Ministry of Agriculture, Nature and Food Quality of the Netherlands

National Forestry Accounting Plan

Submission of the Forest Reference Level 2021-2025 for the Netherlands

3 December 2019

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Samenvatting

Op 30 mei 2018 hebben het Europees Parlement en de Raad van de Europese Unie Verordening (EU) 2018/841 aangenomen inzake de opname van broeikasgasemissies en -verwijderingen door landgebruik, veranderingen in landgebruik en bosbouw (Land Use Land Use Change and Forestry, LULUCF) in het klimaat- en energiekader 2030 (EU 2018). Deze zogenaamde LULUCF-verordening bevat de regels over hoe de emissies en verwijderingen van broeikasgassen voor de verschillende landgebruikscategorieën in de LULUCF sector afgerekend worden. Uitgangspunt daarvoor zijn de emissies en verwijderingen die in de nationale broeikasgasrapportages aan de VN klimaatconventie worden gerapporteerd.

Volgens de LULUCF-verordening moet de afrekening van emissies en verwijderingen uit beheerde bosgebieden, worden uitgevoerd tegen een referentieniveau voor bossen (Forest Reference Level, FRL) voor elk van de perioden 2021-2025 en 2026-2030 zoals uiteengezet in artikel 8 van de LULUCF-verordening. Conform artikel 8.3 van de verordening heeft Nederland vóór 31 december 2018 een nationaal boekhoudplan voor bosbouw (National Forestry Accounting Plan, NFAP) ingediend met daarin het referentieniveau voor bossen en een onderbouwing daarvan. In het voorjaar van 2019 heeft de Europese Commissie in overleg met deskundigen uit EU-lidstaten een technische beoordeling van de ingediende plannen en FRLs van alle lidstaten uitgevoerd en aanbevelingen voor herzieningen gedaan.

Dit rapport is de uiteindelijke herziene versie van het eerste nationaal boekhoudplan voor bosbouw van Nederland met daarin de aanbevelingen uit de technische beoordeling verwerkt. Het bevat het gevraagde referentieniveau voor bossen van Nederland voor de eerste 5 jaar periode van 2021 tot 2025. Bijlage 3 geeft informatie over hoe de aanbevelingen uit de technische beoordeling zijn verwerkt in deze herziene versie van de NFAP.

Dit rapport beschrijft de methodologie die is gebruikt voor het projecteren van het referentieniveau voor bossen en hoe rekening is gehouden met de criteria voor het bepalen van dat niveau zoals vastgelegd in artikel 8 en bijlage IV van de EU LULUCF-verordening. Daarnaast wordt de consistentie tussen de methoden en gegevens zoals die gebruikt zijn voor het bepalen van het FRL en die zoals ze gebruikt worden voor de rapportage van beheerde bosgebieden (bos dat bos blijft) in de nationale inventarisatie van broeikasgasemissies. Die rapportage gebeurt door middel van het indienen van een National Inventory Report (NIR – zie Coenen et al. 2018).

Het FRL omvat de koolstofreservoirs die ook zijn opgenomen in de gerapporteerde nationale inventarisatie van broeikasgasemissies voor bos dat bos blijft en voor geoogste houtproducten (Harvested Wood Products, HWP). Dit zijn boven- en ondergrondse biomassa, dood hout en geoogste houtproducten. Omdat in de NIR wordt gerapporteerd dat emissies en verwijderingen in minerale en organische bodems en in de strooisel laag niet voorkomen werden deze ook niet meegenomen in de bepaling van het FRL (zie paragraaf 2.1).

Het referentieniveau voor bossen wordt uitgewerkt in een twee stappen (zie ook paragraaf 3.1). In de eerste stap wordt de staat van het bos vanuit de 6de Nationale Bosinventarisatie (NBI6) geprojecteerd naar drie momenten in de toekomst, te weten: 1 januari 2021, 2026 en 2031, die vervolgens kunnen worden gezien als virtuele bosinventarisaties. De projecties houden rekening met de ontwikkeling van dynamische leeftijdgebonden boskenmerken en bosbeheerpraktijken zoals die uit de referentieperiode met behulp van de stratificatie van beheerde bosgebieden werd afgeleid (paragraaf 3.2).
Om consistentie te bereiken tussen de koolstofreservoirs binnen het FRL hebben we een uitgebreid bossenmodel (EFISCEN space) toegepast dat de ontwikkelingen van de bossen op plotsniveau projecteert. Daarbij worden de verschillende koolstofreservoirs die in het FRL worden beschouwd, zoals levende biomassa, dood hout en HWP (via oogsten) in relatie tot elkaar geprojecteerd, afhankelijk van groei-, mortaliteit- en oogstfuncties (zie paragraaf 3.3).

Vervolgens werden de geprojecteerde volumes van de staande voorraad vertaald naar biomassa- en koolstofvoorraden (zie paragraaf 3.3.10). Om de consistentie met de NIR-resultaten te garanderen, werden deze geprojecteerde boskenmerken op precies dezelfde manier verwerkt als normaal met de informatie uit de gemeten bosinventarisaties wordt gedaan voor de berekeningen in de NIR.

In de tweede stap werden vervolgens de geprojecteerde koolstofvoorraden die in de eerste stap waren berekend voor 1 januari 2021, 2026 en 2031 in het LULUCF-systeem gebruikt. Daarin worden voor de verschillende reservoirs de veranderingen in koolstofvoorraden tijdens de periode 2021-2025 doorgerekend. De uitkomsten daarvan werden vervolgens vertaald in CO_2-eq. emissies en worden bij elkaar gevoegd om de emissies en verwijderingen van broeikasgassen voor het FRL te bepalen.

Daarnaast werd de veranderingen in de HWP koolstofvoorraad in de periode 2021-2025 op dezelfde manier bepaald als gedaan wordt voor de NIR (zie paragraaf 3.3.10). Daarbij wordt de gemiddelde relatieve verdeling tussen brandhout en de verschillende HWP-categorieën zoals waargenomen tijdens de referentieperiode toegepast op de met het model geprojecteerde totale rondhoutoogst.

Het Nederlandse referentieniveau voor bossen voor de periode 2021-2025 is -1.531.397 ton CO_2-equivalenten per jaar, waarbij het HWP-reservoir 6.973 ton CO_2-eq. per jaar. Als wordt aangenomen dat er sprake is van onmiddellijke oxidatie van HWP, zou het referentieniveau uitkomen op -1.524.424 ton CO_2-eq. per jaar. De negatieve emissies geven aan dat het hier om een sink gaat.

Summary

On 30 May 2018 the European Parliament and the Council of the European Union adopted Regulation (EU) 2018/841 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (LULUCF) in the 2030 climate and energy framework (EU 2018). This LULUCF regulation provides the rules for accounting of the emissions and removals from the land use categories that are reported to the United Nation Framework Convention on Climate Change (UNFCCC) by EU Member States.

According the LULUCF regulation accounting of emissions and removals from managed forest land, i.e. the land that under the UNFCCC national inventory reporting is included as “forest land remaining forest land”, should be done against a Forest Reference Levels (FRL) for each of the compliance periods 2021-2025 and 2026-2030 as detailed in article 8 of the LULUCF regulation. In accordance with article 8.3 of the regulation the Netherlands submitted its National Forestry Accounting Plan before 31 December 2018. In the spring of 2019, the European Commission, in consultation with experts from EU Member States, carried out a technical assessment of the submitted plans and FRLs from all Member States and made recommendations for revisions.

This report is the final revised version of the National Forestry Accounting Plan of the Netherlands, incorporating the recommendations from the technical assessment. It includes the requested Forest Reference Level of the Netherlands for the first 5 years compliance period from 2021 to 2025. Appendix 3 gives information on how the recommendations from the technical assessment have been addressed in this final version of the NFAP.

This report describes the methodology applied for projecting the forest reference level and how the criteria for determining the FRL as set in article 8 and Annex IV of the EU LULUCF Regulation have been taken into consideration. It also shows the consistency between the methods and data used to determine the FRL of Managed Forest Land (MFL) and those used for reporting of managed forest land (FL remaining FL) in the national greenhouse gas (GHG) inventory.

The FRL includes the pools that are also included for reporting FL remaining FL and harvested wood products (HWP) in the national GHG inventory and. These are above- and below-ground biomass, dead wood and harvested wood products. In the national GHG inventory emissions and removals in mineral and organic soils and the litter pool are reported to be not occurring. Therefore these were also included as not occurring in the FRL (see Section 2.1).

The forest reference level is elaborated in a two-step approach (also see Section 3.1). In the first step the state of the forest is projected from the 6th National Forest Inventory (NFI-6) forward to three points in the future: 1 January 2021, 2026 and 2031 which then can be seen as virtual forest inventories. The projections consider the development of dynamic age related forest characteristics and forest management practice from the reference period using the stratification of managed forest land as detailed in Section 3.2. In order to achieve consistency between the carbon pools included in the FRL we applied a comprehensive modelling framework (EFISCEN space) projecting the developments of the forests at plot level, in which the different pools that are considered in the FRL, living biomass, dead wood and HWP (harvests) were projected in relation to each other depending on increment, mortality and harvesting functions (see Section 3.3).

Subsequently projected growing stock volumes were translated into biomass and carbon stocks (see Section 3.3.10). To guarantee consistency with the NIR results, these projected states of the forest were processed in exactly the same way as the actual information from the National Forest Inventories is processed for the calculations in the national GHG inventory.

In the second step then the projected carbon stocks calculated in the first step were used in the LULUCF system to calculate carbon stock changes for the various carbon pools during the compliance periods. The resulting outcomes then were translated into CO_2 eq. emissions and together added to the FRL.

Additionally harvests were used to assess carbon stock changes in HWP in the same way as the approach used for the NIR to calculate HWP from actual harvesting trends (see Section 3.3.10). The distribution of the overall harvest over fuel wood and the different HWP categories of industrial round wood was based on their relative distribution during the reference period.

The forest reference level of the Netherlands for the period 2021-2025 is -1,531,397 tonnes of CO_2 eq. per year, in which the HWP pool constitutes of -6,973 tonnes of CO_2 eq. per year. If instantaneous oxidation of HWP was assumed, the forest reference level would be -1,524,424 tonnes of CO_2 eq. per year.

1 General Introduction

1.1 General description of the Forest Reference Level of the Netherlands

On 30 May 2018 the European Parliament and the Council of the European Union adopted Regulation (EU) 2018/841 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (LULUCF) in the 2030 climate and energy framework (EU 2018). This regulation provides the rules for accounting of the emissions and removals from the land use categories that are reported to the United Nation Framework Convention on Climate Change (UNFCCC) by EU Member States. In this text this regulation 2018/841 is referred to as EU LULUCF regulation.

Accounting of emissions and removals from managed forest land, i.e. the land that under the UNFCCC national inventory reporting (NIR) is included as "forest land remaining forest land", should be done against a **Forest Reference Level** (FRL) for each of the compliance periods 2021-2025 and 2026-2030 as detailed in article 8 of the LULUCF regulation. As required by Article 8.3 of the regulation the Netherlands submitted a first version of its National Forestry Accounting Plan before 31 December 2018, which subsequently has undergone a technical assessment by the European Commission.

This report is the final revised version of the National Forestry Accounting Plan of the Netherlands, incorporating the recommendations from the technical assessment. It includes the requested Forest Reference Level of the Netherlands for the first 5 years compliance period from 2021 to 2025. Appendix 3 gives information on how the recommendations from the technical assessment have been addressed in this final version of the NFAP.

In this report consistency between the methods and data used to determine the FRL of Managed Forest Land (MFL) and those used for reporting of managed forest land ("forest land remaining forest land" under the UNFCCC reporting) is demonstrated. Below we first provide an overview of the system and methodologies used for reporting "forest land remaining forest land" (FL remaining FL) of the LULUCF sector in the national greenhouse gas inventory.

1.1.1 National system for greenhouse gas reporting for the LULUCF sector

For greenhouse gas (GHG) reporting of the LULUCF sector, the Netherlands has developed and improved an overall approach within the National System since 2003. Detailed background information on methods and assumptions have been documented in several publications. The basis for elaboration and comparison of the FRL was the 2018 UNFCCC submission of the Netherlands, which was the most recent UNFCCC submission at the time the draft FRL and NFAP were drafted in the second half of 2018. The methodological background report for LULUCF (Arets et al. 2018), describes the methodological choices and assumptions as applied for the National Inventory Report 2018 (NIR 2018, Coenen et al. 2018). Older background publications include Nabuurs *et al.* (2003, 2005), De Groot *et al.* (2005), Kuikman *et al.* (2003, 2005), Van den Wyngaert *et al.* (2006, 2008, 2009, 2011a, 2011b and 2012), and Arets *et al.* (2013, 2014, 2015, 2017a and 2017b).

The Dutch system of GHG reporting for the LULUCF sector includes, and reports on the entire terrestrial surface of the Netherlands in a wall-to-wall approach. The national system is based on activity data from land-use change matrices for the intervals 1990-2004, 2004-2009 and 2009-2013 that were derived from overlying topographic land-use maps.

These maps, dated at 1 January 1990, 2004, 2009 and 2013, are gridded in a harmonised way and an overlay produced all land use transitions within these periods (Kramer et al., 2009; Van den Wyngaert et al., 2012, Arets et al. 2018). An overlay between the land use maps with the soil map allows estimating the changes in land use on different soils. New land use maps will be compiled on a regular basis and then will be used to derive new land use matrices. In the meantime, in the NIR 2019 (Ruyssenaars et al. 2019) a new land-use map for 2017 has been introduced, which allows a land-use change matrix 2013-

2017 to be developed and used for the annual reporting (Arets et al. 2019). New maps are planned for 1 January 2021 (final accounting KP CP2, start 1st compliance period EU LULUCF regulation), 1 January 2026 and 1 January 2031.

The basic approach to assess carbon emissions and removals from forest biomass follows a stock-difference approach as suggested in the "*2006 IPCC Guidelines for National Greenhouse Gas Inventories*" (IPCC 2006, hereafter referred to as *2006 IPCC Guidelines*). The net change in carbon stocks for *Forest Land remaining Forest Land* is calculated as the difference in carbon contained in the forest between two points in time. Our approach combines activity data from the land-use maps and emission factors from National Forest Inventories.

Carbon stocks in the forest are derived from the growing stock volume from national forest inventories in combination with biomass expansion factors (see Chapter 4.1 in Arets et al. 2018). From 1990 onwards, data from three National Forest Inventories (NFIs) are available for the Netherlands (see Appendix 1): the HOSP data (1988-1992), the NFI-5 data (2001-2005) and the NFI-6 data (2012-2013). With these three repeated inventories, average forest characteristic are assessed (Table 1.1). These then are used in the LULUCF system (bookkeeping model) to assess average changes in biomass and carbon stocks per ha FL remaining FL for the periods 1990-2003 (HOSP - NFI-5) and 2003-2013 (NFI-5 - NFI-6). The annual changes for the years between 1990-2003 and 2003-2013 are determined using linear interpolation. For use in the NIR, the information between 2013 and 2020 was based on projections using the EFISCEN model (Arets et al. 2018; Schelhaas et al. 2007), using 2013 harvest levels as a basis. Once the 7th National Forest Inventory (NFI-7) becomes available in 2020 the reported information for the period 2013-2020 will be updated and recalculated.

Table 1.1. *Forest information in the calculation of the carbon stock changes for forest land remaining forest land in the national GHG inventory. See Chapter 4 in Arets et al. (2018) for further details. Per NFI, its reference year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), biomass conversion and expansion factors (BCEF, tonne dry matter per m^3 stemwood volume), belowground biomass (BGB; tonnes ha^{-1}), root to shoot ratio (R), share of conifer biomass in the total forest biomass, mass of standing deadwood (DWs, tonnes ha^{-1}) and lying deadwood (DWl, tonnes ha^{-1}). The EFISCEN data are based on a model projection (Chapter 4.1 in Arets et al. 2018).*

NFI	Year	GS	AGB	BCEF	BGB	R	Share Conifers	DW Biomass DWs	DWl
HOSP	1990	158	112.8	0.714	20.6	0.18	0.44	0.84	0
NFI-5	2003	195	143.2	0.736	25.8	0.18	0.42	1.33	1.53
NFI-6	2013	217	165.5	0.764	29.9	0.18	0.37	1.88	1.93
EFISCEN	2023	241	182.9	0.758	33.7	0.18	0.39	-	-

1.1.2 Forest reference level, a two-step approach

The forest reference level is elaborated in a two-step approach (also see Section 3.1). In the first step the state of the forest is projected from the NFI-6 forward to three points in the future: 1 January 2021, 2026 and 2031 which can be seen as virtual forest inventories. The projections consider the development of dynamic age related forest characteristics and forest management practice from the reference period using the stratification of managed forest land as detailed in Section 3.2 and the EFISCEN space modelling approach as provided in Section 3.3.

In the second step these projected states of the forest on 1 January 2021, 2026 and 2031 are processed as if they were forest inventories and translated into the same forest characteristics as shown in Table 1.1. To guarantee consistency with the NIR results, these projected states of the forest are processed in the same way as NFI data are processed (see Chapter 4.1 in Arets et al. (2018) for details).

1.2 Consideration to the criteria as set in Annex IV of the LULUCF Regulation

Below is a description of how the criteria for determining the FRL as set in Annex IV of the EU LULUCF Regulation have been taken into consideration. The letter numbering follows that of the criteria in Annex IV of the EU LULUCF regulation, with the criteria in italic.

(a) the reference level shall be consistent with the goal of achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, including enhancing the potential removals by ageing forest stocks that may otherwise show progressively declining sinks.

Accounting of Managed Forest Land against a FRL incentivises EU Member States to implement activities aimed at increasing the sink of Managed Forest Land. In the Netherlands the implications of using a forest reference level, i.e. that the existing carbon sink does not result in credits under the LULUCF regulation, but that additional measures are needed to raise the removals of greenhouse gases beyond what can be expected from business as usual, has contributed to an increased sense of urgency to improve forest management and develop practical climate smart forestry principles.

The FRL of the Netherlands is based on a data driven projection of the future age dependent size class distribution and resulting changes in carbon stocks with the EFISCEN space model (see Section 3.3). The projections do not include effects of current or future policies, nor do they extrapolate historic trends in management changes (see Section 3.3.5). Historic management practice from the reference period 2000-2009 were based on actual observed harvest probabilities as elaborated from best available data from two National Forest Inventory of 2003 and 2012 (Section 3.3.5).

Comparison of the FRL with projections until 2030 for the National Climate and Energy Plan (NECP) which included current (past 5 years) harvest levels, indicated that additional management measures are needed to maintain the removals at the level projected for the FRL (see point (g) below). Moreover, from information from National Forest Inventories (NFIs) and past projections (see Section 2.3) it is known that as a result of aging forests and limited attention to forest management and productivity in the past decades, growing stock in forests continues to increase, but with a slower pace over time. With this knowledge in mind, a number of activities aiming at increasing removals in Managed Forest Land (see Section 2.3) were included in a national Climate Agreement (28 June 2019, Klimaatakkoord)[1] in which the Dutch Government with other public, social and private parties have agreed on actions to reduce emissions and increase removals of greenhouse gasses in the Netherlands.

In the land-use sector the agreed set of measures aim at preventing deforestation, increasing carbon removals in existing systems and expansion of forests and trees outside forests. To further guide choices for effective and scalable activities, since 2018 practical climate smart forest management principles are being tested in a number of pilots. The results of these pilots are shared in an online toolbox[2] for climate smart forest and nature management.

At the same time the Dutch government has adopted a national Climate Act[3], establishing a framework for the development of policies aimed at an irreversible and step-by-step reduction of Dutch greenhouse gas emissions in order to limit global warming and climate change. The act has entered into force on 1 September 2019 and asks for a Climate Plan in which the Government shares the main lines of climate policies needed to reduce emissions by 95% (compared to 1990) until 2050, and more specific actions

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[1] https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord (in Dutch)
[2] https://www.vbne.nl/klimaatslimbosennatuurbeheer/ (in Dutch)
[3] https://zoek.officielebekendmakingen.nl/stb-2019-253.html (in Dutch)

that are necessary to meet the intermediary 49% reduction target set for 2030. The basis for this Climate Plan will be the objectives and actions that were agreed on in the national Climate Agreement.

The long term strategy (LTS) of the Netherlands that is required under Art. 15 of regulation EU 2018/1999 takes the goal of the Netherlands Climate Law, to reduce emissions by 95% by 2050 as a starting point. It has an economy wide orientation including the land use sector and forests and trees as part of that. The LTS points out that concrete sectoral emission reduction targets and measures for 2030 have materialised in the national Climate Agreement (aimed at 49 % emission reduction in 2030) and do fit in and prepare for the long term trajectories for achieving the 2050 Climate Law goals, but also that further choices and preparations for after 2030 will have to be made the coming years.

Progress and future outlooks for meeting the climate targets are monitored annually and reported in climate and energy outlook studies (Klimaat- en Energieverkenning (KEV), first one in 2019, Schoots and Hammingh 2019). The Climate Agreement, Climate Plan and KEV studies subsequently are the main inputs for the National Energy and Climate Plan (NECP) of the Netherlands.

(b) the reference level shall ensure that the mere presence of carbon stocks is excluded from accounting.

Like the reported emissions and removals from managed forest land, those calculated in the FRL are based on changes in carbon stocks, rather than on the stocks themselves. The difference between the projected changes in the carbon stocks and eventually observed changes from new NFI data that are anticipated to be collected by the beginning and at the end of the compliance periods will ensure that the mere presence of carbon stocks in managed forest land is excluded from accounting.

(c) the reference level should ensure a robust and credible accounting system that ensures that emissions and removals resulting from biomass use are properly accounted for.

In order to properly account for emissions and removals from biomass use it is important that the emissions associated with the combustion of wood are accounted for in the LULUCF sector. This is achieved by reporting fuel wood using instantaneous oxidation and by excluding future increases in demand for fuel wood from the FRL (see Section 3.3.5). To improve the fuel wood harvest estimates we have developed a new, improved approach that, combined with industrial roundwood statistics, better comes to terms with the accounts for the actual fellings in the forest on the basis of the wood balance between National Forest Inventories, instead of the unsatisfactory rough estimates of fuel wood harvests from managed forest land (see Section 3.2.1 and Appendix 2) that have been used for FAO reporting so far.

(d) the reference level shall include the carbon pool of harvested wood products, thereby providing a comparison between assuming instantaneous oxidation and applying the first-order decay function and half-life values.

The reference level has been calculated both including harvested wood production with a first-order decay function, and without harvested wood products, providing the result under assuming instantaneous oxidation (see Section 4.1)

(e) a constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009 shall be assumed.

Average annual total roundwood harvests from managed forest land are based on the wood balance calculated from permanent plots in the NFI data (see Appendix 2 for detailed description). The annual industrial roundwood production is taken from the FAO statistics, assuming that the results from the Joint Forest Sector Questionnaire provide a reliable estimate for this category. The difference between the total roundwood and industrial roundwood numbers is attributed to roundwood used as wood fuel (see Appendix 2 for more detailed explanation and justification).

In the period 2000-2009 on average wood fuel made up 38% of total the roundwood harvest volumes (Table 1.2).

Table 1.2. *Roundwood harvest inputs to calculate the constant ratio between solid (FAO industrial roundwood) and energy (wood fuel) use. All values in roundwood underbark. See Appendix 2 for detailed explanations and justification for these values.*

Year	FAO Industrial roundwood	Wood fuel	Total roundwood production
2000	879	399	1,278
2001	729	399	1,128
2002	703	399	1,102
2003	754	502	1,256
2004	736	502	1,238
2005	820	502	1,322
2006	817	502	1,319
2007	732	502	1,234
2008	827	502	1,330
2009	726	502	1,229
Total 2000-2009	7,723	4,715	12,438
% of total	**62%**	**38%**	100%

For allocation of wood harvest to the different HWP categories and fuel wood (energy use of forest biomass) we have applied a constant ratio between the different HWP categories as documented in the reference period (see Section 3.3.10), and hence the ratio between solid and energy use of forest biomass remains constant between the reference period and the FRL. Detailed information is provided in Appendix 2.

