ALTERFOR

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I. Forest Management Models (FMMs) description

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8. Slovakia

8.1. Background and forest history

The history of intentional forest management in Slovakia is very long and extends to 15th century. During the Hungarian Kingdom and Austro-Hungarian Empire very intensive mining activity, over-harvesting, strong agriculture and pasture pressure caused a severe deficiency of wood on Slovak territory.

Due to this, several kings and emperors declared several regulations related to forest protection and utilization. The forest management according to forest management programs (FMPs) for imperial forests was established already at the end of 19th century, mainly due to the existence of Mining and Forestry Academy in Banska Stiavnica which is considered as a first technical university in the Europe.

During the first Czechoslovak republic, the duty to manage the forest was obligatory introduced for all forest owners above 50 hectares. Such important intervention to owner´s rights was mainly motivated by bad state of private forests and emerging concerns about wood availability in the country. The concerns arose from the unregulated utilization of forest sources and increasing demands on wood at international markets and uncontrollable wood trading. The measure lead to more effective forest management, enlargement of forest areas (28 % in 1929 compared to 41 % in 2015, Bavlšík et al. 2010, Green report of Ministry of Agriculture and Rural Development of Slovak republic 2015), steady improvements in health status and quality of forests and steady increase of available stock volumes (171 m3ha-1 in 1970 to 246 m3ha-1 in 2014, Green report of Ministry of Agriculture and Rural Development of Slovak republic 2015).

After 1945, the Czech and Slovak forest management was completely changed in line with the complete change of political system resulting to transition from a market economy based on private ownership to centrally planned socialist economy based on nationalization of all private estates. The management style, ideological paradigms, and applied approaches were very similar to Lithuania.

Key features of forest management in socialist era

• No private owners – all forests were owned by the state and were managed by State Forest Enter-prise.

• Planned economy and strict top-down management hierarchy- economic targets for forestry were prescribed by the national planning committee in 5-year cycles and subsequently, forest planning specialists transferred the national targets into forest management plans. The normal age class forest concept was considered as ideal for planned economy. The general economic goal based on normal forest idea was maximized and even-flow production of high-quality timber (furniture, veneer, sports equipment, sawlogs, pulpwood etc). Especially even-flow target was

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important and age class distribution was regulated for each forest management unit (4000-6000 ha) to approach even normal state guaranteeing the evenness of wood harvests. Prevailing silvicultural system was strip or gap clear-cutting system with subsequent artificial regeneration of forest stand by site suitable species compositions. Natural deciduous species compositions were very often “enriched” by more economic profitable conifer tree species.

• Strictly regulated operational management at stand level - forest management plans strictly prescribed and controlled silvicultural actions and cutting rules and volumes at stand level. Main forestry paradigm at stand level was idea that environmental conditions, site fertility, current species composition and ecological stability predefine possible actions and economic outputs independent of individual human opinion. The needs of human society were completely prioritized. Based on various environmental surveys, the full utilization of site given potential to produce the wood and other benefits (ecosystem services) strived from forester´s point of view, once again independent of individual needs of any particular person. As the main tool for wood production and quality maximization, sufficiently long rotation periods were used.

• The fulfillment of other ecosystem services except for the wood production (especially these ones that were important for society) were assured through forestland spatial zoning according to the preferred forest functions/ecosystem services. The concept was named functionally-integrative forest management, but the integration of fulfillment of different ecosystem services was achieved at forest management unit level through spatially segregating management.

Forestry in Slovakia after 1990

Although the economic environment was completely changed after 1990, the management of forests through forest management plans, FMP (that elaboration is financed by state) remains an obligatory duty of each forest owner subject. Also, main paradigms at stand levels (environment and state of forests prescribe possible actions) and at ownership unit level (forestland zoning) remain intact. FMP are considered as a main political tool of the state for regulation and control of forest management in order to assure the correct fulfillments of requirements of society. At the same time, the FMP through strict rotation ages states the cutting limits preventing to overharvesting of forest estates (limits determined according to old forestry paradigms).

Three categories/management zones of forests were distinguished according to prevailing ecosystem services: commercial, protection, and special-purpose forests. The protection forests oriented to regulative ecosystem services (water, air, nutrient, natural hazards regulation) and environment protection are given by site and environment properties and are determined by planning authority. Similarly, some special-purpose forests are stated independent to owner opinion, especially if their management orientation is stated by some other acts (e.g. military forests, forests for the protection of water reservoirs, forests for nature conservation etc.). All other forests where regulative or social services are not at risks are primarily considered as commercial unless the owner changes their orientation for some preferred cultural service (eg. recreation, hunting ...).

Thus the FMP sets the amount of allowable cuts and profits to forest owners through three mechanisms: forestland zoning, thinning volume determination and prescription of rotation and regeneration period length. Moreover, sustainability of forest is assured by obligatory duty to

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restore the forest stand on cleared areas up to 2 years by Act on Forests. On the other hand, the many regulations and prescribed actions in FMP had lost their obligatory nature i.e. now they are more recommendations than prescriptions.

Although production-oriented paradigm still prevails in contemporary forest management in Slovakia, the important trend of so-called ecologization of forestry has emerged. Whereas the wood and biomass is the primary source of financial benefits for forest owners, today forest management still primarily oriented to sustainable environmentally admissible economic yield based on timber wood production, but the need to fulfil a broader, more balanced variety of ecosystem services already at stand level has been emphasized in recent years. This trend is clearly related to growing demands of broader public and environmental agencies on forest biodiversity and ecological stability in changing climate.

As a consequence, due to some incompatibilities of Act on Forests and Act on Protection of Nature and Landscape and due to different views on forests from environmental professionals and activists' frequent conflicts and disputes arising about FM. Increased public opinion pressure leads to accepting the certification of forests from many owners in Slovakia. Moreover, milder (mostly shelterwood) silviculture systems linked to natural regeneration of stands are applied as standard (the clearcuts almost excluded from planning and practice). Also, close-to-nature approaches based on selection systems are tested now.

8.1.1. Ownership

After 1990, the restoration of private ownership and transition to market economy and parliament democracy profoundly changed the Slovak forestry paradigms and legislation and affected the Slovak forestry practice. Now, half of the forests are owned by the state and another half belongs to different private or communal owners (municipal, communal, church, cooperative, private, etc.) orientation for some preferred cultural service (e.g. recreation, hunting, etc.).

The ownership structure in Slovakia showed some regional differences, but state and non-state ownership is almost fully balanced. The state owns app. 54 % of forests, non-stated subjects 46 %. Within non-state owners, the communal entities dominate (app. 29 %) followed by municipal (10 %) and private owners (8 %).

As it was already mentioned, the forests are managed irrespective the ownership category by the same forestry legislation demanding the management under state-financed FMP elaborated by authorized planning specialists according to the exact rules following the traditional forests paradigms. Therefore, all owners subjects managed their forests by much unified way – even-aged long-rotation non-uniform shelterwood systems associated with natural regeneration are preferred. At the same time, the realization of pre-commercial thinnings, the volume of commercial thinnings and final cuttings are strictly controlled. The economic profits are environmentally predetermined. Generally, forest management is still primarily oriented to sustainable environmentally admissible economic yield based on timber and biomass production, but nature conservation and biodiversity promotion are taken into account to a greater extent than in the past.

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8.2. Case study area

8.2.1. General about the CSA

The case study area corresponds very well to the average country situation in terms of forest production and environmental/natural conditions (6 out 8th forest vegetation zones occurring at the western Carpathians are covered), but substantial differences exist in ownership structure, species composition and also partly in shares of forest management categories. The relatively favourable terrain and site conditions and long-term human utilization of landscape located relatively close to mining cities contributed to the preference of commercial forests dominated by spruce (especially at pre-mountain and low-altitude locations). At the same time, the forests more distant from human settlements at higher altitudes have a very well preserved species compositions and high bio-diversity that make them an interesting from nature conservation point of view. The ownership structure is a markedly biased toward state ownership, probably due to historical development, when the forests in CSA were an estate of kings or several noble families during the Austro-Hungarian empire for hunting purposes and were nationalized after 1948.

Table 35. General information about forestry in Slovakia and the Slovakian CSA.

	CSA	Slovakia
Total area (ha)	151 768	4 903 397
Forest land area (ha)	94 855	2 014 259
Forestland cover (%)	62.5	41.1
Average volume ($m3ha^{-1}$)	249	246
Site productivity 2014 ($m3ha^{-1}year^{-1}$)	6.5	6.33
MAI 2014 ($m^3ha\text{-}1year^{-1}$)	3.77	3.72

8.2.2. Ownership, Slovakia and CSA

Table 36. Ownership of forest land in Slovakia and in the Slovakia CSA.

Ownership	CSA, %	Slovakia, %
State	75	40
Communal	18	20.9
Church	0	2.6
Municipal	0.2	8.7
Cooperative	0	0.3
Private	6.8	10.6
Unknown	0	10.6
Protected areas %	1.6	2.5 (57%)[1]

[1]*the number in parenthesis represent the ratio of the forest area restricted in some way by nature protection*

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Table 37. Forest management categories in Slovakia and in the Slovakian CSA.

Forest management categories	CSA	Slovakia
Commercial forest %	82	71.
Protection forests %	9.6	17.2
Special purpose forests %	8.4	11.2

8.2.3. Tree species in Slovakia and CSA

In Slovakia beech is the most common specie, about 1/3 of the standing volume and spruce the second most important. These two species dominate forest in Slovakia and in the CSA, other species have all less than 10% of the standing volume in the CSA. In the CSA, spruce is the most common, 41% and beech the second most common, 27%.

Table 38. Tree species distribution in Slovakia and in Slovakian CSA (proportion (%) of total volume).

Slovakia	CSA	Region	Country
Species (Latin name)	Proportion (% total volume)	Proportion (% total volume)	Proportion (% total volume)
Picea abies	40.57	20.02	23.73
Fagus sylvatica	27.21	32.11	32.99
Quercus spp.	8.68	19.67	13.16
Carpinus betulus	5.85	9.38	5.86
Acer spp.	3.89	3.05	2.37
Fraxinus excelsior	2.96	1.58	1.59
Abies alba	2.17	3.63	4.02
Larix decidua	1.94	1.41	2.49
Pinus sylvestris	1.67	2.76	6.81
Robinia pseudoacacia	0.74	3.02	1.73
Tilia cordata	0.28	0.44	0.41
Ulmus glabra	0.03	0.03	0.03
Other broadleaves	4.0	2.30	3.70

8.2.4. Growing conditions in the Slovakian CSA

Table 39. Production potential for different tree species and site index.

Species	CAI for growing stock at age 100 years		
	Site index under 24	24-30	over 30
Picea abies	<4,5	4.7-5.5	5.7-6.9

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Abies alba	<4,9	5.1-5.8	6.1-7.0
Fagus sylvatica	<3,9	4.0-4.6	4.8-5.4
Quercus	<2,5	2.6-2.9	3.0-3.2
Pinus sylvestris	<3,0	3.2-3.8	4.0-4.2

Table 40. Production potential for different tree species MAI.

	CAI for total volume production at age 100 years		
Species	under 24	24-30	over 30
Picea abies	<7.7	8.3-10.2	10.7-13.8
Abies alba	<8.6	9.1-11.1	11.8-14.4
Fagus sylvatica	<7.3	7.6-8.9	9.3-10.6
Quercus	<5.2	5.5-6.0	6.2-6.7
Pinus sylvestris	<5.6	6.0-7.3	7.5-8.1

8.3. General about FMMs in Slovakia

In Slovakia Non-uniform shelterwood systems dominated forestry. Clearfelling systems are not used at all. A small proportion is managed with selection systems. There are also some forests with no management/intervention.

Table 41. Summary of FMMs in the Slovakian CSA, corresponding silviculture system, Coverage, % in CSA and Slovakia.

