ALTERFOR

Deliverable 1.1 – FMM descriptions (in report form)

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I. Forest Management Models (FMMs) description

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6. The Netherlands

6.1. Historical background of Dutch forest management

1945 – 1960s: Rationalized timber production

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

1960s – 1970s Dutch forestry in crisis

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

1970s – 1986: multifunctionality

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

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

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

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

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

1986 – 2000: marginalization of timber production

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

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

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

2000 – 2010: forests as part of nature

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

2010 – present: economization of ecology

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

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

6.2. Forest management approaches in the Netherlands

The following two sections are copied and adapted from the report INTEGRAL WP3.1 The Nether-lands

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

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

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

As regards the way management is carried out in IFM, IFM is related to concepts such as "nature oriented" and "pro silva" management (Province of Gelderland, s.a.), and the basic underlying con-ditions that are often considered, are (Province of Gelderland, s.a.):

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- Small-scale felling where possible (not more than 30 acres);
- Natural regeneration where possible;
- More horizontal and vertical structure;
- Mixing with indigenous species;
- Large proportion of standing or fallen dead trees;
- Old forests with substantial old trees.

However, this is where the shared understanding ends. Subject of debate are especially which functions should be integrated, how these functions should be realized, and on what level these functions should be combined.

No agreement exists about which functions should be integrated. In the descriptions of Van der Jagt et al. (2000) and Van Raffe et al. (2005), for example, of IFM, it is specifically mentioned that IFM focuses on the three most important functions: nature, recreation, and wood production. Klingen (2005) disagrees with this view. He states that IFM is about the integration of timber production and nature: these two functions are the two that conflict most and IFM solves this conflict success-fully. The recreational value of a forest has nothing to do with the management of the forest itself, but with the provision of recreational facilities, "such as the size of the parking place, and the condition of the walking tracks" (Klingen, 2005). In Klingen's view, therefore, recreation is not part of IFM. Other views include the combination of nature, and recreation (Van Blitterswijk et al., 2001), or add education as one of the functions of forest (PHN and Ministry of LNV, 2005).

Next to a debate on which functions should be integrated, there is also a discussion on how these functions should be realized. Forests fulfilling multiple functions at the same time is for some al-ready enough to be classified under multi-functional management or IFM (AVIH, 2016). However, several authors state that, because forests always fulfil different functions to a certain extent, an integration also implies that forest managers have concrete objectives for these three functions (Van Raffe et al., 2006; Van der Jagt et al., 2000). "It cannot be that a manager has only timber production objectives, with recreation and nature conservation only 'as a by-product'" (Van Raffe et al., 2006, p. 6).

Discussion also exists about the level on which the integration should take place. Some authors state that the three functions cannot be realized equally everywhere and therefore, main objectives per forest stand have to be set (in other words, integration on landscape level). Van Raffe et al. (2006) distinguish between IFM (integration of functions on stand level) and multi-functional management (integration of functions on landscape level). This means that IFM is always multifunction-al-management.

The following two sections are copied and adapted from the article of Hoogstra-Klein, Brukas and Wallin, currently under review with Ecology and Society:

Despite all the discussions on what the concept entails, most forest managers, when asked, would indicate to follow the ideas of Integrated Forest Management (IFM, Geïntegreerd Bosbeheer). In a survey of Blitterswijk et al. (2001) among 413 Dutch forest owners and managers (with areas > 5 ha), 75% of the respondents indicated to apply IFM. The survey, however, showed that in practice "integrated forest management is used in such a broad way that it means different things to every-

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one" (Van Blitterswijk et al., 2001, p. 53), with, a.o., differences in functions integrated, the balance between the functions, and the level of integration.

The results of the study of Van Blitterswijk et al. (2001) are confirmed by the interviews with the forest managers in the INTEGRAL project. The practices of Dutch forest managers can all classified as multiple-use in the sense that different functions are combined, but the practices are diversified: in the functions combined (varying between two and six functions per owner), the focus on these functions (from almost equal focus on functions to almost single use when one function is favoured), and the spatial strategies (from land zoning to integration on stand level, and the combination of these strategies within management units).

