5.000 €/ha maintenance costs over a period of 10 years 10-15.000 € to compensate initial loss of revenue by farmers. Enrichment planting with truffle seedlings with 100 trees/ha has a cost of 2.800 € including maintenance costs for 3 years.
Regeneration, *uncommon FMMs*			
Stand management, ***Pre-commercial thinning (PCT)***	In principle same as for thinning, please see below.	Pre-commercial thinning is not implemented on regular basis because forest management activities do not aim to	As mentioned, pre-commercial thinning is not implemented on regular basis. In general terms,

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
		maximize wood production, favoring the most productive species, rather to support evolution towards more natural forest ecosystems and multiple functions/services.	thinning is costly and often performed with the support of rural development funds (see below). Cost of pre-commercial thinning is of 5000 €/ha. This is based on use of rural development funds for selective logging. The Lowland Forest Association is now finding opportunities to establish contracts with private doing thinning and getting in change only the thinned wood material (mostly firewood)
Pre-commercial, ***uncommon FMMs***		Pre-commercial thinning is not implemented on regular basis because forest management activities do not aim to maximize wood production, favoring the most productive species, rather to support evolution towards more natural forest ecosystems and multiple functions/services.	
Stand Management, ***thinning common FMMs***	Thinning can favor: - increased future value of wood assortments, although this is not the main objective of the current management activities. The production of limited	The cost of thinning operations might not be covered by revenues from firewood sales. Currently just a minor proportion of the	Thinning is costly and often performed with the support of rural development funds Cost of commercial thinning is of

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	quantities of high quality assortments from oak-hornbeam forests remains possible but very hardly predictable at the current stage since it might be influenced by a number of factors; - firewood and chipwood production; - improved truffle production in coastal and oak-hornbeam forests; - improved pine nuts and wild asparagus production in coastal forests; - improved natural features (composition, structure, etc.) including support to regeneration; - increased carbon sequestration capacity; - increased accessibility by tourists/visitors; - reduced fire risk. Thinning is strongly encouraged by the newly developed forest management plan with a target of 100% forest area thinned/naturalized by 2025.	forest area (less than 30%) is thinned. If not properly conducted/managed thinning operations might favor some invasive species. Local communities are not familiar with/used to forest management operations and might be concerned	5000 €/ha. This is based on use of rural development funds for selective logging. The Association is now finding opportunities to establish contracts with private doing thinning and getting in change only the thinned wood material (mostly firewood). Firewood: 60 €/m^3 (piled, cut to size at road-side) Chipwood: 1-2 €/Mkg (i.e. ton) Conifer wood for packaging, diameter 13-30 cm, length 2-2.4m: 45 €/m^3 Truffle: 150-300 €/ha/year. Use/collection fee: 20-30% Brown truffle production in coastal pine stands: 0.2 to 1.9 Kg/ha/anno. Since in some areas stands are still young and not dense productivity can increase up to 4 to 16 Kg/ha/year if appropriate silvicultural techniques are

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
			implemented. For holm-oak stands values are slightly lower, but normally the production period is longer. Pine nuts: 400-600 €/ha/anno. Collection fee: 20-30% 1 Kg pine nuts need collection/processing of some 25-30 Kg pine cones. Market price for cones ranges between 0.65-0.9 €/Kg; for unpeeled pine nuts 3.9-5.9 €/Kg; wholesale price 14-25 €/Kg. Carbon price (as from monitoring of the Italian voluntary carbon market): 7-10 €/tCO2e. Afforestation/Reforestation = 3.000 €/ha. Improved forest management = 1.000 €/ha
Harvest/final felling *common FMMs*	Firewood and chipwood retrieved from harvesting operations can help to financially support forest management thus	Wood production only limited to firewood and chipwood. More valuable assortments might be retrieved in the	No data.

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	enhancing other ecosystem services. In recent past firewood has been made available to locals in order to make them more familiar with the idea of active forest management.	future, nonetheless this opportunity remains uncertain. Local communities are not familiar with/used to forest management operations and might be concerned	

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

Table 6 Drivers and barriers for implementing common versus uncommon FMMs, Lowland Forest Association (Italy)

Market What is the overall market situation and trends? What kind of assortments (size, species) are favored due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** Since forest management operations and FMMs are not primarily intended for wood production, reference to wood market is not very much relevant. The market for firewood however remains quite active.
	Uncommon FMMs/ remarks Truffle and pine nuts have relevant market potentials and could provide excellent income sources for forest managers, however –especially for truffle- there are no dedicated FMMs in place. Markets remain quite informal. As regards other services (e.g. biodiversity, tourism/recreation, carbon sequestration, etc.) some potential market opportunities exist, however this mostly depend on isolated initiatives and are currently not structured/organized. Forest certification according to FSC standards and the possibility to pilot-test certified ecosystem services and their marketing, as well as the networking/bundling in cooperation with other forest areas might contribute to more visibility and market opportunities. Some private investors have already started to invest in afforestation/reforestation activities in the area for several reasons, including diversification strategies, offsetting/compensations, better reputation and green marketing, etc.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the	***General/common FMMs*** There are no standardized and well-defined FMMs for the management of forest types present in the area. This is even more emphasized by the fact that some of the stands are still quite young (about 20 years old) and have not been appropriately studied yet. This implies management operations are to be defined case-by-case by the forest manager(s). Mechanization level is limited: harvesting is normally performed manually through chain-saw. Wood extrac-

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

choice of FMMs, etc.	tion is normally performed with tractors and trailers, while full mechanization (forwarder) is very limited. Loading operations can be either manual or mechanized, depending on the size and nature of different assortments. Limited mechanization is due to several factors, including forest fragmentation (and consequent limited size of single forest areas), limited relevance od wood production, constraints by proximity to urban/peri-urban areas (use of machinery might create concerns on local population that is not familiar with it) and lack of specific expertise/competences by most of local enterprises.
	Uncommon FMMs/ remarks As regards non-timber forest products and ecosystem services, FMMs are still being developed and, despite an increasing interest, are poorly implemented or not implemented at all in the area.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The case study area is fully covered by a recently approved forest management plan that while addressing all applicable normative requirements also includes innovative issues, such as a tentative focus on ecosystem services. This is not a normative requirement, rather is needed to meet forest certification requirements against FSC standards. At the moment there is still a normative gap in terms of specific legislation regulating delivering and marketing of ecosystem services. Given the specificity and dynamicity of forests within the case study area and the lack of consolidated FMMs and silvicultural approaches for them, the forest management plan defines specific management directions and objectives, but at the same time remains flexible, leaving to the manager the possibility to choose the best solution case-by-case. In line with this approach, criteria for selecting trees to be harvested are not only based on age distribution, but again take into account multiple issues, including health status, present and future potential forest structure, presence of deadwood, presence and status of natural regeneration, accessibility and risk for visitors, etc.
	Uncommon FMMs/ remarks Same remarks and comments as for the general/common FMMs. The case study area presents good potentialities for wild forest product production that is regulated by specific norms (at least with reference to collection activities). As for management planning, there are no spe-

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

	cific FMMs for wild forest products implemented in the area, however -as commented above- the forest manager is given the chance to choose the most appropriate management solutions within the general normative framework.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General/common FMMs*** The most relevant factors (valid for both general/common and uncommon FMMs) are: - lack of standardized and well-defined FMMs due to limited extension of coastal and lowland forests - potentialities but also uncertainties linked to emerging markets for products and services different from wood - huge anthropic pressure on forest resources (tourism and recreation, fragmentation due to agriculture, presence of important infrastructures (highway, railway…), etc.) - visibility of forest areas and potential concerns by local communities (who miss/have lost forest culture) - diversity of stakeholders and multiple interests mirrored by the number of actors directly or indirectly involved in forest management operations
	Uncommon FMMs/ remarks Same as above.

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

2.4. Lithuania

All FMMs identified in the CSA were divided into two groups:

General (or most common) – incorporating the models first of all aimed at timber production and experiencing default management restrictions which apply for all forests and forestry operations in Lithuania. This group includes FMMs with clear final cutting systems allowed, however non-clear cutting may be prioritized due to silvicultural considerations.

Special – in principle, are the FMMs with no clear final cutting allowed. This group includes the FMMs with non-clear final cutting mandatory due to silvicultural or legal considerations or even with no active forest management.

Table 7 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Telšiai, Lithuania

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most common FMMs***	Artificial regeneration is prioritized in pine and spruce dominating forests no matter the ownership, aiming to regenerate the same species with some share of deciduous tree species. Some natural regeneration is also possible on wet soils (up to 30% of FMM area). Natural regeneration dominates in deciduous forests, with some black alder planted on drained peatlands. Soil scarification is always done if artificial regeneration is applied. Seeds are collected locally, as well as seedlings are grown in local nurseries (only local trees are used for artificial regeneration). Some pine plantations in state forests are fenced. Repellents are used in areas with pine and spruce planted	Natural regeneration in private forests is at relatively significant level or even dominating. Usually, there should be more artificial regeneration used in private forests, but it is avoided due to cost saving by private owners. Natural regeneration in combination with non-clear final cutting is much dependent on the competence and professionalism of forestry specialists, this becomes an issue in private forests. Combination of non-clear cutting and natural regeneration sometimes is not economically reasonable, especially in spruce dominated forests.	Relatively high costs of artificial regeneration (around 1000 €/ha for pine, spruce and birch, up to 3000 €/ha for oak). Typically, higher costs of protection against browsing comparing to natural regeneration. Higher expected quality and value of future stands, if seedlings originated from seed plantation are used.
Regeneration, *spe-*	Non-clear cutting requirement is usually	Increasing the share of natural regenera-	Lower costs of regeneration and

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
cial FMMs	associated with the increased importance of natural regeneration, assuming lower regeneration costs and naturalness of forest development. Natural regeneration dominates in private forests, but basically aiming for cost saving. Soil scarification is applied in forests with non-clear final cutting.	tion (except the no intervention forests) should be considered as a long-term forestry objective, however, this can hardly be reached. Artificial regeneration dominates in state forests. The non-clear cutting requirement sometimes is due to legal acts and the geographic location of forests (inside the National parks or near the roads). So, in principle due to natural conditions and importance of recreational and aesthetic values, the natural regeneration should not dominate. Soil scarification is not welcome in Žemaitija NP, leading to decreased regeneration quality.	protection, but higher risk of failure. High costs if natural regeneration is not successful. Lower productivity of stands and expected value of timber.
Stand management, ***Pre-commercial thinning (PCT)***	Lithuanian forestry principles require all stands to be pre-commercially thinned at least once. Depending on site, species and densities, some stands are thinned 2-3 times. Pre-commercial thinning is done manually, using brush saws. Cut timber is usually left in the forest for natural decay.	State forests are thinned practically following the thinning standards, while private forests are significantly under-thinned, most likely due to avoiding extra costs and undervaluing the importance of pre-commercial thinning on the structure and growth of future stand.	One of major issues affecting the precommercial thinning is relatively high thinning cost, 130 – 200 €/ha, depending on the volume of brush. In 2013 – 2020, precommercial thinning are supported by Rural Development Program (197 €/ha).
Pre-commercial, ***special FMMs***	Depends on specifics of FMM. Except the no intervention forests, the pre-commercial thinning need to be used in the way in all forests. Mixed pine stands	Private forests are practically not pre-commercially thinned. Assuming specific purpose of forests under these FMMs, pre-commercial thinning requires extra	Costs of PCT in special cases might be higher comparing with common FFM. Support by Rural Development Program can be