Domestic name in English	Corresponding silviculture system	Coverage CSA, (% forestland)	Coverage Slovakia (% forestland)
1 Mixed beech-oak	Non-uniform shelterwood system	4 %	10 %
2 Mixed oak-beech stands oriented to timber and biomass production	Non-uniform shelterwood system	6 %	17 %
3 Beech stands oriented to high-quality timber production	Non-uniform shelterwood system	4 %	15 %
4 Mixed fir-beech stands oriented to timber and biomass production	Non-uniform shelterwood system	1 %	15 %
5 Mixed spruce-fir-beech stands oriented to timber and biomass production	Non-uniform shelterwood system	1 %	7 %
6 Close-to-nature management in spruce-fir-beech stands oriented to continuous wood and timber production	Selection system	1 %	5 %
7 Spruce dominated stands oriented to timber production	Non-uniform shelterwood system	65 %	23.5 %
8 Specialized management for soil protection	No intervention and/or selection system	9.6 %	13.5 %

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Domestic name in English	Corresponding silviculture system	Coverage CSA, (% forestland)	Coverage Slovakia (% forestland)
9 Nature conservation management without intervention	No intervention	1.6 %	2.5 %
10 Specialized management for water purification	Non-uniform shelterwood system/selection system	6.8 %	1 %

There is a difference in use of FMM between the country and the CSA. The largest difference is the use of spruce. Management of spruce dominated stands oriented to timber production "Non-uniform shelterwood system with spruce", in the case study area this FMM is used on 65% of the forest land and 23 % in entire Slovakia. The main reason for this substantial difference in use of FMM between Slovakia and the CSA is a changed current species compositions in favour of spruce. Many stands on the CSA are spruce dominated. The changes occurred across the different sites, forest vegetation zones and altitudes. Artificial regeneration of spruce and its silviculture promotion (frequently out-side the natural distribution area) enlarged the share of spruce well above the natural level. The main reason is high-volume productivity, better economic profitability and simpler silviculture (lower stem and crown form variability) in comparison to broadleaved trees. In the past, the spruce showed also considerable vitality and regeneration ability on various sites, even outside its natural range, but now the spruce is under strong pressure of the changing climate and natural hazards (drought, windstorms, bark beetle, fungi infestation, browsing).

8.4. Other FMMs in Slovakia

In Slovakia minor additional FMMs are applied for stands with considerable changed tree species compositions, for example, black locust or hornbeam monocultures. Here, non-uniform shelter-wood systems linked to shorter rotation ages (70-90 years) are applied reflecting the faster growth of species, and effort to convert the site-not-suitable and low-profitable (frequently coppice) forests.

Also, selection, permanently uneven-aged forests and other forms of CCF have an application potential, but their actual utilization is a very marginal.

Comments: The information about areas of individual categories and subcategories (management classification into commercial, regulative and socio-cultural forests) were combined with information about areas of forest vegetation zones (environmental /site classifications) in Slovakia in order to estimate the share of potential FMM application at the country level. Source: National Forest Centre, www.forestportal.sk + Green report 2015, Ministry of Agriculture and Rural Development.

8.5. FMMs in Slovakian CSA

8.5.1. Overview

Most of the forest management is classified as non-uniform shelterwood systems. Four (no 1 - 4) are used are used with broadleaves such as oak, beech and two FMMs are used in spruce dominated stands (no 5 and 7). Selection systems are used on small areas with spruce-fir-beech. As

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spruce is the most common tree species in the CSA the most common FMM is non-uniform shelterwood with spruce (FMM 7) that is used on 65% -70% of the area. On 18% of the area managed is focused on soil protection, nature conservation or water shed management. Then no invention is combined with selection cuttings or non-uniform shelterwoods, see Table 41 above.

8.5.2. Common for all models

Origin of trees and seed sources

There is no non-European tree species used, only local species. Approx. 1% of the seedlings are not local, from sources more than 100km distance. For the species *Picea abies, Abies alba, Fagus sylvatica* and *Quercus petraea* there are the forest seeds regions defined in a seed law (Act No. 138/2010) and it is not allowed to transport seeds between forest seeds regions. It is only possible to use seeds from the same seed region and the same altitudinal vegetation zone.

Genetically improved and genetically modified and use of hybrids

No genetically improved or modified seedlings are used. There is priority to conserve the local tree species and original ecosystems.

Herbicides/Pesticides and fertilizers

There are pesticides applied on a small scale usually for application on trap trees (individual trees used to attract bark beetles).

There is no need and use of fertilizer.

8.6. Non-uniform shelterwood systems with broadleaves (FMM no:1-5)

Non shelterwood systems with broadleaves are used in 5 FMMs. Tree species and the vegetation zone are important in choice of FMM, Table 43. FMM1-5 together cover 15% of the area of the CSA at present but it is recommended to increase this area to 63,8% by increasing the amount of broadleaves and reduce the amount of Norway spruce. The main tree species in these FMMs are oak (*Q. petreae*) and beech (*F.sylvatic*a).

The five FMMs (1-5) used differs mainly in the conditions where it is used. They are used in beech-fir vegetation zone 2 to 5 respectively. The important difference between the zones is height above sea level, Table 42.

Table 42. Forest management models (FMMs) for broadleaves, some characteristics and ES

FMM	Proportion of CSA, present and recommended	Where, edaphic conditions	Species
1 mixed oak-beech stands wood and biomass production	4% today Recommended 16%	Mesotrophic, lower-to-average quality sites, relatively warmer 2nd beech-oak vegetation zone, sufficiently supplied by water, pre-mountain or low-mountain locations on regular slopes, (200-550 m a.s.l.)	*Quercus petraea Fagus sylvatica Carpinus betulus Acer platanoides Tilia cordata*
2 mixed oak-beech	6%	Mesotrophic, lower-to-average quality	*Quercus petraea*

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FMM	Proportion of CSA, present and recommended	Where, edaphic conditions	Species
timber production	recommended 18.6%	sites, 3rd beech-oak vegetation zone, drier or heavy moisture soils, lower-mountain locations not extreme slopes, (250-700 m a.s.l.)	*Fagus sylvatica* *Acer platanoides* *Tilia cordata*
3 beech dominated stands (oriented to high-quality timber provision)	4% Recommended 29.2%	Mesotrophic, average and good quality sites , 4th beech vegetation zone, soils with normal or slightly above normal water content, mid-mountain locations on regular slopes, (300 - 800 a.s.l.)	*Fagus sylvatica* *Abies alba* *Acer presudoplatanus* *Acer platanoides* *Tilia coradata*
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	1% Recommended 16.4%	Mesotrophic, medium and high quality sites , 5th fir-beech vegetation zone, soils with optimal water content medium-mountain locations, (650-1150 m a.s.l.)	*Fagus sylvatica* *Abies alba* *Acer pseudoplatanus Ulmus glabra Fraxinus excelsior*
5 non uniform shelter wood system in shade – tolerant spruce fir-beech mixed stands	1% recommended 7%	Mesotrophic average-to-higher quality sites in cool 6th spruce-fir-beech vegetation zone on mesic or moisture, water well supplied deeper soils in mid- and higher mountain locations, (850-1200 m a.s.l.)	*Fagus sylvatica, Abies alba, Picea abies, acer pseudoplatanus Ulmus glabra*

The four shelterwood systems used with broadleaves are recommended to be used on much larger areas than present use, an increase from 15 % to 80%, Table 42. The majority of forest stands potentially managed by these FMMs were under negative human pressure for several millennia. The massive harvests, cattle grazing, litter extraction, destruction by fire, conversion of forest to pasture and arable land were present. Today these areas are dominated by spruce, and managed with a shelterwood model described below.

The severe species composition changes in existing stands are clearly evident. Today, original beech-oak species composition exists only at 25 % of the area. Four characteristic deviations from original species composition exist: On better sites, approx. 15 % of the area dominated by beech, 50-60 % and common hornbeam; 30-40%. The largest areas, about 50 %, is transformed to stands dominated by coniferous. Of this 70 % are Norway spruce, Scots pine and European larch and 30 % beech and hornbeam. Common hornbeam 70-75 %, oak (20-25 %) and beech, 0-5 % is growing on not so fertile sites and on the sites with lowest average, about 7 % of the area, black locust and hornbeam are dominating.

The stand structure was changed mostly by incorrect management (shortened rotation length), some areas were converted into coppices in the past and then re-converted to the normal high for-est. Oakwood and biomass were extensively used by local human population for a wide array of needs: from building construction, furniture, heating, mining, charcoal and transformed to agriculture utilization. Many species compositions were “enriched” by coniferous species to improve wood volume production (“economic admixture”), some stands were converted into

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spruce monocultures. In relation to climate change, non-native Black locust (*Robinia pseudoacacia*) is aggressively spreading over the lowest altitudes from Pannonia.

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Ecosystem services

The ecosystem services provided by FMM 1-5 are described in Table 43.

Table 43. Ecosystem services for FMM 1-5, ranking by forest managers.

FMMs for broadleaves in the Slovakian CSA	ES, ranking/priority by forest manager
1 mixed oak-beech stands wood and biomass production	wood production, hunting and game management, landscape protection, recreation, soil erosion control
2 mixed oak-beech timber production	wood and timber production, game management and hunting, landscape protection and planning, recreation, soil erosion control
3 beech dominated stands (oriented to high-quality timber provision)	wood provision, soil erosion control, landscape protection, recreation, tourism
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	wood production, water regulation, soil protection, landscape protection, recreation, biodiversity
5 non-uniform shelter system in shade –tolerant spruce fir-beech mixed stands	wood production, water regulation, soil protection, landscape protection, recreation, biodiversity

Size of stand and management units

In general, the size of harvested area at one time isn`t regulated. The harvested area is indirectly regulated through the volume of allowable cut, fixed to working plan area then, the cutting is recalculated on each management unit (e.g. forest stand). The average harvested area is 1.5 ha, with a minimum of 0,5ha or for sub-compartments 0,3ha, and a maximum of 3ha. Cutting is typical done in strips with a width of strips and distance between them maximum two tree heights. In a large-scale forestry in parts of the CSA the largest harvest area is 5 ha, or in some cases 7,5ha if a complete area of compartments is regenerated. This is done with shelterwood systems and rarely with clearcutting systems.

In these four systems, the size of gaps are maximum 2000m^2 or 0,2 ha.

Rotation period

Rotation age in Slovakia is used to limit annual cuts in the forest. It is a tool for the state to ensure sustainable and balanced annual allowable cuts in the long-term perspective. It was defined based

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on the rotation age of individual species. The rotation age was defined as the age in which the mean annual volume/value increment culminates (Halaj et al. 1990).

The rotation periods are defined for the group of forest site types (i.e. forests with the same species composition growing on similar site conditions). However, recent research showed the high variability of forest production (expressed by site index) inside the individual forest site types (Kulla et al. 2012). The authors suggested defining the rotation period according to site index categories instead of forest site types. The rotation period should also take into account the potential and current status of natural regeneration.

Table 44. Rotation periods for FMM 1-5, "optimal" and in practical used periods.

FMM	"Optimal" rotation age	In practice used rotation
1: mixed oak-beech, wood & biomass production	150+ years	120 years (in case of mono-specific oak forests)
2: mixed oak-beech, timber production	90-150	100-110 for beech and 120 for oak
3: beech dominated stands (oriented to high-quality timber provision)	90-150. The rotation should be more differentiated taking into account the variability in site production potential. It should also better reflect the needs of individual forest owners.	100-110 for beech and 90-100 years for spruce, 100-110 for fir. In mixed forest a weighted mean rotation period is calculated for species-specific ages
4: non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	90-150. The rotation period should be more differentiated into account the larger variability in site production potential. It should also better reflect the needs of individual forest owners.	100–110 for beech, 100–110 for spruce, and 100–110 for fir. For mixed forests, a weighted mean rotation period is calculated from species-specific rotation ages.
5: non uniform shelter system in shade –tolerant spruce fir-beech mixed stands	As for FMM4.	100–110. The rotation for mixed forest stands is calculated as for FMM4.

The currently used rotation periods follow from the work of Halaj et al. (1990) and are prescribed in forest management plans – so there is no legal possibility to deviate from the prescribed rotation periods. There are some exceptions in cases when the health status or current species composition require using lower or higher rotation periods.

The forest in the case study area have been certified under the FSC and PEFC certification systems. Based on this, they keep 3-5 large trees on each harvested area.