6.3. Dutch Forest management approaches for the ALTERFOR project

As the forest management practices in the Netherlands are manifold and not classified according to forest management models, we base our insights on actual forest management practices on:

1) the data gathered in the Sixth Netherlands Forestry Inventory (NBI6), which has been conducted by Alterra, Probos, Silve and Bureau Daamen, commissioned by the Ministry of Economic Affairs (Schelhaas et al., 2014),

2) the Dutch Subsidy Scheme Nature and Landscape (SNL Subsidy Natuur en Landschap),

3) the insights the EFISCEN SPACE model (our DSS) provides.

6.4. Sixth Netherlands Forestry Inventory, NBI6

The Netherlands Forestry Inventory is held every ten years and provides information on the state of forests in the Netherlands and the developments since previous inventories. One of the topics of inventarization is the "management approach" as found at the different sample plots that were part of the inventory. Based on these approaches and the description of these approaches, we selected the ten approaches that a) rank highest as regards the cover and b) cover together 90% of the total forest area. These are listed in Table 28.

Table 25. Management approaches distinguished for the Netherlands, based on data from the 6th Nether-lands Forestry Inventory (Schelhaas et al., 2014).

Dutch name	English translation	Description	%
Grootschalig vlaktegewijze opstand, gelijkjarig	Large-scale management, with regeneration felling, in even-aged forests	Average dbh > 5cm; even-aged on scale > 0,5 ha; cover of understory/2nd canopy layer (dbh > 5 cm) < 50% or basal area understory/2nd canopy layer < 20%	59%
Grootschalig vlaktegewijze opstand, ongelijkjarig	Large-scale management, with regeneration felling, in uneven-aged forests	Average dbh > 5cm; even-aged on scale > 0,5 ha; cover of understory/2nd canopy layer (dbh > 5 cm) > 50% or basal area understory/2nd canopy layer > 20%; age difference with main canopy layer at least 20 years.	14%
Kleinschalig vlaktegewijze	Small-scale management, with	Average dbh > 5cm; even-aged on scale < 0,5 ha; cover of understory/2nd canopy layer	3.2%

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Dutch name	English translation	Description	%
opstand, gelijkjarig	regeneration felling, in even-aged forests	(dbh > 5 cm) < 50% or basal area understory/2nd canopy layer < 20%	
Kleinschalig vlaktegewijze opstand, ongelijkjarig	Small-scale management, with regeneration felling, in uneven-aged forest	Average dbh > 5cm; even-aged on scale < 0,5 ha; cover of understory/2nd canopy layer (dbh > 5 cm) > 50% or basal area understory/2nd canopy layer > 20%; age difference with main canopy layer at least 20 years	1.6%
Kleinschalig ongelijkjarig bos (uitkap)	Single-tree selection system	Average dbh > 5 cm; un-even aged; mixture of age classes on scale < 0,1 ha	1%
Korte omloophout	Short rotation system	Short rotation forest of willow or poplar; mechanically harvested; rotation < 5 years	1.8%
Hakhout/griend	Coppice system	Coppice of hardwoods; on dry soils; rotation > 5 years willow or poplar; mostly on wet soils, rotation < 5 year	
Park-landgoedbos	Parks and recreation	Open forests; architectural design	2.5%
Recreatiebos			
Spontaan bos	Spontaneous forests	-	6.6%
Overig	Other	-	10%
TOTAL			100%

6.5. Subsidy Scheme Nature and Landscape SNL

The Subsidy Scheme Nature and Landscape (SNL) is based on a nature and landscape index. This is a classification system that "aims to unite all management and policy systems in a single system" (CBS, PBL, Wageningen UR (2014)). As described by the CBS, PBL, Wageningen UR (2015):

"Index NL is a typology of natural areas, describing their nature in terms of management types. These management types can be used to regulate the management of natural areas, and constitute a basis for agreements between the provincial authorities and the area managers about tar-gets and resources. A management type is therefore not a specific form of management, such as integrated forest management, but a type of natural area which requires a particular form of management."

For the purpose of management, natural areas in the Netherlands have been categorised into 17 so-called 'nature types', which are based on a combination of abiotic conditions (water balance, trophic status, and environment) and the management carried out. The 17 nature types are subdivided into 47 management types, comprising a description of a specific type of natural habitat, an average package of management measures, with a standardised cost price (CBS et al., 2015).