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	regenerated after non-clear cutting are thinned to minimize snow damage risks.	costs and high professionalism in forestry. Sometimes the issue becomes avoiding additional forestry activities in protected areas.	applied (197 €/ha), which in most cases is sufficient to cover expenses of PCT.
Stand Management, ***commercial thinning, common FMMs***	Usually 2 commercial thinning are recommended in Lithuanian forests. The 1st commercial thinning in mixed forests is aimed reduce the amount of deciduous trees in the stand. Deciduous trees which are in groups and do not disturb the coniferous, are not removed. Usually weak or so called "wolf" trees are removed; noble deciduous and pine and spruce, if present, are preserved. Pure stands are thinned to reach required number of stems per ha. The 2nd commercial thinning follow the same principles as the 1st commercial thinning, however, the thinning intensity is less, the commercial value of assortments is higher.	In principle, the aim of commercial thinning in Lithuania is declared to be the development of optimal growing conditions for the most productive trees, removing damaged, low productivity, stem form trees, i.e. increasing future potential rather than generating extra incomes currently. The 1st and 2nd commercial thinning are usually under optimal level in state forests, however they are much less applied in private forests. The share of thinned stands in private forests tends to increase with the stand age – i.e. the relatively largest share of thinned stands belongs to the 2nd commercial thinning, when the output of commercially more valuable timber is higher. The 1st commercial thinning in private forests is often avoided.	The 1st commercial thinning operations usually start with minimal, zero, or even negative net profit. The profitability increases with stand age, dimensions and volume of assortments. Depending on logging conditions, the costs of assortments production are 1.5 – 2.3 €/m³ higher comparing to final clearcuts.
Stand management, commercial thinning	Except no intervention forests, the same as for commercial thinning in common FMMs	The same as for common FMMs. There is some seasonal limitation on cutting in forests of protected areas	Depending on FMM, volume, dimensions and value of cut timber might be smaller comparing to common FMMs

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
special FMMs			
Harvest/final felling ***common FMMs***	Chain saws are preferred under shelterwood cutting systems. Chain saws dominate in private forests - harvesters are used in private forests less than 50% of cases. If clear cutting in state forests is applied, then the harvester may be used. Extraction is fully mechanized. Road infrastructure is well developed	The use of harvester may result in loses of timber due to mistreating the stump part of the log and trees with large branches. The last becomes an issue with aspen, oak and birch trees on fertile soils. Also, the use of harvester is associated with more soil damages, however it is more cost efficient and nowadays the harvesting contractors are lacking. Work load for harvesters is relatively low reducing the timber harvesting profitability. Telsiai SFE extracts ~90% of timber using own equipment	Lower logging and extraction costs in clearcuts. Easier organization of production, comparing with special FMMs. Operational costs of logging in final clear cuts is around 13 €/m^3
Harvest/final felling, ***special FMMs***	Chain saws are prioritized. Extraction is fully mechanized. Horses are also used for timber extraction in special purpose forests and Žemaitija National park	The issue is that non-clear final cutting is mandatory on some fertile wet spruce stands, resulting in increased wind damage risk and regeneration of low value tree species and dense brush layer.	Costs of timber assortments production in non-clear felling are higher by around 1.5 €/m^3. Costs of extraction to the roadside are higher as well because smaller volume of timber in area.
Other: (what)	Not less than 3-7 trees per ha with the age over MARA and the diameter over the average value for the compartment are left in the stand during clear cutting	Stand level restrictions are introduced due to woodland key habitats, presence of nests of some birds, potential habitats of EU importance.	

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

Table 8 Drivers and barriers for implementing common versus special FMMs, CSA Telšiai, Lithuania

Market What is the overall market situation and trends? What kind of assortments (size, species) are favored due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** During last decades, large scale sawmilling industry started to dominate in Lithuania. The industry favors larger timber sellers, especially of pine, spruce and birch sawlogs. Common FMMs, when large final cutting areas are allowed, have an advantage in such a situation. Timber trade is strongly influenced by third parties and sometimes non-transparent round timber coming from state forests auctioning and interests on local timber industries.
	Special FMMs/ remarks The composition of timber assortments and organization of timber sales might be ineffective, if small amounts of each assortment are produced in a cutting area, sometimes even below single truck load. In some low intensity non-clear-cut areas with big number of tree species, the number of assortments can exceed 10 – 12, and organization of sales could become really problematic.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	***General/common FMMs*** The main actor in the CSA is the Telšiai SFE managing majority of state owned forests – they cut around half of timber using harvesters. Majority of timber is extracted using own forwarders. Private forest owners usually must rely on services of contractors to perform forest harvesting and transportation. The efficiency of using harvesters is sometimes low – the cutting involves combination of using chain saws and harvesters (e.g. chain saws are used before the harvester to come to the cutting area and after).
	Special FMMs/ remarks Use of harvesters in non-clear cutting has not been proved to be efficient. So, using the chain saws should be considered as the dominating harvesting technique. Increased harvesting complexity and relatively lower profitability may have negative influences on forest management under specific FMMs, especially in private forests and using services of contractors. In principle, this does not introduce the change of FMM (as the FMMs are much predetermined by strict regulations, segregative forest management and natural conditions), however, the implementation of some forestry operations may be affected (e.g. choice of final cutting method, regeneration type, precommercial thinning).

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

Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** Forest management system in Lithuania has its ideological base in the classical theory of normal forests. The silvicultural ideal is to grow productive stands which by the end of the (sufficiently long) rotation can deliver the highest possible amount of timber of sawlog dimensions. Therefore, the forest management is aimed at achieving an even forest age class distribution to ensure the evenness of timber flow. This forestry paradigm is followed in relevant legislation and operational implementation of forestry planning. Forest management planning principles in Lithuania and the CSA are based on strict rotation ages and area control of age classes. Forest management plans are mandatory for forest holdings of more than 3 ha of forest area. The compulsory parts of the forest management plan are the 10-year final cutting norm, forest regeneration, and environmental requirements. For estates of more than 150 ha, the final cutting norm needs to be estimated using age class method – this yields in different approaches for planning the final cutting in state and private forests (the lasts never exceeding estate area over 150 ha). E.g. all mature stands can be included in the 10-year cutting norm in private estate. This has some influence on the implementation of the same FMMs in state and private forests, e.g. resulting in larger ages of stands cut by final cutting. In principle, forest management planning can actively influence choice of FMM, but more likely it will act inside the FMMs defined using higher level legal requirements and practices.
	Special FMMs/ remarks The same forest management planning principles apply here as under common FMMs, however, the planner must consider additional planning conditions due to environmental requirements, planning in protected areas. There are two types of forest management planning in Lithuania: development of internal forest management project for an estate and building forest management scheme for a county. The last option also includes development of proposals for changing forest grouping, what may lead to changing of FMMs. Such changes are relatively small, nevertheless, they usually are leading towards increasing the share of special FFMs.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the	***General/common FMMs*** The forest management paradigm itself is one of key factors having the impact on current FMMs, including the potential for alternative solutions. Normal forest is the forest management ideal with the aim to obtain even maximized timber flow of sawlog dimensions, believing that other ESs are automatically best provided in most indus-

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

most significant role? What trends can be expected? Any important summarizing remarks?	trial timber productive forests. Private and state forest legally are required to be managed in largely the same way. However, actual management under the same forest conditions differs often in state and private forests. The command&control approach in forest management is much inherited from the soviet times and changes that have taken place since restoration of independence have not lead to relaxation of forest regulation and forestry. Rather on the contrary, the regulatory clout was enlarged. However, it becomes obvious, that following national and international challenges due climate change, market globalization, etc. alternative approaches are coming. In principle, introduction of close to the current FMMs but substantially more flexibility in choosing rotation lengths, thinning regimes and other silvicultural measures at stand level or advanced solutions for allowable cut calculations at landscape level are very relevant even under current political forestry environment. Potential reform of state forestry announced by new Lithuanian government (basically assuming delegating the functions of 42 state forest enterprises to one large state forest enterprise) may introduce some modifications in forestry administration, changed legislation and redistribution of current forest management functions, potentially without much influence on operational forestry. However, we have not enough materials to discuss the influence of state forestry reform on the FMMs much.
	Special FMMs/ remarks Special FMMs became increasingly important due to substantial increase of environmental considerations. This was caused much by changing public preferences, international influences (Rio 1992, signing international agreements, joining the EU in 2004) and powerful national patrons of environmental cause. Nevertheless, forest management under special FMMs is in a large extent based on segregative forest management approaches. Namely, forestry is much based on forestland zoning by forest functions (practices applied in the whole USSR) aimed by the Lithuanian authorities to save the (previously depleted) domestic resources due to the possibilities of timber shipments from the Russian Federation. Slightly upgraded grouping was included in Forest act in 1994, hurrying to start forest ownership restitution processes. Forest grouping principles were weakly scientifically supported. The system of protected areas and spatial planning has evolved later and sometimes overlaps with forest groups. However, majority of forestry regulations (well, definitions of FMMs in Lithuania up to some level, too) are built referring to the forest groups. Expected trends can be that forest management regimes are adjusted for each group aiming to obtain max deliveries of targeted ES at a landscape level. Another option – canceling the forest grouping at all, as today there are special conditions for land and forest use used in spatial planning and they incorporate most of restrictions which are duplicated by the forest grouping system. This would require revision of

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

	numerous acts regulating current Lithuanian forestry (and, hopefully, optimization the extent and contents of such acts). One could expect, that the assumed state forest management reform mentioned above, could potentially have larger influence on special FMMS rather than on the common ones. Seeking for more economically efficient forestry, operational approaches under less economically attractive FMMs may result some abandonment of current practices or turning to other ones (e.g. avoiding non-clear cutting and natural regeneration where they are not the most efficient ones but used much due to political will), especially in the areas currently managed by Telšiai SFE.

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

2.5. The Netherlands

Table 9 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Dutch case

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most FMMs***	Choices for a forest managers as regards regeneration (OBN, 2017): - natural or artificial regeneration - large-scale (stand-level/ shelterwood or not), in groups, or individual regeneration - with or without site preparation *Natural versus artificial regeneration* Traditionally, silvicultural systems using natural regeneration did not receive much attention in the Netherlands. However, in the 1970s, after the heavy storms in 1972 and 1973, it was not possible to immediately clear and reforest all of the affected areas, and in many of these areas a good natural regeneration took place. This proved that natural regeneration was silviculturally possible. Moreover, at that time also the subsidy scheme for replanting trees disappeared, which made artificial regeneration too costly. As a consequence, many Dutch forest owners focused on natural regeneration (Mohren and Vodde, 2006). During the last years, this has changed somewhat. With an increased attention for wood production,	Natural regeneration: more cost efficient, but not always providing the right species and good quality/quantity (not only negative for wood production, but on some soils also from an ecological point of view) (OBN, 2017) Artificial regeneration: more costly in comparison with natural regeneration. For both types of regeneration: problem of high game population	Cost of regeneration, depending on: - type of regeneration (natural or artificial) - in case of artificial regeneration: type of species, number of species planted, way of planting - site preparation or not - depreciation of land or not (in case of new forest areas) - etc.

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	species composition and the quality and volume of regeneration have become more important, which was/is not always the best in stands that were naturally regenerated. Hence, more forest owners nowadays make use of articificial regeneration. *Size of regeneration* The size of regeneration (stand, group, individual) depends, a.o., on the objectives of the forest owner (e.g. efficiency for wood production versus other functions), historical background of the forest stand (even-aged or not), species (light demanding species or not), direction towards lights, etc. (OBN, 2017) *Site preparation or not* In some cases, no site preparation takes place. In other situations site preparation takes place, varying from superficial to intensive.		
Stand management, ***Pre-commercial thinning (PCT) and thinning***	(Pre-commercial) Thinning is probably one of the most importants operations for a Dutch forest manager to guide the development of the forest (OBN, 2017). An often-used approach of thinning is a targeted selection of so-called "future trees". These are the trees of the wanted tree species that have (potentially) the best quality (this might be for wood	One of the threaths mentioned of thinning is that regular thinnings can lead to too homogeneous and too light forest stands, disturbing natural developments too much (OBN, 2017.)	