Tree species and species composition

FMM 1-5 are all characterize of mixed stands. The species mixture differs and have changed over time. Thousands of years of exploitation by man especially on lower altitudes in the vicinity of human settlements or near agriculture arable land have influenced species and species mixture. Hu-man pressure significantly changed natural species composition, especially due to overharvesting of wood, grazing, and litter extraction.

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Coniferous species were preferred in planting before and after WWII due to their economic profitability. The preference of spruce monocultures instead of mixed stands during 19th and the first half of 20th century is known across Europe. Artificial addition of conifers into broadleaves stands was also characteristic during socialist era and it was justified as “economic admixture”.

Also climate change have most probably effected some species and forest communities, – the pressure of invasive Black locust has been increased in recent years. Some expert discussions about validity of forest site phytocoenological classifications exist – some experts argue that changes in tree species distribution and mixture is rather a result of classification of vegetation zones, e.g. a part of the area classified as 2nd vegetation zone now belongs to 3th zone where beech dominance is characteristic.

The original oak share was significantly reduced in favour of spruce, pine, beech and hornbeam and partly due to black locust invasion. The oak has a higher representation only in mixtures with conifers on better-than-average quality sites.

Areas suitable for FMM1 where originally dominated by oak but the oak presence was reduced by long-term human pressure on the forests in the vicinity of human settlements, preference of spruce and other conifers within artificial regeneration due to economic reasons, high game browsing pressure in naturally regenerated stands and by climate change impacts causing the black locust invasion.

Beech is the most abundant tree species in natural species composition on sites where FMM2 is suitable. The natural species composition is diverse and rather even, so the beech dominance is not very pronounced. The presence of beech in original stands of 3rd vegetation zone on mesotrophic soils varied between 40-50-55 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

The beech share on original species compositions in stands suitable for FMM3 was significantly reduced in the past. Now only small portion of stands is fully beech dominated in accordance to site potential. Large portion of originally beech stands was transformed into spruce dominated stands or even spruce monocultures. The spruce was artificially introduced into many beech stands frequently regenerated by small-area clear cuttings in the past. The higher wood volume production and lower silviculture costs were strived, even at expense of spreading the spruce outside its natural distribution area.

Although some portion of stands suitable for FMM4 has a well preserved natural species composition, majority of stands were converted into spruce dominated ones from economic reasons. The conversions had a greater extent than it was in beech vegetation zone due to great vitality and re-generation ability of spruce. Moreover, some wrong silviculture actions led to conversion to valuable broadleaved composition (elm, ash, maple). The reasons are the same as it was in lower vegetation zones (FMMs1-3): better economic profitability of spruce monocultures, simpler schematic silviculture, more effective mechanized harvests and past preference of small-area clear cuts linked to artificial regeneration – main forestry framework for a planned economy.

All FMMs used in broadleaves are characterized by mixtures with oak and beech as important and dominating species.

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The FMM1 assume prevalence of oak in the species composition. More than 70 years of phytoceonological research in Slovakia revealed and existing old-growth remnants showed that presence of oak in original stands of 2nd vegetation zone on mesotrophic soils varied between 50-65 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009). Today the admixture is larger and the oak component smaller, in more than half of the area oak is less than 50% of the standing volume.

The oak presence in original stands was reduced by long-term human pressure on the forests in the vicinity of human settlements, preference of spruce and other conifers within artificial regeneration due to economic reasons, high game browsing pressure in naturally regenerated stands and by climate change impacts causing the black locust invasion.

FMM2: the most abundant tree species expected in natural species composition is beech. The natural species composition is diverse and rather even, so the beech dominance is not very pronounced. The presence of beech in original stands of 3rd vegetation zone on mesotrophic soils varied between 40-50-55 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009). The presence of beech on higher quality sites is frequently increased above natural level because oak was not intentionally supported by tending. Moreover, oaks as low-productive species was replaced within planting (following the clearcuts applied in the past) by more effective spruce to increase the economic profitability of stands.

FMM3: the most abundant tree species expected in natural species composition is beech. The beech dominance is rather pronounced. The presence of beech in original stands of 4th vegetation zone on mesotrophic soils varied between 50-75 % at given sites (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009). According the survey of actual species compositions of stands growing at 4th vegetation zone, the presence of beech was frequently lowered in favour of spruce (even spruce monocultures exists).

FMM4: the most abundant tree species expected in natural species composition is beech. The beech dominance is not very pronounced due to participation of higher number of tree species on natural composition. The presence of beech in original stands of 5th vegetation zone on mesotrophic, well moist soils varied between 45-55 % (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

FMM 5: the ratio of beech in stands is partly reduced in favour of fir and spruce as more economic profitable tree species. Today mixtures only marginally deviate from natural composition.

Information about actual beech proportions in stands growing on sites suitable for FMM applications was obtained from FMP databases. The dominance of beech in the current stands was lowered by its substitution by spruce.

Why differences? The beech share on original species compositions was significantly reduced in the past. Now only small portion of stands is fully beech dominated in accordance to site potential. Large portion of originally beech stands was transformed into spruce dominated stands or even spruce monocultures. The spruce was artificially introduced into many beech stands frequently regenerated by small-area clear cuttings in the past. The higher wood volume production and lower silviculture costs were strived, even at expense of spreading the spruce outside its natural distribution area.

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Table 45. Tree species distribution in FMM1-5 today and recommended.

FMM	Tree species distribution today	recommended
1 mixed oak-beech stands wood and biomass production	Four types of changed species composition can be found on sites suitable for FMM1 Beech 50-60 %, hornbeam 30-40 % Norway spruce-scots pine-larch 70 % vs. sessile oak-beech-hornbeam 30 % (40 % of the area mainly on better than average quality sites, hornbeam 70-75 %, sessile oak 20-25 %, beech 0-5 % *Robinia sp*. 75-85 %, hornbeam 15-25 % on worse than average sites.	sessile oak 50-60 % beech 20-35 % hornbeam 0-5 % Norway maple 5-15 % linden 5-10 %
2 mixed oak-beech timber production	Today: 66 % of FMM potential area is covered by stands with changed species composition. Four types of changed species composition can be found on sites suitable for FMM beech 95 %- hornbeam 5% (on -13 %of the area) Norway spruce 50, beech 30, hornbeam 10, other 10 (40 % of the area) beech 50 hornbeam 40 sessile oak 10 (6 %of the area) Robina sp. 40% beech 40% Norway spruce 20 (7 %of the area, mainly on poorer sites.	sessile oak 30-40% beech 40-50% Norway spruce 5-10% linden 5-10%
3 beech dominated stands (oriented to high-quality timber provision)	Today the tree species mixture is typical 85 % of FMM potential area is covered by stands with changed species composition. Two types of changed species composition can be found: beech 80-90% Norway spruce 5, maple 5-20 (8.5 % of the area) ii) Norway spruce 50-55% beech 30-40% Norway Maple 10% and Ash 5% (76.5 % of the area)	beech 55-70% , Silver Fir 15-20%,, Sycamore and Norway maple 5-10%, linden/lime 5-10% (Large leaved lime)
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	Today 93 % of FMM potential area is covered by stands with changed species composition. Three types of changed species composition can be found: beech 60-70%, Silver fir 5-20% Maple 10-20% Norway spruce 5% (4 % of FMM area) Norway spruce 70% beech 25% maple 5% (72 % of FMM area) beech 50% Norway spruce 40% Maple 5% Silver Fir 5% (17 % of FMM area)	beech 45-50%, Silver fir 35-40% Norway Maple 5-10%, elm 5-10%,
5 non uniform shelter system in shade –tolerant	Fagus sylvatica 50% maple 30% ash 20%	Fagus sylvatica 40-55, Abies alba 20, Picea abies 10-20, Maple 5-

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spruce fir-beech mixed stands		15, *Ulmus glabra* 5

Although some portion of stands has a well preserved natural species composition, majority of stands were converted into spruce dominated ones from economic reasons. The conversions had a greater extent than it was in beech vegetation zone due to great vitality and regeneration ability of spruce. Moreover, some wrong silviculture actions led to conversion to valuable broadleaved composition (elm, ash, maple). The reasons are the same as it was in lower vegetation zones (FMM): better economic profitability of spruce monocultures, simpler schematic silviculture, more effective mechanized harvests and past preference of small-area clear cuts linked to artificial regeneration – main forestry framework for a planned economy.

Regeneration

Natural regeneration is dominating, % of the area are natural regenerated, but could be even more

Table 46. Natural regeneration in FMM1-5.

	Proportion of natural regeneration today	Recommended proportion of natural regeneration
1 mixed oak-beech stands wood and biomass production	60%	80%
2 mixed oak-beech timber production	60%	80%
3 beech dominated stands (oriented to high-quality timber provision)	70%	90%
4 non-uniform shelterwood system in shade-tolerant fir-beech mixed stands	70%	90%
5 non-uniform shelter system in shade – tolerant spruce fir-beech mixed stands	80%	95%

The main reason of differences between todays proportion of natural regeneration and recommended depends on the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

The soil scarification is done only on area of the harvested strips before seed production. Generally, it is mostly applied in the broadleaves stands and the current proportion in CSA is only 1% of the area, and where the conditions for spring and growth of seedlings are worse. It depends on slope, soil type and stand exposure. Wild boars and their recently increased numbers indirectly help preparing the forest soils for potential natural regeneration.

Browsing and fencing

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It is especially on the south`s exposures near fields with higher

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frequency of game. It should be up to 1% for full-area fencing and for individual protection up to 10 % of the CSA. On the base of available data, the individual tree protection is applied on the 5% of the CSA.

Stand management

Pre-commercial thinning

The pre-commercial thinnings are applied on 90% of area and usually should be done three or four times (each three till five years). All tending operations are done on the base of Forest management plan. For cutting to 50 years of age can be applied by the adjusting of forest manager. This cutting is classified as priority cutting. The pre-commercial thinnings are applied on 70% of area and usually should be done two or three times (generally each five years, with beginning in tenth year of the stand establishment). In two-layer forest stands, the pre-commercial thinning is usually not done in the bottom layer, although they should be.

Commercial thinning

The commercial thinnings are applied on 90% of the area and usually should be done every five to ten years. The volume percentage of thinning is descending with stand age and it ranges between two and seven percent when before the final harvesting.

The volume of thinnings in stands older than 50 years must be specified in Forest management plan and the total volume of the thinning in the stand can be increased by 15 percent at maximum. (in the act No. 326/2005)

Pruning

Pruning might be an alternative on spruce, then approx. 400 spruces per ha is pruned. For other species and models pruning has no meaning and is not done.

Harvest and transport

Harvester technology is used only on 2.5% of the CSA. It is only used in commercial thinning in the coniferous (spruce-dominated) stands and not in broadleaves stands. Fully mechanized by forwarder is 10 % of the area. The forwarder is used for minimizing skidding damages. Forest wheeled tractors and horses are used on 80 % of the area.

As much as 10% of the logging residues are extracted from the forest stands. This is mainly used for wood chips and firewood.

Nature protection

Nature protection is integrated in the forest management plan (description of stands) through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.7. Close to nature management FMM6

Close to nature management is applicable to 2.5 % of case study area. Today the actual share is 1 % (it`s 40 percent of potential area). The model should be applied in beech as dominant tree species

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for 45 to 50 percent, then fir for 35-40% and in minority maple and elm. This forest management model is applied in stands with natural tree species composition at higher quality sites and usually with proportion of spruce 5-10%. Close-to-nature management is preferred management system in the forest management model. Provisioning services and regulating services are the main services, but cultural services as recreation and aesthetic are expected as well. An average rotation period in the range of 120-150 years is prescribed in spruce-fir-beech stands. Natural regeneration can be achieved on 90 % of the area, there is a tendency to continuous regeneration. The soil scarification is done in the forest management model very rarely (up to 1%). The pre-commercial thinnings have been obligatory done each 5 years (usually two or three times). Commercial thinnings should be done every 5 or 10 year (in practice every 10 years), their volumes are prescribed by forest management plan and actual thinning volume after 50 years of stands can exceed the planned volume up to 15 % limit. The utilization of harvesters and forwarders for wood harvests and extraction is marginal (up to 2,5 %)usually use in coniferous. As much as 10% of the logging residues are extracted from the forest stands. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

This FMM is suitable for mesotrophic average-to-higher quality sites in cool 5th fir-beech and 6th spruce-fir-beech vegetation zone on mesic or moisture, water well supplied deeper soils at mid- and higher mountain locations (650-1200 m a.s.l.). Such sites are naturally dominated by shade-tolerant beech and fir mixed with spruce. The main tree species grow in ecological optimum. The FMM can be applied in stands with natural or near to natural species compositions. The management is balanced – continuous wood and timber production is aimed together with maximization of regulation services provision in combination with biodiversity and natural heritage promotion.