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Four nature types with 13 management types relate to the forests in the Netherlands (Portaal Natu-ur en Landschap, 2015 – own translation):

N14. Wet forest
- N14.01 Riverine forest
- N14.02 Bog forest
- N14.03 Horbeam- and ash forest

N15. Dry forest
- N15.01 Dune forest
- N15.02 Pine-, oak-, and beech forest

N16. Forest with timber production
- N16.01 Dry forest with timber production
- N16.02 Wet forest with timber production

N17. Forest with high cultural value
- N17.01 Wet coppice and middle forest
- N17.02 Dry coppice
- N17.03 Park and stinze forest
- N17.04 Duck decoy forest
- N17.05 Osier
- N17.06 Coppice on slopes

For all these types, descriptions exist of what the type entails (including historic background, species, soil type, allowed level of harvesting, etc.). The management obligations are in all cases limited to the following (Portaal Natuur en Landschap, 2015 – own translation): "The manager needs to maintain the type. How to do this, is up to the manager."

6.6. European Forest Information SCENario model SPACE (EFISCEN SPACE)

The European Forest Information SCENario model SPACE (EFISCEN SPACE) is a large-scale forest scenario model that projects forest resource development on regional to European scale. For the Netherlands a version is available, which makes use of the national forest inventory data (NBI). The model is able to simulate forest development and management for different scenarios at the scale of $1km^2$ (Verkerk et al., 2016).

6.7. FMMs defined for the Dutch forest sector

Based on the three sources described above, we defined 9 FMMs for the Dutch forest sector (Table 29).

Table 26: FMMs defined for the Dutch forest sector in the frame of the ALTERFOR project

FMM	Description	Percentage of area
FMM1	NatureForest Broadleaved	10.4%
FMM2	NatureForest Oak	4.6%
FMM3	NatureForest Pine	7.4%
FMM4	NatureForest Conifers	12.1%
FMM5	Production Forest Broadleaved	11.0%

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FMM6	Production Forest Oak	14.1%
FMM7	Production Forest Conifers	18.3%
FMM8	Production Forest Pine	7.9%
FMM9	Other Forest	14.2%
Total		100%

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II. Ranking of Ecosystem Services (ES)

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2.5. The Netherlands

Initial ranking of the Forest Management Models for the Dutch Case study area in ALTERFOR

Based on the data of the NBI6 and some additional GIS and qualitative assessments by the authors, preliminary assessments of the ecosystem service indicators were made for five ecosystem services: Biodiversity, Cultural Services, Water, Carbon and Risk Reduction.

2.5.1. Approach taken

When possible, the guidelines were followed explicitly. Because the FMMs proposed are data-based, and no official schedules for the application of the FMMs exist, we assess the ecosystem service indicators on the FMMs using a space for time replacement by averaging over all observed plots in the NBI6. Attributes that cannot be assessed based on the NBI6 are qualitatively assessed at FMM level.

All indicators are build up from a number of concepts, that can be measured along one or several dimensions. These dimensions are represented by one or several attributes. To avoid overrepresentation of concepts with multiple dimensions and attributes, each indicator is calculated as the unweighted average of the underlying concepts, which is turn is the unweighted average of the dimensions it is measured along, which is turn are the unweighted average of their attributes.

For many of the attributes it is difficult to identify absolute boundaries, or the observations only occur in a limited range of the possible extend. Other attributes are indicated by index values, or fractions with very clear upper and lower boundaries. To be able to calculate averages, and because the current calculation is only intended for an initial ranking of the FMMs, all observed attribute values were rescaled and normalised using the formula:

$$\frac{x - \mu}{2\sigma}$$

Which was subsequently truncated to the range [0,1]. As a result outliers in the observations (e.g. the extreme 5%) are cut-off and the average for all observations is set to 0.5. As a consequence of skewed observations this can lead to strange cut-offs. This is to be solved later, but the current approach will do for this assessment.

Additional data used

Next to the data reported in the NBI6 database, some additional datasets were used.