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	production, but can, in some cases, also be from a different point of view, e.g. a good tree from a biodiversity point of view or for recreation). These future trees are "set free" by thinning.		
Harvest/final felling *common FMMs*	Until the 1990's, most of the harvesting in Dutch forests was done with a chainsaw in combination with with a tractor/horse. Nowadays, most harvesting is done with machines; in many cases this is a combination of a harvester with a forwarder (boswachtersblog.nl, 2016).	Problems in harvesting encountered are, a.o.: - in general, soil damage by machines - the necessity to harvest (partly) in the (wet) autumn/winter/early spring time due to rules set up in the frame of the Flora and Fauna Act (a.o., inaccessibility, damage to the soil) - Inefficient communication during the harvesting process (leading to a.o., damage to flora and fauna, damage to roads) - harvesting-infrastructure weak	

Table 10 Drivers and barriers for implementing common versus uncommon FMMs, The Netherlands

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due	Marketing of forest products in the Netherlands relate mostly to wood/timber and recreation/tourism. In the following, we will briefly describe these two markets.

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

to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	<u>Wood/timber</u> Dutch timber is mostly used domestically (there are no specific regional markets), but supplies only a small percentage of the annual timber needs of Dutch society. The self-sufficiency rate is about 8.5%, which means that most of the timber needed is imported. Next to import to satisfy domestic demand for timber, the Netherlands import timber for export (7,7 M m^3 per year). In total, 20,3 M m^3 is imported per year to the Netherlands (Probos, 2017). As stated in the sixth Dutch National Forest Inventory (Schelhaas et al., 2014): there is an increasing imbalance between the demand for and the supply of wood coming from Dutch forests. Despite the fact that the demand for Dutch wood has increased, and harvest amounts also increased, the Inventory shows that over the last 10 years in almost half of the Dutch forests no wood has been harvested and the gap between demand and supply seems to be widening. Next to the mismatch between quantities, there is also a mismatch between types of species. While two-third of the demand for wood for industrial applications is for coniferious wood, most of the trees planted nowadays are deciduous trees. One development that might have a profound impact on Dutch forest management in the future (but is still unclear) is the market for woody biomass. The Dutch government aims at increased used of biomass (including woody biomass), but at this moment the supply is still low. Main reasons are the relatively low prices for biomass, uncertainties about the development of the biomass market, the high transport cost, the negative environmental effects (removal of dead wood from the forests), preferences of forest owners for other products. Several forest owners, however, expect to sell (more) biomass in the (nearby) future. <u>Recreation/tourism</u> In a highly urbanized society such as The Netherlands, the need for green areas in the vicinity of cities for recreation and leisure is high. Most forests (73%) in the Netherlands are open to the public. Some forests are closed for several reasons: military, hunting, or nature protection (Probos, 2017). Accessibility is rather high, 37% may be reached by car, indicating that many forests are accessible by a network of local roads (Hoogstra et al., 2013). Despite the fact that the economic value of recreation of forests is high, only part of this is a financial revenue for the forest owner. Revenue models in recreation/tourism for forest owners include campings, bare foot walks, sight seeing tours, paid parking places, etc.

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

Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	Harvesting-infrastructure weak Dutch wood market strongly internationally oriented Decreased knowledge on (traditional) forestry (including silviculture) Large number of hobby forest owners Large number of small forest owners Large diversity in motivations of forest owners
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	The relatively liberal Dutch Forest Law supports an individualistic attitude of forest owners and forest owning organizations. To realize public interests, the government prefers financial policy instruments as the main tools of public intervention (Schanz and Ottitsch, 2004), such as the Subsidy System for Nature and Landscape Management. Forest owners and provincial authorities make agreements about so-called "management types", i.e. a type of natural area, which requires a particular form of management (CBS et al., 2015). Forest owners/organizations are only subsidized if they meet the criteria required by the regulations of the specific management types, which include aspects such as accessibility for recreation, natural value (e.g. % of exotic tree species allowed, number of dead trees, and the presence of certain species), and the level of harvesting allowed (Hoogstra et al., in prep.). In order to receive subsidies in frame of the SNL scheme, forest owners/organization need to be certified following the certification rules of the SNL system. This means, a.o. that forest owners/organizations have to be able to show they have management plans for all their forests, and have a system of regular evaluation (including monitoring). In total, about 45% of the Dutch forest (168.179 ha) is FSC certified (Probos, 2017). Since 2016, it is also possible for forest owners to get certified within the PEFC system. Forest owners certified (either FSC or PEFC) have to follow the criteria set by the certifying bodies in their forest management.

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

Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	Combination of factors: - social developments (such as demographic developments (e.g. demand for recreation), forest ownership) - scientific/technological developments (e.g. new forest management models, technical innovations) - economic developments ((inter)national economics, but also forest markets (e.g. demand for biomass, timber prices)) - environmental aspects and changes (e.g. storms, climate change, drought, frost, pests, diseases) - political rules and regulations (e.g. forest management subsidies, new nature law, flora and fauna act)

LITERATURE USED:

Boswachtersblog.nl (2016). Boswachter, wat doet u nu? Bosbeheer uitgelegd: houtoogst. https://www.boswachtersblog.nl/veluwe/2016/12/09/boswachter-doet-nu-bosbeheer-uitgelegd-4-houtoogst/ Date of access: 8th of May, 2017. In Dutch.

CBS, PBL, Wageningen UR (2015). Index Natuur en Landschap (indicator 1544, versie 03, 15 juli 2015). Index Nature and Landscape. www.compendiumvoordeleefomgeving.nl Date of access: 10th of May, 2017. In Dutch.

Hoogstra-Klein, M.A., Arts, B.J.M, De Bruin, J.O. and R. de Jong (2013). Factors influencing Dutch forest management. Wageningen: Forest and Nature Conservation Policy group, Wageningen University. EU FP7 INTEGRAL D3.1-2.

Mohren, G.J.M. and F. Vodde (2006). Forests and forestry in the Netherlands. https://www.researchgate.net/publication/40110393_Forests_and_Forestry_in_the_Netherlands Date of access: 10th of May, 2017.

OBN (2017). Regulier beheer. Regular forest management. http://www.natuurkennis.nl/index.php?hoofdgroep=2&niveau=4&subgroep=115&subsubgroep=1042&subsubsubgroep=200&deel=inst Date of access: 8th of May, 2017. In Dutch.

Probos (2017). Kerngegevens Bos en Hout Nederland. http://www.bosenhoutcijfers.nl Date of access: 10th of May, 2017. In Dutch

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

Schanz, H., A. Ottitsch (2004) Netherlands: Forest policy paragon or NFP failure? http://www.google.nl/url?sa=t&rct=j&q=schanz%2Bottitsch%2Bpolicy&source=web&cd=1&cad=rja&ved=0CDEQFjAA&url=http%3A%2F%2Fportals.wi.wur.nl%2Ffiles%2Fdocs%2Fforestpolicy%2FNFP_Book_final_version_b.doc&ei=4hJMUc2GCarI0QXM7oH4Dg&usg=AFQjCNGSS0DHAFs5HtMqRIGsfQqykDoOhw&bvm=bv.44158598,d.ZWU . Date of access: 10th of May, 2017.

Schelhaas, M., Clerkx, A. P. P. M., Daamen, W. P., Oldenburger, J. F., Velema, G., Schnitger, P., ... & Kramer, H. (2014). Zesde Nederlandse bosinventarisatie: methoden en basisresultaten (No. 2545). Wageningen: Alterra Wageningen UR.

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

2.6. Portugal

Table 11 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Vale de Sousa CSA, Portugal

Operation	General (strengths possibilities)	Comments (+ weaknesses and threats)	Economy
Regeneration, ***general and most common FMMs***	The experience, equipment for preparation, and seedlings for the most common FMMs (involving either eucalypt or a mix of eucalypt and maritime pine) are available. The forest owners association (AFVS) provides guidance to forest owners.	Due to the frequency of wildfires in the CSA the natural regeneration of the maritime pine is becoming scarce in the area, forest owners choose to plant this species. On the other hand, the *Gonipterus platensis* disease constitutes a major problem for the eucalypt forest that is currently circumvented by the application of pesticides.	The regeneration costs (including preparation and plantation) average is 753€ for eucalypt (and 1317€ for maritime pine in the typical stand-level prescription.
Regeneration, *uncommon FMMs*	The experience, equipment for preparation, and seedlings for chestnut forest systems is available. The forest owners association (AFVS) provides guidance to forest owners.	Wildfires may impact the success of the regeneration.	The average regeneration costs (including preparation and plantation) is 1554.73€ for 1250 seedlings /ha in the typical stand-level prescription.
Stand management, ***Pre-commercial thinning (PCT)***	The experience and knowledge about pre-commercial thinning (PCT) in maritime pine areas in the mixed stands is available. The forest owners association (AFVS) provides guidance to forest owners. There is no need for PCT	In some pine areas the (recommended) PCT may be performed irregularly as a consequence of incipient forest management by some owners.	The costs for PCT is around 1381€ per ha, but varies depending especially on tree height. If forest owners do it when tree height is high, this increases the cost for thinning.

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and threats)	Economy
	in eucalypt areas /stands.		
Pre-commercial, ***uncommon FMMs***	Chestnut trees are typically planted at final spacing. Thus, there is no need for pre-commercial thinning.		
Stand Management, ***thinning common FMMs***	The experience and knowledge about thinning in eucalypt x maritime pine stands is available. The forest owners association (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the thinning. There is no need for thinning in eucalypt areas.	In some maritime pine areas thinning may be done irregularly as a consequence of incipient forest management by some owners.	Maritime pine timber is typically sold before harvesting and stumpage prices are a function of age. The cost is variable and depends on the size of trees. Stool thinning cost In the case of eucalypt coppice stands are around 187.85€/h.
Stand management ***uncommon FMMs***	The experience and knowledge about thinning in chestnut stands is available. The forest owners association (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the thinning.	In some chestnut areas thinning may be done irregularly as a consequence of a) the high mortality of trees in mature stands, caused by *Phytophthora cinnamomi*, responsible for the ink disease, and by *Endothia parasitica* And & And., responsible for the chestnut cancer and b) incipient forest management by forest owners.	The chestnut timber is typically sold before harvesting and stumpage prices are a function of age. The cost is variable and depends on the size of trees.
Harvest/final felling ***common FMMs***	The experience and knowledge about both final harvest and coppice harvests in mixed pine x eucalypt stands is available. The forest owners associ-	In the mixed forest, the harvests of eucalypt and maritime pine are performed independently, when the species reach the harvest age (e.g. euca-	Both pine and eucalypt timber are sold before harvesting.

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and threats)	Economy
	ation (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the harvests. The maritime pine areas are typically harvested using chain saws. A harvester is used only in the case of the eucalypt share of area that is managed by the industry. Extraction is fully mechanized (100%): skidder in areas managed by the industry and tractor with winch in the remaining areas,	lypt may be harvested thrice, during one rotation of maritime pine). Nevertheless, there is no information available on the impact of the harvests in the eucalypt areas over the growth of pine and vice versa.	
Harvest/final felling, ***uncommon FMMs***	The experience and knowledge about both final harvest of chestnut stands is available. The forest owners association (AFVS) provides guidance to forest owners. Contractors have the experience and expertise to implement the harvests. Chestnut stands are typical harvested with chainsaw. Extraction is done with tractor equipped with winch.		Chestnut timber is sold before harvesting.