Ecosystem services

The ecosystem services are wood production, biodiversity, wood production, biodiversity, nature conservation, carbon sequestration, water, air and nutrition cycle regulation, soil protection, recreation, landscape protection.

Size of management unit and rotation period

This is in individual selection system and the size of harvested area at one time, management unit, are not regulated. The harvested area is indirectly regulated through the volume of allowable cut, fixed to working plan area. Then, the cutting is recalculated on each management unit (e.g. forest stand). (in the act No. 326/2005). The average size of stands where this system is used is 9ha.

For selection silvicultural system is the size of maximal harvested area depend on forest stand are. The cutting is planned for a stand especially thinnings and regeneration cutting together. The allowable cut can be exceeded by 30 percent of total current increment. If gap-like type of the selection system is used, the size of gap depends on mean height of stand with maximum width of two mean heights. Maximum size of gap is 2 000 m2. Total area of gaps together in the compartment is up to 3 ha. (in the act No. 326/2005). The average width of gap in case study area is between one and two mean height of forest stand. (expert judgement).

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No rotation period is used in practice if selection system defined for the forest stand. Harvesting then follows the principles of the selection system. However, there are cases when the forest structure allows applying selection system. Harvesting is based on “rotation age” of individual trees. However, tree level models should be developed and used to define individual tree rotation age. There is an ongoing research aiming to define it, but there are no clear results yet released

Tree species and mixture

The most abundant tree species expected in natural species composition should be beech. The beech dominance is not very pronounced due to participation of higher number of tree species on natural composition. The presence of beech in original stands of 6th vegetation zone on mesotrophic, well moist soils should be around 45-55 % (Zlatník, 1959, Vološčuk, 2000, Rizman et al. 2009). Recommended tree species mixture is; Beech 45-50%, Silver fir 35-40%, Elm 5-10% and Maple 5-10%. The model application is possible only for stands with original compositions and natural structure, therefore no major differences against natural composition is expected

Forest regeneration

Around 95% of the forest area should be established by natural regeneration but is today approx. 90%. Calamities increase the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favorable conditions to establish forest stand and the planting is used instead.

Scarification are not used in this FMM.

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It is especially on the south`s exposures near fields with higher frequency of game. It should be up to 1% for full-area fencing and for individual protection up to 10 % of the CSA. On the base of available data, the individual tree protection is applied on the 5% of the CSA. In practice the protection of stands is done along with commercial thinning, generally by chemical application to individual trees. Only a small part of the protection is done by fencing.

Stand management

The pre-commercial thinnings are applied on 20% of the cutting area and usually should be done two or three times (generally each five years, with beginning in tenth year of the stand establishment).). It is recommended to increase the area of PCT to 50%.

Commercial thinnings are applied on 90% of area and usually should be done every five to ten years. The commercial thinning is the part of selection cutting. The volume percentage of thinning is descending with stand age and it ranges between two and seven percent when before the final harvesting.

Pruning is not used in the CSA. Usually the branches on the coniferous trees are kept till commercial thinning to prevent from debarking by deer species.

Harvesting

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Harvester is not used in this FMM. Fully mechanized by forwarder is 10 percent of the area. The forwarder is used for minimizing skidding damages. Forest wheeled tractors and horses are used on 80 percent of the area. As much as 10% of the logging residues are extracted from the forest stands.

Nature protection

Nature protection is integrated in the forest management plan (description of stands) through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.8. Non-uniform shelterwood systems with spruce FMM7

Spruce should be growing and managed on approx. 0.5 % of case study area, the actual share today is applicable to 65 %. The model should be applied in spruce as dominated tree species for 80 to 90 %, then acer and rowanberry in minority. This forest management model is applied in stands especially with changed tree species composition and minority in original species composition. Non-uniform shelterwood system is preferred management system in the forest management mod-el. In lower extent can be used individual selection system, especially on sites with high degree of nature regeneration. From ecosystem services are made mainly provisioning services and regulating services. The average rotation period is prescribed in Slovak conditions 110 - 150 years (generally lower in the shelterwood system and higher in the individual selection). Natural regeneration can be achieved on 50-90 % of the area (lower in changed stands), there can be tendency to continuous regeneration for a natural stand. The soil scarification isn`t done in the forest management model. The pre-commercial thinnings have been obligatory done each 5 years (usually two or three times). Commercial thinnings should be done every 5 or 10 year (in practice every 10 years), their volumes are prescribed by forest management plan and actual thinning volume after 50 years of stands can exceed the planned volume up to 15 % limit. The utilization of harvesters and forwarders for extraction of wood are mainly in spruce but marginal (up to 2,5 %). Logging residues utilized for a chip wood production and fire wood are extracted from the app. 20 % of stands with final cut-tings and from 100 % of thinned stands. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

Based on environmental survey and management categorization, the FMM area corresponding to a specific site, forest type and selected management orientation is known from current FMP data-bases.

The FMM is suitable for mesotrophic medium and lower-to-average quality sites in cool 7th spruce dominated vegetation zone where trees are growing in harsh mountain climate typical for low temperatures, high humidity, short vegetation period and high annual snowfall on shallow soils in high-mountain locations (1050-1500 m a.s.l.). Such sites are naturally dominated by spruce with small admixture of fir and sycamore. Broadleaved species are severely limited in their growth and are therefore present only sporadically in forests around the bottom range limit. The management is focused on wood and timber production on not extreme slopes and/or soil protection, water regulation and carbon sequestration on more extreme sites.

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The secondary artificial spruce monocultures or spruce prevailing/dominated stands occupying an extensive area outside the spruce natural distribution. Each forest vegetation zone has a significantly changed species composition, the spruce presence was very often favoured instead of original species from economic reasons. The spruce was used as a main tree species within artificial regeneration of stands in the past, but it also shows excellent competition abilities and good natural regeneration potential on many sites outside of its natural distribution today. Moreover, spruce dominance was highly demanded in areas primarily oriented to water purification and protection

Ecosystem services

This FMM produce wood and timber, water regulation, water purification, soil erosion control, carbon sequestration, recreation, tourism.

Tree species

This FMM are used for management of especially spruce but in such stands also Sycamore maple, *Acer pseudoplatanus, Sorbus aucuparia*, and Silver fir *Abies alba* occur.

Size of stand

In general the size of harvested area at one time-point isn`t regulated. The harvested area is indirectly regulated through the volume of allowable cut, fixed to working plan area. Then, the cutting is recalculated on each management unit (e.g. forest stand). (in the act No. 326/2005)

In the CSA the mean area of harvest is 1,5ha. The minimum is 5 ha if it is a compartment and 0,3ha for sub compartment for this FMM.

In the system for spruce, the harvested area is maximum is 3ha. Cuttings are done in strips and the maximal with of a strip is two tree heights and the distance between the two harvested strips is one strip width.

Rotation period

The rotation age is regulated. The rotation period is used to limit annual cuts in the forests. It is a tool for the state to ensure sustainable and balanced annual allowable cuts in the long-term perspective. It was defined based on the rotation age of individual species. The rotation age was defined as the age in which the mean annual volume/value increment culminates (Halaj et al. 1990). An optimal rotation period is 100-150 years (Kulla et al. 2012). The rotation period should be more differentiated taking into account the large variability in site production potential (Kulla et al. 2012). It should also better reflect the needs of individual forest owners. In the CSA it is around 110-120 years. The currently used rotation periods follow from the work of Halaj et al. (1990) and are prescribed in forest management plans – so there is no legal possibility to deviate from the prescribed rotation periods. There are some exceptions in cases when the health status or current species composition require using lower or higher rotation periods.

The forests in the study area have been certified under the FSC and PEFC certification systems. Based on this, they keep 3-5 large trees on each harvested area.

Tree Species and tree species composition

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Spruce strongly dominates in this FMM. The dominance of spruce is expected in original species composition. The presence of beech in original stands of 7th vegetation zone on oligotrophic and mesotrophic, well moist soils varied between 90-95 % (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

Today in many stands spruce grow in mixture with other species. The mixtures vary a lot, from spruce dominated to stand where spruce proportion is less than ¼. Experts recommend spruce to dominate (75-95%) and grow in mixture with beech.

The dominance of spruce is expected in original species composition. The presence of beech in original stands of 7th vegetation zone on oligotrophic and mesotrophic, well moist soils varied between 90-95 % (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

Many stands from 2nd-to 6th vegetation zones have species compositions changed in favour of spruce. Due to this high diversity of spruce presence can be found on CSA.

The main reason of differences is the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

Forest regeneration

Around 90% of the forest area should be established by natural regeneration. Currently, around 80% of the area of FMM is established through natural regeneration (available data). The main reason of differences is the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

There is no need to use soil scarification in this FMM.

Browsing and fencing

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It is especially on the south`s exposures near fields with higher frequency of game. It should be up to 1% of the CSA for individual protection. (expert judgement) On the base of available data, the individual tree protection is applied on the 1% of the CSA.

In practice the protection of stands is done along with the commercial thinning, generally by mechanical protection of individual trees.

Stand management

Pre-commercial thinning

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The pre-commercial thinnings should be applied on 50% of area and these are a part of selection cutting, (each ten years). All tending opearations are done on the base of Forest management plan. For cutting to 50 years of age can be applied by the adjusting of forest manager. This cuttings are classified as priority cutting. The pre-commercial thinnings are applied on 20% of selection cutting area and usually should be done once. (expert judgement).

The main reason of divergence is usually in smaller number of even age stands. In practice, the pre-commercial thinning is not done in the understory. (expert judgement).

Thinning

The commercial thinnings are applied on 80% of area and usually should be done every ten years. In practice they are done every ten to fifteen years. The volume percentage of thinning near the time of regeneration is increased and it ranges between twenty and twenty 5 %.

Pruning

No pruning is not done and shall not be done in this FMM.

Harvest and logging residues

Harvester is used only on 2,5% of the area of the CSA. It is only used in commercial thinning in the coniferous (spruce-dominated) stands.

For extraction Forwarder is used on 10% pf the area, Forwarder is used to minimize skidding damages. Forest wheel tractors and horses are used on 80% of the area

As much as 70% of the logging residues are extracted in this FMM.

Nature protection

Nature protection is integrated in the forest management plan (description of stands) through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.9. Three FMMs for soil protection, nature conservation and water purification

In Slovakia CSA three forest managing models are used where management goals are other than wood production, for soil protection, for nature conservation and for water purification.

Soil and soil protection, FMM8. App. 9.6 % of CSA should be managed under a special model, FMM8. The forest management model should be applied in beech, oak, fir and spruce stands. There are grown also hornbeam and pine as minority species. These stands are mainly grown on extreme sites with low production mainly with stabile natural tree species composition. The preferred ecosystem service is a regulating service at first (soil protection, landscape protection, water regulation, biodiversity. Selection system is prescribed with average rotation period 150-250 years. The rotation period is generally continuous in this management model. Natural regeneration can be achieved on 90 % of the area. The soil scarification isn`t done (it`s protected in this FMM). The pre-commercial thinnings are done obligatory 10 years (if it`s necessary in better conditions). Commercial should be done every 10 years (in practice every 10-15 years), their volumes are prescribed by the forest management plan and actual thinning volume after 50 years of stands can

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exceed the planned volume up to 15 % limit. The utilization of harvesters and forwarders aren`t done in the FMM. Logging residues are extracted for a chip wood and firewood production up to 5 %. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP

Nature conservation and cultural heritages are the main goals for this management model, FMM9, covering 1.6 % of CSA. The model should be applied in beech stands, maple-silver fir -beech stands (for CSA 50 %), spruce-silver fir-beech and spruce stands (25% for CSA). These stands are located in natural protected areas with no intervention management allowed and with the original tree species composition. The preferred ecosystem service is a cultural service at first. The rotation period is not defined and is not relevant. The soil scarification is strictly inhibited in this FMM. No forest management and other interventions are allowed in the FMM. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

Based on environmental survey and management categorization, the FMM area corresponding to a specific site, forest type and selected management orientation is known from current FMP data-bases.