1. The age of forest-landuse was assessed using a number of (historical) landuse maps: HGN1900[1], HGN1960, HGN1970, HGN1990, LGN4, LGN6 and LGN7[2]

[1] http://www.wur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/Environmental-Research/Faciliteiten-Producten/Kaarten-en-GIS-bestanden/Historisch-Grondgebruik-Nederland.htm

[2] http://www.wur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/Environmental-Research/Faciliteiten-Producten/Kaarten-en-GIS-bestanden/Landelijk-Grondgebruik-Nederland.htm

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2. Carbon calculations and coefficients used therein were based on the Dutch reporting for UNFCCC and Kyoto protocol (Arets et al. 2015)
3. Vulnerability classes for individual trees were loosely based on Schelhaas et al. (2010) in combination with the Dutch growth and yield tables of Jansen et al. (1996)

2.5.2. Ecosystem Service calculation

The full overview of subindicators used and how they are hierarchically nested into attributes, dimensions and concepts into indicators is given in Table 30. Most subindicators are derived from the NBI6. Specific additional calculations are explained per indicator below. The FMMs used are based on the SNL subsidy system in the Netherlands. Three levels of protection are recognised: Nature area (SNL Nature forest), Production area (SNL Production forest) and Other (no SNL, or a non-forest SNL). For both the protection status and the felling frequency, default values are attached to the subsidy level, rather than at individual FMM level. Values are shown in Table 31.

Biodiversity

The guidelines were followed as explicitly as possible. Based on FSC and SNL guidelines, exotic species were: Abies alba, Abies grandis, Acer platanoides, Chamaecyparis spp, Exotic broadleaved, Larix decidua, Larix kaempferi, Other Abies, Other conifers, Other picea, Other pinus, Other Quercus, Picea abies, Picea omorika, Picea sitchensis, Pinus contorta, Pinus nigra laricio, Pinus nigra nigra, Pinus pinaster, Pinus rigida, Pinus strobus, Platanus spp, Prunus serotina, Pseudotsuga spp, Quercus rubra, Robinia pseudoacacia, Tsuga spp.

Carbon

Plotlevel above and below ground biomass is calculated using the main tree species and the total volume of timber reported for the plot, following the Dutch LULUCF guidelines for UNFCCC and Kyoto (Arets et al. 2015). No forest soil carbon pools are reported in the Netherlands, due to lack of data. Harvested wood products are neglected in this assessment because it no data is available on the differential allocation to the different HWP categories for the different FMMs.

Cultural Services

The guidelines were followed as explicitly as possible. Landuse age was determined using the available maps from the Historical landuse and landuse maps for the Netherlands (HGN and LGN series). These maps are the most consistent set available for the years 1900, 1960, 1970, 1980, 1990, 2000, 2004, 2009. A classification was made based on the number of consequetive maps (starting from the most recent) the pixel that a NBI6-plot is located on was classified as forest.

Risk Reduction

Two risks are taken into account: risk of wind damage and risk of fire damage. In general risk can be assessed using three dimensions: hazard, vulnerability and exposure. For the current assessment only vulnerability is assessed. Hazard is mainly external to the FMM applied (in the case of wind and fire risk they are mostly climatic, Schelhaas et al. 2010). Exposure will be added in a later stadium.

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Vulnerability is assessed through three attributes: tree level vulnerability, stand susceptibility and stand structure. For the tree level vulnerability, the vulnerability of individual trees in the stand is assessed using a diameter class index loosely based on Schelhaas et al. (2010), Table 30. Stand susceptibility to wind damage is expected to be indicated by the dominant height of the stand, to fire damage is expected to be indicated by the understory cover. Stem density is taken as a stand structural attribute dampening the vulnerability to wind damage. The Gini index on basal area is taken as stand structural attribute dampening the vulnerability to fire damage (with less variability decreasing the vulnerability).

Water

Grazing data were not available. Grazing in forests is mainly due to game (roe deer, red deer, boar) and (semi) free roaming cattle and horses. Forest fire data are sparsely available, but forest fire frequencies are generally low. No FMM specific data are available. Chemicals are rarely used in the Dutch forests.

Table 30 overview of indicators, concepts, attributes and subindicators.