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

Table 12 Drivers and barriers for implementing common versus uncommon FMMs, Vale de Sousa CSA, Portugal

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** The case study is situated in an area where supply of raw material to the forest based industry, mainly sawmills and pulp and paper industries is of primary interest. Indeed, three FMM target the supply of eucalypt pulpwood and two of them maritime pine fuelwood and sawlogs in the list of ecosystem services provided by Vale de Sousa CSA. The area further provides hardwood volume and carbon storage. At present pure eucalypt stands extend over approx. 66% of the area, as expected most ownership types in the 'Economic' class focus on the supply of wood products, thus confirming the importance of economic factors as drivers to forest management. However, the supply of hardwood (chestnut) volume and of forest services (e.g. biodiversity) is perceived and interesting by stakeholders and may increase with the success of policy or market payments for ecosystem services as well as the ZIFs (Forest Intervention Zones) eligibility to further support by forest policies. Paper companies and forest organizations that are dependent on a continuous supply of pulpwood and timber assortments provide information and advice regarding forest management to private forest owners.
	Uncommon FMMs/ remarks A considerable increase in wooded areas (forest stands) with chestnut (+48%) has been suggested by stakeholders to develop a landscape mosaic that may better address the demand of hardwood sawlogs and of other ecosystem services.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management in-	***General/common FMMs*** The Vale do Sousa Forest Owners' Association (AFVS) is the only forest owners' association in the case study area. Therefore, it is the only voice representing the forest owners (360 landowners who are members of the ZIF - Forest Intervention Zones) in the dialogue with public authorities and other stakeholders. It is, also the most important organization providing technical support to forest owners, and the only one having forest sapper brigades to carry on preventive silvicultural works for reducing the risk of forest fires. Thus , AFVS constitutes the most powerful actor, together with the paper industry , and several local sawmills. The level of self-employment among private forest owners in harvesting has dropped substantially over the last

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

tensity, the choice of FMMs, etc.	decades and the forestry owners contract entrepreneurs for thinning and final felling. The ZIF was designed to overcome the main bottlenecks to the implementation of the FMMs, namely at landscape/level management planning: property fragmentation and incipient management by some forest owners)
	Uncommon FMMs/ remarks The traditional dominance of market actors in forest management planning promotes the dominant FMM (clearcutting with eucalypt/ pine), since it is associated with a large market demand reducing the interest for other management models. Nevertheless, there is a trend for increasing diversity and providing additional forest products and services and there is knowledge and experience for the implementation of the chestnut FMM.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The Vale do Sousa Forest Owners' Association (AFVS, Associação Florestal do Vale do Sousa) is the major actor that produces forest management plans to private forest owners under the ZIFs (Zonas de Intervenção Florestal, DL 127/2005, 5 de Agosto DR 150).The ZIFs are joint management areas that must encompass at least 1,000 ha and 50 forest owners and that promote the integration of multiple owners' forest management plans to address wildfire prevention goals. ZIFs have a management board that may consist of a forest owner's association. This management board is responsible for developing the ZIFs forest management plans. Typically, the management board holds meetings with representatives from each ownership type as well as with representatives from other stakeholders e. g., other non-governmental organizations (NGOs), forest service, to engage them in the development of the forest plan. The forest owners with forest stands within the perimeter of a ZIF are compelled to follow the forest management plan after its approval by the general assembly of the ZIF and by the National Forest Authority. Forest management plans are not mandatory but required to obtain certification. The Vale de Sousa CSA extends over an area of 14,840 ha of ZIF: Entre-Douro-e-Sousa (north of the Douro river) and Paiva (south of the Douro river). The landscape-level FMM results thus from the spatial distribution of stand-level FMM agreed by the ZIF's forest owners. Management planning has to comply with silvicultural rules in the Tâmega Regional Forest Plan (PROF-T), approved in 2007 by Minister of Agriculture (www.icnf.pt/portal/florestas/profs/tamega). It specifies, for example, that in areas without a Forest Management Plan (PGF), contiguous clearcut areas should not exceed 10 ha. Typically, in the CSA, harvest areas in properties with Forest Management Plans do not exceed 50 contiguous hectares to address

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

	environmental concerns with impacts of harvests. Also, the minimum rotation period is defined in the Tâmega Regional Forest Plan (PROF-T), that prescribes eucalypt coppice cycles ranging from 9 to 14 years, in practice rotation range is slightly lower, 10 to 12 years. Besides that, there is a stipulation stating that an authorization is needed from the National Forest Authority (ICNF) for premature cuts in maritime pine in areas greater than 2 ha and in eucalypt in areas greater than 1 ha (Decree-Law No. 173/88 of 17 May).
	Uncommon FMMs/ remarks In practice the optimal stand-level rotation depends on the site index and on financial considerations, At the same time the preservation of biodiversity is prioritised by legislation as well as by local stakeholders. There are regulations about rotation length for broadleaved trees in the CSA. This complies with sylvicultural rules in the Tâmega Regional Forest Plan (PROF-T) that sets the minimum rotation of chesnut at 40 years. In addition, the legislation implies that clearcut not exceed 50 contiguous hectares to address environmental concerns with impacts of harvests.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General/common FMMs*** The combined effect of market, technical and human capacities play the largest role in maintaining the current almost total dominance of the production system with the eucalypt and maritime pine. Forest owners as well as wood-buyers/planners are uncertain regarding the performance/management and future market demand for alternative species. Reflecting the stability of current forest management practices, the level of experiential knowledge and practical know-how is much more advanced for clearcutting with eucalypt and maritime pine which favors its application in practice. The losses caused by wildfires are one of the major sources of uncertainty when projecting timber supply in the CSA. The decrease of maritime pine and the expansion of eucalypt plantations were the most significant trends in the last decades. Wildfires are a severe threat also to eucalypt plantations, which provide key raw material for the pulp and paper industry. However, eucalypt grows fast compared to other species growing in the CSA. Dominant height after 10 year are in the same magnitude as after 45-50 years for maritime pine and chestnut. Community ownership (local parish) accounts for 35% of the ZIF_Vale Soua area. Medium and large private properties (area greater than 5 ha) extend over 60% of the ZIF_VS area. The remaining 5% are owned by small or very small forest owners. The Vale do Sousa Forest Owners' Association plays an important role in those small properties. Under these tenure conditions, effective intervention to protect forests and increase its profitability is made possible through cooperation within forest owners associations and through the establishment of partnerships (e.g.

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

	ZIFs). Ownership of forests might influence forest management, environmental performance, the production of timber and other forest products and services, e.g. on the global level private forests provide more market based goods such as timber, while public lands produce proportionally more fuel wood and multiple-use goods and services. Those active and representative institutions support active management and protection of private and communal forests.
	Uncommon FMMs/ remarks The framework described above applies too to the least represented FMM. At present chestnut management model cover approx. 1 % of the area. Nevertheless, as suggested recently by stakeholders the area of mixed eucalyptus – maritime pine stands) may be converted to pure (even-aged) chestnut stands to increase the supply of hardwood saw logs and other ecosystem services. Scenario outlined above - the success of policy or market payments for ecosystem services as well as the ZIFs (Forest Intervention Zones) eligibility to further support by forest policies – may further contribute to increase the importance of this FMM.

Authors:

- Brigite Botequim, PhD. and Researcher at ISA - Instituto Superior de Agronomia (School of Agriculture)
- José G. Borges, PhD and Associate Professor at ISA - Instituto Superior de Agronomia (School of Agriculture)

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

2.7. Slovakia

The tables below briefly describe the "technological landscape" in the **CSA Podpoľanie, Slovakia**.

The FMMs in the Slovakia are mainly about timber production under consideration of the current legislation and FMPs that are mandatory. Furthermore, the management with the special focus mainly either on cultural, recreation or nature values could be described as "uncommon FMMs" (no-management, soil management, or water management FMMs).

Table 13 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Podpoľanie

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most commonFMMs***	More than 60% of the area of all FMM is established through natural regeneration. Artificial regeneration is well known, decades of experiences. All equipment and seedlings are available.	Mainly artificial regeneration should be fenced to avoid browsing damage. It should be up to 1% for full-area fencing and individual protection up to 10 % of the CSA (expert judgement). Individual tree protection is applied on 1 - 5% of the CSA, based on available data. It is only possible to use seeds from the same seed region and the same altitudinal vegetation zone (defined in a seed law Act No. 138/2010). It is not allowed to transport seeds between forest seeds regions. On the CSA, there are many seed sources which are utilised for production of seeds. Genetically improved or modified trees and also hybrids are not used due conservation of local tree species and original ecosystems.	The average cost for artificial regeneration in Slovakia is 1 878 €/ha. The number of seedlings per ha for artificial regeneration depends on tree species. The number varies from 1000 to 8000 seedlings per ha. Plantation cost of one seedling with all necessary works varies from 0.20 to 0.50 € (approx. - expert judgement). The average cost for young plantation care in Slovakia is 167 €/ha. The average cost for the protection of young forest stands in Slovakia is 152 €/ha.

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
		Artificial regeneration is at present done through outsourcing (supplying private companies or persons).	
Regeneration, *uncommon FMMs*	More than 80% of the area of all FMM is established through natural regeneration. Artificial regeneration is well known, decades of experiences. All equipment and seedlings are available. In Natural protected areas for nature conservation is 100% of the area established through natural regeneration.	Protection against browsing damage is not allowed in Natural protected areas for nature conservation. Protection against browsing on other areas is similar as with common FMMs. Artificial regeneration on extreme sites and high slopes is difficult and not always successful and needs to be repeated. Applications of chemicals (herbicides, pesticides, fertilisers, etc.) is not allowed in Natural protected areas for nature conservation and near to drinking water reservoir. It is only possible to use seeds from the same seed region and the same altitudinal vegetation zone (defined in a seed law Act No. 138/2010). Genetically improved or modified trees and also hybrids are not used due conservation of local tree species and original ecosystems. Artificial regeneration is at present done	The average cost for artificial regeneration in Slovakia is 1 878 €/ha. The cost for artificial regeneration on extreme sites and high slopes is higher than the average cost in Slovakia. The average cost for young plantation care in Slovakia is 167 €/ha. The average cost for the protection of young forest stands in Slovakia is 152 €/ha.

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
		through outsourcing (supplying private companies or persons).	
Stand management, ***Pre-commercial thinning (PCT)***	Science-based guidelines are available. The intensity and type of the thinning depend on the species composition and whether the stand was established by planting or by natural regeneration. Thinnings are usually done once per decade and are prescribed in the forest management plans (so the forest owner is obliged to carry out them). It mainly includes modification of species composition and reducing stand density.	Pre-commercial thinning are at present done through outsourcing (supplying private companies or persons) and the quality of thinning (e.g. damage to standing trees) decreased since the change of the system (from own employees to outsourcing). Due to relatively high costs and no income, pre-commercial thinning are often not carried out leading to increased stand density and reduced the static stability of the stands in the future.	Pre-commercial thinnings are costly (100 – 300 €/ha), and no income is generated in general. Costs are higher for the stands established by natural regeneration as these are much denser than the forests from planting. However, pre-commercial thinnings are considered important to increase the quality of wood and so increase the potential income from the future commercial thinning and final fellings. Timely and intensive thinnings lead to an increased volume increment and may thus reduce the rotation period necessary to reach desired assortments.
Pre-commercial, ***uncommon FMMs***	Pre-commercial thinning are either not applied at all (no-management FMM) or are done with very small intensity (soil protection and water management FMMs)	Pre-commercial thinnings are required in some soil protection FMMs to keep the forest structure diversified. However, in many cases, the pre-commercial thinnings are not done at all.	Minimum (soil protection FMM) or no (no-management FMM) costs for thinning and no income generated. Other than timber production functions are preferred and ensured.
Stand Manage-	Knowledge background on the intensity	Due to increasing frequency and intensity	Both the costs and income de-