FMM 9 is applied in stable old growth/virgin forests with very-well preserved species composition, uneven-aged structure with diverse horizontal and vertical distribution of trees. The stands do not show any signs of past human activities, have a great biodiversity and presents the natural benchmark for regularly managed even-aged forests. The forests are under 5th degree of nature protection (i.e. national natural reservation), that means they are fully left to self-regulation. Such stands exist in 5^{th}-7^{th} vegetation zone (fir-beech, spruce-fir-beech and spruce zones) at localities more distant from human settlement. The management is focused on nature conservation, natural heritage protection and tourism. The utilization of provisioning services is fully excluded.

Water and water purification, FMM10. On 6.7 % of CSA management is focused on water management. The forest management model should be applied by fir-spruce stands (coniferous) near the water reservoirs, acer-fir-beech stands and acer-fir-beech stands in buffer zone. These stands are mainly grown on sites near drink water reservoirs with different production and tree species com-position. That must be changed to coniferous dominance for better quality of water. The preferred ecosystem service is a regulating service at first (water regulation, soil protection, landscape protection). Non-uniform shelterwood system is prescribed with average rotation period 80-120 years. Natural regeneration can be achieved on 90 % of the area (for stands near reservoir usually planting regeneration). The soil scarification isn`t done (it`s protected in the areas where FMM19 is used). The pre-commercial thinnings are done obligatory 10 years. Commercial thinnings should be done every 10 years (in practice every 10-15 years), their volumes are prescribed by the forest management plan and actual thinning volume after 50 years of stands can exceed the planned volume up to 15 % limit (it is necessary to keep horizontal canopy). The utilization of harvesters and forwarders aren`t done in FMM10 (mainly by horses). Logging residues are extracted for a chipwood and firewood production up to 5 %. Nature protection and conservation requirements are fully integrated into stand-level management through recommendations, restrictions and prescriptions incorporated into obligatory FMP.

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Ecosystem services

ES are, different from the FMMs described above oriented to other values than wood production, see Table 47

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Table 47. Ecosystem services for FMM 8-10 for soil protection, nature protection and water management.

FMM	Ecosystem services
8. Soil protection	soil protection, natural hazard protection, landscape protection, water regulation, carbon sequestration, biodiversity and natural heritage protection, tourism
9. Nature protection	natural heritage, biodiversity, water and air, nutrient regulation, soil protection, natural hazards protection, recreation and tourism
10. Water management	water purification and quality, soil erosion control, nutrient regulation, carbon sequestration, wood provision

The three management models for soil and nature protection and water management include many different silviculture systems, see Table 48.

Table 48. Characteristics for the three FMM for nature, soil protection and water management.

FMM	Characteristic of Forest management system
8 Soil protection	Selection system
9 Nature protection	No intervention
10 Water management	Non-uniform shelterwood system, also some elements of individual selection system can be applied, especially in close vicinity of reservoirs where very specialized management have to be applied.

Tree species and composition

All three models are characterized by many species in mixture and structure of mixtures depending on Forest vegetation zone. There are some differences between today's tree species mixture and recommended mixture, Table 49.

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Table 49. Tree species in the three models focusing on non-wood products.

FMM	Species Mixture Today Present Situation:	Recommended Specie Mixture on Different FOREST VEGETATION ZONE
8 Soil protection	Forest Vegetation Zone 2, beech (23 % Of FMM Area)	
	1) Oak 40-50% Beech 25-30% Hornbeam 10%-15% Beech 5% (5 % Of FMM Area) 2) *Robina* 35% Hornbeam 30%% Norway Spruce 15% Beech 15% Oak 5% (18 % Of FMM Area)	Oak 50%-55%, Beech 15-20%, Maple 5%, Lime 5%. Hornbeam 5%, *Sorbus torminalis* 5%, Scots pine 10%
	Vegetation Zone 3 and 4 beech and beech-fir (52% of FMM area)	
	Beech 50% Hornbeam 40% Oak 10% (7 % Of FMM Area) 2) Hornbeam 50% Beech 40% Oak 5% Norway Spruce 5% (18 % Of FMM Area) 3) Beech 75% Silver Fir 20% Norway Spruce 5% (3 % Of FMM Area) 4) Beech 50% Norway Spruce 45% Oak 5% (24 % Of FMM Area)	Vegetation zone 3 beech (25% of FMM) Oak 15-40%, Beech 40%-75%, Lime 5%, Maple 5% Vegetation zone 4 fir-beech (27% of FMM) Beech 55-65%, Silver Fir 10%-15%, Maple 5%, Lime 5%
	Forest Vegetation Zone 5 spruce-fir-beech (24% of FMM)	
	1) Beech 70% Silver Fir 15% Maple 10% Norway Spruce 5% (1 % of FMM Area) 2) Norway Spruce 45% Beech 40% Silver Fir 15% (21 % of FMM Area) 3) Beech 55% Norway Spruce 25% Silver Fir 20% (2 % of FMM Area)	Beech 40%-45%, Silver Fir 15-35%, Maple 15-30%, Elm 5%
9 Nature protection Present situation and recommended, no difference	Forest Vegetation Zone 4, Beech-Fir (10 of FMM area) Beech 70%, Silver Fir 20%, Maple 10% Forest Vegetation Zone 5, (50% of FMM area) Beech 40% Silver Fir 30% Maple 20% Elm 10% Forest Vegetation Zone 6, (15 % Of FMM Area) Beech 35% Silver Fir 25% Norway Spruce 20% Maple 10% Elm 10% 7th Forest Vegetation Zone (25 % Of FMM Area) Norway Spruce 80% Maple 15% Sorbus 5%	
10 Water management	In vicinity of reservoirs : (1 % of FMM Area) Norway Spruce 100% In Buffer Zone (4th And 5th Forest Vegetation Zone,) 99 % Of FMM Area) 1) Beech 95% Norway Spruce 5% (8 % Of FMM Area) 2) Norway Spruce 60% Beech 30% Maple 5% Ash 5% (91 % Of FMM Area) 3) Beech 65% Norway Spruce 10% Maple 10% Ash 15% (2 % Of FMM Area)	In vicinity of water reservoirs: Norway Spruce 80%-90%, Silver Fir 10%-20% Forest vegetation zone 4 (70% of FMM area): Beech 55-70%, Silver Fir 15-20%, Maple (Sycamore and Norway) 5-10% Lime 5-10% Forest vegetation zone 5 (29% of the area): Beech 45-50%, Silver Fir 35-40%, Maple 5-10%, Elm 5-10%

Although degree of changes in species composition is lower than in commercial forests, same tendency of increased shares of coniferous species above natural levels is evident. At the same time, the black locust invasion and artificially enlarged shares of hornbeam at low altitudes in beech- oak zone is also obvious. Black locust invasion can be regarded as early sign of climate

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change, increased presence of conifers is probably caused by their spreading on extreme sites from surrounding commercial forests through natural regeneration.

The optimal species compositions are differenced according to distance from water reservoirs and forest vegetation zones (FVZ) existing in buffer zone (Zlatník 1959, Vološčuk 2000, Rizman et al. 2009).

In the water purification model the share of beech in buffer zone is lowered in comparison to expectations. The reason is intentional promotion of spruce dominance due to better ability to preserve the quality of water. The quickly decomposing broadleaved litter may infiltrate the water by nitro-gen, therefore the beech and other deciduous species are not considered as convenient.

8.9.1. Soil protection model

Compared to other FMM with the wood production as the priority function, the rotation periods in this FMM are much longer with a long regeneration periods. The aim of this FMM is to ensure continuous forest cover and required forest structure to fulfilling non-wood special-purpose forest functions (soil protection – protection against soil erosion, etc.).

The rotation period larger than 150 years is used, depending on species composition and the purpose for which the forest is managed. Although the rotation period is defined, the principles of selection system are applied in this FMM.

The optimal rotation period depends on species composition and site productivity. However, the rotation period has only informative character and is based on the expected life span of species. The main criterion is to ensure continuous forest cover, rather than rotation age or target diameter.

8.9.2. Nature protection model

No cutting is done and rotation period is not relevant.

8.9.3. Water purification model

In this FMM, the aim of the management is to protect water sources from contamination. There are two zones of water protection with different requirements on forest management. The first zone (a) is a narrow belt surrounding the water source. Here the selection cutting with the principles of se-lection system is preferably used. In the zone (b) the normal forest management is mostly applied, so the normal rotation periods are used but taking into account water protection (e.g. gap-size re-generation).

In the study area, the rotation period of 80 – 110 years is used, depending on the health status of the forest stands (especially the spruce stands). In the zone (a), the rotation period should be based on the potential species life span (so should be large) and forest management should ensure continuous forest cover. In the zone (b), the rotation periods should reflect the variability in site production potential. Selection system with target tree diameter should be preferred.

8.9.4. Regeneration

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

Only natural regeneration is used in the nature protection where the non-invention model is used. It is recommended that 90% of the new seedlings should be natural regenerated in the models used for soil protection and water purification natural regeneration. Today it is 90%. New forest is established with natural regeneration.

The main reason of differences is the occurrence of calamities and consequently the need of planting or combined regeneration (both planting and natural regeneration). After a disturbance occurred, the forestry law dictates the forest manager to establish the new forest through planting, no matter whether the site conditions would in near future allow natural regeneration to occur. Then there are sites on which natural regeneration does not have favourable conditions to establish forest stand and the planting is used instead.

Site preparation is not used in any of the three Models, it is not needed and in the nature conservation areas it is forbidden.

Browsing and fencing

The area under regeneration (mainly artificial regeneration) should be fenced in the zone with migration or concentration of game. It should be up to 1% for full-area fencing and for individual protection up to 5% of case study area. (expert judgement).

In areas for nature protection no fences are used.

Stand management

Pre-commercial thinning

The pre-commercial thinnings are applied on 30% of area and usually should be done once (generally each ten years). (expert judgement). The pre-commercial thinnings are recommended to be applied on 50%% of area and these are a part of selection cutting each ten years in the model for soil protection. The main reason of divergence is usually in smaller number of even age stands. In practice, the pre-commercial thinning is not done in the understory).

In the areas for water purification the pre-commercial thinnings are currently applied on 70% of area and usually should be done two or three times (generally each five years, with beginning in tenth year). It is recommended to increase the area to 90% of area and usually should be done three or four times (each three till five years). The main reason of divergence is usually in smaller number of even age stands. In practice, the pre-commercial thinning is not done in the understory.

In areas for nature protection no pre-commercial thinning done.

Commercial thinning

The commercial thinnings are applied on 90% of area and usually should be done every ten to fifteen years. The commercial thinning is usually the part of selection cutting. The beginning of regeneration is earlier than in production forest and restoration is longer. The volume of thinning in stands older than 50% years must be specified in Forest management plan and the total volume of the thinning in the stand can be increased by 15 % at maximum.

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The commercial thinnings are recommended to be applied on 90% of the area and usually should be done each ten years till the age of 70 years. Before the time of regeneration cutting (increment thinning) the commercial thinnings are usually not done in practice. The divergences are only at the beginning of commercial thinnings, where the trees with non-commercial parameters are avoided. In some cases, near before the regeneration cutting and when the planned thinning volume is low, thinnings are not done.

No thinning is done in areas for nature protection

Pruning

Pruning is not done in any of the three models. Usually the branches on the coniferous trees are kept until commercial thinning to prevent from debarking by deer species.

Harvest

In the nature protection areas no harvester are used.

In areas for soil protection extraction of timber is done by forest wheel tractor and horses and in areas for water purification some forwarders are used and horses (80%).

Logging residues are extracted up to 70% in soil protection areas and 10% in water purification areas.

Nature protection

Nature protection is integrated in the forest management plans through the nature protection degree, nature protection zone and name of protected area. It is also integrated in the forest categorization, especially at higher degree of nature protection.