(f) the reference level should be consistent with the objective of contributing to the conservation of biodiversity and the sustainable use of natural resources, as set out in the EU forest strategy, Member states' national forest policies, and the EU biodiversity strategy;

The forest management practices in the FRL are based on the actual harvesting as derived from National Forest Inventories. For decades the average growing stock in Dutch forests has been increasing continuously (Schelhaas et al. 2018a) Based on the information form the NFI-5 and NFI-6 Schelhaas et al. 2018a inferred that between 2003 and 2013 only 55% of the increment was harvested. Moreover about 40% of the Dutch forests is designated as nature areas, and 58% is multifunctional forests in which various functions including recreation and wood production are shared. Conservation of biodiversity and sustainable use of forests are important elements in Dutch forest policy and management for a long time, also including the reference period(see Section 2.3). As a result it is very plausible that also the FRL is consistent with the objectives in this criterion.

(g) the reference level shall be consistent with the national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks reported under Regulation (EU) No 525/2013;

Until 2019 the Netherlands reported its projections of anthropogenic greenhouse gas emissions by sources and removals by sinks as required under article 14 of regulation (EU) No 525/2013 in its energy outlook (Nationale Energieverkenning, NEV, until 2017). The most recent article 14 report in 2019 was based on the projections in the NEV 2017 (Schoots et al. 2017). The projections in the NEV 2017 used the EFISCEN model to project future state of the forest, which then was included in the LULUCF bookkeeping model in the same way as was done for the NFI data used in the NIR and the projections for the FRL. Therefore the approaches are consistent, but the used forest models (EFISCEN vs EFISCEN space) and assumptions on harvest differ (FRL; based on continuing forest management practices as applied during the reference period, vs NEV; based on latest harvest level). More importantly, also the methodology for LULUCF reporting since 2017 has seen major changes. For forests an important change is that units of land with "trees outside forests" are no longer included under the forest land category, but instead now are reported under grassland (see the NIR 2018 for more detailed explanations for this change, Coenen et al. 2018). As a result the projected sink for forest land remaining forest land differs a lot between the NEV 2017 and the projections of the FRL in this report.

In 2019, however, the first climate and energy outlook (Klimaat- en Energieverkenning; KEV; Schoots and Hammingh 2019) with projections until 2030 has been prepared and published. As required by the Climate Act, this outlook will be updated annually to monitor progress of the Climate Plan. It will also act as a basis for the projections in the integrated National Energy and Climate Plans (NECP) of the Netherlands as required by EU regulation 2018/1999. In support to the drafting of the KEV 2019 (Schoots and Hammingh 2019) the LULUCF projections have been carried out by the same team that is responsible for the FRL projections (background document: Velthof et al. 2019). This included an updated projection for the FRL ("updated" FRL), which was considered to be more relevant for policy evaluation than the submitted FRL. The parameters for running the EFISCEN space forest model were kept the same as used for the submitted FRL (see Section 3.3 of this NFAP). This means that development of growing stock and harvests probabilities follows the same developments over time and thus is based on the management practice of the reference period.

In order to comply with the requirements laid down in EU Regulation 2018/841 and following the approaches provided in the guidelines, the FRL is based on the assumption of a constant area of managed forest land starting from 2009. In the projections of the emissions and removals for the "updated" FRL as used in the KEV 2019, however, also observed changes in the area of managed forest land between 2009 and 2017 as well as projections of changes in area after 2017 have been included. These do not comply with the requirements of regulation 2018/841 or the approaches provided in the guidance document. Nevertheless these are considered to be more meaningful for assessing the future effects of climate policies. Before final accounting the FRL will need future technical corrections to account for the actual changes in area of managed forest land, which will be too late to implement policy corrections. A comparison of the sink in managed forest land between the FRL (provided here) and updated FRL (in the KEV 2019 and in Velthof et al. 2019) shows that the values are actually very close together (Figure 1.1). This is partly because losses and gains of managed forest land area are close together in the projected area changes. With the future implementation of policies and actions aiming at reducing deforestation as put forward in the Climate Agreement it can be expected that the trend will be converted to an increase in the area of managed forest land, leading to an increase of the removals that need to be considered under the FRL.

In addition to an "updated" FRL projection, Velthof et al. (2019) also include a projection in which harvest probabilities have increased by 25% to match current levels of wood harvesting from managed forest land. The results in Velthof et al. (2019) show that with the current harvest intensities and without additional measures, during the first compliance period the CO_2 removals in managed forest land and HWP annually will be about 400 kt CO_2 lower than in the FRL (i.e. potentially resulting in debits). The aim is that the effects of climate smart forestry actions and policies as proposed in the Climate Agreement will be assessed in forthcoming projections and outlook studies.

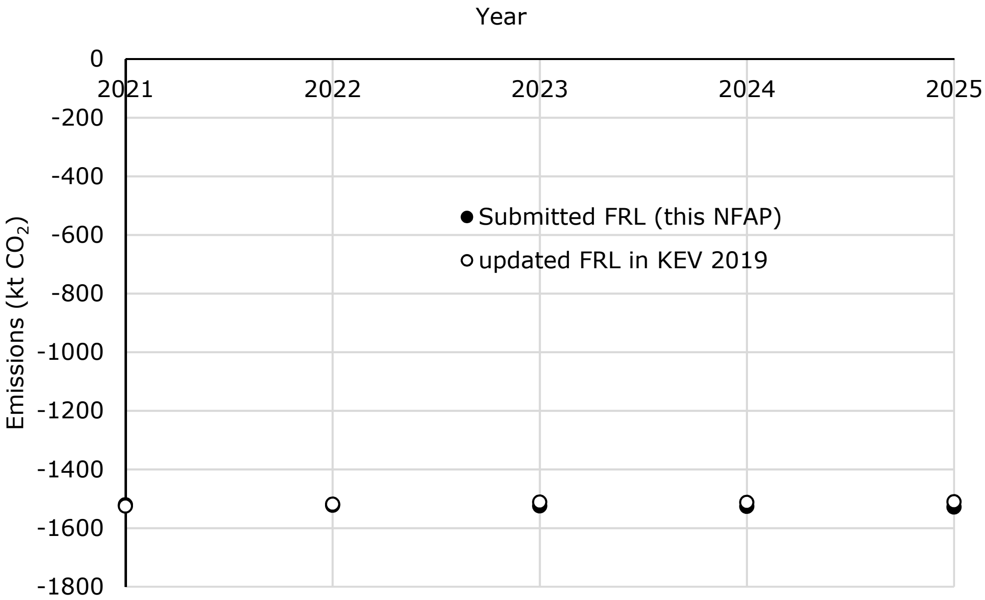

Figure 1.1. *Emissions (kt CO_2, negative values indicating removals) for Managed Forest Land (without HWP) for the FRL submitted in this NFAP and the updated FRL as used in the KEV 2019 (see Velthof et al. 2019)*

(h) the reference level shall be consistent with greenhouse gas inventories and relevant historical data and shall be based on transparent, complete, consistent, comparable and accurate information. In particular, the model used to construct the reference level shall be able to reproduce historical data from the National Greenhouse Gas Inventory.

The approach for assessing the forest reference level follows the same methodological approach as applied for the NIR 2018 (see Section 1.1). Improved harvest statistics as will be used from the NIR 2019 (Ruyssenaars et al. 2019 and Arets et al. 2019) have been used for improved consistency (see Section 1.1). In Section 4.2 consistency with the greenhouse gas inventory is demonstrated. The starting point of the projections is 1 January 2009 with an constant area of Managed Forest Land of 326 kha. This is the same as the reported area for "Forest Land remaining Forest Land" reported for (31 December) 2008 in the NIR 2018.

Elements of the national forestry accounting plan

Table 1.3 indicates where information on the elements of this national forestry accounting plan as required in Annex IV.B of the EU LULUCF regulation can be found.

Table 1.3. *Equivalence table indicating where the information required from Annex IV.B can be found in this national forestry accounting plan. NA: not applicable.*

Annex IV B. item	Elements of the national forestry accounting plan according to Annex IV B.	Section(s) in the NFAP	Page
(a)	A general description of the determination of the forest reference level.	1.1 3.1	11 27
(a)	Description of how the criteria in LULUCF Regulation were taken into account.	1.2	13
(b)	Identification of the carbon pools and greenhouse gases which have been included in the forest reference level.	2.1	19
(b)	Reasons for omitting a carbon pool from the forest reference level determination.	2.1.2	20
(b)	Demonstration of the consistency between the carbon pools included in the forest reference level.	2.2	21
(c)	A description of approaches, methods and models, including quantitative information, used in the determination of the forest reference level, consistent with the most recently submitted national inventory report.	3.3	35
(c)	A description of documentary information on sustainable forest management practices and intensity.	2.3.1 3.3.5	21 45
(c)	A description of adopted national policies.	2.3.1	21
(d)	Information on how harvesting rates are expected to develop under different policy scenarios.	2.3.2	24
(e)	A description of how the following element was considered in the determination of the forest reference level:		
(i)	• The area under forest management	3.1.2	28
(ii)	• Emissions and removals from forests and harvested wood products as shown in greenhouse gas inventories and relevant historical data	1.1.1 3.2.1 3.2.2 3.3	11 28 29 35
(iii)	• Forest characteristics, including:		
	– dynamic age-related forest characteristics	3.3.2 3.3.4 3.3.5	36 42 45
	– increments	3.3.4	42
	– rotation length and	NA, see 3.3.5	45
	– other information on forest management activities under 'business as usual'	3.3.5	45
(iv)	• Historical and future harvesting rates disaggregated between energy and non-energy uses	3.3.5 3.3.10 3.3.11 Appendix 2	45 51 52

2 Preamble for the forest reference level

2.1 Carbon pools and greenhouse gases included in the forest reference level

2.1.1 Greenhouse gases

The forest reference level (FRL) considers the same greenhouse gases as included in the National Inventory Report (NIR) and as detailed in Annex I of the LULUCF regulation; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

In the NIR Nitrous oxide and methane emissions associated with Forest land remaining Forest land (FL remaining FL), and hence Managed Forest Land (MFL) under the EU LULUCF regulation relate to:

- direct N_2O emissions from nitrogen inputs to managed soils (CRF Table 4(I)),
- direct N_2O emissions from nitrogen mineralisation associated with loss/gain of soil organic matter resulting from change in land use or management (CRF Table 4(III)),
- emissions from drainage and rewetting of organic soils (CRF Table 4(II))

In the NIR of the Netherlands, these emissions, however, are considered to be 'not occurring' in FL remaining FL. Therefore we also consider these emissions to be not occurring for Managed Forest land under the FRL projections. If, as a result of new insights, emissions for any of these sources are included in future NIRs up to 2027, this will trigger the need for a technical correction of the FRL 2021-2025 to be carried out before the compliance check by 2027.

Below we summarise the reasons for applying "not occurring" for the different potential sources. More detailed justification for this can be found in the LULUCF chapter in the NIR 2018 (Coenen et al. 2018) and the methodological background to the NIR 2018 (Arets et al. 2018), which is also considered to be an integral part of the NIR 2018 (see Annex 7 of the NIR2018, Coenen et al. 2018).

Direct N_2O emissions from nitrogen inputs to managed soils

There is limited information on the actual application of fertilizers in forests in the Netherlands. Although it is allowed to apply fertilizer to forest soils, actual application of fertilisers in forests is not a common practice because maximizing wood production is not a high priority in forest management. Additionally, given the high background levels of nitrogen deposition in the Netherlands, application of additional nitrogen in forests is considered to be not economically valuable.

Direct N_2O emissions from nitrogen mineralisation associated with loss/gain of soil organic matter resulting from change in land use or management

In the NIR currently only nitrous oxide emissions from soils resulting from disturbance associated with land-use conversions are calculated. In FL remaining FL it is assumed that carbon stocks in mineral soil do not change. Consequently also no N_2O emissions associated with loss of organic matter are considered.

Emissions from drainage and rewetting of organic soils

Drainage of organic soils is not a common practice in forests in the Netherlands. Therefore the CH_4 and N_2O emissions from drained and rewetted organic soils under FL remaining FL are not estimated. Nevertheless, forests that have been planted on organic soils that were under agriculture use before may still experience effects of old drainage systems. A recommendation from the 2017 UNFCCC review requires an estimation of the forest area on drained organic soils. This is still work in progress, but once such estimate is included in future NIR's, this will also be addressed in forthcoming technical corrections to the FRL 2021-2025.

2.1.2 Carbon pools

The carbon pools as referred to in Annex I of the LULUCF regulation are included in the national GHG inventory and FRL as summarised in Table 2.1.

Table 2.1. *Carbon pools as included in the NIR and FRL (R: reported, NO: not occuring).*

Use	CHANGE IN CARBON POOL REPORTED						
	AGB[1]	BGB[1]	Litter	Dead wood	Soil		HWP
					Min	Org	
Inventory	R	R	NO	R	NO	NO	R
FRL projection	R	R	NO	R	NO	NO	R

[1]In the GHG inventory reporting and FRL both above- and belowground biomass are considered and calculated, but the resulting outputs are aggregated to living biomass as is required for UNFCCC reporting.

In the sections below the way the different carbon pools are considered is explained in more detail. Also the pools for which no carbon stock changes are considered to occur (NO in Table 2.1) are explained.

a and b) Above- and below-ground biomass

In the NIR 2018 carbon stock changes in living biomass (above and below-ground) in FL remaining FL is included using a carbon stock difference approach that follows the 2006 IPCC guidelines. Living biomass carbon stocks in forest land are assessed for different points in time from growing stock information from the National Forest Inventories and biomass expansion factors (see Chapter 4.2.1 in Arets et al. 2018). Carbon stock changes in living biomass are also considered in the FRL. These are based on projected growing stock information (see Section 3.3.10) and the same biomass expansion factors as applied in the calculations in the NIR.

c) litter

In the NIR 2018 carbon stock changes in the litter pool are reported to be 'not occurring'. Analyses of carbon stock changes based on collected data have shown that there is most probably a build-up of carbon in litter in Dutch forest land. Data from around 1990, however, are very uncertain. Therefore, this highly uncertain sink is not reported in order to be conservative (see Chapter 4.2.1 in Arets et al., 2018). To remain consistent with the NIR reporting the litter pool is also included as zero in the FRL. However, new analyses on carbon stock changes in litter that include additional information from the NFI-6 are under way and results are expected to be included in the NIR 2019. Subsequently these results will also be included in future technical corrections to the FRL.

d) dead wood

In the NIR 2018 carbon stock changes in dead wood are included based on the NFI data. Calculations of changes in carbon stocks in dead wood follow the same approach as used for living biomass (see Arets et al. 2018). Also in the FRL projections dead wood is included, allowing for the inclusion of changes in the dead wood carbon pool of MFL in the FRL (see Section 3.3.9).

e) soil organic carbon

Following a Tier 1 approach, carbon stock changes in mineral soils under FL remaining FL are considered to remain constant in the NIR 2018. Changes in carbon stocks are considered to only occur during the 20 year transition period after land-use conversions. Currently no detailed information is available on carbon stock changes in managed forest soils. Therefore carbon stock changes in mineral soils are not considered for MFL in the FRL.

Currently, however, a programme for improving climate relevant soil information is being implemented in the Netherlands. It is expected that under this programme also more data on carbon in forest soils will become available. If this happens, in the future also carbon stock changes in managed forest soils will be included in the NIR for FL remaining FL. Once that is the case, this information will also be included in future technical corrections of the FRL.

According the NIR 2018 also no carbon stock changes in organic soils are occurring. CO_2 emissions may occur as a result of drainage of organic soils, but drainage of forests on organic soils is not commonly practiced in the Netherlands. Therefore also no carbon stock changes in organic soils are considered for MFL in the FRL.

However, forests that have been planted on organic soils that were under agriculture use before may, still experience effects of old drainage systems. A recommendation by the 2017 UNFCCC review now requires an estimation of the forest area on drained organic soils. When such estimate is available and implemented in a future NIR, this effect will also be included in future technical corrections to the FRL. The effect is expected to be small.

f) harvested wood products in the land accounting categories of afforested land and managed forest land.

In the NIR 2018 carbon stock changes in the harvested wood products (HWP) pool are considered using inputs from harvest statistics and a first order decay function. The methodology used follows the 2013 supplementary guidance for KP-LULUCF (IPCC 2014) and default carbon conversion and half-life factors (see Chapter 10 in Arets et al. 2018). After correction of the amount of wood coming from deforestation, all remaining wood harvests are considered to take place on FL remaining FL. The same methodology is applied to assess carbon stock changes in HWP for the FRL scaled for the projected tot harvests but using the relative average distribution over the different HWP categories and fuel wood from the period 2000-2009 (see Section 3.3.9).

In this respect it should be mentioned that improved fuel wood harvest estimates have been used compared to the NIR2018. This improved approach for fuel wood combined with industrial roundwood statistics, better accounts for the actual fellings observed in the forest on the basis of the wood balance between National Forest Inventories (see Section 3.2.1 and Appendix 2). 39% of the total wood harvests is fuel wood.

2.2 Demonstration of consistency between the carbon pools included in the forest reference level

In order to achieve consistency between the carbon pools included in the FRL we applied a comprehensive modelling framework projecting the developments of the forests at plot level, in which the different pools that are considered in the FRL, living biomass, dead wood and HWP (harvests) are projected in relation to each other depending on increment, mortality and harvesting functions (see Section 3.3).

Consistency between the FRL and NIR is achieved by applying the same approaches to translate state of the forest to carbon stocks and changes thereof to the actual NFI plots for NIR reporting and to the projected state of the forest for the FRL. This consistency is demonstrated in Section 4.2.

2.3 Description of the long-term forest strategy

2.3.1 Overall description of the forests and forest management in the Netherlands and the adopted national policies

The forested area in the Netherlands in 2017 was 365.5 kha, which is 9% of total area included under LULUCF. Current forest stands are mostly planted mature stands. After almost all forests had been degraded or cut from the Middle Ages until the 19th century, from the end of the 19th century on reforestation began, resulting in the forest area to date. The largest part of the forested area in the Netherlands was planted using regular spacing and just one or two species in even-aged stands, with wood production being the main purpose. A change towards multifunctional forests that serve multiple purposes (e.g. nature conservation, recreation and wood production) was started in the 1970s, and has had an impact on the management and appearance of these even aged stands.

Dutch forests are dominated by Scotch Pine (32%) that was introduced to reclaim heathland and inland driftsands in the 19th century and first half of the 20th century. The dominance of unmixed coniferous stands is gradually decreasing in favour of mixed and broadleaved stands. In the NFI-6 about 50% of the Dutch forests is categorised as mixed (i.e. dominant species makes up less than 80% of the stand) (Schelhaas et al. 2014). Natural regeneration plays an important role in the transformation process from the even-aged, pure stands into stands with more species and more age classes.

Sustainable forest management

Most of the forest area in the Netherlands is considered to be managed according to sustainable forest management principles. In general forest in the Netherlands is protected by a set of laws and (mostly spatial planning) regulations both on a national, provincial and municipal level. The whole forest area in the Netherlands is protected by the forest act which aims to prevent the forest area from decreasing. Only after thorough weighing of different public interests it can be decided to change the land-use destination from forest land to other land-uses like infrastructure or settlement. In such cases the deforestation needs to be compensated with afforestation of an equal area elsewhere. The exception to these rules is when conversion to priority nature takes place on the basis of ecological arguments, like on the basis of Natura 2000 management plans. In such cases forest conversion can take place without compensation.

Additionally sustainable forest management is one of the criteria in the nature subsidy scheme (below) that is in place in the Netherlands and from which most of the forest owners receive subsidies (FAO 2014).

Apart from laws, regulations and subsidies, the maintenance and enhancement of forest resources is also fostered through for instance policy documents, education, communication and information, monitoring and research and development of knowledge (Hendriks 2016).

Third party independent forest certification shows an increasing trend in the Netherlands (FAO 2014). By the end of 2017 about 47% (171 kha)[4] of the Dutch forest area was certified. More than 98% of this certified forest area was FSC certified, and the remaining certified forest area had a PEFC certificate. In the Netherlands there is no obligation for either public or private forest owners to have a forest management plan. The availability of long term management plans is assumed for the total forest area owned and managed by public organisations and nature conservation organisations, and for about one third of the private forest owners (FAO 2014). Since forest management plans are required by FSC and PEFC certification all certified forests will have one.

The national government also has adopted policies that directly or indirectly stimulate sustainable production and use of wood. For instance the national government commits to procure 100% sustainable timber through a set of clear criteria for procurement. The Dutch Timber Procurement Assessment Committee (TPAC) assesses whether timber certification systems meet these criteria and advises the responsible Dutch Ministry of Infrastructure and Environment (I&M) on the outcome. Three certification systems have been accepted at this moment: PEFC, FSC and MTCS (see Hendriks 2016). These rules apply both to domestically produced timber as well as to imported timber.

[4] http://www.bosenhoutcijfers.nl/nederlands-bos/boscertificering/ (accessed on 22 November 2018)

Nature policy and subsidies
Over the past decades, forest policy in the Netherlands has been integrated into the nature policy, which reflects the change towards multi-purpose forests in which more functions are combined (e.g. nature, recreation). The development of a national nature network is a central theme of the nature (and forest) policy. Implementation of nature policy including the development and preservation of the national nature network has been decentralised from the central government to the provincial governments. The national nature network is a cohesive network of high-quality wetland and terrestrial nature reserves, including forests. Up to 1 January 2017 already 594 kha of the network was completed (based on IPO 2017). The aim is to extend the network to 640 kha by 2027.

Subsidies are an important instrument for provinces to realise these nature development goals. Through the currently prevailing subsidy scheme for nature and landscape (Subsidiestelsel Natuur en Landschap, SNL), the provinces grant subsidies for the conservation and development of nature reserves, including forests, that are part of the National Nature Network and for agricultural nature management.

These subsidies are also an important source of income for forest owners. Forest owners covering in total 80% of the Dutch forest area receive a SNL subsidy. Of this subsidised forest area, 60% falls under the scheme for forests with production function, i.e. forest with explicitly integrated nature conservation and timber production objectives. In the other 40% that is subsidised as natural forests, harvests are limited to 20% of the increment.

Forest management and wood removals
The Dutch timber market is fairly homogeneous. Sawmills in the Netherlands can only handle stems of up to 60 cm diameter. As a result that is an important factor guiding forest management and maximum diameter of felled trees. Furthermore, forest managers have received very similar training, while there is only a limited number of contractors who take care of timber harvesting in Dutch forests.

Harvesting is mainly targeting stemwood, while some larger branches of broadleaved species may be removed as fuel wood. Due to concerns about soil fertility extraction of felling residues is limited. The majority (95%) of harvesting is done using harvesters and forwarders. In occasional cases, like the harvest of individual trees with large diameters, manual operations are performed.

For the forests that are subsidised under the SNL natural forest scheme, harvesting activities are limited to 20% of the increment. These are generally aimed at removing exotic species or improving forest structure. Forests with a production function usually integrate wood production with other functions like nature conservation and recreation. Harvesting in these forests therefore is usually limited to thinnings and small group fellings (<0.5 ha). Recently, however, also larger regeneration fellings (up to 5 ha) are applied in order to favour regeneration of species demanding more light.