Indicator	Concept	Dimension	Attribute	Subindicator	Direction	Data source
Biodiversity	Composition	Diversity	Tree species diversity	Shannon evenness	positive	NBI6
Biodiversity	Composition	Local species pool	Proportion of exotics	Basal area share of exotic species	negative	NBI6
Biodiversity	Structure	Deadwood	All deadwood	Total deadwood	positive	NBI6
Biodiversity	Structure	Deadwood	Large deadwood	total standing deadwood with DBH > 30 cm	positive	NBI6
Biodiversity	Structure	Large trees	Volume of large trees	Total volume of trees with DBH > 30 cm	positive	NBI6
Biodiversity	Structure	Large trees	Basal area of large trees	Total basal area of trees with DBH > 30 cm	positive	NBI6
Biodiversity	Structure	Structural diversity	Volume diversity	Gini index calculated over volume of trees	positive	NBI6
Biodiversity	Structure	Structural diversity	Basal area diversity	Gini index calculated over basal area of trees	positive	NBI6
Biodiversity	Disturbance	Harvest	Frequency of final fellings	Frequency of final fellings	negative	Default
Biodiversity	Disturbance	Harvest	Area of felling	Stand area index	negative	NBI6
Biodiversity	Disturbance	Harvest	Proportion removed	Harvest / standing stock	negative	NBI6
Biodiversity	Protected area	Protected area	Protection status	Protection index	negative	Default
Cultural	Stewardship	Sense of care	Harvest residues	Residue index	negative	Default
Cultural	Naturalness	Alteration	Area of felling	Stand area index	negative	NBI6
Cultural	Naturalness	Alteration	Frequency of final fellings	Frequency of final fellings	negative	Default
Cultural	Naturalness	Natural value	Naturalness of the stand	Naturalness index	positive	Default
Cultural	Naturalness	Wilderness	Amount of Deadwood	Total deadwood	positive	NBI6

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Indicator	Concept	Dimension	Attribute	Subindicator	Direction	Data source
Cultural	Naturalness	Intrusion	Naturalness of forest edges	Forest edge index	positive	Default
Cultural	Complexity	Diversity	Tree species diversity	Shannon evenness	positive	NBI6
Cultural	Complexity	Variety	Tree size variation	Gini index calculated over basal area of trees	positive	NBI6
Cultural	Complexity	Spatial pattern	Tree spacing	Tree spacing index	positive	Default
Cultural	Visual scale	Openness	Visual penetration	Stem density	negative	NBI6
Cultural	Visual scale	Visibility	Understory density	Understory index	negative	NBI6
Cultural	Historicity	Historical richness	Age of the stand	Stand age	positive	NBI6
Cultural	Historicity	Historical continuity	Age of land use	Land use age index	positive	NBI6/GIS
Cultural	Ephemera	Seasonal change	Presence of broadleaved	Basal area share of broadleaved species	positive	NBI6
Water	Water yield	Harvest	Proportion removed	Harvest / standing stock	positive	NBI6
Water	Water yield	Species composition	Presence of broadleaved	Basal area share of broadleaved species	positive	NBI6
Water	Flood protection	Harvest	Proportion removed	Harvest / standing stock	negative	NBI6
Water	Flood protection	Grazing	Intensive grazing	Intensive grazing index	negative	Default
Water	Flood protection	Burning	Frequency of fires	Fire frequency index	negative	Default
Water	Flow maintenance	Harvest	Proportion removed	Harvest / standing stock	positive	NBI6
Water	Erosion control	Burning	Frequency of fires	Fire frequency index	negative	Default
Water	Erosion control	Grazing	Grazing	Grazing index	negative	Default
Water	Chemical condition	Chemicals	Amount of chemicals used	Chemical use index	negative	Default
Water	Chemical condition	Harvest	Proportion removed	Harvest / standing stock	negative	NBI6
Water	Chemical condition	Burning	Frequency of fires	Fire frequency index	negative	Default
Water	Chemical condition	Species composition	Presence of broadleaved	Basal area share of broadleaved species	positive	NBI6
Water	Chemical condition	Forest age	Age of the stand	Stand age	Optimum	NBI6
Carbon	Carbon stock	Biomass	Aboveground Biomass	Total carbon in aboveground biomass	positive	NBI6
Carbon	Carbon stock	Biomass	Belowground Biomass	Total carbon in belowground biomass	positive	NBI6
Carbon	Carbon stock	Biomass	Deadwood mass	Total carbon in deadwood	positive	NBI6
Risk reduction	Wind risk	Vulnerability	Tree vulnerability	Average wind vulnerability index per tree	negative	NBI6