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
ment, ***thinning common FMMs***	and timing of the commercial thinning is good and science-based. It should be done three or four times (each five years). Depending on the current forest state (stand age, site index, species composition and stand density) the thinning intensity ranges between 5% and 80% of the standing volume (merchantable volume).	of catastrophic events (windstorm and bark beetle attacks) the commercial thinnings are not carried out.	pend on many factors – site index, tree size, species composition, assortment structure. Usually, thinnings give positive results, but the older and larger-sized is the stand the higher the income can be generated. However, this is the situation when there is demand for all assortments produced by thinning. In case, all the timber cut in thinning would be sold as pulpwood or fuelwood; the net income would be smaller. On average, the costs for thinning ranges between 15 and 25 €/m3. The average income can reach 30-50 €/m3 (mainly pulpwood).
Stand management ***uncommon FMMs***	As in the case of pre-commercial thinning, commercial thinnings are done at less intensity (soil protection FMM) or no thinnings are done at all (no-management FMM). Some exceptions might apply to water management FMM.	The same holds true for commercial thinning as for pre-commercial thinning (in soil protection FMM). No thinnings are allowed in no-management FMM.	Minor costs for thinning in soil protection FMM and no costs for no-management FMM.
Harvest/final felling ***common FMMs***	Manual workers with a chainsaw in combination with skidder are predominant due to the dominance of broadleaves.	Skidding machines used in forest stands are often outdated due to the contractor's way of carrying out harvest opera-	Costs for final felling in the case of using manual workers with chainsaw ranges from 10 to 18

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	Harvesters are used for thinning where conifers are dominant, but they are not used often. The selection of the harvesting technology also depends on the terrain conditions.	tions. Because of low harvest prices, contractors are unable to buy new skidding or harvest machines. Despite the increasing rate of natural regeneration, there are relatively high costs of cultivation (protection against weeds, animals) except the close-to-nature FMM	€/m^3 and for using harvesters are relatively higher with an average of 20 €/m^3. Cost is higher when performing harvesting in areas with high slopes and extreme sites (lower tree volumes).
Harvest/final felling, ***uncommon FMMs***	Biodegradable lubricants produced from natural oils and fats are used in skidders; cable system is used in forest stands with soil protection function.	Relatively high cost of cable system technology and the use of biodegradable lubricants and lubricants. In the case of no management FMM, no final felling is allowed.	Costs for using cable system starts on 18 €/m^3 up to 30 €/m^3. It depends on skidding and pulling distance.

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

Table 14 Drivers and barriers for implementing common versus uncommon FMMs, CSA Podpoľanie Slovakia

Market What is the overall market situation and trends? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, regarding management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for round wood– spruce, pulpwood and fuelwood in Slovakia. The round wood is largely processed by the large but also many small sawmills. Although the large proportion of broadleaved forests in Slovakia in general and in the CSA particularly (including the future developments towards broadleaved species), present are rather processing capacities and also demand for coniferous round wood– mainly spruce. In contrast, processing capacities for high-quality assortments, especially in the case of broadleaves species (e.g., production of veneers) are absent in Slovakia. Often, these assortments are exported. This situation is even more pronounced in the CSA for which are typical long rotation periods, large and/or long logs among others. Broadleaved pulpwood and other industrial round wood are mainly processed by the pulp and paper industry for the production of pulp. Significantly lower volumes are utilised by the producers of particleboards. The importance and demand for fuelwood in Slovakia and particularly in the CSA grew considerably. Not only it is used for energy production by the heating plants or CHP plants, but also households increasingly use fuelwood as a source of production of heat energy. The situation in the timber processing industry is important to forestry in general and the forest owners in particular. This is mainly because the sale of timber provides approximately 80% of their revenue. Additionally, recent developments concerning the promotion of energy from renewable resources, lack of processing capacities of high-value assortments or enlarged protected areas among others, are all triggering a significant shift from the traditional utilisation of timber as a material for the production of wood products towards being a main renewable energy source. As a consequence, these trends influence wood utilisation patterns and thus the competition between material and energy production. They also influence the competition between different forest uses as the forestry in Slovakia is traditionally focused on the production of high-quality assortments. Largely, most of the FMM are thus oriented towards timber production under current legislation and rules concerning FMM and FMP. In other words, timber production is based on available resources as a result of FMP, but also by the increased proportion of salvage felling. Nevertheless, timber production follows also developments on the markets and situation in the wood processing sector, which tries to steer forestry in general and forest owners in particular towards increased management intensity.

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

	Uncommon FMMs/ remarks In the case of uncommon FMMs, the special focus is placed on supporting, regulating or cultural ES. Few FMMs (e.g., water management) also provide marginal timber output. The market for other than provisioning ES as an output of these FMMs is almost non-existing in Slovakia. An exception could be found in the CSA, which has a well-developed market for some non-provisioning ES, especially associated with game management (e.g., deer game, the harvest of trophy deer, the infrastructure of huts for hunters, protection of deer population, research on deer population biology and large beast). Delivery of supporting, regulating or cultural services is commonly associated with costs for which forest managers and especially forest owners do not have available resources— unless they are covered by the provisioning of timber or by the subsidies (e.g. via EU Rural Development policies).
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks that impact the management intensity, the choice of FMMs, etc.	***General/common FMMs*** The level of mechanisation on forest stand establishment and afforestation is currently very low, focusing mainly on soil preparation in support of natural regeneration and planting of seedlings during artificial forest regeneration. The engineering of these works significantly reduces field and soil conditions. Therefore, it is only to a limited extent. Despite the significant increase in the recent period and general preferences and support, the proportion of natural forest regeneration still does not correspond to natural conditions, which increases the need for artificial afforestation and increases costs. In the case of artificial afforestation, mainly bare-root seedlings are used, with losses after afforestation being high. Natural restoration is complicated by forest stands instabilities, early recovery after accidental fellings, failure to comply with management and recovery plans, weather extremes and harmful factors impact. The production of seedlings for artificial reforestation has been strongly concentrated in a few specialised nurseries, which has led to the maintenance of personnel professionalism and an adequate level of specific equipment and mechanisation of the most activities. However, production cycle is too long, and it does not take full advantage of the possibility of growing the planting material under controlled conditions - foil plants, greenhouses and high production substrates. Pre-commercial thinnings and commercial thinnings up to 50 years are performed exclusively moto manually. The share of harvesters in thinnings over 50 years and in final fellings is also very low, and their usability is limited also objectively

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

	due to the high proportion of the broadleaves in the stands and the high share of broken terrains with a slope of 50%. Long timber - stem technology is predominant with the production of assortments at the hauling place (forest yard) or expeditionary (central) yard. Nearly 70% of the timber extraction is performed by tractors and horses. The total length of the forest road network in Slovakia is about 37,000 km with a density of about 18.5 m/ha and dominance of non-paved roads, which is inadequate. The distribution of the roads is very uneven, especially in the higher mountainous areas roads are significantly missing. The length, structure and distribution of roads mostly adversely affect the application of logging and transportation technology. This builds on the applicability of forest regeneration practices and the use of biomass production potential for energy purposes. Significant impact on the application of logging technologies also has a high rate of accidental fellings, mainly as a result of wind calamities and other abiotic pests influence. The volume of investment into the technological equipment and road construction is insufficient. The level and knowledge and personal professionality of the whole forestry profile are reasonable and sufficient. Developed, structured and sufficiently functional is forestry specialised education and research. However, the process of innovation and the transfer of the latest knowledge and research results into practice is stagnant. The innovation cycle is too long; there is a lack of productive collaboration between research and development institutions, manufacturers and users of the results. Investments into the research, particularly from the private sector, are rare. There are no investments in forest opening-up and infrastructure development. A particular problem is the maintenance of existing forest roads, in particular as a result of reprivatisation. In the majority of forestry holdings, the level of equipment of machinery for the mechanisation of harvesting, manufacturing and transportation does not correspond to still increasing demands for the reduction of negative environmental impacts. By the majority of forest managers, the lack of financial sources is perceived as a main barrier in the innovation process. Many forestry holdings implement the realisation of forest management activities by contracts (outsourcing). Since the contracts are short-term, there is a problem for forest operation enterprises to realise renovation of technology park through a loan, leasing, etc. It has finally an impact on the quality of realised works, obsoleteness of technical equipment working in the forests and a negative effect on the environment.

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

	Uncommon FMMs/ remarks In the case of uncommon FMMs, the special focus is placed on supporting, regulating or cultural ES. Forest opening in high slopes and Natural protected areas is low in comparison to common FMMs. Well-developed is a network of hiking paths and cycle routes. In water management, FMM is necessary to use biodegradable oils in chain saws and avoid contamination of the environment by oil from machinery. Supporting of cultural ES is under development.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** Forest management planning in Slovakia is governed by the Act on Forests (Act No 326/2005 Coll. on Forests) through the state financed forest management plan. The state will obtain information about the state of the forest lands, which is updated throughout the ten years period in the whole territory of Slovakia. The forest management plan prescribes the exact framework governing the owner. The forest manager must not exceed planned felling in forest stand over 50 years of age about 15 percent, and the planned felling in the forest management plan must not be exceeded for the whole area of forest management plan creating. In the case of adjusting the level of the felling, it is necessary to make a change to the plan, which is financed by the forest owner. The law imposes an obligation to the owner to afforest the unstocked area for the age of two years. In the case of pre-commercial thinning, the emphasis is placed on the area of thinning. The forest manager enters to the planning process of forest management plan creating as an actor. Management planning is based on the particular state of forest stands and their stability while minimising the potential risk. The restoration of the forests begins with a precisely defined age set according to rotation and regeneration period determined by stand maturity, which makes provision for the maximisation of the production but also the representation of the highest quality assortments. Forest owners and wood processors do not enter directly into the planning process.
	Uncommon FMMs/ remarks Planning of management in forests with a dominant non-production forest function is carried out through a forest management plan, where the support of a specific forest function in practice is implemented through the adjustment of indicators (especially it is a reduction or complete exclusion of felling, modification of the tree species composition, support of uneven forest structure, etc.). FMM with no management is applied in nature reserves, and the owner is financially

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

	compensated by compensations. There is a 100-meter buffer zone around each of no management area, where the management is adjusted to minimise of damages in the conservation area. Compensation is not paid to the owner in practice, even though it is covered by Act No. 543/2002 Coll. On Nature and Landscape Protection. There is a high proportion of protected areas in Slovakia, and there are frequent conflicts between conservation and forestry sector, which in the case of the territory of Polana does not apply.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising remarks?	***General/common FMMs*** Slovak forestry is commercially oriented forestry aiming for high and "even-flow" timber yields. Similarly to many CEE countries, it still shared some of a socialist legacy of strong technical forestry, long rotations (based on a concept of 'production maturity' rather than 'economic maturity'), shelterwood cuts, and annual allowable cut below mean annual increment. The provision of other ecosystem services on the landscape level is achieved through spatially segregating management zonation (some parts of the forest are managed to fulfil other services than wood production primarily). The selection of management and application of FMM's is firstly guided by **policy and legislation** (eg. Act no. 326/2005 of the Coll. on Forests or Act no. 543/2002 of the Coll. on The Nature and Land Protection) incorporating the sustainability and maximal wood production paradigm, secondly by the **environment properties and forest state** assessed by forestry planning specialists and thirdly, by **wood and biomass market** situation. The provisions of regulative and cultural services are regarded as external benefits of proper wood-oriented management usually. **Policy and legislation** together with **site and forest state** play a dominant role in FMM selection. All forests are managed according to mandatory plans (elaboration financed and regulated by the state). The plan is the instrument by which the state define and regulate the allowable profit from wood for owners to secure the forest sustainability and provision of non-profitable regulative and cultural/social services. The ownership rights are highly restricted, and their application is strictly controlled. Selection of current FMMs is made by planning authority almost independent of the owner will – the site properties, current species composition and ecological stability of the forest combined with paradigms of full utilisation of site production capacity and continual existence of forest on given area almost fully predetermine the application of FMM. Changes in such settings are not expected shortly, although some initiatives of non-state forest owners exist. The forestry section within Ministry of Agriculture has a minor influence and only limited possibilities effectively affect the major political decisions in this sector. The dominant opinion of state administration is that financially profitable forestry (in