In multifunctional forest, harvesting rates are on average 5.7 m^3 per ha per year, while in natural forests on average 2.9 m^3 is harvested per hectare per year (Schelhaas et al. 2018a). The growing stocks on average increase annually by 2.0 m^3 per hectare in multifunction forests to 2.9 m^3 per hectare for natural forests (Schelhaas et al. 2018a).

New developments
The ongoing trend of a transition to a more circular bio-economy will increase the demand for woody and non-woody biomass. As a result, in the near future the sustainable production of biomass will be a prominent challenge to address. In the Netherlands currently a number of policy developments and programmes are relevant. For instance, the National Biomass Vision 2030 (Ministerie van Economische Zaken 2015) states that an increase in the supplies of biomass is needed for sustainable green growth. This would imply a need for an increase in the productivity in forestry as well as for increased import (see Nabuurs et al. 2016). As part of the national program for a national circular economy, transition agendas are being drawn up (Ministry of Infrastructure and the Environment and Ministry of Economic

Affairs 2016). For forestry and wood the agendas for biomass & food and for construction are relevant. Furthermore in the 2013 energy accord (SER 2013) between the Dutch Government and social and private partners an agreement was reached on the increased use of (woody) biomass for energy production. A stimulating policy to implement this is now under development. Woody biomass for large scale energy production will however most probably be imported from abroad.

Also the forest and wood sector in the Netherlands is developing plans to address the challenges ahead. In October 2016 they presented an action plan for investments and development of the forest and wood sector and related carbon storage possibilities. Amongst suggestions for improvements in forest management, the action plan also proposes actions potentially adding up to planting 100,000 ha (~25% increase in the current forest area) of new forest in the Netherlands and increasing the use of wood as substitution for fossil-energy-intensive materials in, for instance, construction. In general afforestation in the Netherlands is hampered particularly because of high competition on land area for other purposes and the associated high prices for land. Currently this action plan is being considered within the context of the National Climate Agreement (see further below).

On 28 June 2019 the Dutch Government agreed with other public, social and private parties on a National Climate Agreement (Klimaatakkoord)[5] on actions to reduce emissions and increase removals of greenhouse gasses in the Netherlands. Additionally the government has adopted a Climate Act[6], establishing a framework for the development of policies aimed at an irreversible and step-by-step reduction of Dutch greenhouse gas emissions in order to limit global warming and climate change. The act has entered into force on 1 September 2019 and asks for a Climate Plan in which the Government should share the main lines of climate policies up to 2050 and more detailed plans for reaching an intermediary 2030 target. The target of the Climate Act and Climate Plan is to reduce greenhouse gas emissions in the Netherlands by at least 49 percent in 2030 compared to 1990. The basis for this Climate Plan will be actions that were agreed on in the climate agreement.

The National Climate Agreement divides efforts and responsibilities among 5 economic sectors and the partners involved to meet its goals. The forest sector (including the wood chain), as part of the agriculture and land use sector also will have to deliver its share to achieve the CO_2 reduction goal. Measures aim at preventing deforestation, increasing carbon removals in existing systems and expansion of forests and trees outside forests. Success depends on the ability of the sector to mobilize forest owners to take effective measures and together with the provincial and national government and other stakeholders to organize the appropriate incentives. For this the government of the Netherlands invests in developing and sharing knowledge that is needed for further improving the climate mitigation function of landscapes and forests. For this purpose, since 2018 practical climate smart forest management principles are being implemented and tested in a number of pilots. The results of these pilots are shared in an online toolbox[7] for climate smart forest and nature management.

2.3.2 Description of future harvesting rates under different policy scenarios

Nabuurs et al. (2016) explored how demand and supply of wood in the Dutch forest sector can be matched sustainably under the quickly increasing wood demand for the bio-economy. For this they applied the EFISCEN Space model to a number of scenarios. The results showed that under the reference scenario in which wood consumption increases from 15 million m^3 roundwood equivalents (rwe) at present to 25 million m^3 rwe in 2030, the annual harvest from forests in the Netherlands could be increased sustainably from about 1.2 million m^3 per year presently to 1.7-1.8 million m^3 per year in 2030. This scenario assumes that it is possible to increase harvest to 75-80% of the increment without damaging nature values.

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[5] https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord (in Dutch)
[6] https://zoek.officielebekendmakingen.nl/stb-2019-253.html (in Dutch)
[7] https://www.vbne.nl/klimaatslimbosennatuurbeheer/(in Dutch)

In addition we explored what would be a range of maximum and minimum harvest rates that could realistically be achieved over the coming decade, up to 2030. For this we assessed the harvesting levels under the assumption that the total national forest area would be managed according the harvesting probabilities inferred for one of each of the combinations as identified in the stratification of forest types, ownership and management as observed in the reference period 2000-2009 (see 3.2.3, and 3.3.5): as multifunction forest, nature forest, or in the way large non-industrial private owners or small non-industrial private owners would manage the forest. The modelling approach was the same to the approach applied for the FRL projections with EFISCEN space, only with adjusted stratification of management practices.

The range in the outcomes is considered to illustrate the possible range of harvest levels that can realistically be influenced by policy interventions (Figure 2.1). Particularly the difference of harvest levels between 100% nature and 100% multifunctional will be illustrative in this respect, since it is not likely that all forest area in the future will be managed in the same way as non-industrial forest owners do. Not surprisingly the harvests would become highest under the scenario where the total Dutch forest area would be assumed to be managed as multifunctional forest (Figure 2.1). The FRL that represents the mix of management objectives from the reference period, is somewhere between the full multifunctional and full nature scenario in Figure 2.1. The trend in harvests over time is fully steered by the probabilities of tree harvests as a function of tree species, size class and management objective in combination with the size class distribution. The decreasing trend is partly the result of more and more trees growing bigger than the maximum size classes that are harvested during the reference period.

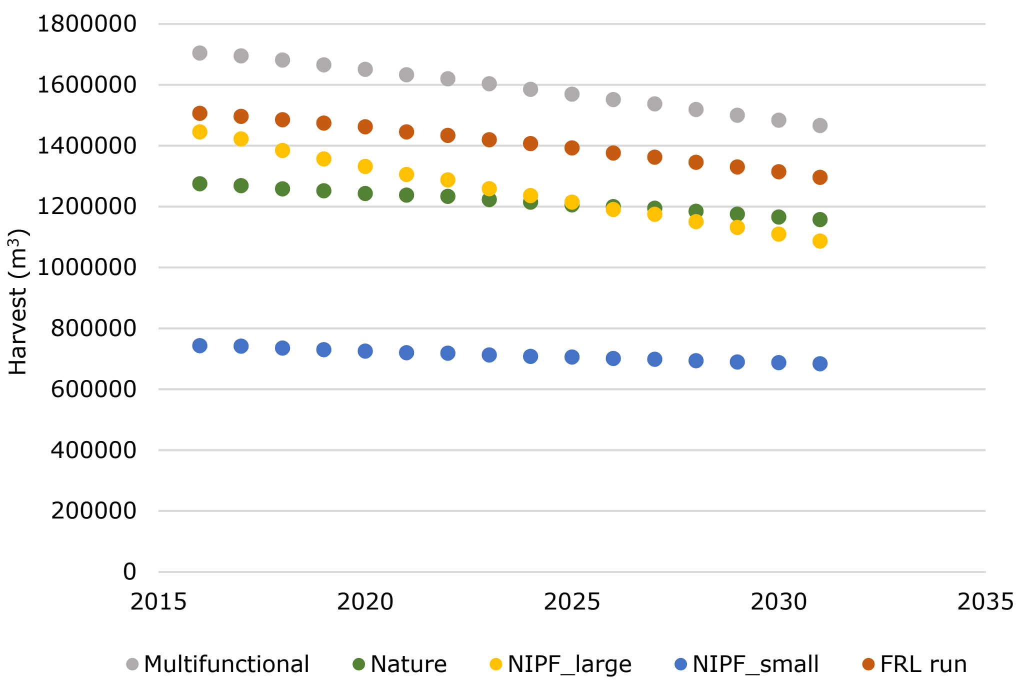

Figure 2.1. *Development of annual harvest (m^3) up to 2031 under the assumptions that total Dutch forest area would be managed either as multifunction forest, nature forest, or in the way large non-industrial private owners (NIPF_large) or small non-industrial private owners (NIPF_small) would manage the forest. Additionally the projected harvest levels for the FRL are included. This represents the mix of management objectives as practiced during the reference period (see Sections 3.2.3, and 3.3.5)*

3 Description of the modelling approach

3.1 Description of the general approach as applied for estimating the forest reference level

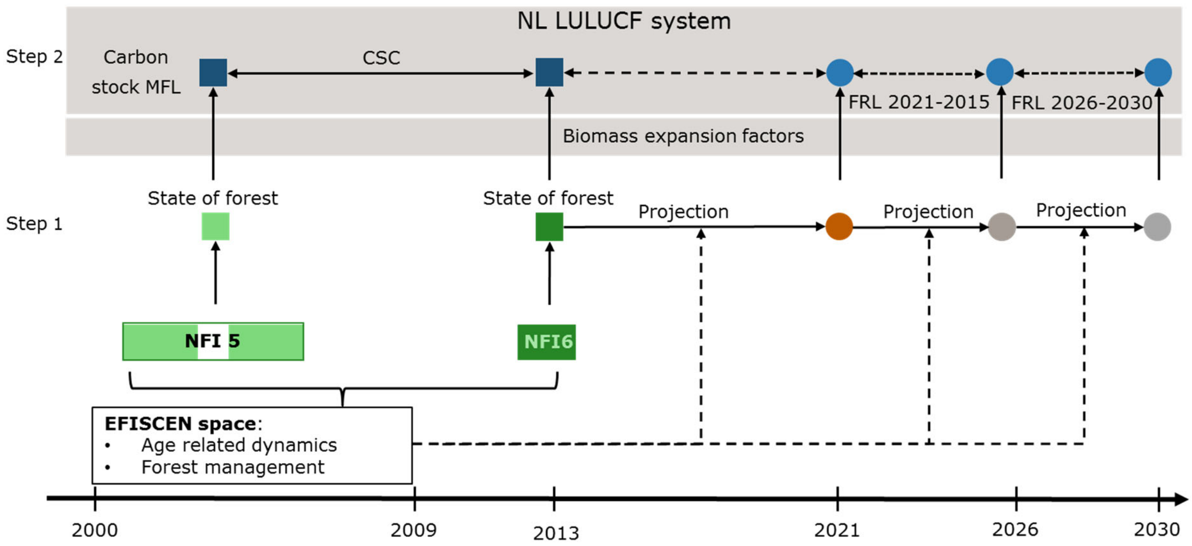

Figure 3.1. *Graphical overview of the approach applied for estimating the forest reference level. For information on the forest inventories NFI-5 and NFI-6 see Appendix 1.*

The forest reference level is elaborated in a two-step approach. In the first step the state of the forest is projected forward to three points in the future: 1 January 2021, 2026 and 2031 (Figure 3.1, step 1). The projections consider the development of dynamic age related forest characteristics and forest management practice from the reference period using the stratification of managed forest land as detailed in Section 3.2 and the EFISCEN space modelling approach as provided in Section 3.3.

Subsequently projected growing stock volumes then are translated into biomass and carbon stocks (see Section 3.3.10). To guarantee consistency with the NIR results, these projected states of the forest are processed in exactly the same way as the actual information from the National Forest Inventories is processed for the calculations in the NIR (see Chapter 4.2.1 in Arets et al. 2018 and Table 1.1 in this report).

In the second step then the projected carbon stocks calculated in the first step are used in the LULUCF system to calculate carbon stock changes for the various carbon pools during the compliance periods. The resulting outcomes then are translated into CO_2 eq. emissions and together will add to the FRL.

Additionally harvests will be used to assess carbon stock changes in HWP in the same way as the approach used for the NIR to calculate HWP from actual harvesting trends (see Section 3.3.10).

Eventually new information from currently executed and planned NFI's will become available to assess the actual state of forest on 1/1/2021, 1/1/2026 and 1/1/2031. These will then be used in the same way as the projected state of forest. The results of the actual measured carbon stock changes will then be compared to those calculate for the reference level.

3.1.1 Assumptions regarding climate change

We did not consider climate change effects in the projections of forest development. The modelling approach to project future forest structure uses an empirical model (EFISCEN space, see Section 3.3). The increment models included are climate-sensitive, but the mortality models are based on observations and are thus not climate-sensitive. For reasons of consistency between increment and mortality we have assumed a constant climate for the projections.

3.1.2 Assumptions regarding the development of MFL area during the compliance period
For assessing the FRL the same forest definition is applied as in the NIR 2018. Forest land is defined as all land with woody vegetation, now or expected in the near future (e.g. clear-cut areas to be replanted, young Afforestation areas). This is further defined as:

- forests are patches of land exceeding 0.5 ha with a minimum width of 30 m;
- with tree crown cover of at least 20% and;
- tree height at least 5 metres, or, if this is not the case, these thresholds are likely to be achieved at the particular site.

This corresponds with the minimum values for area size, tree crown and tree height parameters as included for the Netherlands in Annex 1 of the EU LULUCF regulation.

For the projection of the FRL we assumed that the area of managed forest land does not change from 2009 onwards and that the observed trends in forest area change are ignored. This follows the approach as outlined for Alternative 1 in box 19 of the FRL guidance document (Forsell et al. 2018). We understand that independently of the selected approach for projecting MFL area, a technical correction is due by 2026 to correct for the difference between assumed area development and actual MFL area development up to, and during the compliance period.

The MFL area, based on "FL remaining FL" was 326 kha by 1 January2009 and was kept constant during the whole FRL projections.

As mentioned in Section 1.1.1 the inclusion of new land-use maps dated 1 January 2021 and 1 January 2026 are planned to be included in the LULUCF GHG calculations in the future. These will be used to determine the actual development of MFL area to be used in the technical correction.

3.1.3 Natural disturbances
At this time no decision has been taken yet regarding the use of the natural disturbance provision. Therefore natural disturbances have not been considered explicitly in the FRL. However, if circumstances require so, the Netherlands may decide to apply the provision. If this is the case a technical correction will be applied to the FRL to include the natural disturbances background level.

3.2 Documentation of data sources as applied for estimating the forest reference level

3.2.1 Methodologies compared to the NIR 2018
The methodologies and data used to elaborate the Forest Reference Level largely follow those as included in the NIR 2018 (Coenen et al. 2018) and further detailed in the methodological background to the NIR 2018 (Arets et al. 2018), which is considered to be an integral part of the NIR 2018 (see Annex 7 of the NIR2018, Coenen et al. 2018). Exception on this is a methodological improvement on harvest statistics that will also be included in the NIR 2019. As a result of methodological inconsistencies in the FAO statistics on wood fuel harvests from 2015 onwards (see Appendix 2) a revision of the methodology as used in the NIR was already required.

Furthermore, while working on the FRL projections with the EFISCEN space model (see Section 3.2) additional analyses on the wood balance based on National Forest Inventories were done. This wood balance provides actually observed fellings of trees and is used to elaborate harvesting probabilities for trees to be used in the FRL projections (see Section 3.3.5). It also showed a consistent gap between the (roughly) estimated harvests as reported to the FAO and the actual wood harvests as determined from the wood balance based on the NFI's.

The use of the harvest information based on the NFI's wood balance for the FRL projection, while keeping the FAO statistics for reporting in the NIR would create inconsistencies between the two. Since the actual wood harvests based on NFI's wood balance are considered to be the best available data, it was decided to improve the method as used in the NIR to become consistent with the FRL approach. Therefore the FRL projections are not compared to the NIR 2018 result, but to an update to the NIR 2018 results in which the improved harvest information is used as described in Appendix 2. Consequence of the improved methodology for the FRL is discussed in Appendix 2.

State of forest according NFI-6
For the purpose of checking consistency between the forest reference level and the NIR the parameters for the state of forest in 2013 that were based on the NFI-6 data and used to assess the carbon stock changes in FL remaining FL in the NIR 2018 (Table 1.1) had to be corrected. While assessing the consistency of carbon stock gains and losses in biomass between the forest reference level and the NIR we found that the state of the forest as used in the NIR was based on all NFI-6 plots instead of the subset that represents FL remaining FL. The average growing stock of all NFI-6 plots was 217 m^3/ha (Table 3.1), but this also included 37 plots that were not yet classified as forest in 2003 (NFI-5) and hence do not represent FL remaining FL. If only the plots from NFI6 were used that actually represent FL remaining FL, the average growing stock in 2013 was 221 m^3/ha (Table 3.1). The consistency in Section 4.2 is therefore not assessed on the basis of the original data from the NIR2018, but on the results of a new consistency test run of the LULUCF system in which the harvesting data were improved as described in the paragraphs above and the corrected state of forest in 2013 as described in this paragraph were used. This issue will also be addressed and corrected in the forthcoming NIR 2019.

Table 3.1. *Corrected state of the forest in 2013 based on NFI-6 data. It appeared that the parameters used for the NIR 2018 were also based on plots that do not well represent FL remaining FL. For the consistency test this corrected to only include the NFI-6 plots that actual represent FL remaining FL for assessing the state of the forest in 2013. The parameters are average growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), biomass conversion and expansion factors (BCEF, tonne dry matter per m^3 stemwood volume), belowground biomass (BGB; tonnes ha^{-1}), root to shoot ratio (R), share of conifer biomass in the total forest biomass, mass of standing deadwood (DWs, tonnes ha^{-1}) and lying deadwood (DWl, tonnes ha^{-1}).*

NFI	Year	GS	AGB	BCEF	BGB	R	Share Conifers	DWs	DWl
NIR2018	2013	217	165.5	0.764	29.9	0.18	0.367	1.88	1.93
Adjusted NIR 2018	2013	221	165.5	0.744	29.9	0.18	0.404	1.97	2.03

All other methods and data in this update remained the same as in the published NIR 2018.

3.2.2 Available data sets and their timing
The NFI-5 (2001-2005) and NFI-6 (2012-2013) forest inventories (see Appendix 1 for more detailed information) represent the best available data that allow for direct quantification of forest management practice, assessment of the state of the forest and to derive the forest dynamics information needed for projecting the state of forest for the FRL in the compliance periods (see Section 3.3). The information from the earlier HOSP forest inventory (see Appendix 1) cannot directly be linked to the NFI-5 inventory. Because the HOSP did not have permanent sample plots that were re-measured during the NFI-5 and because its methodology and sampling design differed from the subsequent NFI-5, the HOSP could not be used for the parameterisation of the modelling framework used to do the FRL projections.

The timing of the measurement of the permanent plots in the NFI-5 and NFI-6 is used in different ways. To assess increment rates (Section 3.3.4) the actual time interval for the two measurements in NFI-5 and NFI-6 is used. Because of the nature of the mortality (Section 3.3.6) and harvesting (Section 3.3.5) functions, for these the average time interval between for all permanent plots was applied (9.6 years).

For initialisation of the projections the timing of the NFI-5 was set at 2003 and for the NFI-6 was set at 2013, which follows the approach used in the NIR reporting.

The time period between the NFI-5 and NFI-6 (2003-2013) overlaps with most of the reference period (2000-2009) that should be used for quantifying the management practice to be applied in the FRL. Although it is not fully synchronous the advantages of using these two to derive actually observed management practice instead of applying prescribed management practice are considered to outweigh the slight mismatch with the reference period. Because harvesting is the most important factor in forest management that would affect the results, we tested whether total harvesting as observed during the would period 2003-20013 deviates from the total harvesting during the reference period 2009.

The comparison was based on the updated and improved harvest data as provided in Appendix 2.3 The average annual harvest during the reference period 2000-2009 was 1,244,000 m^3 (with stdev of 78,000 m^3), while the average annual harvest during the period 2000-2013 was 1,264,000 m^3 ± 56,479 m^3 (stdev). The difference between the two of 20,000 m^3 is thus less than 1 standard deviation from the actual harvest. Based in this we conclude that management practice during 2003-2013 does not significantly differ from that in 2000-2009.

3.2.3 Documentation of stratification of the managed forest land

In the GHG inventory of the Netherlands forest land there is no need for stratification. It uses average carbon stocks representing the whole forest area based on NFI data. For the determination of the FRL we use the EFISCEN space model for the dynamic age related forward projection of the state of the forest under the 2000-2009 harvesting regime (see details in Section 3.3).

The increment model included is species-specific and sensitive to variables such as soil, climate and growing space, while mortality is currently included as observed probabilities for the Netherlands as a whole (see section 3.3**Error! Reference source not found.**). As a result stratification is only needed for the management component of the model.

The underlying strategy for the stratification analysis is to base it as much as possible on actual actions in the forest as can be inferred from forest inventory data, rather than on hypothesised behaviour of different forest owners. In the context of the FRL, harvesting behaviour is the most important component of the actual management. We used the methodology developed by Schelhaas et al. (2018b) to determine harvest probabilities for certain strata, based on an analysis of re-measured permanent NFI plots. For more details of this method see Section 3.3. For the stratification we included 3 types of strata:

a) management objective,
b) ownership type and size, and
c) tree species

In our analysis we first combined management objective and ownership to find meaningful groups to classify forest, which were (for further reasoning and analysis see below):

- Multifunctional forest land of organised forest owners (State Forest Service, Other public owners, Nature conservation organisations, Organised private owners like companies, trusts, churches)
- Nature forest land of organised forest owners
- Forest land of small non-industrial private owners (owning less than 5 ha forest land)
- Forest land of large non-industrial private owners (owning more than 5 ha forest land)

Then we assessed a meaningful further stratification according to tree species (result in Table 3.3).

Management objective

For the larger owners management objectives are broadly known from published visions, by-laws and public debates, but their objectives may vary depending on the location and forest type at hand. Management objectives for the smaller owners are hardly known at all. Determination of management objectives is not part of the regular NFI. It is thus impossible to exactly determine the management objective for all NFI plots individually. However, management subsidies are an important source of income for Dutch forest owners, and many owners actually receive management subsidies. Moreover, the different types of subsidies reflect to a certain extent the management objective, and the more nature-oriented subsidies come with restrictions on harvesting. For past subsidy schemes the actual spatial allocation of subsidies paid is available, while for the prevailing subsidy scheme maps are available that show the potential subsidy to be obtained for each parcel. Most of the larger owners actually do get subsidies. An analysis by Schelhaas et al. (2018a) confirmed that a stratification according to the potential subsidy to be obtained showed clearly differing patterns in terms of harvesting and growing stock, consistent with expectations. Schelhaas et al. (2018a) distinguished between forest managed for nature, and forests managed in a multi-functional way. We use the same stratification here.

The prevailing subsidy scheme that was applicable during the reference period was called Programma Subsidie Natuur (PSN). It included a general subsidy for forest ('Bos'), as well as specific subsidies for natural forest ('Natuurbos'), forest with increased nature value ('Bos met verhoogde natuurwaarde') and forest where the nature value should be increased ('Bos met te verhogen natuurwaarde'). We classified plots with the general subsidy as forests with a multifunctional management objective, and parcels in one of the three other categories as forests mainly oriented towards nature conservation. We obtained maps for the actual subsidy allocation in 2006 and 2009 and classified all plots measured in NFI-5 or NFI-6 as indicated above.

The current subsidy scheme that is applicable since 2010 is called Subsidiestelsel Natuur en Landschap (SNL), and has a higher number of subsidy types, more targeted towards specific forest types (https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/de-index-natuur-en-landschap/natuurtypen/). We classified N16.01 (Dry forest with production) and N16.02 (Moist forests with production) as forests with a multifunctional management objectives and all other types as forests mainly oriented towards nature conservation. Most of the latter types have the restriction that at maximum 20% of the annual increment may be harvested, on 80% of the area. On the remaining 20% more may be harvested, but only if aimed at increasing the nature value. The analysis by Schelhaas et al. (2018c) showed that the realised harvest level for these forests was very close to the theoretical level as calculated using these restrictions. The harvest level in the multifunctional forest was much higher, and Schelhaas et al. Schelhaas et al. (2018a) concluded that the restrictions imposed by the subsidy scheme seem to be complied to. The potential subsidy type according to the SNL scheme was already determined during NFI-6 and is included in the online NFI database.