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Indicator	Concept	Dimension	Attribute	Subindicator	Direction	Data source
Risk reduction	Wind risk	Vulnerability	Stand susceptibility	Dominant height	negative	NBI6
Risk reduction	Wind risk	Vulnerability	Stand structure	Stem density	positive	NBI6
Risk reduction	Fire risk	Vulnerability	Tree vulnerability	Average fire vulnerability index per tree	negative	NBI6
Risk reduction	Fire risk	Vulnerability	Stand susceptibility	Understory index	negative	NBI6
Risk reduction	Fire risk	Vulnerability	Stand structure	Gini index calculated over basal area of trees	positive	NBI6

Table 31 Qualitatively assessed default values per FMM

FMM	Felling residues	Felling fre-quency	Natural-ness stand	Natural-ness edges	Tree spacing	Grazing	Intensive Grazing	Burning fre-quency	Che-micals	Pro-tection status
FMM1	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM2	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM3	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM4	0.75	0.9	0.66	0.66	0.66	0.25	0	0.01	0	0.75
FMM5	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM6	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM7	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM8	0.25	0.33	0.33	0.33	0.33	0.25	0	0.01	0	0.25
FMM9	0.5	0.5	0.5	0.5	0.5	0.25	0	0.01	0	0.5

Table 32 Vulnerability per diameter class per species group for wind and fire damage.

Concept	Species group	DBH<10	DBH<20	DBH<30	DBH<40	DBH<50	DBH>50
wind	conifers	1	1	2	3	4	4
wind	populus	1	2.5	4	4	4	4
wind	broadleaved	1	1	1.5	2	2.5	3
wind	picea	1	3	5	6	6	6
fire	conifers	3	2.5	2	1.5	1	1
fire	broadleaved	2	1.5	1.5	1	1	1
fire	pinus	4	3	3	2	2	2

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2.5.3. Results

In total 3077 plots are used in this assessment (which is the total national forest inventory of the Netherlands).

The final results are shown in Figure 37 and **Fehler! Verweisquelle konnte nicht gefunden werden.**. From these results the two oak FMMs rank first and second, while the coniferous forests rank lowest. In general the production forests rank lower than the nature forests.

Looking in more detail per Ecosystem service indicator, we see that biodiversity is mostly associated with the subsidy type, and the other services are mostly associated with the main species of the FMM, with strong interactions for some (e.g. water, carbon) and less interactions for others (e.g., risk reduction).