8.9.5. References

The information collected from the available data of Forest management plans and interviewed of practice experts (P. Kral, M. Rejko, I. Nevolná) from Forests, state estate. Forest management model description was elaborated by R. Sedmak PhD., M. Bosela PhD., J. Bahyl PhD. and R. Smrecek PhD.

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ALTERFOR

II. Ranking of Ecosystem Services (ES)

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2.7. Slovakia

2.7.1. Biodiversity services assessment

Qualitative rating of biodiversity protection and enhancement for each FMM was performed by a panel of scientific experts (members of our ALTERFOR team) based on Biodiversity assessment guidelines and evaluation example from Adam and Matts All provided ratings were discussed, and the final rating is a consensual agreement. By Biodiversity example, we used the scale 1-7 for assessment, where one means the worst impact on biodiversity and seven is related to the maximal support of biodiversity.

The assessment respected the suggestions of the Swedish team, and three major dimensions were considered. For each dimension, we used the following indicators relevant for Slovak CS according to our opinion:

- Tree species compositions– total tree species diversity, proportion of broadleaves (for some FMM and forest types)
- Forest structures – horizontal and vertical tree distribution, number of tree layers, tree age distribution, height and diameter differentiation
- Spatio-temporal patterns – degree of natural disturbance emulation, proportion of older stands

Within the evaluation process, the secondary spruce monoculture was taken as a comparative benchmark with the lowest biodiversity. Moreover, we assumed the validity of following assumptions, relations and known facts:

- Regarding tree species composition – the growing number and evenness of tree species participating on tree species compositions and increased proportion of broadleaves in forests with the artificially enlarged presence of conifers were considered as positive for biodiversity. The spruce monocultures were rated by value 2 or 3 because we did not suppose the existence of genetically improved or breeded trees on our CSA.
- Regarding forest structure – the FMM supporting the greater variation in tree age, horizontal distribution, dimensions and vertical arrangement in growing space were assessed as biodiversity promoting. The presence of deadwood was considered only marginally due to its absence in the majority of FMM. The value 1 (the worst rating) was reserved for short-term industrial plantations, spruce even-aged monocultures were rated as 2, and old-growth native forests in natural reserves has been rated by value 7 (best rating).
- Regarding spatiotemporal patterns – the FMM using the thinning and harvest strategies similar to natural disturbance patterns were considered as positive for biodiversity protection. Therefore, three FMM using no intervention or individual tree selection interventions were assessed as superior to others. Contrary, FMM based on active management were a slight difference in regard this criterion due to the relatively high

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uniformity of final fellings – all models use the non-uniform, small-area, two – or three-phase shelterwood cuttings to achieve and maintain the natural regeneration of stands.

Table 34 Biodiversity services assessment, Slovakia

ES	Indicator	FMM									
		I - oak_timber	II - oak-beech_timber	III - beech_timber	IV - fir-beech_timber	V - spruce-fir-beech (timber)	VI - spruce-fir-beech (close-to-nature)	VII - spruce (timber)	VIII - soil (protection)	IX - no intervention	X - water purification
Biodiversity	**tree species composition**	6	6	4	6	7	7	3	4 - 7	4 - 7	2
Ranking 1 - 7	**forest structure**	2	4	3	5	6	7	2	3 - 7	3 - 7	2
1 worst - 7 best	**disturbance regime**	4	4	4	5	5	6	5	6	7	3
	Overall ranking	**4**	**5**	**4**	**5**	**6**	**7**	**3**	**4-7**	**4-7**	**2**

FMM I Oak – wood provision

The model supports the presence of native broadleaves in stand species compositions, although oak dominance is predetermined by site and habitat conditions.

Due to natural oak dominance as fast-growing light demanding species in main tree layer and even-aged character of managed stands, the spatial and dimensional variability is not too large i.e. the uniformity is rather high.

The degree of natural disturbance regime emulation is average, clear-cuts are prohibited, spatial uniformity is allowed but not preferred and longer regeneration periods are usually applied.

FMM II Oak-beech - timber provision

The similar evaluation was used as in the previous case. The model supports the presence of native broadleaves in stand species compositions. The main tree layer is composed of two main species which dominance is predetermined by site and habitat conditions.

The spatial and dimensional variability is higher than in the previous case due to complementary nature of faster-growing, light-demanding oak and slower-growing, shade tolerant beech. On the other hand, the even-aged character of forest reduces the spatial, structural and dimensional variability of trees to an average level.

The degree of natural disturbance regime emulation is average, clear-cuts are prohibited, spatial uniformity is allowed but not preferred and medium regeneration periods are usually applied.

FMM III Beech – timber provision

The species composition of stands managed by the model has rather low diversity. The beech in given natural conditions shows clear tendency to form monocultures with the almost exclusive dominance of European beech. Together with the even-aged character of managed forests, the high species, spatial and structural uniformity similar to spruce monocultures appears. The smaller degree of uniformity is expected compared to spruce monocultures due to the greater incremental plasticity of beech trees and higher proportions of overstorey thinnings against the spruce.

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Natural disturbance emulation is similar to previous cases – once again, spatially non-uniform shelterwood cuttings with medium length of regeneration period is preferred

FMM IV Fir-Beech – wood and timber provision

The high species diversity characteristic for forests managed by the model is intentionally supported. Main tree layer is usually formed by broadleaved European beech and coniferous Sliver fir, an admixture of other valuable (elm, ash, maple) is very frequent.

The species diversity supports also high structural and spatial diversity of trees even within the frame of even-aged concept. The utilization of growing space is high due to different demands of different species in different developmnetal life stages.

Degree of natural disturbance regime emulation is average or slightly above average due to use of prolongated regeneration periods within non-uniform shelterwood system aiming to natural regeneration of trees.

FMM V Spruce-Fir-Beech – timber provision

The description of the previous model is almost completely valid also for this model. The differences lie in even greater species diversity of the main tree layer also manifested in greater dimensional and spatial variability of trees within the even-aged stands. The degree of natural disturbance regime emulation is equal to the previous case and reaches above-average level.

FMM VI Spruce-Fir-Beech – Close to nature

The high species diversity of forest consisting of main tree species in upper canopy layer is supported. Large age, structural and spatial diversity is intentionally supported and maintained. Low intensity, individual selection cuttings irregularly distributed in space quite precisely mimics the natural disturbance patterns.

FMM VII Spruce – Timber

The lower species diversity is characteristic for forests managed by the model regardless of whether they are natural or artificial. Subsequently the dimensional and structural diversity of even-aged monocultures is only at lower than average level even when they are regenerated by non-uniform shelterwood systems.

FMM VIII Soil protection

The species composition diversity in the forests managed by this model is very high due to only slight human interventions of natural processes. The model is used in a broad range of site conditions covering all species composition when prevention of soil erosion is needed. Due to slight human interventions and low commercial utilization the tree species diversity varies between average level (in natural „monocultures“ – oak-dominated stands at lower altitudes, beech dominated stands at medium altitudes or spruce-dominated stands at higher altitudes) and high level (mixtures of conifers with broadleaves at higher elevations or species-rich mixtures of broadleaved at lower elevation). Equivalently to species diversity varies the spatial, structural and dimensional variability of almost natural forests – from average to high levels. The natural disturbance patterns are almost completely emulated.

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FMM IX Nature conservation/No intervention

The species diversity of the forest is very high; the forests managed as natural reserves are intentionally situated in the localities and ecosystems with high species, structural and dimensional diversity. At the same time, they are intentionally exposed to natural disturbance regime. The protection of the natural disturbance regimes is the essence of the model. Despite this assessment, the range of ratings was given for two reasons: (i) old-growth forests are characteristic by the change of three developmental stages – ingrowth, optimum and decay phase on small patches. Moreover, especially the optimal phase is characteristic by the smaller dimensional diversity of trees for a certain period. (ii) Larger scale disturbance is also expected and possible in old-growth forest. When such options occur, the character and diversity of the next tree generation are very similar to even-aged forests.

FMM X Water purification

The forests managed by the model have a nature of artificial even-aged spruce monocultures tended to create the highly unified structure and dense stands. Moreover, the small area clear cuts and frequent large-scale disturbances associated with artificial regeneration of stands are frequently used or needed.

2.7.2. Carbon sequestration assessment

Qualitative assessment of CC sequestration capacity of each FMM was performed by a panel of scientific experts (members of our ALTERFOR team) taking into account Kevin Black's C sequestration Guidelines and some CS area specificities. That means all provided ratings were properly discussed and the final rating is a consensual agreement. By Biodiversity example, we used the scale 1-7, where one means the worst C sequestration ability and seven is related to the maximal level of C sequestration.

The assessment respected the three main C pools agreed to concentrate in Zvolen. For each category, we identified the following driving factors affecting the carbon sequestration:

- Above and below ground biomass – site fertility, rotation age and species compositions
- Deadwood – amount of natural deadwood, amount of harvest residues
- Harvested wood product – the proportions of round wood, pulpwood and fuelwood on growing stocks

Within the assessment process, we assumed the validity of following assumptions, relations and known facts:

- C sequestration is better on good quality sites – we were taken into account knowledge about the spatial distribution of individual FMM on CS area predetermining increased occurrence of lower quality sites in particular FMMs.
- The longer rotations mean more C sequestrated and maintained in growing stocks - the Slovakian rotation ages are determined to utilise of site potential to produce wood biomass fully. Therefore no over-mature forests with lowered sequestration ability exist on CSA, and

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longer rotations mean higher average growing stocks simply due to a longer time of biomass accumulation.

- The different tree species have different ontogenetically given potential to produce biomass - three main species (Norway spruce, European beech and Silver fir) are considered as equivalent from biomass point of view (conifers have a higher volume but lower wood density and vice versa), but oaks and Scots pine are worse (75 % and 60 % from maximum, Sedmák 2013, Halaj, Petráš 1998, STN 480010). Subsequently, if some FMM and their sites supports spruce, fir or beech, they were assessed as better for C sequestration.
- FMM based on active management actions result in a less amount of natural deadwood but a higher volume of harvest residues, but we expected that amount of natural deadwood (if it is left in the area) is always greater than an amount of harvest residues. At the same time, a *higher amount of deadwood was considered as positive from C sequestration point of view because we expected that mean half-live and decay time of Deadwood is larger than half-live of industrial product mix produced from harvested wood.* Due to this, FMM based primarily on passive approaches were assessed as better. Differencing among active FMM was hard due to similar character intensity of thinnings and nature of final cuttings (usually two or three phase non-uniform shelterwood cuttings) and tendency to fully utilise of wood for commercial purposes.
- Regarding harvest products, the proportion of three broad assortment classes (roundwood, pulpwood and fuelwood) on growing stocks and harvests were estimated. We expected that life cycles of products made from roundwood are longer in general than from pulpwood and pulpwood products have longer life cycles than fuelwood ones. The FMM with higher proportions of round- and pulpwood were considered as better for C sequestration.

Table 35 Carbon sequestration assessment Results Slovakia

ES	Indicator	FMM									
		I - oak_timber	II - oak-beech_timber	III - beech_timber	IV - fir-beech_timber	V - spruce-fir-beech (timber)	VI - spruce-fir-beech (close-to-nature)	VII - spruce (timber)	VIII - soil (protection)	IX - no intervention	X - water purification
C sequestration	site fertility	2	3 - 4	4 - 6	7	7	4 - 5	4 - 7	2 - 5	4 - 7	4
Ranking 1-7	species composition	4	5	7	7	7	7	7	4 - 7	7	7
1 worst - 7 best	rotation age	4 - 6	2 - 4	2 - 4	3 - 5	3 - 5	5	1 - 3	7	7	1
	biomass production	**3-4**	**3-4**	**4-6**	**6**	**6**	**5-6**	**5-6**	**4-6**	**6 - 7**	**4**
	deadwood	**4**	**4**	**4**	**4**	**4**	**4-5**	**4**	**6-7**	**7**	**4**
	roundwood	45	40	30	35	40	50	40	-	-	30
	pulpwood	35	50	60	55	50	40	50	-	-	60
	firewood	10	10	10	10	10	10	10	-	-	10
	products	**5**	**4**	**2**	**3**	**4**	**5**	**4**	**6**	**7**	**2**
	Overall ranking	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**6**	**7**	**3**

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FMM I Oak – wood provision

The forests managed by the model have a slightly lower-than- average or average biomass production potential, mainly due to oak-dominance and lower than the average fertility of sites (long-term pressure of local consumption, grazing, litter extraction, ...). Contrary, very long rotation ages (up to 170-180 year) support C sequestration and partly off-set the negative effects of lower fertility of sites.