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

	comparison to problematic agriculture) need not be reformed for that setting. The distribution of political power in the current system is clearly biased toward the state administration (unfortunately frequently affected by various lobbies groups) what is considered as satisfying. The additional payments for non-provisioning ecosystem services or other dramatic changes in forestry financing schemes in such situation are almost surely excluded. The main source of financial incomes for forest owners is likely to remain the wood sales, even for more distant future, although the clear tendency for a higher proportion of incomes from biomass can be forecasted. Selection of FMM is markedly affected by **tree species composition and health and ecological status of the managed forests**. Negative impacts of climate change on Slovak forests are especially severe, and they are visible everywhere. Large-scale disturbances and a high proportion of random fellings on the total annual cut (from 50-70 %) highly impacted the wood market. Wood supply is irregular and wood quality supplied on the market is frequently worsened. Moreover, the ecological stability of many stands has been decreased, and provision of regulative and cultural services in many areas was lowered. Climate change is also reflected in changed growth abilities of main tree species. Growth deterioration of spruce at lower altitudes and outside of the natural range, regeneration of growth depressed fir and improved production of beech and spruce at higher elevations are registered across the all Slovak territory. At the same time, positive growth trends at higher elevations are dampened by negative effects of increased weather variability resulting in increased occurrence of extreme events (droughts, frost, icing, ...) Growing fears about the growing stocks raise the pressure to reduce the length of rotation periods that are likely to be reduced. The expectation of increased broadleaves proportions on species composition also exist. Although at least somewhat increased growth productivity of broadleaves and their extended distribution in Slovak forests are expected, still, the regeneration of Norway spruce stands is supported by a majority of practitioners due to its great economic importance. Therefore the spruce is preserved wherever possible, partly due to missing wood processing facilities for broadleaved assortments, despite the demands for nature-mimicking management in response to fears about the ecological stability of forests in Slovakia. Orientation to the wood production of common FMMs predetermines an important role of **trends in wood-related industries** (wood processing, furniture, construction, housing market, energy sector, local wood consumptions, ...) within their selection (and far more within their operational implementation). A significant shift from the traditional utilisation of timber as a material towards being a main renewable energy source is expected. As a consequence, these trends in-

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

	fluence wood utilisation patterns and causes the competition between different forest uses as the forestry in Slovakia is traditionally focused on the production of high-quality assortments. The pressure on forests as a source of renewable energy can enlarge the demands for management intensification in the future, that means, demands for a better utilisation of mean annual volume increment can be more pronounced. However, overall, the orientation on shelterwood natural regeneration and certified management regarding biodiversity in response to public pressure for close-to-nature management will probably prevent the intensification of forest harvests, especially until the negative effects of disturbances on ecological stability of the forest will not be diminished. The application of common FMM is relatively less affected by **infrastructure, technical and human capacity**. The infrastructure and the technical situation are relatively bad due to long-term absence of sufficient investments into financially undermined, highly regulated forestry sector. The level of equipment of machinery for the mechanisation of harvesting, manufacturing and transportation does not correspond to still increasing demands for the reduction of negative environmental impacts. By the majority of forest managers, the lack of financial sources is perceived as a main barrier in the innovation process. On the opposite side, the human capacity is high due to the historically high level of forestry specialised education and research. The forestry professionals have profound knowledge about the forest ecosystem processes, ecology and economics of forest production and they are willing for reasonable innovations. Moreover, due to legislative regulations, they fully govern the strategic forest management aside from the forest owner opinions. However, the process of innovation and the transfer of the latest knowledge and research results into practice is stagnant (low investments into the research), and the low salaries reduce the willingness of young people work in the sector that can endangered human capacity in the future.
	Uncommon FMMs/ remarks The bad ecological situation of the spruce stands outside its natural distribution, negative effects of pronounced droughts and the occurrence of large-scale wind and bark beetle disturbances in combination with improved environmental education and the increased activity of nature protection NGOs triggered fears of the public about the existence of the forest. Subsequently, changing public opinion on forestry also greatly affected the applied management approaches. Over the last 25 years, the pressure of public opinion towards the more close-to-nature management and biodiversity protection

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

	was manifested in a shift away from the clearcutting systems linked to the artificial forest regeneration to the shelter-wood management with an increased share of natural regeneration. Clear cuts were completely prohibited. At the same time, the forest owners and managers are more willing to manage its forest according to certification schemes (FSC or PEFC certification are most widespread). CCF principles are educated and promoted by PRO-SILVA initiative and are actively tested in various Slovak regions. Moreover, the CCF ideas becoming very attractive also for small forest owners whereas they enable to harvest the wood resources continually and allow to meet demands for wood assortments on markets better. Within the elaboration of FMP, some uncommon FMM (e.g., water purification, soil protection, nature conservation) are supported by management zonation (called categorization) based on the idea of multi-functional forestry which is obligatory implemented into FMP. Once again, public interests for water, environment protection or nature heritage or biodiversity take precedence over private interests without the compensation, what is secured by legislation. The application of uncommon FMM for cultural services (e.g., recreation or biodiversity promotion) stemming from the owner decision is very rare due to the restriction of financial incomes from the wood production. On the other side, as it was already mentioned, the introduction of the payments for non-marketable, common-pools, non-rivalry utilised ecosystem services from the state initiative are almost excludable because the current situation and idea of superiority of the public interests over the private ones is considered as unchangeable status quo.

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

2.8. Sweden

Table 15 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, CSA Kronoberg, Sweden

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most common FMMs***	Planting spruce and pine is a well-known and there are equipment for site preparation, seedlings available and knowledge.	Natural regeneration of pine becomes more and more uncommon due to high browsing pressure	Cost for regeneration (planting) very roughly 1500€/ha. Including site preparation, seedlings and planting. This is true for plantation of spruce approx. 2500 seedlings /ha
Regeneration, *"special" and uncommon FMMs*		Planting broadleaves are costly, sometimes need fencing	
Stand management, ***Pre-commercial thinning (PCT)***	There is a lot of experience and knowledge about Pre-commercial thinning PCT is done by manually, (brush saw). Most common is regulating tree species mixture, cutting.	Many forest owners don't perform PCT or do it when tree height is high, this increase the cost for thinning	Average cost 2500 sek (260€/ha), but varies depending on tree height
Pre-commercial, ***uncommon FMMs***		There is a lack of knowledge about stand management in broadleaved stand and in stands for nature conservation	
Stand Management, ***thinning common FMMs***	There is a lot of experience and knowledge about thinning, e.g. thinning guidelines Harvesters are almost always used.		Cost depends very much on size of trees (small trees high cost) while income (pulpwood, timber) increase with trees size. Normally all thinnings give a positive result also 1st thinning,

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Stand management ***uncommon FMMs***	There is technology about thinning that can be used in almost all kind of stands	The experience and knowledge about stand management of mixed stands and broadleaved stands are limited	Thinning is sometimes costly as there is no market for pulpwood for some species
Harvest/final felling ***common FMMs***	Harvesters are almost always used		Harvest cost is low for final felling,
Harvest/final felling, ***uncommon FMMs***	Most often harvesters and forwarders can be used, reducing the cost for felling	Harvesting technology in Sweden is developed for clearcuttings and alternatives, e.g in selective cuttings are expensive if they exist. Manual workers with chainsaw is expensive	

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

Table 16 Market and Legislation that can be drivers and barriers for development of FMMs, CSA Kronoberg, Sweden

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for pulpwood and timber of spruce and pine, and a good situation for pulpwood of many broadleaved species. Forest companies and organizations that are dependent on a continuous supply of conifer assortments provide information and advice regarding forest management to private forest owners. Reflecting the interest of these organizations, as well as an uncertainty and lack of knowledge regrading suitable alternatives among their staff, spruce and pine are consequently favored when forest owners select species in reforestation. In addition, these industrial actors steers forest owners towards increased management intensity.
	Uncommon FMMs/ remarks The market situation for broadleaves in southern Sweden is bad. There is now only one sawmill buying broadleaved timber, that is Kährs flooring industry that buy oak and ash. This reduces the interest for uncommon species and uncommon management models.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the choice of FMMs, etc.	***General/common FMMs*** The forest sector is well organized and optimized for the production of conifer timber and pulpwood through the clearcutting system. In Kronoberg County, the forest owner association Södra constitutes the most powerful actor, together with the Stora Enso affiliate Sydved, and various sawmills. The level of self-employment among private forest owners in harvesting has dropped substantially over the last decades and the forestry actors' therefore contract entrepreneurs for thinning and final felling. Large and expensive harvest machinery, sometimes coupled with the investment in the maintenance or construction of forest roads implies that the fixed cost associated with harvesting is substantial. Consequently, an "economies of scale" favor large concentrated removals (e.g. clearcutting rather than continuous cover forestry). Reflecting the stability of current forest management practices, the level of experiential knowledge and practical know-how is much more advanced for clearcutting with Scots pine and Norway spruce which favors its application in practice.

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

	Uncommon FMMs/ remarks Tradition and knowledge reduce the interest for other management models than clearcutting systems with pine and spruce. But there is a clear trend for more diversity, more nature conservation, and other species and mixed forest than spruce.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** Overall, the liberal Swedish forest policy, guided by the principle "Freedom with responsibility" gives private forest owners almost a total freedom in the selection of FMMs. Forest management plans are not mandatory but required to obtain certification. Industrial actors are the major actors that produces forest management plans to private forest owners, while the activity of the Swedish forest agency has been reduced due to budgetary cuts. The dominance of market actors in forest management planning thus promotes the dominant FMM (clearcutting with pine/spruce), since it is associated with a large market demand.
	Uncommon FMMs/ remarks The management of the areas dominated by noble broadleaves (mainly Oak, Beech) is regulated in the noble forest act. The legislation implies that reforestation with noble broadleaves is mandatory after final felling. The government can formally protect forests with high conservation value (currently approximately 2 % of the productive forestland in Kronoberg), this involves financially compensating the private forest owners for their economic losses. These areas are assigned no intervention or nature conservation oriented management depending on the conservation objective. Restrictions in the certification standards influence the distribution of FMMs at the level of the single private property. The certification standards require a minimum level of nature conservation (≥5 % of the productive forestland) and broadleaved dominated stands (≥5 % of the productive forestland on mesic/moist soils). In addition, there are restrictions regarding the use of exotic species (≤ 5 % FSC/≤ 25 % PEFC of the productive forestland).
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the	***General/common FMMs*** Lacking both prescriptive legislation and forest management planning procedures (with the exception of the few requirements in the certification standards), the combined effect of market, technical and human capacities play the largest role in maintaining the current almost total dominance of the clearcutting system with the native coni-

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

most significant role? What trends can be expected? Any important summarising remarks?	fers. Forest owners as well as wood-buyers/planners are uncertain regarding the performance/management and future market demand for alternative species. Hence, the different factors are highly interlinked, and the continuation of the current dominant practices is strongly connected to a reliance on experiential knowledge obtained, and institutionalized, through experiences in the past. When it comes to alternatives to clearcutting, higher harvesting costs and a fear of storm felling, the later explained by massive storm fellings in the near past, constitute great barriers towards implementing different continuous cover approaches. The stability of the current dominant practices despite major challenges can be exemplified by the reforestation efforts in the aftermath to the Gudrun storm in 2005. Despite a generous system of subsidies that compensated for the higher establishment cost of broadleaves, > 90 % of the reforestation area after the storm was regenerated with Norway spruce, a species that suffered disproportionally high damages. Looking into the future it is therefore most likely that future challenges will be tackled within the current dominant management approaches, rather than inducing large-scale changes to other systems (CCF) or species (broadleaves). One such trend, that is already evident, is changes induced by an increased awareness of the risk of storm felling, the development towards fewer thinning's and shorter rotation periods will therefore most likely continue. Another challenge for the future is to uphold a decent level of profitability, because the increased cost for labor has not been coupled with associated increases in the prices of timber/pulpwood. Reducing the planted seedling density and increasing the share of naturally regenerated broadleaves in conifer plantations is therefore a possible alternative for the future. This also overlaps with goals associated with risk reduction and nature conservation. Finally, the current high browsing pressure constitutes a major challenge that needs to be tackled to uphold forest management programs for Scots pine. As a final remark, it is important to consider that a massive shift to broadleaves not only is constrained by the anthropocentric factors covered here, but also by the characteristics of the ecosystem. The performance of these species generally requires fertile soils, which at least in the short and medium term constrains the possibilities for its large-scale application (because in the long run climate change might of course induce major changes). Consequently, the current dominant forest management practices will most likely prevail on the land managed for wood production also in the future.
	Uncommon FMMs/ remarks The barriers that currently constrain the use of alternative FMMs have already been covered in the previous section. But to summarize, the current production oriented forest management paradigm, combined with a long period where the forest sector has been optimized for the production of a narrow set of assortments (pulpwood and