Using the subsidy information, for each plot in NFI-5 and/or NFI-6 we could infer the management objective in 2006, 2009 and 2013, classified as multifunctional, nature, or unknown. Plots can have a different management objective at each observation. For the final classification we gave prevalence to the classification in 2009 since it is in the middle between NFI-5 and NFI-6 measurements. When no subsidy scheme is present the management objectives are unknown. Because only in case of a Nature subsidy scheme there are legal restrictions on the harvest, for cases without a subsidy scheme and hence unknown management objective, a multifunctional objective is assumed. This also is the most common management objective in the Netherlands. All possible combinations and their final classification are listed in Table 3.2.

Table 3.2 *Combinations of management objectives as derived for 2006, 2009 and 2013 and the final classification used to characterise management in a plot.*

2006	2009	2013	Final
Multifunctional	Unknown	Unknown	Multifunctional
Nature	Unknown	Unknown	Nature
Nature	Nature	Nature	Nature
Nature	Multifunctional	Nature	Multifunctional

2006	2009	2013	Final
Multifunctional	Nature	Multifunctional	Nature
Multifunctional	Multifunctional	Multifunctional	Multifunctional
Nature	Multifunctional	Multifunctional	Multifunctional
Multifunctional	Nature	Nature	Nature
Multifunctional	Nature	Unknown	Nature
Nature	Nature	Multifunctional	Nature
Multifunctional	Unknown	Multifunctional	Multifunctional
Nature	Unknown	Multifunctional	Multifunctional
Nature	Nature	Unknown	Nature
Multifunctional	Multifunctional	Nature	Multifunctional
Multifunctional	Multifunctional	Unknown	Multifunctional
Nature	Multifunctional	Unknown	Multifunctional
Nature	Unknown	Nature	Nature
Unknown	Unknown	Unknown	Multifunctional

Ownership type

In the NFI-6 forest owners were classified into 5 groups: 1) State Forest Service, 2) Other public owners, 3) Nature conservation organisations, 4) Organised private owners (companies, trusts, churches, etc.) and 5) non-industrial private owners (NIPF). Size of the ownership is often hypothesised as a major driver for harvesting behaviour (e.g. Clerkx et al. 2016; Eggers et al. 2014). Therefore we classified each plot according to the size of the owner as well.

From the cadastre we obtained a list with the owners of all known forest parcels. For each owner of a NFI plot we calculated the total forest area owned and classified the ownership in 8 classes: <1 ha, 1-5 ha, 5-10 ha, 10-50 ha, 50-100 ha, 100-500 ha, 500-1000 ha, 1000-5000 ha and >5000 ha. For each ownership type we plotted the observed harvest probability for each of the ownership size classes, separated into multifunctional and natural forest management objective, as described above. We compared the patterns over size classes and judged (subjectively) if the differences were large enough to split according to size classes, also taking into account the number of observations in each class.

Only for NIPF owners the size of the property seemed to have an influence, and we decided to distinguish between small NIPF owners (<5 ha) and large NIPF owners (5 ha or more) (Figure 3.2). Next, we compared the harvest probabilities for the resulting six owner groups to see if we could merge some of the groups (Figure 3.3). Based on this figure and after discussions with a stakeholder group made up of different types of forest owners, we decided to merge all non-NIPF owners but to keep the distinction between management objectives for these owners, and to ignore the management objectives for both NIPF groups. The reasoning behind the merger of non-NIPF owners is that all these owners are bound to the same subsidy regulations, and operate under the same market conditions. Differences between owners are merely expressed in the type of forest they own and in the distribution of management objectives in their forests, but not in the way they manage their forests within a certain management objective. NIPF owners often do not receive subsidies even if they are allowed to and are thus less likely to follow the subsidy rules (Clerkx et al. 2016). Table 3.3 shows the distribution of plots over the different datasets, as well as the average harvest probability per stratum as derived from the re-measured permanent sample plots from NFI-6.

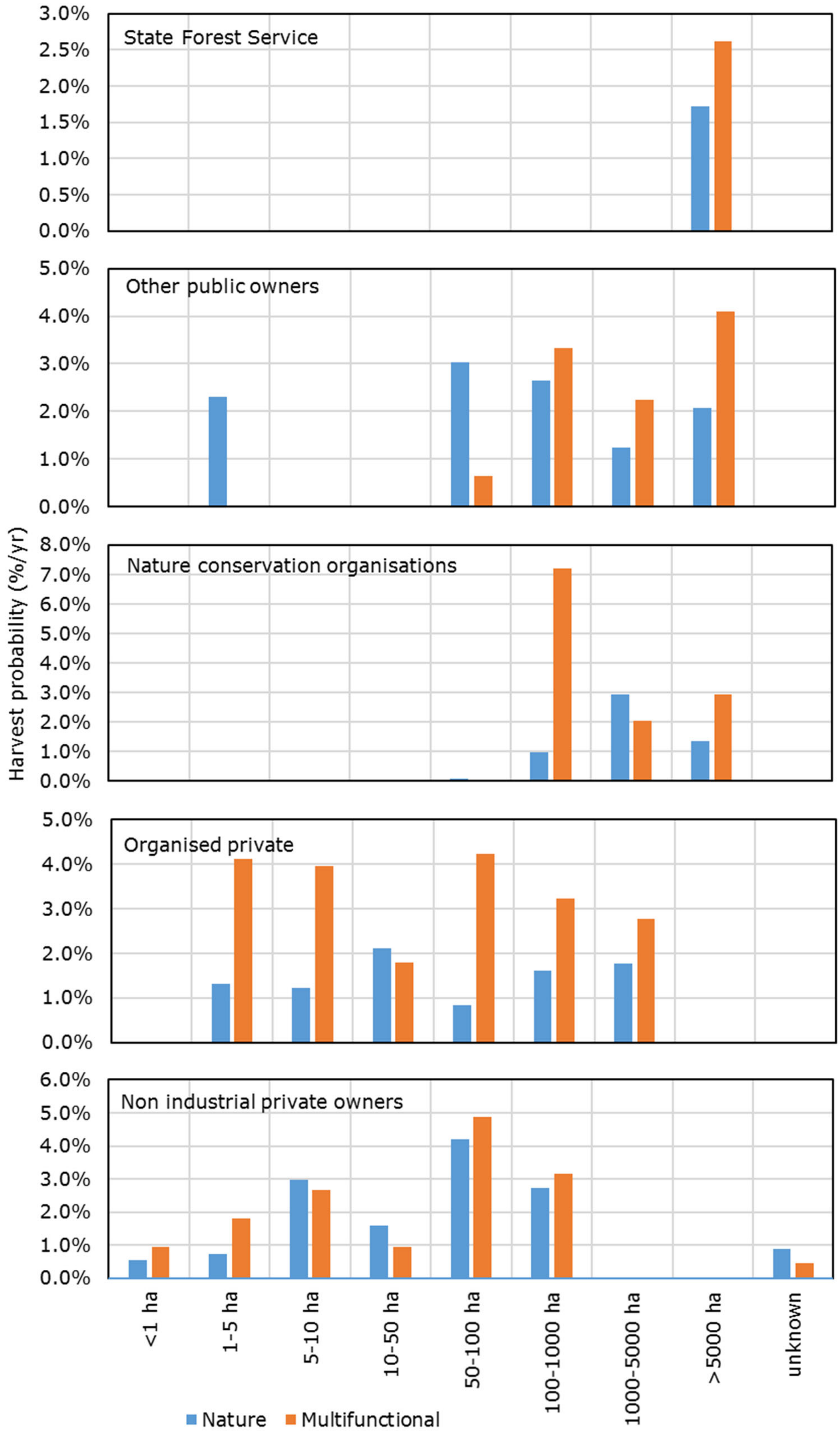

Figure 3.2 *Observed harvest probabilities for 5 different ownership types, differentiated between management objective and size of the property. For Non industrial private (NIPF) owners a distinction is made between small NIPF owners (<5 ha) and large NIPF owners (5 ha or more).*

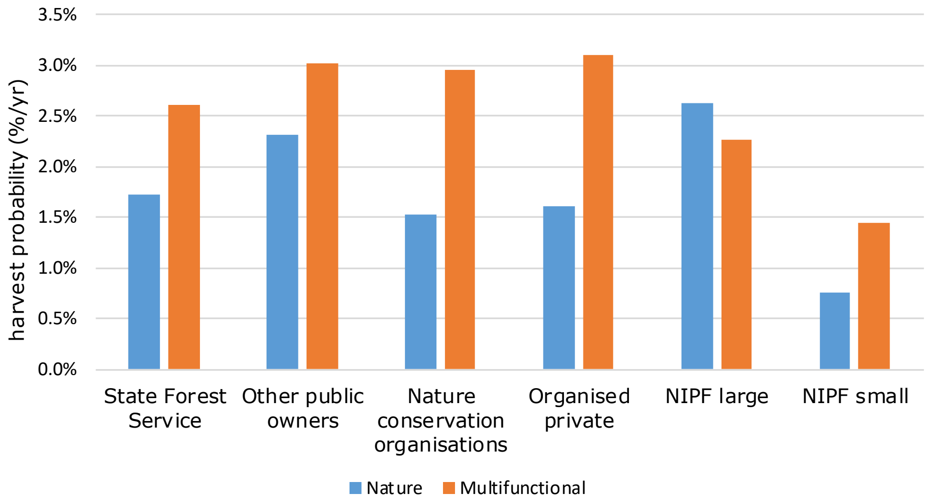

Figure 3.3 *Observed harvest probabilities for the 6 intermediate ownership types and management objectives.*

Table 3.3 *Distribution of plots over the final strata for NFI-5, NFI-6 total and for re-measured permanent plots only, and average harvest probability per stratum.*

Stratum	NFI-5		NFI-6 all plots		NFI-6 re-measured permanent plots		harvest probability
	number of plots	%	number of plots	%	number of plots	%	%
Organised multifunctional objective	1526	52	1665	52	636	52	2.9
Organised nature objective	853	29	990	31	374	31	1.7
NIPF large	392	13	432	14	101	8	2.3
NIPF small	191	6	101	03	114	9	1.3

Tree Species

In NFI-6, in total 72 tree species are defined. We merged them to 8 species groups, depending on their share in the total number of trees observed, their importance for wood production, their harvest probability, and other relevant characteristics. Table 3.4 gives an overview of the species groups used, what species are included in these groups, the number of observations available for determining the harvest probabilities and their average harvest probability.

Table 3.4 *Overview of species groups, the number of trees included and the observed average harvest probability per group.*

	species included	number of trees	harvest probability
Scots pine	Scots pine	6437	2.3%
Larch and other pines	Larch and other pines	2186	3.1%
Dark conifers	all other conifers, mostly Douglas fir and Norway spruce	2759	3.0%
Oak	Quercus robur and Q. petraea	4702	1.3%
Birch	Birch	3658	1.6%
Indigenous broadleaves	Beech, poplars, walnut, Acer, Fraxinus etc.	4226	2.1%
Exotic broadleaves	Robinia, Quercus rubra	1500	3.4%
Shrubs	Prunus, Amelanchier, Corylus, Sorbus etc.	94	1.5%
Total		**25562**	**2.2%**

In the final stratification, the owner type and tree species groups are combined, and harvest probabilities are determined for each combination and 5 cm diameter size class (see Section 3.3.5).

3.2.4 Documentation of sustainable forest management practices as applied in the estimation of the forest reference level

The quantification of sustainable management practices is based on the methodology developed by Schelhaas et al. (2018b) resulting in harvest probabilities per size class for the stratified forest types (species x owner type x nature/multifunctional forest). Detailed information is provided in Section 3.3.5.

The effect of the forest management practices applied in each of the strata can be inferred from information on growth, mortality and harvest probabilities from the NFI-5 and NFI-6 forest inventories. This approach does not provide information on specific management practices applied, but rather directly quantifies the actual effect of the set of management practices applied in a specific stratum (resulting in growth, mortality, harvest). An important advantage of this approach is that no interpretations on the effect of individual management practices are needed, which may introduce deviations from actual implemented management practices. Instead the approach directly applies the observed effects from the national forest inventories.

Quantification of the management practice is done on the basis of data from two National Forest Inventories (see Appendix 1), which are considered to provide the best available data for the reference period.

3.3 Detailed description of the modelling framework as applied in the estimation of the forest reference level

For the forward projection of the state of the forest under the 2000-2009 harvesting regime, we applied the EFISCEN Space model. EFISCEN Space was developed as a successor for the European Forest Information Scenario (EFISCEN) model that has been in use for decades (Nabuurs et al. 2001; Sallnäs 1990; Schelhaas et al. 2007; Verkerk et al. 2016). While the EFISCEN model was designed to work on aggregated NFI data for essentially even-aged forests, EFISCEN Space is designed for all types of forests, can handle a wide range of management systems and works with detailed NFI data. Parts of the model have been published already (Schelhaas et al. 2018b, 2018c), but so far a full description of the model is not available yet. Since the model is designed to work across Europe, we both include the general description as well as how we modified the European approach for the specific projections of the FRL for the Netherlands.

3.3.1 Model concept
In a national forest inventory (NFI), the whole of the forest is represented by a certain number of inventory plots. Each plot is considered to be representative for a specific forest area, typically in the range of 100–2000 ha, depending on the density of inventory plots. Similarly, in EFISCEN Space the future development of the forest is modelled through the development of the same set of inventory plots. The state of the forest at each of the inventory plots at a certain point in time is depicted as the number of trees per 25 mm diameter class, distinguishing 20 species or species groups. These 20 groups (Table 3.5) are constructed so that the most important species in Europe are covered, including species with an important share in Europe as a whole (*Pinus sylvestris* (L.), *Picea abies* L. (H. Karst), *Fagus sylvatica* L., *Quercus robur* L. and *Q. petraea* (Matt.) Liebl., *Betula pendula* (Roth) and *B. pubescens* (Ehrh.)), as well as important species in a certain region of Europe, either in terms of production or in coverage. Remaining species are merged in three rest groups. The model uses 40 diameter classes, with the first diameter class being 25-49.9 mm and the last class >= 1000 mm. It uses an annual time step. Growth is simulated by moving trees to a higher diameter class, while harvest and mortality are modelled as the removal of trees from the simulation. Regeneration or ingrowth will be simulated by adding new trees to specific diameter classes. Transition probabilities for growth, management and mortality are calculated

separately given the current diameter distribution, but applied at once. Figure 3.4 gives an overview of the structure of the model.

Table 3.5. *Species groups and their reason for inclusion: A = important for European coverage; B = important commercial species; C = important for regional coverage; D = rest group (Schelhaas et al. 2018c)*

Species (group)	reason for inclusion	Species (group)	reason for inclusion
Abies spp.	A	*Betula spp.*	A
Larix spp.	A	longlived broadleaves	D
other conifers	D	shortlived broadleaves	D
Picea abies	A	*Castanea sativa*	C
Picea sitchensis	B	*Eucalyptus spp.*	B
Pinus nigra+mugo	C	*Fagus sylvatica*	A
Other indigenous pines	C	Populus plantations	B
Pinus sylvestris	A	*Quercus ilex*	C
Pseudotsuga menziesii	B	*Quercus robur+petraea*	A
		Quercus suber	C
		Robinia pseudoacacia	B

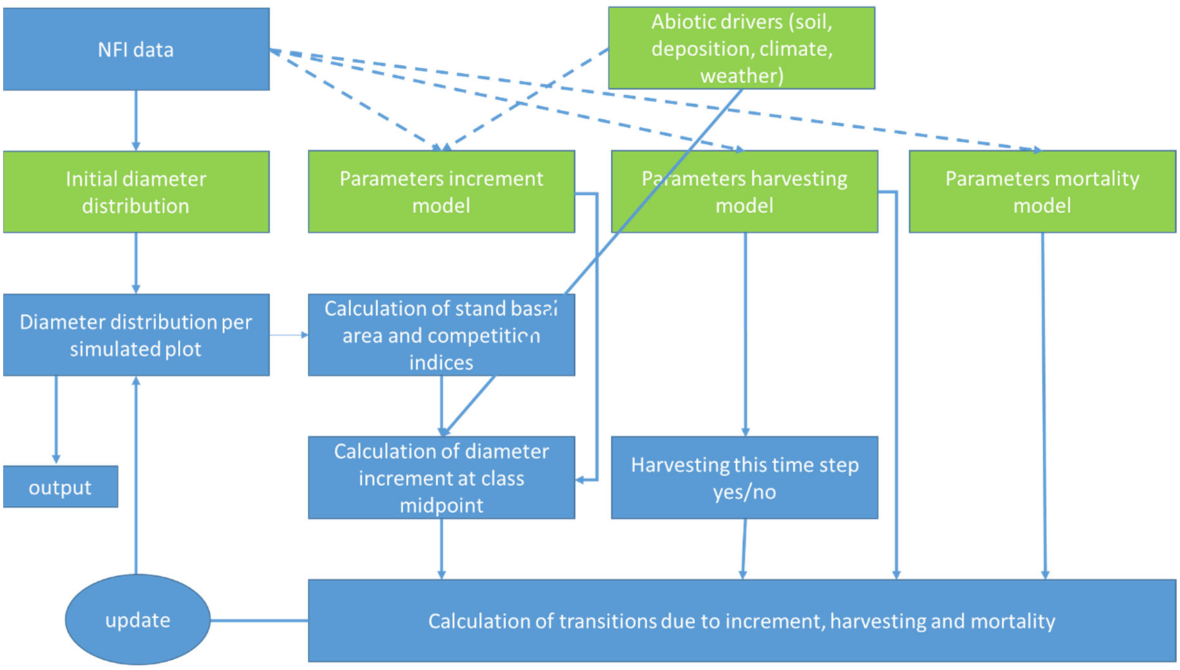

Figure 3.4. *Flowchart of calculations in the EFISCEN Space model. Green boxes represent information that is present in the EFISCEN Space database. Dashed arrows present information flows that are used offline to estimate parameter values.*

3.3.2 Initialisation procedure

Each live tree recorded in an NFI plot is classified to one of the 20 species groups. Based on the DBH, it is assigned to the appropriate 2.5 cm diameter class. Furthermore, for each recorded tree we determine how many trees it represents on a per hectare basis, calculated as simply 1/plot area. In case of the Netherlands, the DBH threshold used is 5 cm, but the plot area varies with the tree density of the plot. Finally, all records per plot are summed up, resulting in an initial stem number distribution (N/ha) over 2.5 cm diameter classes for 20 species groups, for each NFI plot. We illustrate the initialisation procedure for NFI plot NL_27377. This plot is a typical example of an older Scots pine forest mixed with some oak, with undergrowth of birch and *Prunus serotina*. It has a radius of 8 m. Table 3.6 shows how species groups, diameter classed and stem numbers are added to the original observations. Table 3.7 shows the resulting aggregated information as listed in the initialisation database, visualised as diameter distributions in Figure 3.5.

Table 3.6. *Original NFI observations for live trees in plot NL_27377 (shown in white) and additional information added for the initialisation (shown in grey).*

Id	PlotID	TreeID	Original Species	DBH (mm)	LocalName	ScientificName	SpeciesGroup	Species-Group Code	Diameter-ClassCode	Diameter-Class_mm	Stem-Number
112938	27377	5	EI	220	Inlandse eik	*Quercus robur + petraea*	*Quercus robur&petraea*	16	7	200	49.7
112940	27377	7	GD	444	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	16	425	49.7
112942	27377	9	GD	256	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	9	250	49.7
112946	27377	13	GD	352	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	13	350	49.7
112949	27377	16	GD	256	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	9	250	49.7
112950	27377	17	GD	296	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	10	275	49.7
112952	27377	19	GD	190	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	6	175	49.7
112953	27377	20	EI	90	Inlandse eik	*Quercus robur + petraea*	*Quercus robur&petraea*	16	2	75	49.7
112954	27377	21	GD	181	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	6	175	49.7
112955	27377	22	EI	325	Inlandse eik	*Quercus robur + petraea*	*Quercus robur&petraea*	16	12	325	49.7
112959	27377	26	BE	159	Berk	*Betula spp.*	*Betula spp.*	10	5	150	49.7
112960	27377	27	GD	311	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	11	300	49.7
112961	27377	28	GD	229	Grove den	*Pinus sylvestris*	*Pinus sylvestris*	6	8	225	49.7
112962	27377	29	AV	88	Amerikaanse vogelkers	*Prunus serotina*	Other short-lived broadleaves	20	2	75	49.7

Table 3.7. *Aggregated information for plot NL_27377 as listed in the in the initialisation database.*

plot	SpeciesGroupCode	DiameterClassCode	StemNumber
NL_27377	16	2	49.7
NL_27377	20	2	49.7
NL_27377	10	5	49.7
NL_27377	6	6	99.5
NL_27377	16	7	49.7
NL_27377	6	8	49.7
NL_27377	6	9	99.5
NL_27377	6	10	49.7
NL_27377	6	11	49.7
NL_27377	16	12	49.7
NL_27377	6	13	49.7
NL_27377	6	16	49.7

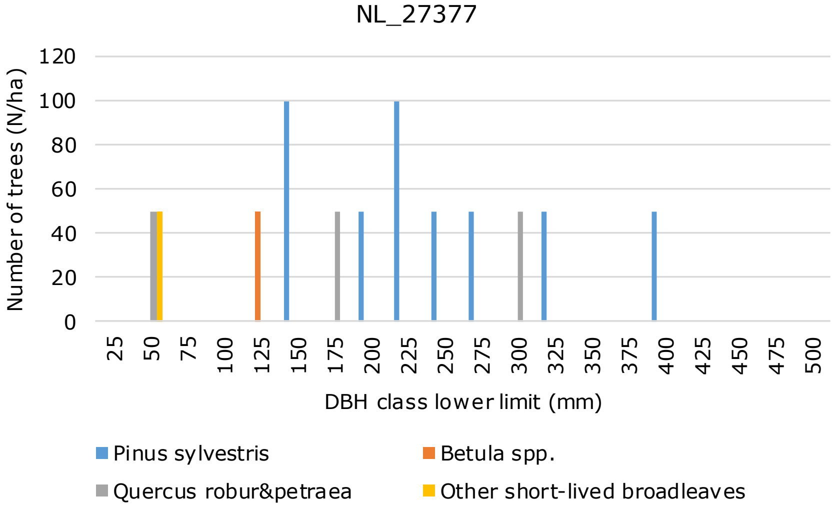

Figure 3.5. *Initial diameter class distribution of plot NL_27377.*

3.3.3 Size class structure

Age dependent projections are based on the transition of trees to higher diameter classes. The projections are done at the plot level (see eg. Figure 3.5)Since most experts and reviewers are more familiar with age or size class for the whole forest area, here the total size class distributions of a species across all plots per stratum are provided (Figure 3.6 to Figure 3.13) for transparency reasons. These size class distributions are based on the NFI-6 data, the starting point for the projections.