The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood). This justification is fully valid for all FMM which are based on active management of normal age class forests oriented to financial incomes from wood and biomass market.

Assortment structure is rather favourable. The long rotations and orientation of silviculture on the production of thicker, highly valuable oak assortments increase the roundwood proportions obtained from harvests, although this tendency is partly offset by the lower quality of sites covered by oak-dominated forests.

FMM II Oak-beech - timber provision

Similar to the previous model, forests managed by FMM II have slightly lower-than- average or average biomass production potential, but the main reason is changed – the typical rotation ages are much shorter than in the previous case (up to 120 years). At the same time, the presence of oak as the species with smaller biomass production potential in the species compositions is still remarkable. On the other side, typical site fertility is better in comparison to oak-dominated stands, and the beech has a greater biomass production potential than oak in general.

Evaluation and justification of deadwood are equal to the previous case. The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood).

Assortment structure is a little less favourable in comparison of oak-dominated forests, the proportion of roundwood is smaller. The main reasons are shorter rotation ages in combination with the higher presence of beech on species composition which results in a higher proportion of trees with smaller dimensions at the end of the rotation period. However, the difference is not large due to the somewhat higher fertility of sites covered by oak-beech forests.

FMM III Beech – timber provision

The forests managed by the model have average to higher biomass production capacity, mainly due to beech-dominance and good quality of sites. Rotation ages are average and typical for beech stands in Slovak conditions (up to 120 years).

The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood).

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Assortment structure is less favourable. The smaller proportion of roundwood in favour of a higher proportion of pulpwood is expected due to general tendency of beech produce less valuable assortments (the creation of heartwood at rather young ages is a frequent problem).

FMM IV Fir-Beech – wood and timber provision

The forests managed by the model have higher biomass production capacity because main tree species (beech, fir) have the high biomass production potential, and mixed stands are more productive than monoculture due to better use of growing space and greater ability to mainly due to beech-dominance and good quality of sites. Rotation ages are average and higher-than-average due to fir presence in species composition which is typically managed by longer rotations (up to 140 years) due to its slow rate growth nature, low requirements for light and great increment plasticity even in older ages.

The amount of deadwood and harvest residues left in actively managed stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production for commercial purposes (including the effort to meet a high demand of local population for fuelwood). The fir residues are frequently burned on site to prevent random fire risks.

The good quality of sites and participation of Silver fir on species composition lead to a higher ratio of roundwood in growing stocks in comparison to beech-dominated stands. Still, the percentage of roundwood remain lower than it was for FMM with the oak presence (shorter length of rotation).

FMM V Spruce-Fir-Beech – timber provision

The highly-productive species composition characteristic for forest managed by the model is partly negatively balanced by shorter rotation periods of Norway spruce (90-110 years) and somewhat less fertile sites (higher altitudes). Overall, the biomass production capacity is above-average approaching the environmentally given maximum.

The amount of deadwood and harvest residues left in stands is rather low (minimal requirements of FSC certification) due to effort maximally utilise of wood production. The Norway spruce and Silver fir harvest residues are frequently burned on site to prevent random fire risks.

The proportion of roundwood is the same as it is in mixed broadleaved stands due to higher participation of conifers with less stem form variability, good site conditions and average or less than the average length of rotation.

FMM VI Spruce-Fir-Beech – Close to nature

The favourable tree species composition managed to support species, dimensional and spatial variability and longer rotation ages (close to 160-180 years) initially determine high biomass productivity. On the other hand, the effort to maintain continual regeneration of stands lead to the selection of lower quality sites for the model application (to prevent the weed problem). Overall, the biomass production capacity of the model is still above average, although not to such level as it was in the previous case in the forest with similar species composition.

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The amount of deadwood left in the stands is a higher than in previous models, harvest residues are all left in the stand whereas harvest interventions have a character of selection cut and removal of harvest residues encounters a series of technical obstacles.

The longer rotation periods and assessment of tree felling maturity according to the target dimensions together with the high presence of conifers in tree species composition lead to increased proportions of roundwood that is favourable for carbon sequestration.

FMM VII Spruce - Timber

Spruce-dominated stands are very productive from biomass point of view. The spruce stands belonging to the described model are twofold: (i) spruce-dominated original stands growing at highest altitudes of the mountain range at relatively less fertile sites, (ii) secondary spruce monocultures out of its natural range growing on fertile sites at low and medium altitudes. The first group of stands has an only average predisposition for biomass production, but the second group is characteristic by high production capacity. Rotation ages are significantly shorter than previous cases (between 70-100 years) which partly dampen the previous positive assessment of C sequestration capacity.

The amount of deadwood and harvest residues left in stands is rather low (minimal requirements of FSC certification) due to effort completely utilise of wood production. The harvest residues are frequently burned on site to prevent random fire risks.

The proportion of roundwood is average, on the one hand, the spruce is fast-growing highly-productive species (especially on fertile sites), on the other hand, shorter rotations prevent to attain large dimensions of harvested trees.

FMM VIII Soil protection

The model cover a broad range of species compositions from lowest altitudes to highest parts of CSA, but generally on bad quality sites with very low to low fertility. Another characteristic feature of forest managed by the model is a very long rotation and slight selective interventions irrespective the tree species compositions to maintain the full cover of soils usually situated on steep slopes. That fact leads to the assessment of average or above average biomass production capacity when a very long rotation periods and almost absence of intentional harvests prevails the poor site quality in the final decision.

The amount of deadwood and harvest residues left in stands is high. All amount of natural deadwood and any harvest residues are left on the stand area to cover soil surface and prevent water or wind soil erosion.

The proportion of assortment classes was not performed, the commercial utilisation of harvested wood is possible only in rare cases due to high harvest and transportation costs and lower quality of wood.

FMM IX Nature Conservation

The model is applied to mixed highly-productive forests at medium or higher altitudes (exceptionally on worse sites) and supports natural, human non-disturbed growth of trees within its

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whole life cycle. The biomass and carbon sequestration capacity are very high. Moreover, all amount of deadwood remain in the ecosystem, and any human intervention is performed due to passive management. No wood products are produced. It follows the almost ideal carbon sequestration capacity of the model.

FMM X Water purification

The model is applied in the narrow protection zone of the water reservoir in artificial spruce monoculture. The production capacity of the site is average. The rotation periods are short (70-90 years) due to the lower ecological stability of nivelised, even-aged mono-specific forests.

No deadwood is allowed, all harvest residues are strictly removed from the stand (to protect water quality against N leak).

The proportion of roundwood on growing stock is lowered/below average in comparison to other models, primarily due to short rotation ages and maintaining the forest in high density negatively affecting the dimension of trees (high number of trees with smaller dimensions characteristic for over-dense stands).

Due to adverse effects of species composition and rotation ages in forest growing on average site quality, the absence of deadwood and relatively low proportion of roundwood on assortment structure the capacity of the model for carbon sequestration was assessed as slightly below average.

2.7.3. Cultural Services assessment

Assessment of cultural ES was based on expert judgement, no DSS or quantitative data has been used in the assessment. Panel of experts was created from ALTERFOR members. Assessment was based on Guidelines for Cultural Services from Marjanke and Geerten. We used the scale from 1 (worst provision of ES) to 7 (best provision of ES). In some cases comparison baseline was used. The baseline was represented by artificial spruce monoculture.

Sense of care – Amount of residue from harvesting and thinning per ha

7 is representing state, where no residue from harvesting and thinning are left in the stand. This state is in FMM IX, where any active human interventions are prohibited and in FMM X where all residue are strictly removed due possible contamination of drinking water by these residue. In FMM I to V are left some residue (branches), but most residue are removed or burned. This is prevention against insect and fungi spread and fire in forest stands.

Alteration – Area of final felling / Frequency of final felling

Clear cuts are not allowed in Slovakia. In FMM VII (spruce) are often disturbances on bigger area and result is similar to clear cuts. Rotation and regeneration periods in most FMMs are long, around 100 years and longer. Only in FMM X is rotation period shorter and also due possible damage due disturbances is the rank lower.

Natural value – Naturalness of forest stands

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According to guidelines FMM I, II, III, IV and V belongs to Semi natural forests. In each FMM could be differences according to site condition and to this related management and species mix. Therefore interval 3 – 5 was used. FMM IX is natural forest, on the other hand FMM X is relatively far from natural forest - artificial spruce monoculture with strict management rules. FMM VIII is used on extreme site condition (soil protection). Forest stands are under management with respect to site condition. But some parts could be without management in regard to high slope, or other conditions that limits management of these forests.

Wilderness – Amount of natural dead wood

In FMM I to VII is most of dead wood removed from forest stands. . This is prevention against insect and fungi spread and fire in forest stands. More dead wood is left in forest stand that are under certification. More dead wood is left in FMM VIII, because remove of this wood is sometimes not economically effective and dead wood (trees) increase stability of soil until new trees grow up. All dead wood is left in FMM IX, and all dead wood has to be removed in FMM X - possible contamination of drinking water.

Intrusion – Naturalness of forest edges / edge effects

Clear cuts are not allowed in Slovakia. Shelterwood management is used in most of FMMs. Linear (not natural) edges are created by roads and in neighbourhood of fields with intensive agricultural management. In higher altitude are more natural edges, due fact, that there is not so intensive human intervention. According to forest management are FMM I to V and VII with lower ranking.

Diversity – tree species diversity within stand

Species mix in forest stands of Slovakia could be rich, with more than tree species. FMM goals and possible species mix was used for assessment. Assessment was in regard to species richness according to Slovak conditions. The goal of FMM X is spruce monoculture without broadleaves. In FMM VII are other species mostly as admixture. In FMM VIII is number of tree species different according to altitude and site conditions.

Variety – Variation in tree size within stand / Age structure

The variety of commercial forest depends on species in forest stand. Oak in FMM I has less tree size variety than beech in FMM III. Higher tree size variety is in FMM IV, V and VI due mixture conifer and broadleaves species. In FMM VI is also high variety in age structure. Variety in FMM VII depends on altitude and site conditions. Highest variety in tree size and age is in FMM IX due prohibition of human activities. On other hand, lowest variation is in FMM X - spruce monoculture.

Spatial pattern – Variation in tree spacing within stand

In FMMs that are closer to natural conditions is spacing irregular. In FMM VIII is irregular spacing due site conditions. Regular spacing is used by artificial regeneration, but this regular spacing is lost through pre-commercial thinning, thinning and felling (FMM I to V). Regular spacing after artificial regeneration in FMM VII and X could be identify for longer time.

Openness – Visual penetration / density of obstruction

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The basic philosophy was how the “play of light and shadow” in forest stands is; leak of the light through crown canopy. Thinning from above is used in forest stands with broadleaves. Canopy is therefore opened. On other hand, in conifers (spruce monoculture) thinning from below is used. In even age oak stands under FMM I is higher uniformity than beech stands under FMM III. Oak is light demander and all gaps in crown canopy are quickly filled. In higher altitude (on hills) forest stands in FMM VII are more opened than in lower altitude. Frequent management actions in FMM VI leads to opening of canopy. Openness in FMM IX depends on altitude and to this related species in stand and growing phase of forest. Goal in FMM X is dense crown canopy. FMMs with mixed main tree species are more opened due different tree size. Forest stands in FMM VIII are more opened due extreme site conditions.

Visibility – Presence of understory in stand

From 1 – dense understory and therefore very low visibility in forest stand; to 7 – no understory in forest stand. Understory is not present in FMM X; shrubs and trees in understory are removed. Lot of trees in understory is in FMM VI – different age classes on small place. Lot of shrubs and trees in understory could be in FMM VIII, depends on altitude and site condition. Similar situation is also in FMM IX.