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

	timber of the native conifers), with one dominant methods (clearcutting), altogether constitute a major obstacle for wider application of other FMMs. However, alongside the stability of the practices oriented to wood production, the importance of nature conservation in the forest sector has increased over the last decades. A development that has been induced by new policies and legislation (the forest act in 1993, environmental objectives in 1999) and market instruments (certification). Considering the policy goals related to biodiversity conservation the share of set-asides will increase in the future if current policies remain intact. In addition, the Swedish FSC standard is currently under revision, and the preliminary proposals include higher requirements regarding nature conservation. All in all, the areas left unmanaged (NO) or managed actively for nature conservation purposes (NS) will most likely increase in the future, and relative to the current low proportion, probably quite substantially. Climate change, increased demands to supply a growing bio economy, and discussions regarding risk spreading are all discourses in the forest sector that have the potential to increase the utilization of alternative species. Despite the constraints connected with the current ecosystem conditions, a possible increased use of broadleaves on fertile sites is therefore a likely development in the future. In a possible future where increased production is emphasized, a wider use of Hybrid larch could be a possible alternative, a species that not are restricted by the soil conditions to the same extent and overall shows a good performance in Kronoberg.

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

2.9. Turkey

Table 17 Strengths and opportunities of implementing FMMs, dissected by the common forest management operations, Gölcük Case Study Area

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Regeneration, ***general and most FMMs***	Both natural and artificial regeneration of pine and beech are established well and all necessary infrastructure, equipment for site preparation etc., seedlings and knowledge are available	Natural regeneration is a bit difficult in beech stands due to the difficulty to capture the appropriate seeding year and high social pressure like grazing.	Cost for regeneration (planting) very roughly 886€/ha. Including site preparation, seedlings and planting. This is true for plantation of beech and oak approx. 3500 seedlings /ha. However, cost for natural regeneration is nearly 425 €/ha.
Regeneration, ***uncommon FMMs***		Where the objective of management is nature conservation, regeneration is uncommon. Thus no well-designed method is used.	No economic return is calculated
Stand management, ***Pre-commercial thinning (PCT)***	There are technical experiences and knowledge about Pre-commercial thinning (PCT). PCT is conducted manually, (brush saw). Most common aim of PCT is to manage the density of stands (i.e., reducing density).	There are lots of stands where PCT was not applied due to managerial and operational problems. Most of the practitioners (Foresters) don't perform PCT due to insufficient workforce or budget allocated.	Average cost for PCT is (98€/ha)
Pre-commercial thinning, ***uncommon FMMs***	PCT can be a tool to control the density of fire-prone stands and increase nature values.	There is a lack of experience and partly knowledge about stand management allocated for values other than stand and in timber production	

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
Stand Management, ***thinning common FMMs***	Thinning beech and pine are very common forest operations. There is a lot of practical experience and knowledge about thinning, e.g. thinning guidelines for beech and pine. Manual chain saw is common.	The level, intensity and time interval of thinning for all commercial tree species are not quantitatively described to put them in the guidelines. Yet, some practical and qualitative description of thinning is mentioned in the guidelines. There exist conventional/poor stand management practices. Furthermore, the thinning response (post-thinning performance) is not modelled. Lack of stand density management.	The average cost per ha for thinning is 65 Euro. Normally all thinning give a positive result.
Stand management, ***uncommon FMMs***	There are technologies for thinning that can be used in almost all kind of stands.	Same problems exits. Plus, there is a lack of experience and technical knowledge about stand management for other forest values or ES. For example, the thinning level, intensity and interval are unknown for water production or mushroom production oriented stands.	Thinning cost is unknown. Foresters often hesitate to actively manage forest with e.g. nature values
Harvest/final felling ***common FMMs***	Harvesters are rarely used. However, chainsaw is commonly used in harvesting operation. Animals and tractors are used for hauling. Infrastructure as forest roads, market and more are relatively developed.	Manual harvesting is cumbersome and costly. Manual workers with chainsaw increase the cost. Occasional unavailability of workers often create problem. The maintenance of roads is poor.	Harvest cost is low for final felling, and there is a large market for saw timber, particle board (chip production) and timber. High cost for shelterwood FMM
Harvest/final felling, ***uncommon FMMs***	Harvesters are rarely used. However, chainsaw is commonly used in harvesting operation. Animals and tractors are	Harvesting other than CC is expensive. Manual workers with chainsaw increase the cost. Providing incentives to coopera-	

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

Operation	General (strengths possibilities)	Comments (+ weaknesses and treats)	Economy
	used for hauling. Infrastructure as forest roads, market and more are relatively well developed.	tives provides problems.	

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

Table 18 Drivers and barriers for implementing common versus uncommon FMMs, Gölcük Case study area.

Market What is the overall market situation and trends,? What kind of assortments (size, species) are favoured due to the existing market demand and how does that affect forest management, in terms of management intensity, the choice of FMMs, etc.?	***General/common FMMs*** There is a large market for particle board (wood chip) and timber industries for almost all species, and a good situation for furniture and veneer of oak and beech tree species. Fast developing private forest companies and organizations that are dependent on a continuous supply of wood assortments provide information and advice regarding harvesting material to state forest organizations, not much on forest management in general. In addition, these private actors have recently started to steer state forest institutions towards increased management intensity. Due to higher costs, requirement for location specific knowledge and practices and intensive management, practitioners do not favor continuous cover FMM.
	Uncommon FMMs/ remarks The particle board industry does not commonly favor or buy Oak and Chestnut. Yet, the state forest organizations put pressure on the companies to buy them too. Other companies buy oak and chestnut. This reduces the interest for uncommon species and uncommon management models.
Infrastructure, technical and human capacity To what extent are the current FMMs dependent on infrastructure, machinery and available human capacity? Any problems or bottlenecks, that impact the management intensity, the	***General/common FMMs*** The state forest institutions are well organized to carry out the forest management operations. In the meantime, Kastamonu Entegre in Gölcük area constitutes the most powerful private actor, together with the local cooperatives and various other small sawmills. The level of forest workers in harvesting has dropped substantially over the last decades and the state forest organizations therefore contract entrepreneurs for thinning and final felling. The rough topography prevents to use various harvesting machineries and increases the maintenance or construction of forest roads and limits the use of certain FMM. Due to regular management practices, the level of experiential knowledge and practical know-how, clearcutting and shelterwood are still a favorable FMM.

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

choice of FMMs, etc.	***Uncommon FMMs/ remarks*** Tradition and knowledge reduce the interest for other management models than clearcutting and shelterwood systems. But there is a clear trend for more diversity, more nature conservation, and other species and the maintenance of mixed stands than pure stands.
Forest management planning and legislation To what extent are the current FMMs dependent on forest management planning and legislation?	***General/common FMMs*** The Turkish forest policy and management guidelines do not usually give a total freedom to select and practice various FMMs. Forest management plans are primarily mandatory, yet not required to obtain certification. State forest industries are the major actors that develop and prepare forest management plans while some forest management plans are prepared by some small and relatively new private forest companies. Pine and fir are preferred by market actors in forest management planning. In fact, almost all FMMs are described how and what stand to apply in silvicultural guidelines developed in association with forest management planning guidelines.
	Uncommon FMMs/ remarks The management of the areas dominated by mainly Oak, Chestnut, Poplar and other broadleaved trees is also regulated in the silvicultural principles in the guidelines. The legislation implies that any artificial regeneration must keep the same/previous species mix after final felling regardless of FMM used. New regulations were developed to manage areas for NWFP The state formally protects forests with conservation of forest for other regulatory services. No intervention is assigned to “nature conservation areas”. No green certification is in place in the case study area.
Concluding remarks Concerning the impact on FMMs, which of the above factors (markets, etc.) play the most significant role? What trends can be expected? Any important summarising re-	***General/common FMMs*** The legislation and forest management planning and silvicultural procedures play the most significant role in maintaining the current FMMs. There is a little impact of market, technical and human capacities on the use of various FMMs in the case study area. Since the solo owner of the forest resources is state, the centralized approach towards the use of FMMs in forest management planning dominates the other approaches. For instance, “continuous cover forest FMM” has been implemented over nearly two decades in the past, yet the management authority in the state almost abandoned the FMM leaving less room for the practitioner to try and implement any FMMs. Clearcutting is only implemented in pine stands (primarily on Calabrian pine) and not implemented in other spe-

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

marks?	cies. Shelterwood FMM seem to the primary FMM implemented in most of the stands in the case study area, except some Oak stands where coppicing is exercised. No management interventions is required or implemented in conservation areas. The major driving factor is the state forest policy and regulations that almost always dominate the implementation of FMM in any state forest areas. The major challenge is to describe the appropriate FMM for a forest management unit designated or managed for ES other than timber, such as water production. Forest management areas where timber production is the leading objective, FMMs is well-established in terms of market, knowledge, technical and legislative infrastructure. Another major challenge is the rehabilitation of degraded areas (areas with trees sparsely distributed <10% crown closure). Appropriate FMM using planting is to be developed for multiple use forest management approach. Another challenge for the future is the accountability of SFM using certification process where the Turkish forestry principally accepts to go through on an incremental basis. Due mainly to state forest management, accounting for a decent level of profitability in terms of market values has been one of the important challenges in forest management planning. The increased cost for labor coupled with the increases in the prices of timber/particle board and severe competition in international forest market necessitate to uphold the economy of forest management interventions. Using appropriate stand management practices, site preparation, improved seedlings seem to be a possible alternative for the future. Finally, the discussion and the pressure between the conservation of forests and economic use constitutes a major challenge that needs to be tackled to uphold forest management planning approaches/models. As a final remark, although ecosystem based multiple use forest management approach has been accepted as a leading/dominant forest management policy and regulations, wood production will most likely prevail in forested landscape in the future.
	Uncommon FMMs/ remarks There is not any important barrier in forest management legislation to implement appropriate forest management model for ES other than timber production. Yet, lack of technical and experimental knowledge constitutes a major obstacle for wider application of other FMMs. There is a widespread use/implementation of ecosystem based multiple use forest management approach that paves the way for all forest values to account for in the preparation of forest management plans. Biodiversity and nature conservation areas are increasing, NWFPs are gradually taken into account, recreational areas are set aside. Yet, the challenge is to scientifically come up with the appropriate forest management models for the management of other ES. In addition, green certification in Turkish for-

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

	estry will probably effect the forest management practices in the future as it started in other forested areas. Modelling the risk management, economy of ES and the effects of climate change will likely be the focus of future forest management planning approach in Turkish forestry.

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

ALTERFOR

Appendix 1 FMMs Questionnaire

Part 1 background

Stand level forest management models (FMMs)

ALTERFOR WP1 Questionnaire

The objective of this survey is to provide documentation of current FMMs that are implemented in the case study (CS) areas and hence give information to the ontology of FMMs and FMMs descriptions. These are among the deliverables of ALTERFOR, to be reported on Wikipedia. The documentation of the CS-specific FMM will support the communication of FMM to other CS in a later stage when new FMMs are implemented and assessed. Furthermore, the survey addresses issues that are suitable for scientific publications. Expectedly several such publications can be produced by multi-author research teams of ALTERFOR. The questionnaire is divided into two parts. The first part aims at giving a broad overview of FMMs, followed by more detailed information for specific FMMs in the second part.