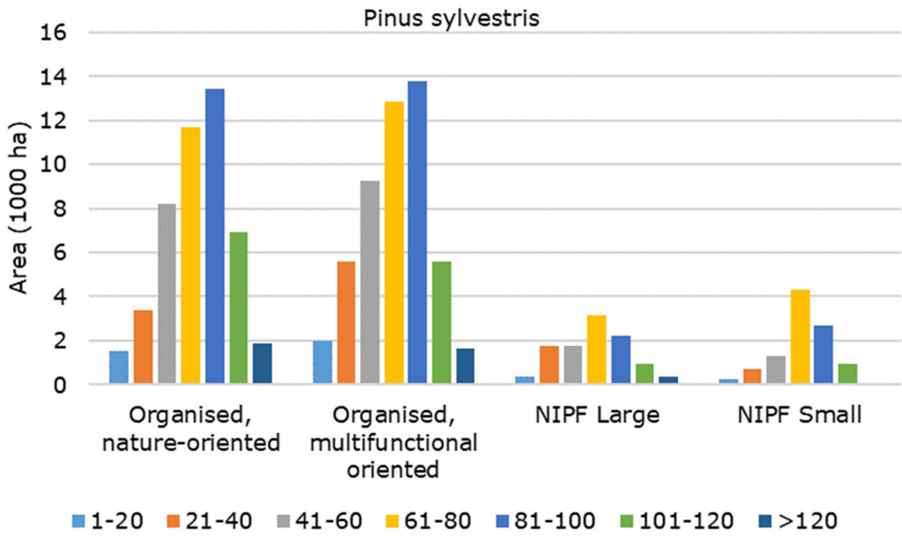

Figure 3.6. *Diameter class distribution for scots pine per management objective/owner stratum based on the NFI-6 data.*

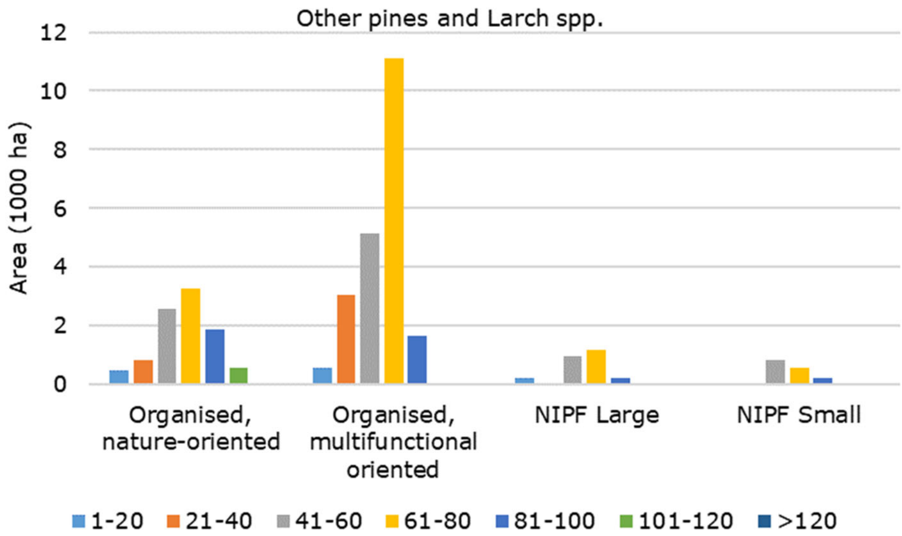

Figure 3.7. *Diameter class distribution for other pines and larch species per management objective/owner stratum based on the NFI-6 data.*

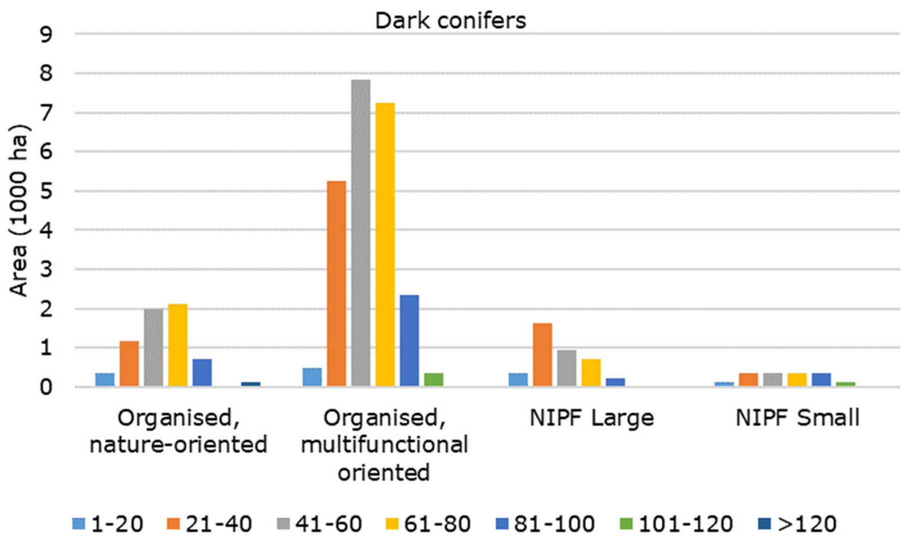

Figure 3.8. *Diameter class distribution for dark conifers per management objective/owner stratum based on the NFI-6 data.*

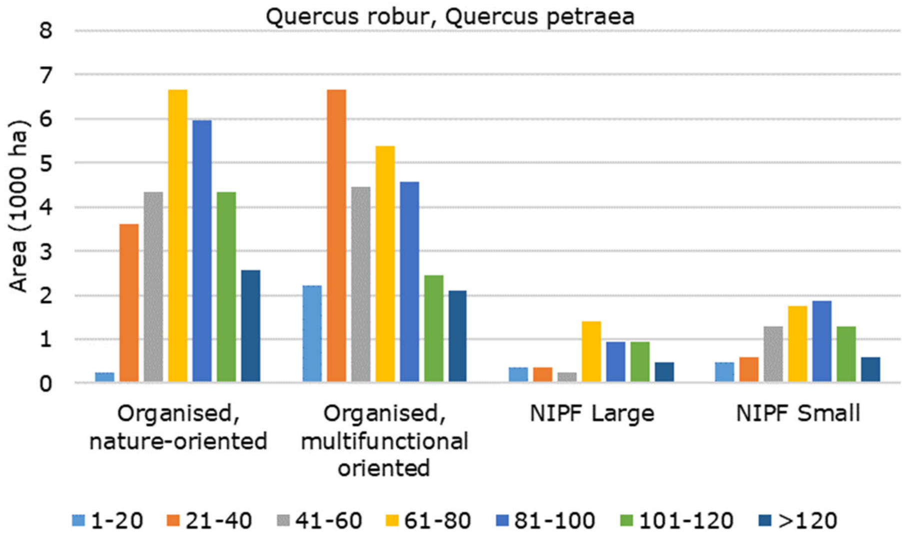

Figure 3.9. *Diameter class distribution for oak per management objective/owner stratum based on the NFI-6 data.*

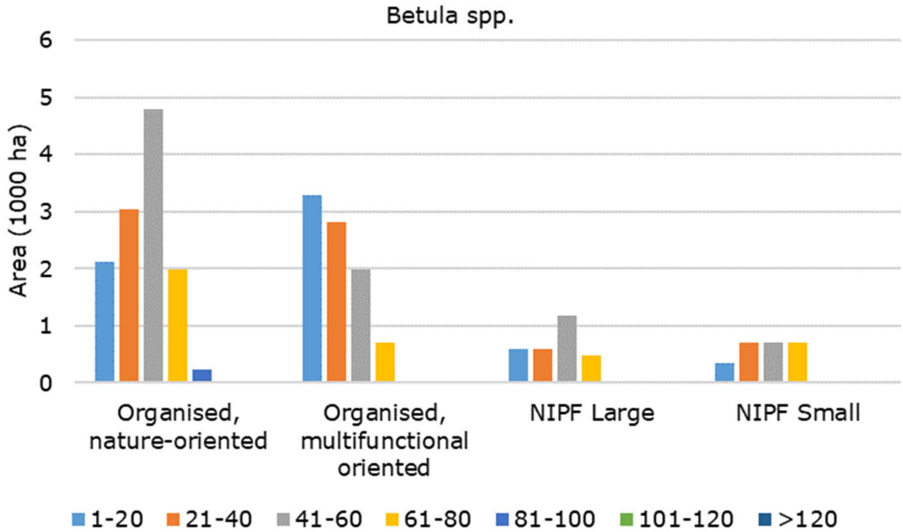

Figure 3.10. *Diameter class distribution for birch per management objective/owner stratum based on the NFI-6 data.*

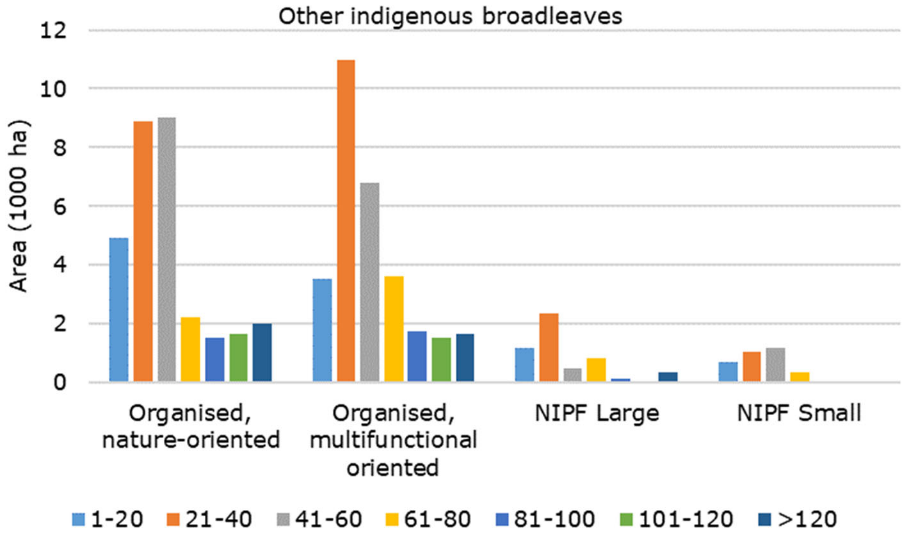

Figure 3.11. *Diameter class distribution for indigenous broadleaves per management objective/owner stratum based on the NFI-6 data.*

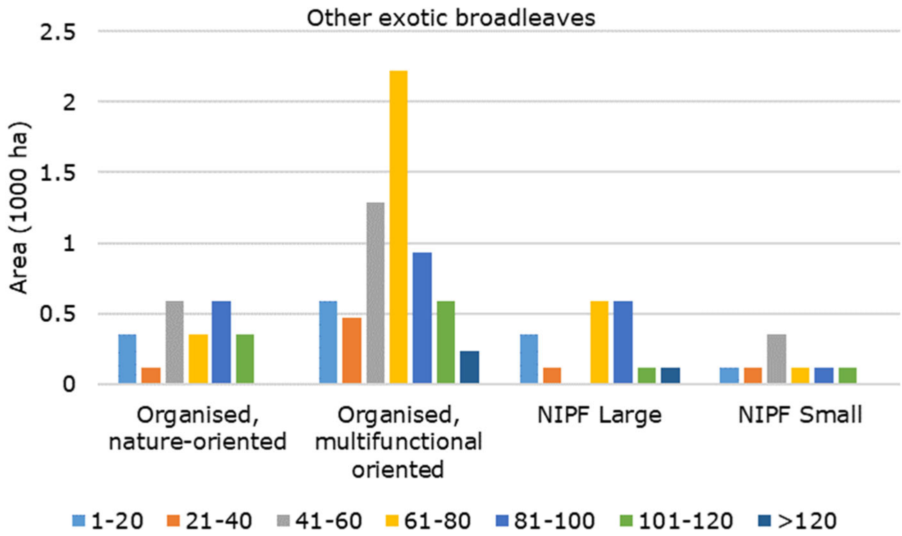

Figure 3.12. *Diameter class distribution for other exotic broadleaves per management objective/owner stratum based on the NFI-6 data.*

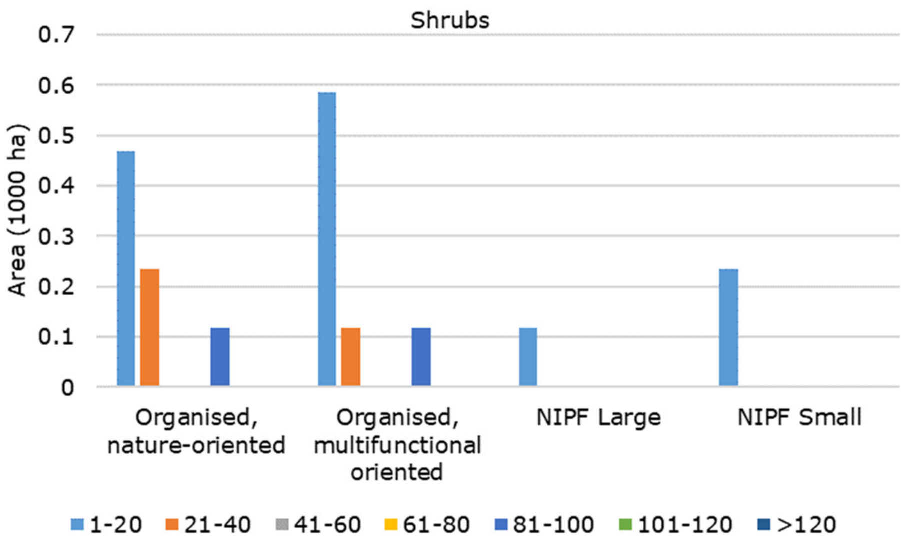

Figure 3.13. *Diameter class distribution for shrub species per management objective/owner stratum based on the NFI-6 data.*

3.3.4 Modelling of increment

Increment is incorporated in the model as the transition of trees to a higher diameter class. The fraction of trees that moves to a higher diameter class due to increment is calculated as:

$$g_{ijk} = \Delta dbh_{ijk}/c \qquad \text{(Eq. 3.1)}$$

with *g* the fraction of trees of species *i* in diameter class *j* in plot *k* moving to diameter class *j*+1, *Δdbh* the diameter increment of a tree with a dbh equal to the midpoint of diameter class *j*, and *c* the diameter class width. For European applications, diameter increment models were derived for each of the 20 species groups, based on a large set of repeated measurements on individual trees throughout Europe (Schelhaas et al. 2018c). In these models, diameter increment is sensitive to diameter, basal area in the stand and a number of abiotic variables, such as soil, deposition, weather and climate. However, a quick evaluation of these models revealed a considerable overestimation of the increment for the Dutch dataset. The most likely explanation for this deviation is that the extremely poor sands characteristic for forests in the Netherlands are not well represented by the European soil databases used for model fitting. Therefore, we developed a new set of growth models using the same procedure as in Schelhaas et al. (2018c), but only using the Dutch data. For estimating diameter increment the derivative of the Gompertz equation is used:

$$\frac{dDBH}{dt} = \beta_1 DBH + \beta_2 DBH \ln DBH + \varepsilon \qquad \text{(Eq. 3.2)}$$

with *dDBH/dt* the diameter increment (in mm per year), DBH the diameter (in mm), β_1 and β_2 parameters, and ε is the error term with an assumed distribution $N \sim (0, \sigma)$. These parameters are a function of a set of independent variables X_i expressed as:

$$\beta_1 = c_1 + \sum_{i=1}^{p} \theta_{i,1} X_i \qquad \text{(Eq. 3.3)}$$

$$\beta_2 = c_2 + \sum_{i=1}^{p} \theta_{i,2} X_i \quad \text{(Eq. 3.4)}$$

For both β_1 and β_2 the variables X_i used to estimate the parameters are the same. The procedure for the selection of the *p* variables that best explain the diameter increment is described in Schelhaas et al. (2018c). Values for c and θ are estimated using ordinary least squares (OLS) by substituting Eqs. 3 and 4 in Eq. 2. For model fitting we used the tree diameter measurements of the trees on the permanent sample plots that were measured both in the NFI-5 (2001-2005) and in the NFI-6 (2012-2013). For some species, too few observations were available for a reasonable fit, these were included in their respective rest-groups: *Abies* spp., *Picea sitchensis* and indigenous pines with too few observations were included under other conifers, while *Castanea sativa* and *Robinia pseudoacacia* were included in long-lived broadleaves. Table 3.8 gives a summary of the data that were used, Table 3.9 gives the variables that were selected and the corresponding parameter estimates, while Table 3.10 gives an explanation of the variables.

Table 3.8. *Overview of data used for model fitting*

	Number of trees	Mean dbh (mm)	Max dbh (mm)	Mean increment (mm.yr-1)
Larix spp.	717	265	695	4.1
Other conifers	216	213	567	3.7
Picea abies	635	202	554	4.7
Pinus nigra	681	240	534	3.2
Pinus sylvestris	4622	250	660	3.2
Pseudotsuga	1023	255	910	5.5
Betula spp.	2677	128	567	2.1
Long-lived broadleaves	2113	186	798	4.1
Short-lived broadleaves	767	140	890	2.9
Fagus sylvatica	1047	278	987	3.7
Populus plantations	284	277	675	10.4
Quercus robur&petraea	3513	231	1191	2.8

Table 3.9. *Selected variables and parameter estimates per species group.*

	Larix spp.			Other conifers			Picea abies		
		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$
c		7.55E-01	-1.26E-01		-1.05E+00	2.01E-01		6.56E-01	-9.26E-02
X1	D-DepRedN	-7.07E-05	1.17E-05	W-MaT	1.06E-01	-2.00E-02	F-lnBA	-4.42E-02	5.46E-03
X2	F-lnBA	-4.02E-01	6.91E-02				W-TaP	1.04E-03	-1.66E-04
X3	W-MweqT	2.81E-02	-4.80E-03				C-TaP	-1.65E-03	2.57E-04
X4	F-BA	1.41E-02	-2.47E-03						
	Pinus nigra			Pinus sylvestris			Pseudotsuga		
		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$
c		7.39E-02	-8.62E-03		-1.18E-01	2.50E-02		1.27E-01	-1.49E-02
X1	F-lnBA	-1.92E-02	2.73E-03	W-aTR	3.16E-02	-5.31E-03	F-lnBA	-1.71E-02	1.90E-03
X2				F-lnBA	-4.47E-02	6.88E-03			
X3				W-MaT	-3.92E-02	6.49E-03			
X4				W-McoqP	2.44E-03	-4.23E-04			
X5				S-ORCDRC	6.35E-04	-1.06E-04			
	Betula spp.			Long-lived broadleaves			Short-lived broadleaves		
		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$
c		-5.84E-01	1.17E-01		1.69E-01	-1.15E-02		3.70E-01	-6.77E-02
X1	F-lnBA	-7.26E-02	1.15E-02	S-CEC	1.69E-03	-2.16E-04	W-aTR	-5.21E-02	9.37E-03
X2	F-BA	2.52E-03	-4.27E-04	F-lnBA	-6.38E-02	9.82E-03	S-BLD	1.71E-04	-1.88E-05
X3	F-rDiffDq	-5.14E-02	8.14E-03	W-MaT	7.84E-03	-2.52E-03	S-CEC	1.18E-02	-2.27E-03
X4	W-SDmPET	2.16E-02	-4.04E-03				S-CRFVOL	2.63E-02	-5.10E-03
X5	S-SLTPPT	-3.62E-03	6.57E-04				F-lnBA	-1.17E-02	3.28E-05
	Fagus sylvatica			Populus			Quercus robur+petraea		
		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$		$\theta_{i,1}$	$\theta_{i,2}$
c		6.41E-01	-1.05E-01		-8.31E-01	1.43E-01		2.36E-01	-3.43E-02
X1	W-ISO	-6.85E-01	1.06E-01	W-aTR	7.68E-02	-1.23E-02	D-DepOxN	4.69E-05	-6.12E-06
X2	F-lnBA	-7.26E-02	1.01E-02	F-lnBA	-1.12E-01	1.59E-02	D-DepOxS	-3.04E-05	4.30E-06
X3	W-MweqT	-1.23E-02	1.84E-03				F-lnBA	-6.57E-02	9.54E-03
X4	W-SDmPET	3.29E-03	-2.19E-04				F-BA	1.25E-03	-1.80E-04
X5							F-rDiffDq	-8.97E-03	1.77E-03

Table 3.10. *Explanatory variables included*

Type	Source / time span / resolution	Variable name	Explanation	Unit
Forest structure	NFI / at first year of inventory	F-BA	basal area of the plot	m^2/ha
		F-lnBA	Ln(F-BA)	-
		F-rDiffDq	proxy for tree social position	-
Weather	Agri4Cast (agri4cast.jrc.ec.europa.eu/) / during observed growth period / 25 km	W-MaT	mean annual temperature	°C
		W-aTR	annual temperature range	°C
		W-ISO	isothermality	index
		W-TaP	total annual precipitation	mm
		W-SDmPET	standard deviation of monthly PET	mm
		W-MweqT	mean wettest quarter temperature	°C
		W-McoqP	mean coldest quarter precipitation	mm
Deposition	EMEP (www.emep.int)/ average 1990-2010 / 50 km	D-DepOxN	deposition of oxidised nitrogen	mg(N)/m^2
		D-DepOxS	deposition of oxidised sulphur	mg(S)/m^2
		D-DepRedN	deposition of reduced nitrogen	mg(N)/m^2
Soil	SoilGrids (Hengl et al. 2014)/ NA / 1 km	S-BLD	bulk density of the fine earth fraction	kg / m^3
		S-CEC	cation exchange capacity	cmol/kg
		S-CRFVOL	coarse fragments (> 2 mm fraction) volumetric	%
		S-ORCDRC	soil organic carbon	%
		S-SLTPPT	silt content mass fraction	%
Climate	GENS (Metzger et al. 2013)/ average 1950-2000 / 1 km	C-TaP (var20)	total annual precipitation	mm

3.3.5 Modelling of harvesting

The age dependent projections of forest structure and forest management practices are based on actual harvesting probabilities as derived from the National Forest Inventories. This does not include specific rotation lengths as often used in forest projections. Moreover for a long time wood harvesting in Dutch forests was usually limited to thinnings and small group fellings without prescribed rotation lengths. Only more recently also larger regeneration fellings are applied, but since these have been highly criticised in public opinion, this practice was abandoned again. The modelling approach that is used in the EFISCEN space model is consistent with this practice. Harvesting is implemented as the removal of a certain fraction of trees of a certain species in a certain diameter class, where the annual harvesting probabilities were derived from NFI data. As a result neither information on rotation length is needed as an input, nor will it be possible to provide information on rotation lengths from the model output.

From our repeated NFI data, we computed annual probabilities for a tree being harvested using the following formula (Schelhaas et al. 2018b):

$$z = 1 - (1 - \frac{\sum M_h}{\sum M})^{(\frac{1}{X})} \quad \text{(Eq. 3.5)}$$

where z is the annual probability that a tree of a certain population is harvested, M the number of live trees of that population in the first measurement, Mh the number of trees of that population that have been harvested between the first and the second measurement, and X the average interval between the observations. In this case our populations consisted of 5-cm DBH class, and species and owner classes as described in the stratification chapter. Harvesting was assumed to take place every 5th year, with a randomly assigned starting year (between 1 and 5) for each plot. Annual probabilities were accumulated to 5-year fractions (f) using:

$$f = 1 - (1 - z)^5 \quad \text{(Eq. 3.6)}$$

Figure 3.14 to Figure 3.21 show per species group (see Table 3.4) the annual harvest probabilities over diameter classes for each of the management objective/owner strata (see Table 3.3) as calculated from the NFI data.