Historical richness – Age of trees in stands

Assessment was based on situation in Slovakia. Most of forest stands are even aged. Rotation and regeneration periods were used for this assessment. They are long, for some tree species more than 100; especially oak and fir. Rotation period in stands with spruce is from different reasons shortened (bark beetle calamity, damage due different harmful factors). Trees with different age in one forest stand (some more than 200 years) are in stands under FMM IX. Old trees are located also in stands under FMM VIII. Tree size as felling criterion is used in FMM VII. Trees with different age are in forest stands under FMM VII, but there are not over-mature trees.

Historical continuity – Age of current land-use

Historical research has to be done. Our assessment was based on assume, that most of forest land on CSA is longer than one rotation period (rank 7). After WWII began afforestation of agricultural and pasture land. The afforestation was made mostly with spruce – FMM VII. Water reservoir Hriňová was built in 1965. Around this reservoir are forest stands under FMM X.

Seasonal change – Presence of broadleaves

First criterion was presence of broadleaves. FMM X is spruce monoculture. Spruce in forest stands under management FMM VII could be mixed with some broadleaves. Second criterion was also mix of broadleaves and their different time of flowering and defoliation. Better rank is for FMMs with more broadleaves.

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Table 36 Cultural Services assessment, Slovakia

ES	Indicator	FMM									
		I – Oak (timber)	II - Oak-Beech (timber)	III – Beech (timber)	IV - Fir-Beech (timber)	V - Spruce-Fir-Beech (timber)	VI - Spruce-Fir-Beech (close-to-nature)	VII - Spruce (timber)	VIII - Soil protection	IX - No intervention	X - Water purification
Cultural	sense of care	5	5	5	5	5	6	5	6	7	7
	alteration	7	7	7	7	7	7	5 - 7	7	7	6
	natural value	3 - 5	3- 5	3 - 5	3 - 5	3 - 5	5 - 6	1 - 7	5 - 7	7	1
	wilderness	2 - 3	2 - 3	2 - 3	2 - 3	2 - 3	2	2 - 3	7	7	1
	intrusion	3 - 5	3- 5	3 - 5	3 - 5	3 - 5	4 - 6	3 - 5	4 - 6	7	2
	diversity	3	3	3	5	5 - 7	5 - 7	1 - 2	3 - 7	5 - 7	1
	variety	3	4	4	5	6	6	2 - 4	5	6 - 7	1
	spatial pattern	4	4	4	4	4	6	2	6	7	2
	openness	5	4	3	4	4	5	2 - 5	3 - 5	3 - 6	1
	visibility	4	5	5	5	5	1	5	1 - 4	2 - 5	7
	historical richness	4 - 6	2 - 4	2 - 4	3 - 5	3 - 5	5	1 - 3	7	7	1
	historical continuity	7	7	7	7	7	7	5 - 7	7	7	5
	seasonal change	5	6	5	5	4	4	1 - 3	5 - 7	3 - 6	1
Overall ranking		4-5	4-5	4-5	4-5	4-5	5	3-4	5-6	6-7	3

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2.7.4. Regulatory Services assessment

Every year the biggest damage to forests is caused by wind. In the winter, coniferous stands under the age of 50 are particularly vulnerable to severe wet snow and frost. Further, the stands are damaged to a greater extent by dryness, insects and fungi. Fire as a disturbance factor in Slovakia is not significant. In the period 1996-2014 wind damage reached 17.3 million. m^3 of wood with a majority share of spruce and beech (with peaks in 2004 and 2014), insect damage in the period 1993-2013 reached 24.7 million. m^3 of wood, in the period 1990-2014 damage caused by fungi was registered 4 mil. m^3 of wood.

Ranking is based on expert judgement of project research team, supported by earlier research from actual CSA. It is based on general characteristics as dominant tree species (root system type), presence of understory (stabilizing element) and forest stand structure (greater height variation). Ranking was in values from 1 to 5. 5 to most vulnerable forest stand on catastrophic event (non-native spruce stands as most vulnerable were used as comparison base).

Wind

The oak-dominated portions (FMM I) are stable with low occurrence of wind throw. On the contrary, in the stands where the dominant beech (FMM II-IV) occurs, the probability of the occurrence of the wind calamity increases. Landscapes with a larger proportion of different tree species (FMM V, VI and IX) and relatively greater height variability act as a stabilizing element. Also resistant are forest stands with soil protection function (FMM VIII), where thanks to the unfavorable natural conditions structure is resistant to wind - they are thinner, with a lower growth, etc. The most vulnerable are spruce stands usually with spruce dominance in the vicinity of water tanks (FMM X) and non-native spruce monocultures, which are at high risk of wind damage, but also include vertebrae relatively resistant to wind.

Snow and icing

Occurrence of damage caused by snow and icing mainly coincide with wind damage occurrence with exceptions in forest stands with beech dominance and higher presence coniferous tree species. In these forest stands occurrence increases. Broadleaves, especially beech (FMM II, III, IV, V, VI) are vulnerable to snow and icing damage in spring and fall when they are foliaged.

Pests

Oak forest stands (FMM I) are often damaged by Lymantria dispar as most important pest in oak forests. As beech dominance rises (FMM II), resistance increases. Spruce (FMM VII) is very often damaged by pests so stands where is present are less resistant with exception with spruce stands on mountain tops (in his production optimum) where is more resistant to disturbances. In stands with no intervention formed by a different mixture of tree species, especially occurrence of spruce, reduce resistance to pests (high damage of natural spruce stands in present protection land area). Stands with soil protection function mainly of deciduous trees, which are not intensely attacked by pests.

Aridity

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Forest stands with applied FMM I-IV are not endangered by drought, tree species composition is more resistant. Due to increased requirements for water content, spruce is especially sensitive to droughts. Nevertheless, in higher locations, lack of available water supply is not a problem. Due to higher precipitation and lower evaporation.

Fungi

Forest stands with intensive management are relatively resistant to fungal diseases, more frequent occurrence only in the case of the weakening of whole stands, where the fungus is occurred secondary. Fungal diseases in case of spruce monocultures are most frequent in non-native spruce stands in lower altitudes and in the vicinity of water tanks are least resistant.

Fire

Fire is not a very damaging factor in our conditions. It occurs especially in the vicinity of settlements, hiking trails and facilities, while working in the stand (burning residue from harvesting and thinning), and burning grass. In recent years there has been an increase in fires. The rating was 2 for FMM X and FMM VII (young conifers are more susceptible). The other FMM was assigned a value of 1.

Table 37 Regulatory services assessment

FMM	Vulnerability to catastrophic events						
	Wind	Snow and icing	Pests	Aridity	Fungi	Fire	Overall ranking
I - oak (timber)	2	2	3	2	2	1	2
II - oak-beech (timber)	3	3	2	2	2	1	2
III - beech (timber)	3	4	1	2	2	1	2
IV - fir-beech (timber)	3	3	1	2	2	1	2
V - spruce-fir-beech (timber)	2	2	2	3	2	1	2
VI - spruce-fir-beech (close-to-nature)	2	2	2	3	2	1	2
VII - spruce (timber)	2-5	3-5	3-5	3-5	2-5	2	3-5
VIII - soil (protection)	2	2-3	2-3	2-4	1-3	1	2-3
IX - no intervention	1-2	2-4	2-4	2-3	1-2	1	2-3
X - water purification	5	5	3-5	5	4-5	2	4-5

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2.7.5. Water related services assessment

In our assessment, we used the recommendations defined in the Guidelines for Water 2 with respect to the assessment of specific/partial ES (water yield, flood protection, water flow maintenance, erosion control, chemical conditions), usable indicators as well as parameters, data and metrics usable for future more detailed assessments using DSS. We emphasized manner of performing the final logging (the potential for clear-cuts creating), the tree species composition of the stands, the age and structure of the stands (age layers existence, brush undergrowth existence, complex stand structure) due felling age/rotation, type of final logging as well as the need for opening-up/road density for management/logging interventions performance. In all cases, we used a 7-degree qualitative scale 1 – for the worst ES performing, 7 – for the best ES performing.

The evaluation is very general with some simplifications, a generalisation of details and based on expert judgment. The values in Table 38 are the result of a multi-expert discussion as a consensus of a relative qualitative comparison with the application of basic assessment on the stand level. At the same time, we have begun consultations with forest hydrology experts to verify the validity of the Guidelines rules for local Slovak conditions, the existence of relevant domestic knowledge, and/or the need to correct the Guidelines recommendations. It can also be noted, that such an interim evaluation has highlighted a number of open questions and lack of precise knowledge in this area and provided interesting suggestions for future CSA stand assessment using DSS, as well as the need to take into account the context of more detailed assessments and/or assessment on landscape level**.**

Water yield

The logic applied - the forest uses water for transpiration, the older ones, the more, a run-off is higher from the clear-cuts, broadleaves are more water productive than the coniferous, the longer rotation, the water yield will be lower.

FMM I – Oak timber: Oak-dominated broadleaved forest, typical of the long rotation, the frequent occurrence of brush undergrowth, lower biomass production compared to European beech (75%).

FMM II – Oak-beech timber: Taking into account the effect of tree species composition.

FMM III – Beech timber: Beech-dominated broadleaved forest, shorter rotation compared to oak, more biomass than oak vegetation, typically without understory but with the possibility of low layer stand existence.

FMM IV – Fir-beech timber: Taking into account the effect of tree species composition.

FMM V – Spruce-fir-beech timber: Taking into account the effect of tree species composition.

FMM VI – Spruce-fir-beech close to nature: Taking into account the effect of tree species composition and higher management intensity.

FMM VII – Spruce timber: Pure coniferous vegetation, relatively short rotation, the possibility of using a small clear-cuts, a more intensive management.

FMM VIII – Soil protection: Typically the overall higher representation of the broadleaves, the creation of storeys.

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FMM IX – No Intervention: Natural, highly structured forests retain the most water.

FMM X – Water purification: Pure coniferous forest, short rotation, spruce with high water requirements.

Flood protection.

The logic applied - coniferous stands, long rotation and storeys formation were preferred, virgin forests protect the area from floods.

Water flow maintenance.

The logic applied - the more management/logging interventions, the higher run-off fluctuation during the year, Close-to-nature stands are typical of the different age stages that form the pitches/layers, in the stands, No management is similar to CTN but with a larger distribution in the space, for spruce dominant stands are typical clear-cut-like interventions (even as a result of calamities), the natural conditions of Protective Forests do not allow large water retention - they have shallow soils, overheated sites, etc.

Erosion control – corresponding with Flood protection

Chemical conditions

The logic applied - benefits are old trees, deciduous trees, long rotations and few management and logging interventions (risk of oil and fuel pollution, etc.)

FMM I – Oak timber: Oak-dominated broadleaved stands, long rotations.

FMM II – Oak-beech timber: Taking into account the effect of tree species composition.

FMM III – Beech timber: Beech-dominated broadleaved stands, shorter rotations.

FMM IV – Fir-beech timber: Taking into account the effect of tree species composition.

FMM V – Spruce-fir-beech timber: Taking into account the effect of tree species composition.

FMM VI – Spruce-fir-beech close to nature: Frequent management interventions, permanent soil cover.

FMM VII – Spruce timber: Unfavourable chemistry, shorter rotations in the lower vegetation zones.

FMM VIII – Soil protection: Prevailing of deciduous tree species, very long rotations, management interventions are not frequent and intensive.

FMM IX – No intervention: Occurrence of old trees, no management interventions, absolutely without application of chemicals.

FMM X – Water purification: Unfavourable chemistry, short rotations, frequent and intensive management interventions, even if it is forbidden to use mineral oils in a saw.

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Table 38 Water related ES assessment Slovakia

ES	Indicator	FMM									
		I – Oak (timber)	II - Oak-Beech (timber)	III – Beech (timber)	IV - Fir-Beech (timber)	V - Spruce-Fir-Beech (timber)	VI - Spruce-Fir-Beech (close-to-nature)	VII - Spruce (timber)	VIII - Soil protection	IX - No intervention	X - Water purification
Water	water yield	5	4	4	4	3	2	2	3	1	3
	flood protection	3	4	4	4	5	6	4 - 6	5	7	5
	water flow maintenance	3	4	4	4	5	7	2	4	7	2
	erosion control	3	4	4	4	5	6	4 - 6	5	7	5
	chemical condition	6	5	5	5	5	4	1 - 3	6	5 - 7	2
Overall ranking		4	4	4	4	5	5	3-4	5	5-6	3

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