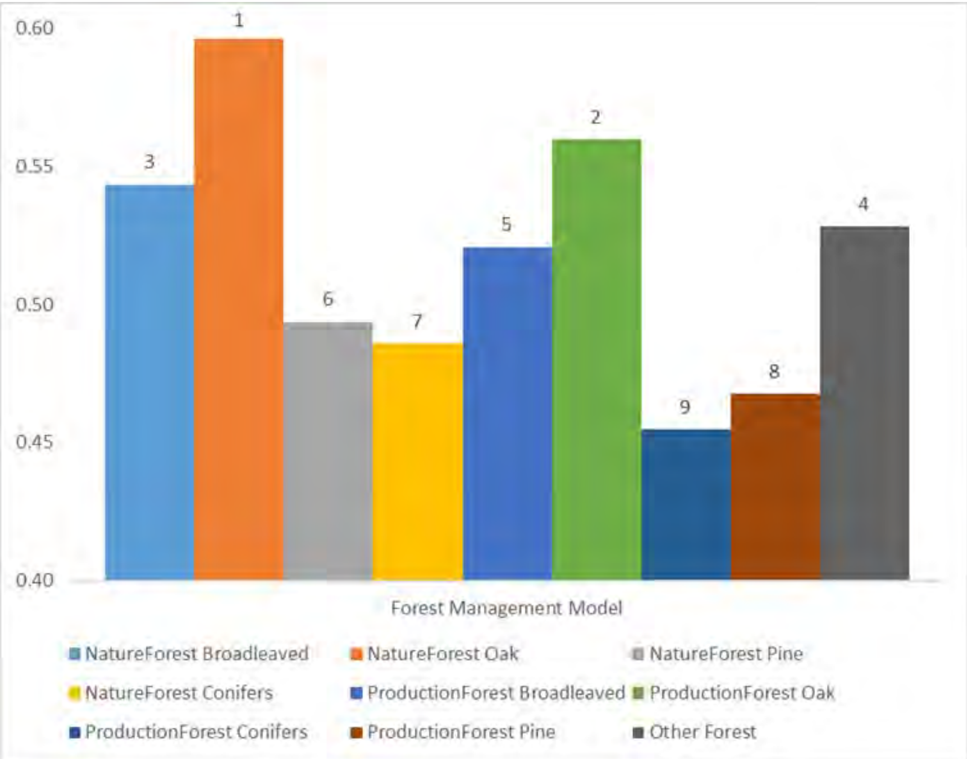

Figure 37 Final ranking of the FMMs over all Ecosystem services. Y-axis shows the average index, numbers above the bars show rank of the FMM.

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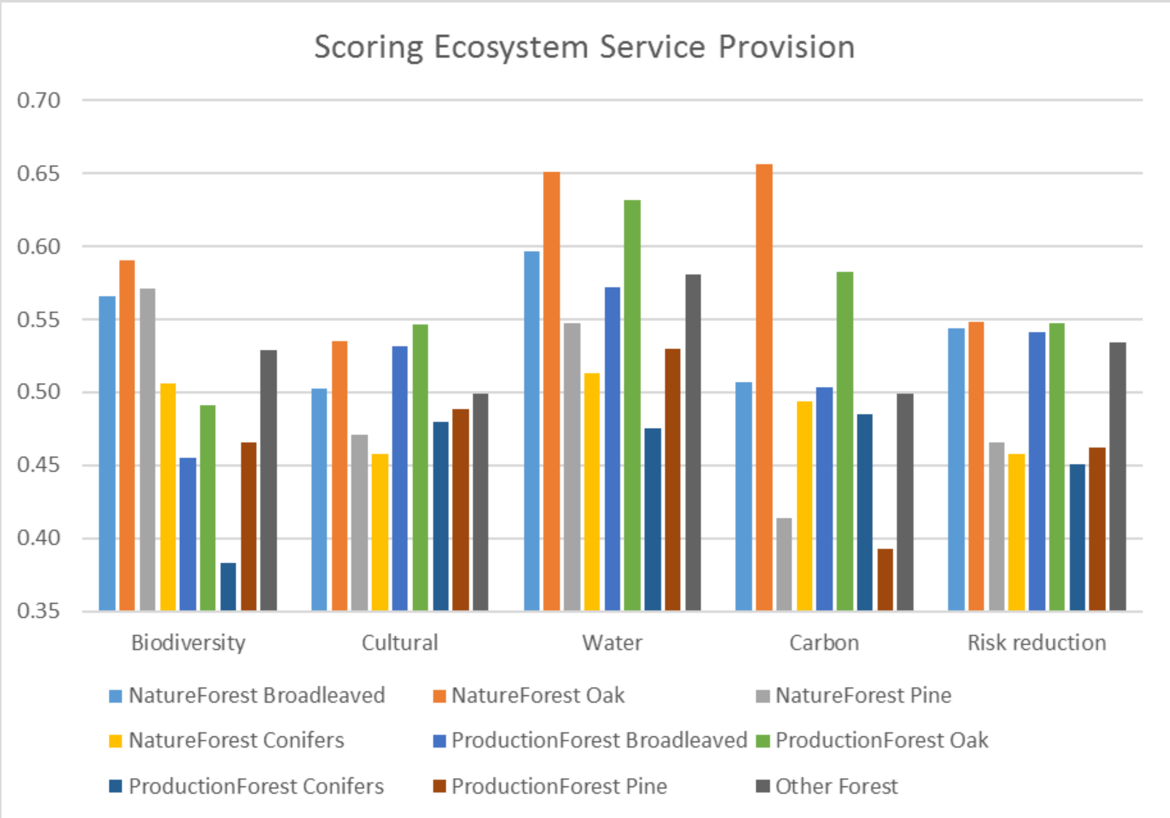

Figure 38 Final ranking of the FMMs over all Ecosystem services. Y-axis shows the average index, numbers above the bars show rank of the FMM.

2.5.4. References

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