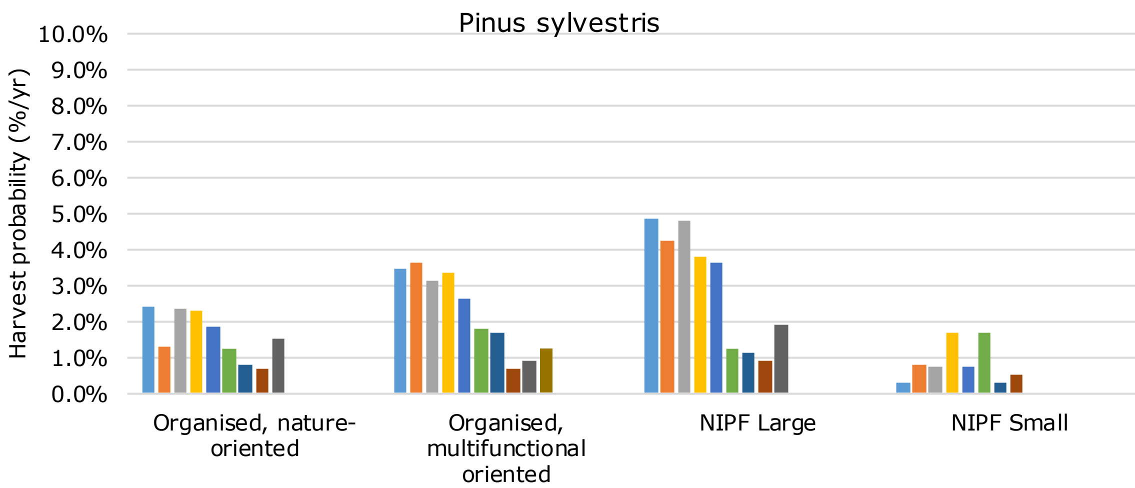

Figure 3.14. *Annual harvest probabilities for scots pine per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

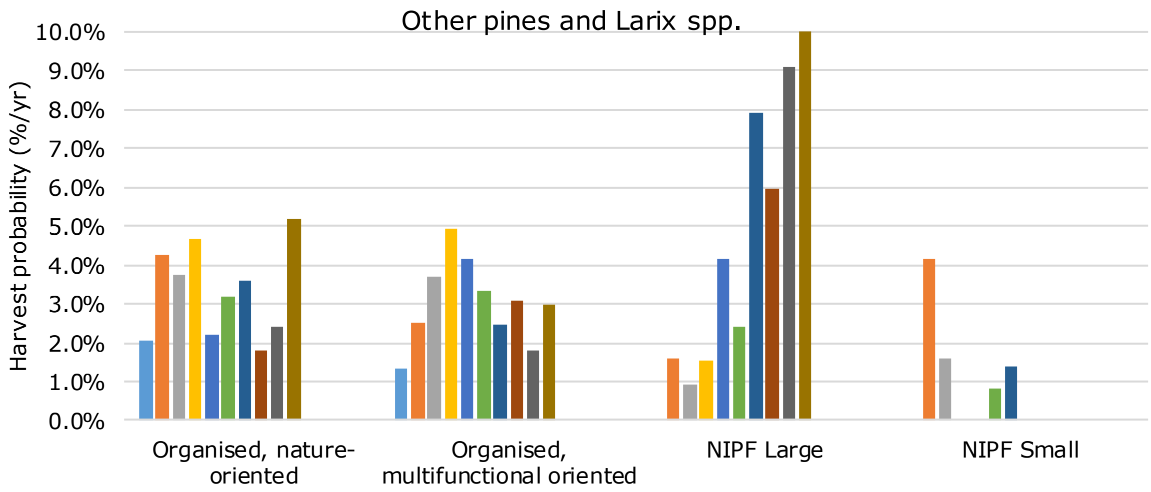

Figure 3.15. *Annual harvest probabilities for other pines and larch species, per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

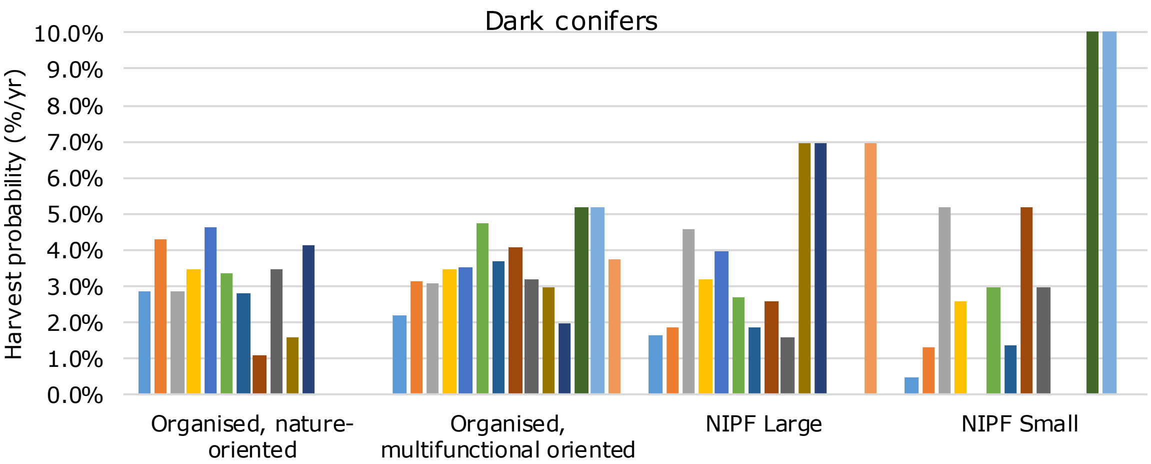

Figure 3.16. *Annual harvest probabilities for dark conifers per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

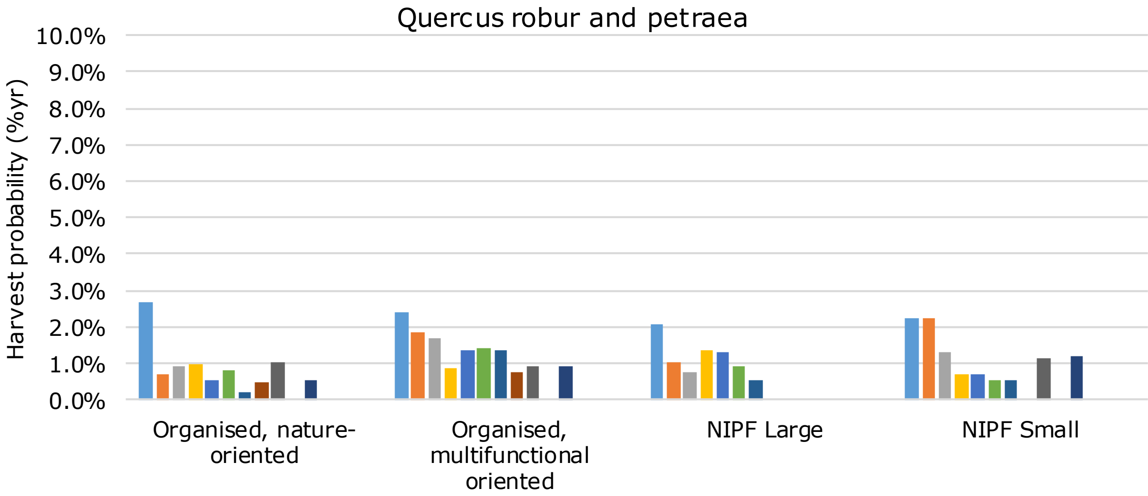

Figure 3.17. *Annual harvest probabilities for oak per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

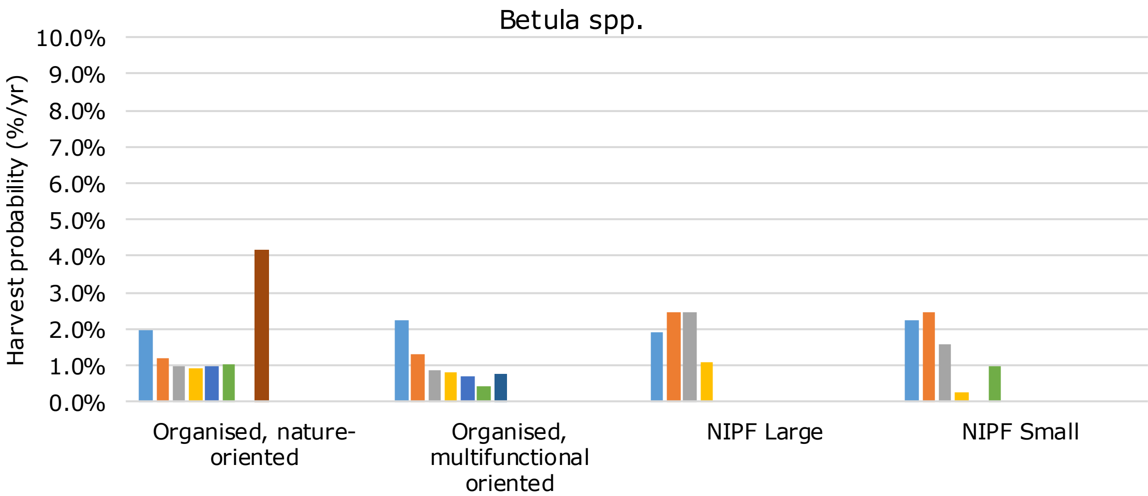

Figure 3.18. *Annual harvest probabilities for birch per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

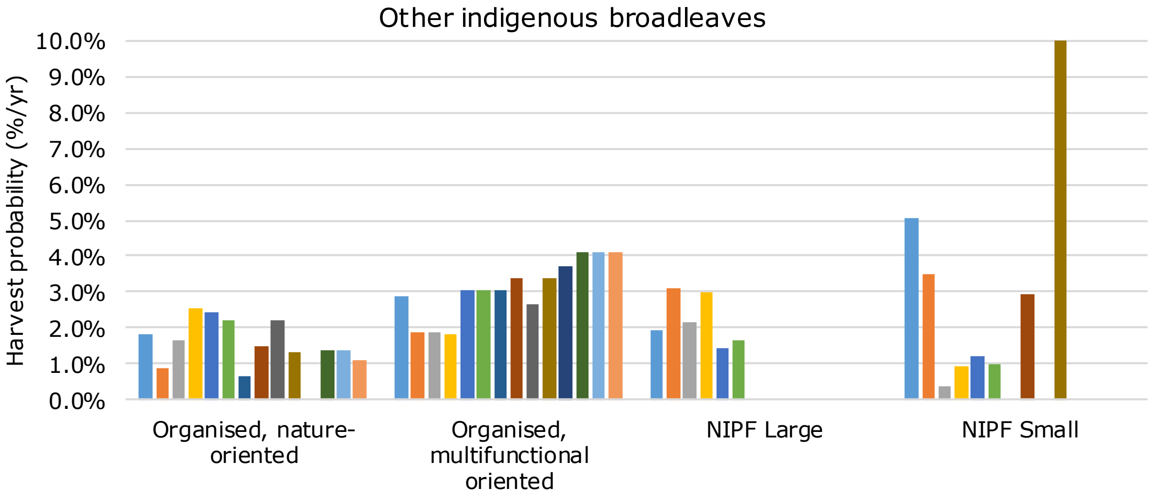

Figure 3.19. *Annual harvest probabilities for indigenous broadleaves per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

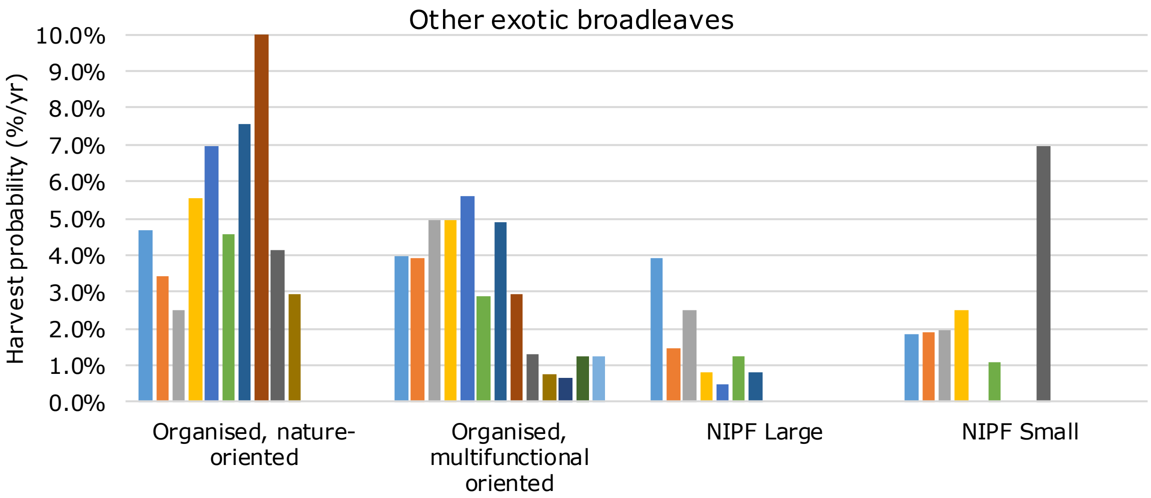

Figure 3.20. *Annual harvest probabilities for exotic broadleaves per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

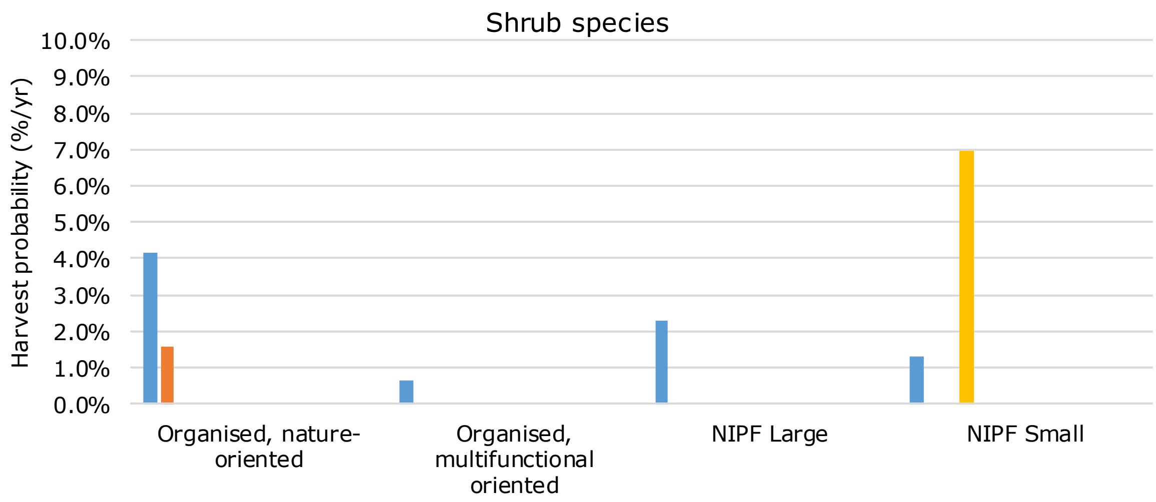

Figure 3.21. *Annual harvest probabilities for shrub species per management objective/owner stratum and per 5-cm diameter class as calculated from the NFI data. The first class (blue bar) is the 5-10 cm diameter class.*

3.3.6 Modelling of mortality

Mortality is implemented in EFISCEN Space as the removal of a certain fraction of trees of a certain species in a certain diameter class. On the longer term, the aim is to derive mortality fractions from mortality models that are sensitive to competition and abiotic factors such as weather. Until these are available, mortality probabilities are estimated in the same way as done for harvesting (Section 3.3.5). Mortality is applied each year, while harvesting is only applied every 5 years. Mortality probabilities were estimated per species and 5-cm diameter class, ignoring possible differences between owners and their management objectives. Mortality probabilities (Figure 3.22 and Figure 3.23) were copied from the study by Nabuurs et al. (2016) where EFISCEN Space was applied for the Netherlands for the first time, based on the same Dutch NFI data as for the harvesting probabilities in Section 3.3.5. These mortality estimates were done for the original 20 species groups included in EFISCEN Space. Mortality probabilities at higher diameter classes (where no observations were available) were assigned a constant value, based on the last observed values.

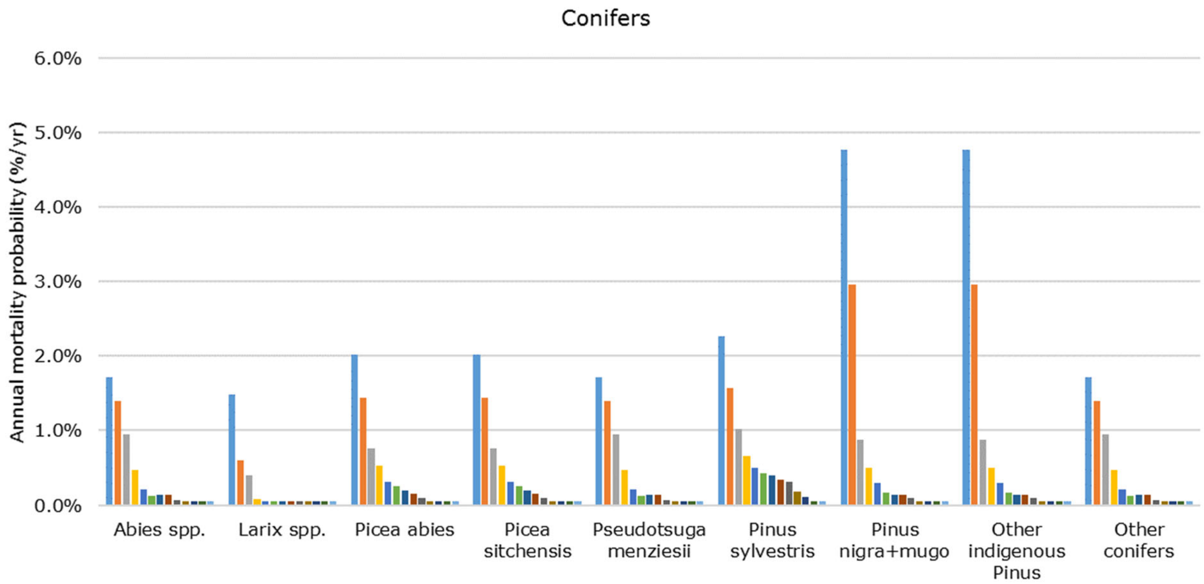

Figure 3.22. *Annual mortality probabilities for conifers per 5-cm diameter class (Nabuurs et al. 2016).*

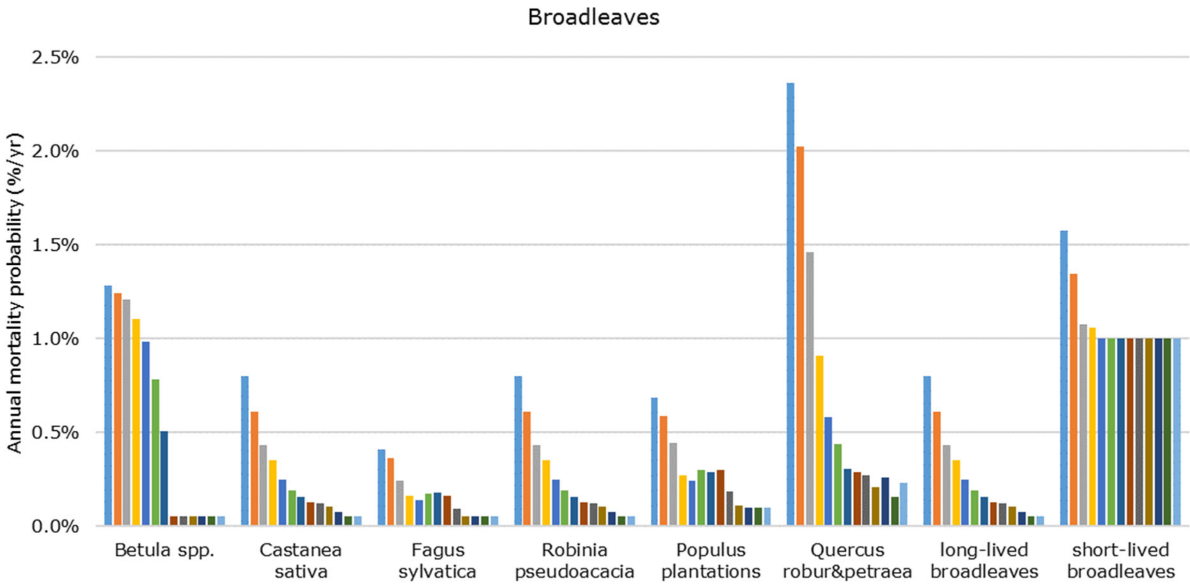

Figure 3.23. *Annual mortality probabilities for broadleaves per 5-cm diameter class (Nabuurs et al. 2016).*

3.3.7 Modelling of ingrowth

Ingrowth, the insertion of a certain number of trees in the smallest diameter class, is currently not implemented in EFISCEN Space. For the derivation of the FRL we used the following procedure to account for ingrowth. Two types of ingrowth were distinguished: 1) ingrowth in plots with initial forest cover, and 2) ingrowth in plots without initial forest cover. We estimated both ingrowth types from the permanent sample plots that were measured both in NFI5 (2001-2005) and in NFI6 (2012-2013). The average ingrowth component on all plots (1217 plots) with forest cover in NFI5 was 0.47 m^3 ha^{-1} yr^{-1}. The average ingrowth component on all plots (20 plots) without forest cover in NFI5 was 5.42 m^3 ha^{-1} yr^{-1}. At the moment, EFISCEN Space can only be initialised with plots with forest cover. The projected development of average growing stock over time was therefore increased with 0.47 m^3 ha^{-1} for each simulation year. In 2013, the correction was 0.47 m^3 ha^{-1}, in 2014 the correction was 0.94 m^3 ha^{-1}, etc. For the plots without initial forest cover, an (in)growth of 5.42 m^3 ha^{-1} for each simulation year was assumed. In 2013, the average growing stock was 5.42 m^3 ha^{-1}, in 2014 10.84 m^3 ha^{-1}, etc. The final growing stock was taken as the weighted average of the growing stocks of the plots with and without initial forest cover.

3.3.8 Output

The raw output consists of the number of trees present per diameter class per species per simulated plot for each annual time step, as well as the number of trees that have been harvested and the number of trees that died. For each species, the stem volume of one average individual in each diameter class is estimated using the midpoint of the diameter class. We use local volume models, derived from NFI data using a 2- or 3-degree polynomial function:

$$v = b0 + b1 \times dbh + b2 \times dbh^2 + b3 \times dbh^3 \qquad \text{(Eq. 3.7)}$$

with *v* the stem volume (dm^3) of a tree with diameter *dbh*, and *b0-b3* parameters (Table 3.11).
By multiplying the number of trees (present, harvested or dead) with the estimated volume of an average individual in that diameter class, total volume can be estimated. Plot totals (numbers, basal area or volume) can be aggregated in various ways (by species, by diameter classes), and national totals can be derived using the individual plot weights.