List of content:

- Part 1: Overview of FMMs in CS
- Part 2: FMM details (separate files to be filled in for each FMM)
- Annex 1: FMM definitions
- Examples of Part 1 and 2 from Lithuania (Annex 2) and Sweden (Annex 3)

Instruction

- Read through all the documents, including the definitions and examples, before starting.
- The questionnaire consists of two parts. The objective of Part 1 is to give an overview of the CS area and it´s FMMs.
- In Part 2 each specific FMM, together covering ≥90 % of the forest area, is to be described.
- Save the descriptions in separate files (one FMM = one copy of Part 2) named by the CS and FMM and list the file-names in Part 1.
- The division into FMMs should be done firstly according to the definitions of silvicultural systems in Annex 1.
- If tree species that are significantly different in biology but management are according to the same silvicultural system, these should be described as separate FMMs (e.g. species with very short (e.g. 20-40 years) and very long (e.g. >100 years) rotation periods managed by clearcutting).
- Each CS should not give detailed descriptions of more than 10 FMMs.
- More FMMs can be described briefly at the end of Part 1.

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

- In Part 2 some questions are divided in to two parts. One describing an ideal situation and one describing how things are done in the reality. The ideal situation should be according to your expertise. It should describe how the FMMs are to be implemented to deliver the target output ESs and balance between different ESs. In many cases, it can correspond to the "textbook silviculture" as promoted in your country.
- When a question refers to regulation of certain management, please indicate how this is regulated, e.g. legislation, certification schemes etc.
- Supply answers within the textboxes that follows the questions.

PART 1: Overview of FMMS

1. Briefly describe what is the historical background to the current forest management orientation and dominant FMMs in your country. Consider such general aspects as societal developments, main ideas around forest management, and forest policy development. In what context (main stakeholders, ownership structure, governance model) is current FMMs applied in your country? (Max 1 page)

Answer:

2. What is the tree species distribution in the case study area (+ region, country). List the species by decreasing proportion.

Species (Latin name)	CSA	Region/province	Country

Comments: [1]

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

3. According to the best available knowledge and your expert judgment, indicate how are the edaphic conditions (site productivity, soil moisture) are distributed within the case study area. Provide the percentage of the forestland that belongs to each unique combination in the grid, the sum should be 100 %. Please also indicate what high, medium and low site productivity corresponds to (in m^3 ha^{-1} yr^{-1}) in the case study area.

Productivity/soil moisture	Dry	Mesic	Moist	Wet
High				
Medium				
Low				

Comments:

4. Describe the most dominant FMMs in the case study area (together covering ≥90 % of the forest area) in the table below. Indicate, according to the best available knowledge and your expert judgment, how large area of the CS and the country the FMM covers, and in which file the detailed description is to be found.

   The division into FMMs should be done firstly according to the definitions of silvicultural systems in Annex 1. If tree species that are majorly different in biology and management are managed by the same silvicultural system, these should be described as separate FMMs (e.g. species with very short (e.g. 20-40 years) and very long (e.g. >100 years) rotation periods managed by clearcutting). In case of smaller but still significant difference, they can be expediently described in comments under relevant questions. Each CS should not, however, describe more than 10 FMMs.

Domestic name in English	Corresponding FMM (appendix 1)	Coverage CSA (% forestland)	Coverage country (% forestland)	File name

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

Comments:

5. If there is a substantial difference between the case study and the entire country regarding the coverage of FMMs? What is the major reason(s) behind this divergence?

Answer:

6. Which additional minor FMMs exists within the case study areas? Provide a short description of these FMMs (max 400 words per FMM)

Answer:

7. Describe main preconditions for managing forests (such as forest cover, ownerships structure and protected areas in forests), compare between CSA and the whole country, region. Indicate any feature that you consider to be of high importance.

	CSA	Region/province	Country
Total area (ha)			
Forestland (ha)			
Forestland cover (%)			
Productive forestland (ha)			
Productive forestland cover (%)			
Average volume (m^3ha^{-1})[2]			
Site productivity ($m^3ha^{-1}year^{-1}$)[2]			
MAI 2011-2015 ($m^3ha^{-1}year^{-1}$)[2]			
Ownership forestland (%) Companies Private			

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

Stand level forest management models (FMMs)

ALTERFOR WP1 Questionnaire

PART 2: FMM details

Stand level forest management model (one file per FMM)

General questions

1. What's the name of the FMM in the local language and English translation?

   Local language:

   English:

2. According to your expert judgment, how large share (%) of the forest area in the CS **should** be covered by this FMM? Please motivate your answer.

   Answer:

3. How large share (%) of the forest area in the CS **is** actually covered by this FMM?

   Answer:

4. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

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

Answer:

5. Which is the target ecosystem service(s) of the FMM within the case study area (including wood)? If more than one, please rank them by decreasing importance (most important first).

Answer:

6. Which of the following management systems (see definitions in Annex 1) does the FMM resemble most?
   A. Clear cutting systems
   B. Uniform shelterwood systems
   C. Non-uniform shelterwood systems
   D. Selection systems
   E. Coppice systems
   F. No intervention

Answer:

7. How does the FMM differ in practice from the definition of the management system you have chosen?

Answer:

8. Which main tree species are managed by this FMM within the CSA? List the scientific names by decreasing importance (share of standing volume within FMM).

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

Answer:

Size of stand or management unit

9. Is the size of area harvested at one time-point (e.g. clearcut area or area with shelterwood) regulated? No/Yes, in what way?

Answer:

10. What is the size (ha) of individual harvested areas at one time-point in the CSA?

Minimum:

Maximum:

Mean:

11. What is the normal size (m^2) of gaps (only system 3)? Answer with an area interval. Explain the reasons behind the interval of area.

Answer:

Rotation period

12. Is the rotation period (systems 1-3, 5)/target tree age (system 4) regulated?

Yes/No:

Comments:

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

13. According to your expert judgement, which is the **optimal** rotation period (systems 1-3, 5)/target tree age (system 4) of this FMM in relation to the output of ES? Answer with an interval of years. Explain the reasons behind the interval of years.

Answer:

14. What is in **practice** the rotation period (systems 1-3, 5)/target tree age (system 4) of this FMM? Answer with an interval of years. Explain the reasons behind the interval of years.

Answer:

15. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

16. Are standards (overwood, large trees) used (only system 5)? If yes, how many per ha?

Answer:

Distribution over edaphic conditions

17. According to your expert judgement, under which edaphic conditions **should** this FMM be applied (tick as many boxes as needed)?

Productivity/soil moisture	Dry	Mesic	Moist	Wet
High				
Medium				
Low				

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

18. Under which edaphic conditions **is** this FMM applied in practice (tick as many boxes as needed)?

Productivity/soil moisture	Dry	Mesic	Moist	Wet
High				
Medium				
Low				

19. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

Tree species composition

20. According to your expert judgement, how dominant **should** the most abundant tree species be (pole stage and larger)? Indicate how large share of the standing volume on the stand level that should be allocated to the most abundant species and if this varies within the FMM (e.g. only monoculture 95+ = 100%)

Share of the most abundant tree species on stand level	Share of area within FMM and CSA
% of standing volume	% of FMM area
95+	
75-94	
50-74	
25-49	
0-24	
Sum	100

Comments:

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

21. How large a share of the standing volume on the stand level **is** allocated to the most abundant tree species (pole stage and larger)?

Share of the most common tree species on stand level	Share of area within FMM and CSA
% of standing volume	% of FMM area
95+	
75-94	
50-74	
25-49	
0-24	
Sum	100

Comments:

22. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

23. According to your expert judgement, in this FMM, which tree species should be used and how **should** the standing volume on the stand level be distributed under the (pole stage and larger) conditions that are most typical for the CSA?

Answer:

24. Which tree species **is** used and how **is** the standing volume on the stand level distributed under the (pole stage and larger) conditions that are most typical for the CSA?

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

Answer:

25. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

Forest regeneration

26. According to your expert judgement, how large share (%) of the trees reaching the pole stage **should** be established through natural regeneration?

Answer:

27. How large share (%) of the trees reaching the pole stage **is** established through natural regeneration?

Answer:

28. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

29. According to your expert judgement, to what extent **should** soil scarification be done to facilitate regeneration? I.e. how large share (%) of the area should be scarified?

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

Answer:

30. To what extent **is** soil scarification done in practice? I.e. how large share (%) of the area is scarified?

Answer:

31. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

32. According to your expert judgement, how large share (%) of the area under regeneration **should** be fenced to prevent browsing by game?

Answer:

33. How large share (%) of the area under regeneration **is** in practice fenced to prevent browsing by game?

Answer:

34. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

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

Answer:

35. To what extent are tree species non-native to Europe used?

Percent of the seedlings:

If not at all, what is the reason for this:

36. To what extent are European tree species non-native to the CS country used?

Percent of the seedlings:

If not at all, what is the reason for this:

37. To what extent are non-local seed sources used (more than 100 km distance)?

Percent of the seedlings:

If not at all, what is the reason for this:

If seeds are moved, what is the reason for this:

38. To what extent are **genetically improved** trees used?

Percent of the seedlings:

If not at all, what is the reason for this:

39. To what extent are **genetically modified** trees used?

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

Percent of the seedlings:

If not at all, what is the reason for this:

40. To what extent are **hybrid** trees used?

Percent of the seedlings:

If not at all, what is the reason for this:

41. Are herbicides and/or pesticides) applied at any stage of management? If yes, by which cause? This question does not apply to use in nurseries and timber yards. Seedlings treated at nurseries to protect against pests in the forest should be included.

Yes, which:

No, why not:

42. Are fertilizers applied at any stage of management? This question does not apply to use in nurseries. If not at all, what is the reason for this? If yes, in which type of forests (species, age) and to what extent (as a share of CSA forests)?

Yes/No:

Comment:

Stand management

43. According to your expert judgement, to what extent **should** pre-commercial thinnings be done? How large share (%) of the area where this FMM is applied should be pre-commercially thinned at least once during a rotation period?

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

Answer:

44. To what extent **are** pre-commercial thinnings done in practice? How large share (%) of the area where this FMM is applied is pre-commercially thinned at least once during a rotation period?

Answer:

45. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

46. According to your expert judgement, to what extent **should** commercial thinnings be done? How large share (%) of the area where this FMM is applied should be thinned at least once during a rotation period?

Answer:

47. To what extent **are** commercial thinnings done in practice? How large share (%) of the area where this FMM is applied is thinned at least once during a rotation period?

Answer:

48. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

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

Answer:

49. According to your expert judgement, to what extent **should** pruning or other similar tending of trees be done? How large share (%) of the area where this FMM is applied should be treated at least once during a rotation period?

Answer:

50. To what extent **is** pruning or other similar tending of trees done? How large share (%) of the area where this FMM is applied is treated at least once during a rotation period?

Answer:

51. If there is a difference in the answers to the two preceding questions. What is the reason(s) behind this divergence?

Answer:

Harvesting

52. How large share (%) of the wood harvest is fully mechanized (harvester)?

Answer:

53. How large share (%) of the wood extraction is fully mechanized (forwarder or skidder)?

Answer:

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

54. How large share (%) of the logging residues (branches >5cm) is extracted?

Answer:

55. Is nature protection integrated in the stand-level management? If yes, how? If no, why not?

Answer:

The primary sources

56. What have been the primary sources in answering the questionnaire? Including both the team of the participating or consulted experts and primary written sources for describing both the ideal and the actual forest management.

Answer:

FMM summary

57. Short summary summarizing key features of the FMM

Answer:

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