Table 3.11. *Results of parameter estimation for volume models, based on the sample trees from NFI-6*

species	n	Minimum dbh (cm)	Mean dbh (cm)	Maximum dbh (cm)	Minimum stem volume (dm^3)	Mean stem volume (dm^3)	Maximum stem volume (dm^3)	R^2	b0	b1	b2	b3
Abies spp.	22	5.5	30.5	79.3	5.11	1279	7090	0.990	-33.4898	2.310599	0.491089	0.007766
Larix spp.	291	5.1	29.8	76.2	7.39	932	5541	0.965	100.7136	-22.099	1.660194	-0.00703
Other conifers	52	5.2	21.4	56.5	5.79	520	2640	0.987	141.5385	-30.1305	1.886729	-0.0097
Other indigenous Pinus	20	8	36.9	53	16.95	1021	2350	0.897	117.1139	-12.3765	0.901887	
Picea abies	197	5	25.3	58.6	4.10	644	2923	0.983	88.81569	-21.2212	1.698283	-0.00884
Picea sitchensis	21	5.5	33.1	62.9	4.24	1201	3735	0.964	37.70824	-12.7673	1.411985	-0.00554
Pinus nigra+mugo	157	6.4	32.0	68.2	8.11	880	4793	0.950	-226.86	28.68507	-0.54398	0.017932
Pinus sylvestris	1226	5.1	29.5	70.8	4.20	710	3976	0.932	54.42766	-12.2648	1.122489	-0.00293
Pseudotsuga menziesii	365	5	30.6	91.7	5.08	1181	10371	0.985	-105.171	10.91738	0.314955	0.007837
Betula spp.	1072	4.9	16.2	49.8	3.04	195	1491	0.947	17.68273	-6.31768	0.902483	-0.00401
Castanea sativa	65	5	28.8	64.7	5.84	708	3357	0.975	84.95559	-17.2453	1.126191	-0.00171
Fagus sylvatica	378	5	32.2	109.6	3.09	1166	11600	0.973	63.35606	-13.2521	1.040318	-0.00031
long-lived broadleaves	849	5	23.2	81	3.36	563	5833	0.966	13.11966	-6.7476	0.931077	-0.00046
Populus plantations	122	5.1	42.1	99.4	6.26	1727	7692	0.944	256.3364	-34.6048	1.76174	-0.00628
Quercus robur&petraea	1317	5	27.2	131.3	2.03	752	17238	0.962	-15.4285	-4.14593	0.811682	0.001484
Robinia pseudoacacia	29	5.8	22.4	63.2	3.71	547	2492	0.990	173.8573	-36.7829	2.384958	-0.01899
short-lived broadleaves	1096	4.8	11.8	98.6	2.74	131	5717	0.957	59.95333	-14.8448	1.177223	-0.0046

3.3.9 Deadwood

Currently, EFISCEN space does not contain a module to estimate the amount of deadwood. For the purpose of deriving the FRL, we use a simple balance calculation:

$$DW_{i+1} = DW_i + input_1 - DW_i \times k \quad \text{(Eq. 3.8)}$$

with DW_i the deadwood stock (m^3/ha) at time *i*, $input_i$ the amount of mortality as simulated by EFISCEN Space in time step *i* and *k* the loss rate. On the permanent sample plots, the amount of deadwood present in NFI5 was 9.6 m^3/ha and in NFI6 12.6 m^3/ha. The input of new dead trees was 0.91 m^3 ha^{-1} yr^{-1} and the loss was 0.59 m^3 ha^{-1} yr^{-1}. The loss rate compared to the stock (average between NFI5 and NFI6) was 5.32% per year. For the FRL we initialised the deadwood stock with the value average from all measured plots (13.25 m^3/ha).

3.3.10 Setup of EFISCEN Space and connection to LULUCF system

For the initialisation of EFISCEN Space we used all plots that were measured in NFI6. From the 3190 plots available, 3051 plots could be run by the model. For 12 plots part of the abiotic data was missing from the corresponding data layers. We corrected for the number of plots were needed, assuming no bias was introduced by not simulating the 12 plots without abiotic data. The 127 plots that did not have trees on them, were included as described in Section 3.3.7.

For the conversion of EFISCEN Space output to input for the LULUCF system we used the same procedure as is being used for processing NFI data, treating the EFISCEN Space output as a virtual NFI for 1 January in the years 2021, 2026 and 2031. For each of these years we extracted for each simulated plot the average growing stock volume for all species together, and we determined the dominant species on that plot as the species with the largest growing stock volume. In addition, we assigned to each plot the projected average deadwood stock from the corresponding year, distributed over standing and lying deadwood using the 2013 ratio (49.4% of deadwood was standing). Conversion to carbon was done using the standard LULUCF method (Arets et al. 2018), using the BCEF of the dominant tree species. The average growing stock for each FRL year as computed by the system was then corrected for the 12 missing plots and for ingrowth using the procedures described above.

Harvested Wood Products
The total harvest level (after correcting for the 12 missing plots) and the share of conifers and broadleaves were taken directly from the EFISCEN Space output. For the calculation of Harvested Wood Products we scaled each years' production values compared to the average over the period 2000-2009:

$$a_i = \bar{a} \times H_i / \bar{H} \qquad \text{(Eq. 3.9)}$$

with a_i the value of HWP production category *a* (sawnwood, paper, panels) for year *i* , $\bar{a}$ the average production in the period 2000-2009, H_i the total harvest in year *i*. and $\bar{H}$ the average harvest in the period 2000-2009. These historic harvest levels that were used differ from those used in previous GHG inventories, but will be the same as used in the forthcoming GHG inventories, starting from the NIR 2019 (Arets et al. 2019). In the projections the actual numbers for import and export of the HWP categories have been used up to 2015, the last available year as used in the NIR 2018. From 2015 onwards the Imports and Export values for are kept the same as for 2015. (See Table A2.2 in Appendix 2).

3.3.11 Results of the EFISCEN space runs

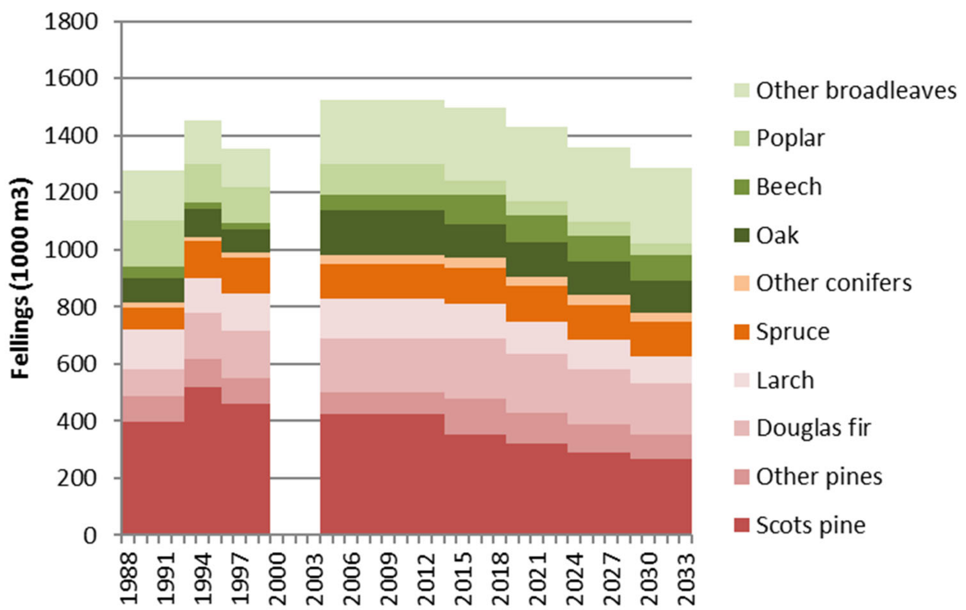

Figure 3.24. *Fellings by species as observed in the past (up to 2012) and as projected by EFISCEN Space (averaged over per 5 years for better comparison).*

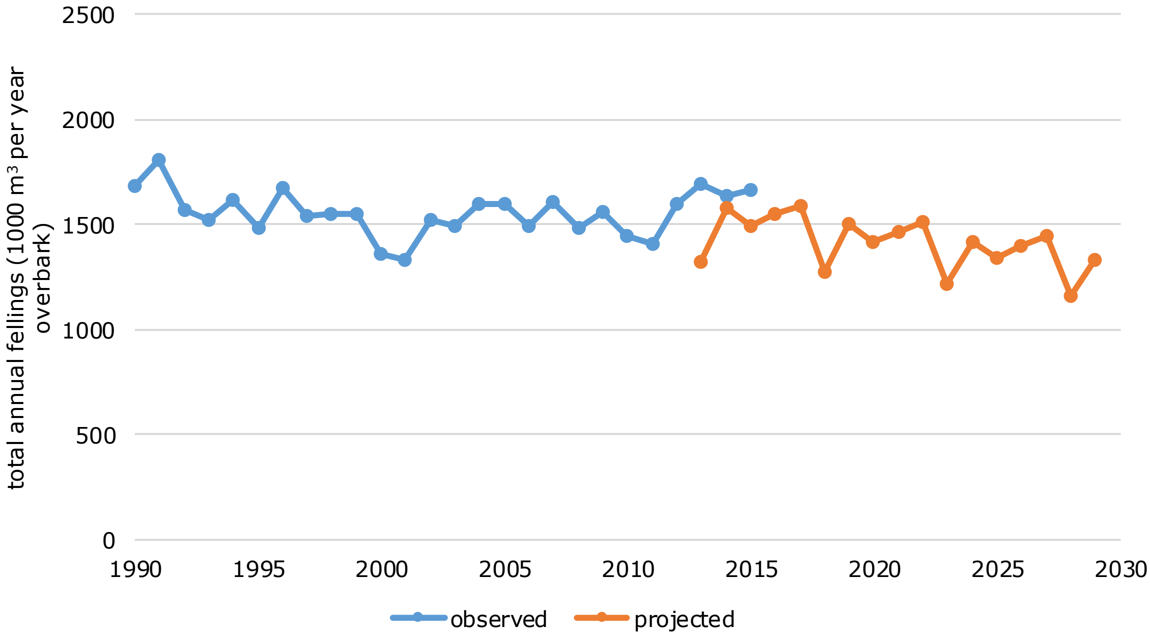

Figure 3.25. *Total fellings as observed in the past and as projected by EFISCEN Space. Fluctuations and 5-year patterns in EFISCEN Space projections are caused by the random assignment of the first harvesting year for each plot and the subsequent 5-year harvesting cycle.*

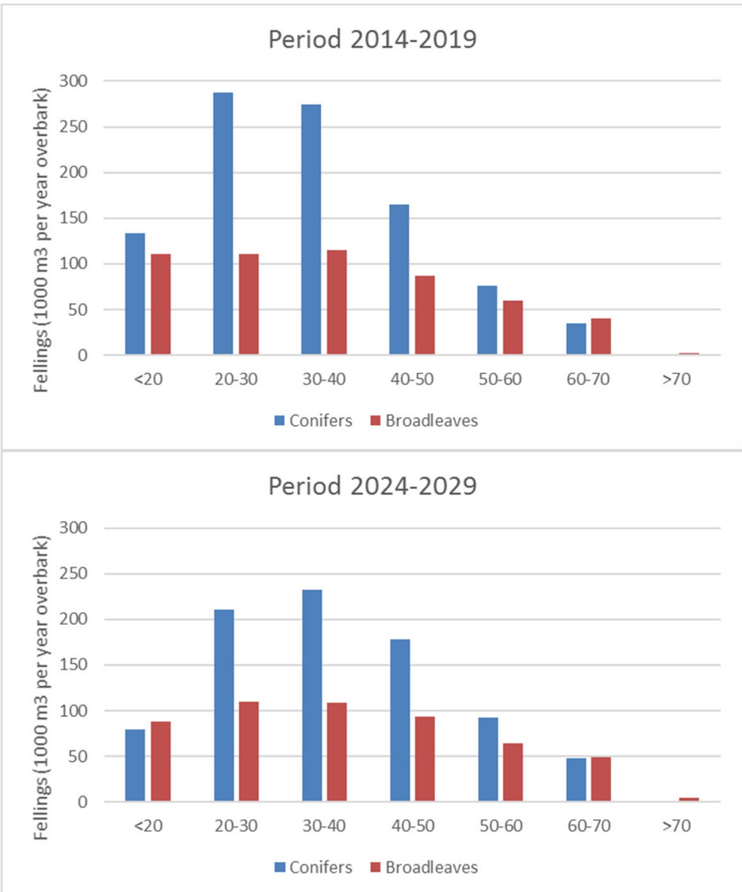

Figure 3.26. *Distribution of fellings over diameter classes in the period 2014-2019 and 2024-2029.*

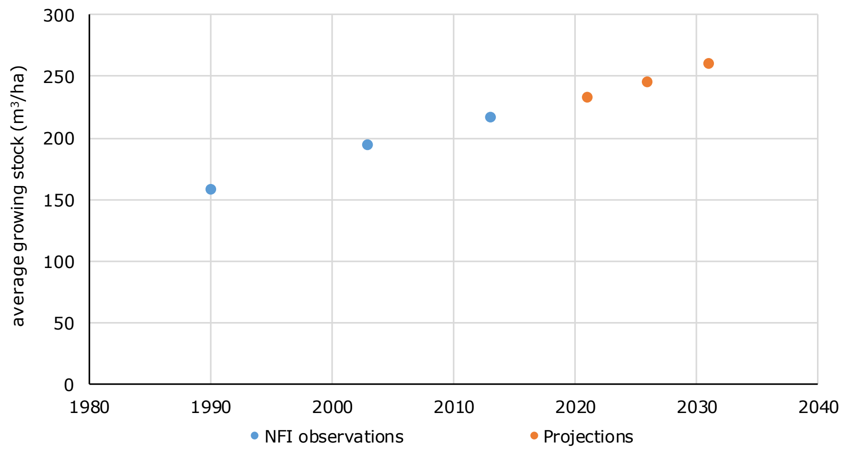

Figure 3.27. *Development of growing stock as observed in the past (from NFIs) and the future projections by EFISCEN Space.*

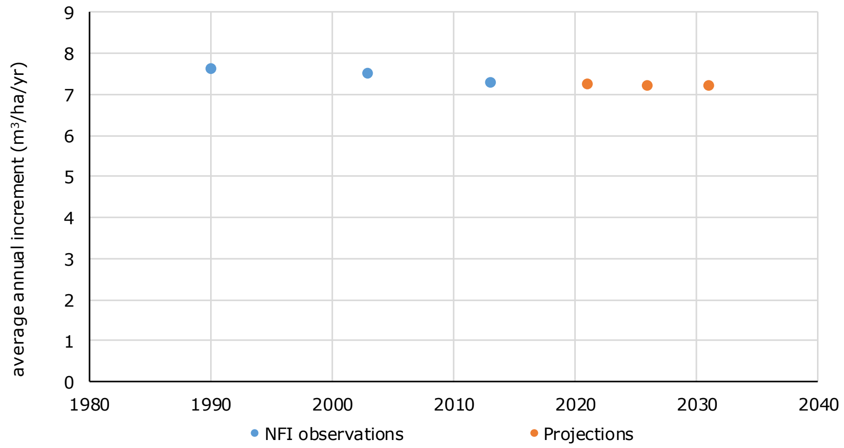

Figure 3.28. *Development of increment as observed in the past (from NFIs) and the future projections by EFISCEN Space.*

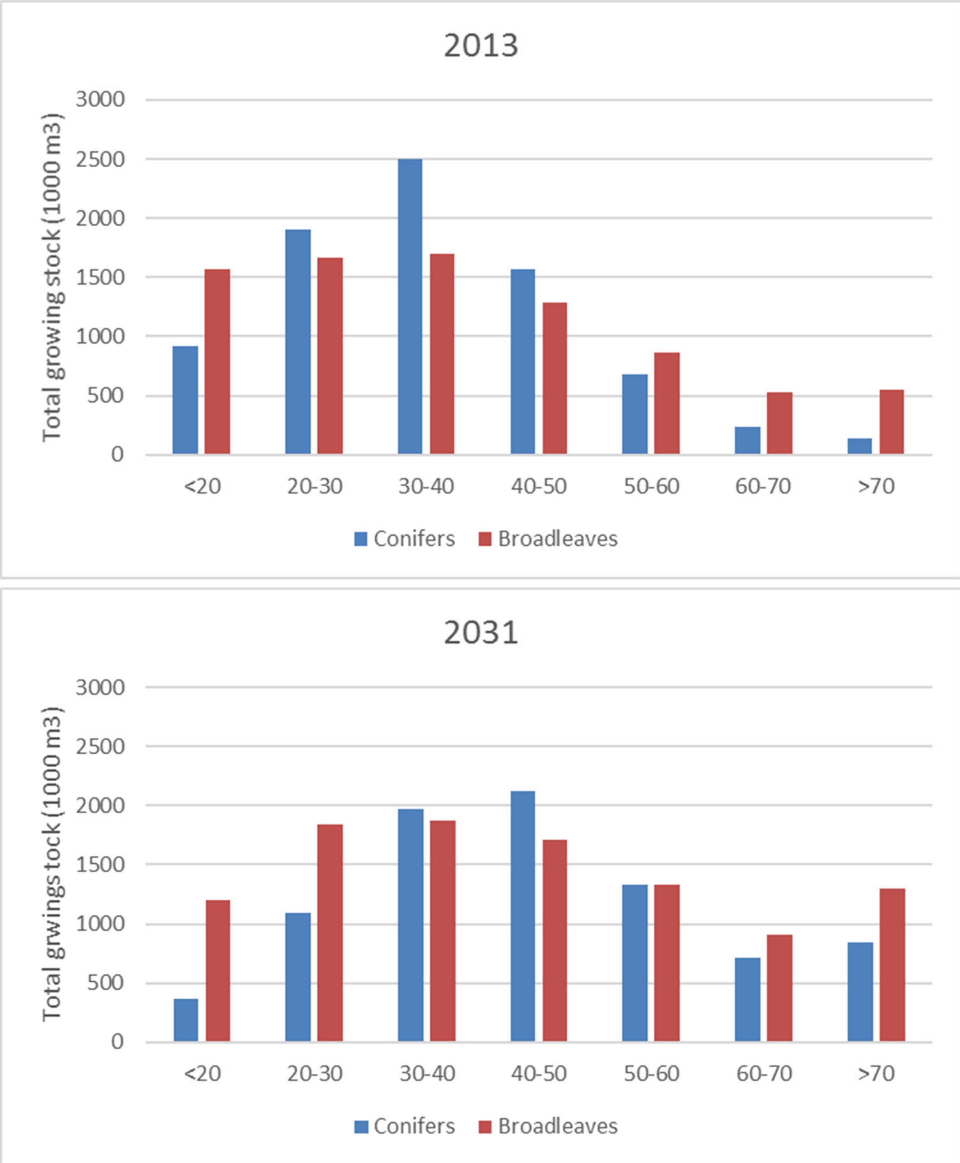

Figure 3.29. *Distribution of growing stock over diameter classes in 2013 and 2031.*

Table 3.12. *Per NFI inventory and projected state of the forest (EFISPACE), its reference year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), biomass conversion and expansion factors (BCEF, tonne dry matter per m^3 stemwood volume), belowground biomass (BGB; tonnes ha^{-1}), root to shoot ratio (R), share of conifer biomass in the total forest biomass, mass (tonnes ha^{-1}) of standing deadwood (DWs) and lying deadwood (DWl). The EFISCEN Space data are based on the model projections. See Chapter 4 in Arets et al. (2018) for how this is further implemented in the national system and compare with Table 1.1)*

NFI	Year	GS	AGB	BCEF	BGB	R	Share Conifers	DWs	DWl
HOSP	1990	158	112.8	0.714	20.6	0.18	0.436	0.84	0
NFI-5	2003	195	143.2	0.736	25.8	0.18	0.414	1.33	1.53
NFI-6	2013	217	165.5	0.764	29.9	0.18	0.367	1.88	1.93
EFISPACE2021	2021	233	184.4	0.791	32.6	0.18	0.338	2.18	2.23
EFISPACE2026	2026	246	195.4	0.794	34.5	0.18	0.331	2.28	2.33
EFISPACE2031	2031	260	207.1	0.796	36.6	0.18	0.326	2.34	2.40

4 Forest reference level

4.1 Forest reference level and detailed description of the development of the carbon pools

The forest reference level of the Netherlands for the period 2021-2025 is -1,531,397 tonnes of CO_2 eq. per year, in which the HWP pool constitutes of -6,973 tonnes of CO_2 eq. per year. If instantaneous oxidation of HWP was assumed, the forest reference level would be -1,524,424 tonnes of CO_2 eq. per year (see Table 4.1).

Table 4.1. *Value of the forest reference level (tonnes CO_2 eq. per year) with: (A) emissions and removals from HWP using the first order decay function and (B) assuming instant oxidation of HWP.*

A	B
-1,531,397	-1,524,424

During the compliance period the projected emissions and removals over the different carbon pools included in the FRL (see Section 2.1) developed as shown in Table 4.2.

4.1.1 Calculated carbon pools and greenhouse gases for the forest reference level

A detailed description and justification for the included and excluded carbon pools is provided in Section 2.1. Carbon stock changes in the carbon pools living biomass (both aboveground biomass and belowground biomass), dead wood, and HWP contributed to the forest reference level. The annual emission values (Gg CO_2) for these pools during the period 2021-2025 are provided in Table 4.2.

Table 4.2. *Development of projected emissions (Gg CO_2 eq.) for the different carbon pools over time during the period 2021-2025.*

Year	Carbon pool reported						
	Living biomass	Litter	Dead wood	Soil		HWP	Total
				Min	Org		
2021	-1497	NO	-23.6	NO	NO	-17	-1537
2022	-1499	NO	-23.6	NO	NO	-23	-1545
2023	-1501	NO	-23.6	NO	NO	15	-1509
2024	-1503	NO	-23.6	NO	NO	-10	-1537
2025	-1505	NO	-23.6	NO	NO	0	-1529
Average 2021-2025	-1501	NO	-23.6	NO	NO	-7	-1531

4.2 Consistency between the forest reference level and the latest national inventory report

The methodologies as applied for assessing the emissions and removals for the forest reference level and the category forest land remaining forest land in the national inventory reporting are the same. The modelling approach with the EFISCEN space model as provided in Chapter 3 projects a new state of the forest in 2021, 2026 and 2030 (Table 3.12) conform the requirements and criteria as set out by the EU LULUCF regulation. The projected information on state of the forests is then processed into emission factors in the same way as the data from the National Forest Inventories that are input to the LULUCF system (Table 1.1) are processed. The subsequent calculations in the LULUCF system, combining emission factors and spatial explicit activity data are then the same (also see Section 3.1).

Here we test if the results that we obtained with the EFISCEN space projections are consistent with the information provided in the latest national inventory report. While developing the approaches for calculating the FRL a number of issues with the calculations for the NIR 2018 were identified and addressed (see Section 3.2.1). These related to improved harvest information and correction of the state of forest as derived from the NFI-6 to better represent the state of FL remaining FL (Section 3.2.1). Rather than assessing consistency with the actual NIR 2018, which had some issues, we consider it more appropriate to assess consistency for the FRL with the adjusted results from the LULUCF system in which the improvements mentioned in Section 3.2.1 are considered. Here we will refer to this as 'adjusted NIR'. These improvements will also be addressed in the forthcoming NIR 2019.

For testing consistency with historic GHG inventory data from the adjusted NIR 2018, we also applied the EFISCEN space model with the same parameters as detailed in Section 3.3 for the FRL projections, but starting from the 2003 state of the forest as derived from the NFI5. The result of this is a new simulated state of the forest in 2013, which then is used as input to the LULUCF system to assess the carbon stock changes. Table 4.3 gives the resulting set of parameters describing the state of the forest to assess the carbon stock change between 2003 and 2013. This thus applies the modelling approach used for calculating the reference level to the historic period 2003-2013. We refer to this run as the consistency test run, which then will be compared to the adjusted NIR 2018 results.

Table 4.3. *Input to the LULUCF model for the consistency test run. Per NFI inventory and projected state of the forest (EFISPACE), its reference year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), biomass conversion and expansion factors (BCEF, tonne dry matter. per m^3 stemwood volume), belowground biomass (BGB; tonnes ha^{-1}), root to shoot ratio (R), share of conifer biomass in the total forest biomass, mass (tonnes ha^{-1}) of standing deadwood (DWs) and lying deadwood (DWl). The EFISCEN Space data are based on the model projections.*

NFI	Year	GS	AGB	BCEF	BGB	R	Share Conifers	DWs	DWl
HOSP	1990	158	112.8	0.714	20.6	0.18	0.436	0.84	0
NFI-5	2003	195	143.2	0.736	25.8	0.18	0.414	1.33	1.53
EFISPACE2013	2013	225	165.5	0.764	29.9	0.18	0.367	1.76	2.01

4.2.1 Consistency of the management practice

We first checked on the consistency of the modelled management practice with the actual management practice. For this we compared the actual average annual harvest for the period 2003-2013 of the adjusted NIR 2018 results (Section 3.2.1, Appendix 2) with the average annual harvest during this time period with the projections starting from the NFI-5 (consistency test run, Figure 4.1). The difference between the actual and projected average annual harvest is smaller than one standard deviation of the actual harvest (Table 4.4), indicating the projections are consistent with the actual data. From Figure 4.1 and Figure 4.2 it can be inferred that also the trend is consistent for the period 2003-2013 and continuing to 2021.

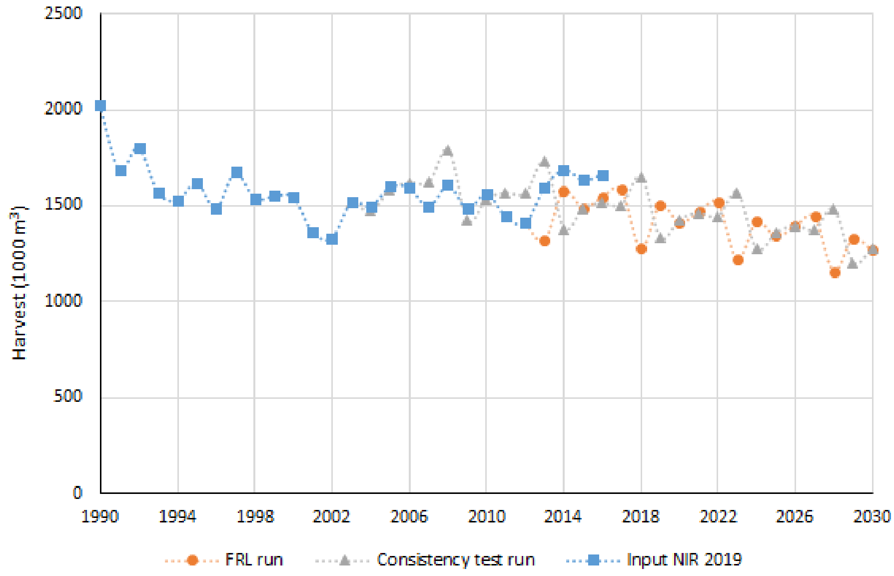

Figure 4.1. *Annual harvests (1000 m3) of roundwood for the actual data (Input NIR 2019), the FRL projections starting from the NFI-6 forest state in 2013 (FRL run) and the consistency test run projecting forest development and harvest from the NFI5 state of forest in 2003.*

Table 4.4. *Consistency check actual data and projections starting from the NFI-5 (consistency test in Figure 4.1). For Both the average annual harvest (1000 m³/yr) and standard deviation and the difference.*

	Actual harvest which will be input to NIR 2019	NFI-5-run	Difference
Average	1,529	1,590	61
StDev	72	110	

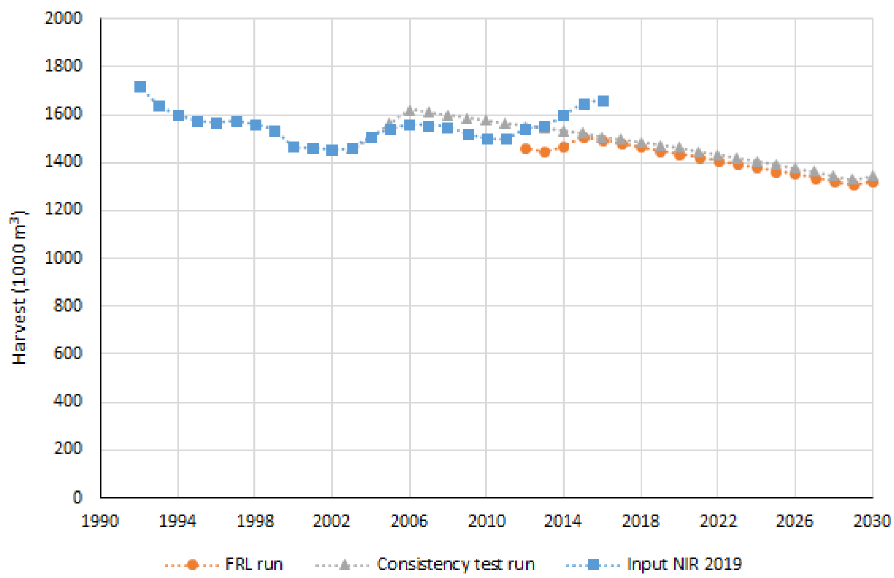

Figure 4.2. *5 year moving average for annual harvests (1000 m3) of roundwood for the actual data (Input NIR 2019), the FRL projections starting from the NFI-6 forest state in 2013 (FRL run) and the consistency test run projecting forest development and harvest from the NFI-5 state of forest in 2003.*

4.2.2 Consistency of the emissions and removals

As in Section 4.2.1 the verification of consistency of the emissions and removals between projections and GHG inventory is based on the period between 2003 (NFI-5) and 2013 (NFI-6). Since in the current NIR the development of the state of forest is based on another model projection (see Chapter 4.2 in Arets et al. 2018), comparison beyond 2013 is not considered to be useful for verification purposes at this time. The currently reported carbon stock changes beyond 2013 that are based on model projections will be replaced by measured effects once the data from the currently ongoing 7th National Forest Inventory become available by 2020. This then will make it possible to also include the period 2013-2020 in the verification. This will be included in future technical corrections to the FRL 2021-2025.

The validation of consistency of emissions and removals was first done on the level of the net carbon stock changes and removals for living biomass, dead wood and HWP. The FRL guidance document recommends that this verification ideally be based on the reported carbon stock gains and losses.

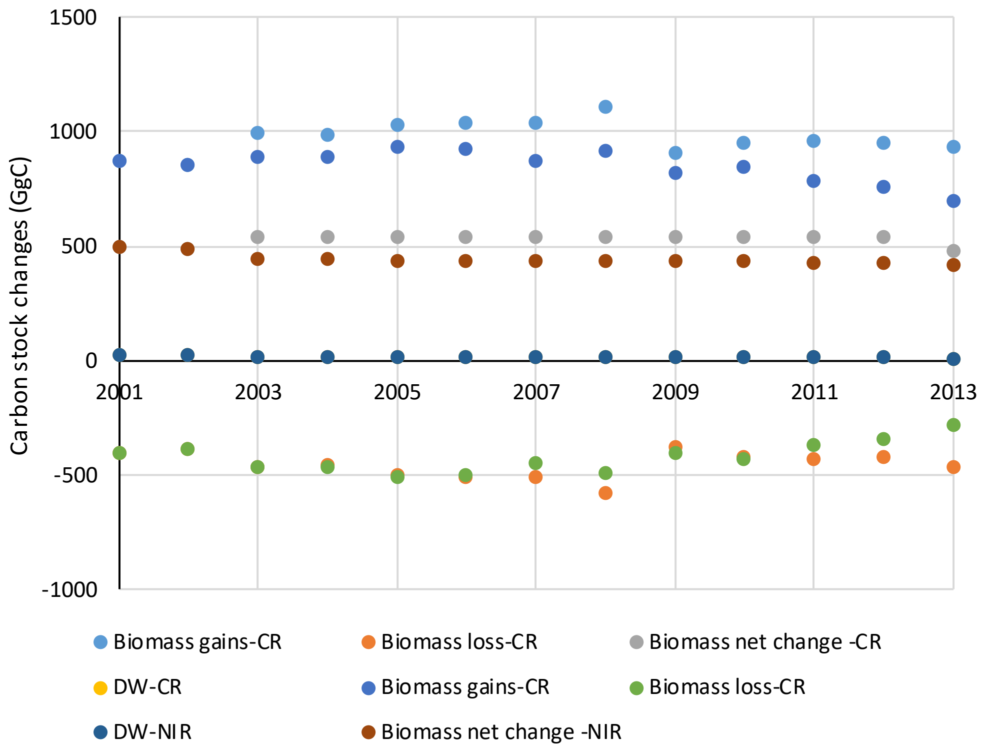

Figure 4.3. *Carbon stock gains and losses in living biomass (biomass gains; biomass loss), net carbon stock changes in living biomass (biomass net change) and net carbon stock changes in dead wood (DW) for the consistency run (CR) and the adjusted NIR 2018 results (NIR). DW-CR and DW-NIR largely overlap.*

Because in our case the gains and losses reported in the GHG inventories are based on the yearly wood harvests (see Chapter 4.2 in Arets et al. 2018), the test to compare the results of the consistency run and adjusted NIR2018 as suggested in the FRL guidance document would be a repetition of the checks in Section 4.2.1. The basis of our calculations in the NIR and FRL are the net carbon stock changes calculated form a stock-difference approach (see Chapter 4.2 in Arets et al. 2018) were average stock changes per ha of FL remaining FL (or projected state of forest) are calculated as the average of the total change between the two moments in time of forest inventories. As a result there is no variation in net carbon stock changes or emissions among years in between two inventories (i.e. NFI-5 and NFI-6) or projections. Therefore, the test to check if the average net carbons stock changes or net emissions or removals in the historic period as based on the consistency test run are within one standard deviation of those based on the adjusted NIR results as suggested by the FRL guidance (Forsell et al. 2018) cannot be done.

Instead we tested for consistency by comparing the average growing stock information of the actual NFI-6 (including the corrections mentioned in Section 3.2.1) in 2013, with the projected average growing stock of the EFISCEN space projections starting from the NFI-5. This average growing stock is the basis for the calculation of the average carbon stock in 2013. Therefore, if the projected average growing stock is sufficiently similar to the reported average growing stock from the NFI-6, this would indicate that also the net carbon stock changes in biomass and hence net emissions and removals from biomass are consistent between the FRL approach and observed for the adjusted NIR 2018.

For this we assessed the average growing stock of all plots in the NFI-6 data that represent FL remaining FL (221 m^3/ha based on 2728 plots) and calculated the corresponding 95% confidence interval of the average growing stock (218-227 m^3/ha). The projected average growing stock of 225 m^3/ha from the EFISCEN space projections is well within the 95% confidence interval of the average growing stock from the NFI-6 data. Figure 4.4 Based on this we are confidently conclude that the projected net removals in the consistency test run are consistent with the observed emissions and removals from the adjusted NIR 2018.

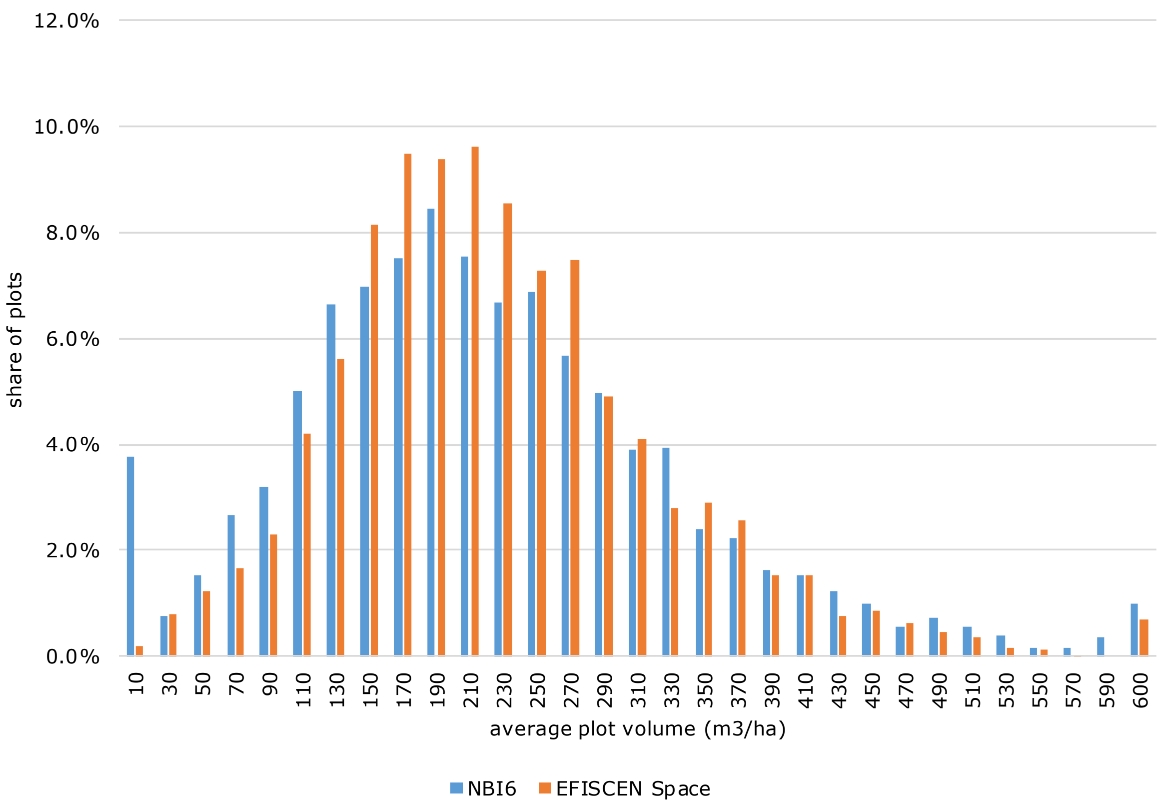

Figure 4.4. *Histogram of average plot growing stock volume (m^3/ha) in 2013 based on 1) the NFI-6 plots that represent FL remaining FL and 2) the EFISCEN space projections starting from the NFI-5 state of forest in 2003.*

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Appendix 1 – Data sources

A1.1 National Forest Inventories

For parameterisation of the modelling framework presented in Chapter 3, the data from two National Forest Inventories are used, covering the period 2001-2013: NFI-5 and NFI-6.

In the LULUCF reporting in the NIR also information from the HOSP inventory is used. Because its methodology and sampling design differs from the subsequent NFI-5, the HOSP could not be used for the parameterisation of the modelling framework used to do the FRL projections.

It should be noted that although within this document the naming of the Forest Inventories was harmonised, other documents to which we refer may use different names or Dutch names. Those alternative names are indicated in the descriptions below.

HOSP

The HOSP (Hout Oogst Statistiek en Prognose oogstbaar hout) inventory was designed in 1984 and conducted between 1988 and 1992 and 1992-1997 (Schoonderwoerd and Daamen 1999). For the LULUCF calculations only the data from the time period 1988-1992 were used, as these best represent the situation in the base year 1990. The HOSP was not a full inventory and its methodology was also different from earlier and later forest inventories. It was primarily designed to get insight in the amount of harvestable wood, but it still provides valuable information on standing stocks and increment of forest biomass. In total 3,448 plots were characterized by age, tree species, growing stock volume, increment, height, tree number and dead wood. Each plot represented a certain area of forest ('representative area') of between 0.4 ha and 728.3 ha, and together they represented an area of 310,736 ha. From this total number of plots, 2,500 measurement plots representing 285.000 ha were selected for re-measurements in subsequent years. After 1997 only 2 annual re-measurements were carried out on about 40% of the original sample plots (Schoonderwoerd and Daamen 2000).

QA/QC

Instructions for the measurement in the HOPS were defined in a working paper (Anonymous 1988). According to Hinssen (2000) these instructions were very clear, leaving little room for alternative interpretations, which should guarantee consistent results over time. In every measurement year 2-3 days were included to randomly check measurements carried out during that year. Trees that were measured during a census were also always measured during subsequent censuses. The project coordinator regularly checked results from the database. Suspicious data and errors were checked in the field and results of these checks were discussed with the field staff and if needed the measurement instructions were improved (Daamen and Stolp 1997).

5th National Forest Inventory

The 5th National Forest Inventory (NFI-5) of the Netherlands, also referred to as Meetnet Functie Vervulling Bos (MFV), was designed as a randomized continuous forest inventory with 3622 sample plots in a 1×1 km unaligned systematic sampling design. The plots were inventoried in 2001, 2002, 2004 and 2005 (not in 2003 because of a contagious cattle disease). Half of the plots were made permanent plots for which tree coordinates were mapped.

Trees were measured and recorded on a circular plot. The plot radius is established so that each plot includes at least 20 trees, but with a minimum radius of 5 m and a maximum of 20 m. All trees with a diameter at breast height (1.3 m above the stump) of at least 5 cm were measured, including standing dead and lying trees. In addition to the tree measurements, characteristics of the plot and/or stand are assessed including ownership, stand size, forest type, soil type, and age. In 2004 and 2005 also litter layer thickness was measured in stands on poor sand and loess soils (Daamen and Dirkse, 2005).

QA/QC
The density of sample points in the monitoring network resulted in an estimated confidence level of plus or minus 10% in the most forest rich provinces (Dirkse et al. 2007). The confidence levels and quality of the methodology were tested in a pilot study by Dirkse and Daamen (2000). Further justification for the methodologies used during the collection of data for the NFI-5, and the subsequent analysis of the data is provided in an Annex to Dirkse et al. (2007).

6th National Forest Inventory
Between September 2012 and September 2013 the 6th National Forest Inventory (NFI-6) was conducted (Schelhaas et al. 2014). In Dutch this is referred to as Zesde Nederlandse Bosinventarisatie (NBI6). This forest inventory was implemented with the aim to also support reporting of carbon stock changes in forests to the UNFCCC and Kyoto Protocol. To facilitate the direct calculation of carbon stock changes between the NFI-5 and NFI-6, the methodology of the NFI-6 closely followed the methodology of the NFI-5 (see Schelhaas et al. 2014). Measurements were done on 3190 sample plots, of which 1235 were re-measurements of permanent sample plots that were established and measured in the NFI-5.

QA/QC
The field measurements were carried out using a digital tree calliper that directly recorded the measurements in a database. The software then directly compared and validated the information with information from the NFI-5 inventory. In this way erroneous and impossible values would be signalled and could be checked and corrected while still in the field. After uploading of the data from the callipers into the inventory database the data were again checked for impossible combinations of values and missing values.

Appendix 2 – Method change for harvest statistics in NIR 2019

In this short Appendix we discuss recent data issues with roundwood production statistics in the Netherlands that have an effect on the quantities of wood removals and fellings as used in the calculations and reporting of greenhouse gas emissions and removals of the LULUCF sector.

Up until the NIR 2018 FAO statistics were used for harvesting of roundwood. As we will show in section A2.2, the FAO statistics from 2015 onwards include large amounts of wood fuel that are not exclusively based on wood from forest land, but also includes other wood sources. Additionally a comparison between the wood balance based on forest inventory data and the current FAO statistics indicate that FAO statistics up to 2015 underestimate the amount of harvested wood fuel.

Below, we will first introduce how information of wood harvests was considered in the LULUCF reporting up to the NIR 2018 (section A2.1), then we will indicate and explain recent issues with the data source for wood production that is used until the NIR 2018 (section A2.2) and then in section A2.3 present a new approach that will be used from the NIR2019 onwards and has also been used for establishing the Forest Reference Level. Consequences of the implementation of this new approach are provided in section A2.4.

A2.1 LULUCF approach up to NIR 2018

Information on wood harvests is used in various calculations in the LULUCF reporting. Firstly it is used in the calculations of carbon gains and losses in forest biomass (see section 4.2.1. in Arets et al. 2018). Net carbon stock changes in forest biomass are calculated based on subsequent forest inventories that provide information on carbon stocks at certain points in time. To also calculate the gross gains and losses the carbon in wood harvests is added to the net gains and at the same time also included as losses. As a result the wood harvest do not have an effect on the net carbon stock changes, but only have an effect on the reported gains and losses.

Secondly, information on wood removals is also used for calculating changes in the Harvested Wood Products (HWP) pool. Here wood removals from deforestation events and wood that is used as fuel wood are included under an assumption of instantaneous oxidation (i.e. all carbon is released in the year of wood removals). Carbon in domestically produced wood that is used in solid wood applications (i.e. paper, panels and sawn wood) is assumed to enter the HWP carbon pool in the year of harvest, after which it is assumed to be released gradually over time assuming a first order decay function. The half-times used in the decay function depend on the type of solid wood application (paper, panels or sawnwood, see Chapter 10 in Arets et al. 2018).

Current data source for wood harvests
In the situation up to and including the NIR 2018 national level information on annual volume of wood harvesting was taken from FAO production statistics (www.fao.org). Using a number of conversion factors (see Arets et al. 2018) then the total amount of wood felled in the forest is determined.

The roundwood harvested from the forest consists of two major components: Roundwood harvested for industrial purposes, reported as **Industrial Roundwood** in the FAO statistics (item code 1865), and roundwood harvested for fuelwood, reported under **Wood fuel** (item code 1864). The quantity of industrial roundwood production is determined annually through a questionnaire to the major woodworking industries.

Until recently, the category Wood fuel consisted mainly of fuelwood used by households. This amount is very difficult to estimate, not only due to the fact that it concerns many households with very variable consumption patterns, but also because wood fuel can originate not only from roundwood from the forest, but also from large branches and residues in the forest, as well as landscape and garden maintenance. Before 2003, the amount of Wood fuel originating from roundwood harvested in the forest was estimated annually by an expert. For the period 2003-2013 a fixed amount of 290,000 m^3 underbark was applied, also based on expert judgement. For 2014, this amount was estimated at 357,000 m^3, to account for increased used of wood fuel also in more industrial applications.

A2.2 Recent data issues

In 2016, while preparing the NIR over 2015 it was observed that total round wood production in FAO statistics almost doubled (from 1.25 million m^3 in 2014 to 2.25 million m^3 in 2015, see Figure A2.1). A check with the organisation that prepares the Joint Forest Sector Questionnaire that is used for reporting forestry statistics to various UN statistics, including the FAO forest production statistics, learned that this was a result of a new method to assess the amount of wood fuel production in the Netherlands. While until 2015 the produced amount of wood fuel was based on an expert judgement, from 2015 onwards the results of a new household survey were included, with an estimated total amount of Wood fuel consumed of 1,397,000 m^3. This includes all sources in and outside forests, and no estimation is given how much of this quantity is roundwood harvested from the forest.

While further investigating this issue and also for preparation of the Forest Reference Level under the EU LULUCF regulation (EU 2018) we also further looked into a wood balance on the basis of the NFI-5 (measured 2001-2005) and NFI-6 (2013) national forest inventories (NFIs). With observations from permanent plots that were assessed in both inventories Schelhaas et al. (2014) were able to estimate the total amount of roundwood that was harvested between the two inventories at 1.267 million m^3 overbark annually felled in the forest. Further investigation, however, revealed that this estimate was probably too low because it does not correct for the growth of the trees in the period between the initial measurement and harvesting. The interval between the measurements is about 10 years. If we assume that all harvested trees have grown on average 5 years before they were harvested, we arrive at a new felling estimate of 1.528 million m^3 roundwood overbark (+20.6%). According to the LULUCF methodology, we assume that 6% of the felled roundwood is left in the forest, and we assume 12% of the overbark volume to be bark (see Arets et al. 2018). This yields an estimated amount of 1.264 million m^3 roundwood underbark annually produced for the period 2003-2013.

For this same period, the FAO reports an average of 1.052 million m^3 roundwood production annually. This indicates that the statistics reported to the FAO underestimate the total amount of produced round wood in the Netherlands. Since the industrial roundwood production in the FAO statistics is based on data collected in a questionnaire to the woodworking industry and the amount of wood fuel is based on a rough expert judgement, it is likely that particularly the amount of harvested wood fuel is underestimated in the FAO statistics.

A2.3 Implemented solution for NIR 2019

From the NFI-5 (2003) onwards it is possible to generate a wood balance from subsequent observations in permanent sample plots, as has been done for the period 2003-2013 above. This then would give the average annual total roundwood harvesting from forests, which for the period 2003-2013 was 1.264 million m^3 roundwood underbark. If we then assume that the industrial roundwood production from the FAO statistics is correct, the difference between these numbers then can be considered to be the amount of roundwood used as wood fuel.

For the period 2003-2013, the FAO reports an average production of 761,543 m^3 (underbark) of industrial roundwood. The difference with the total amount of roundwood then results in an average production of 502,400 m^3 (underbark) of wood fuel.

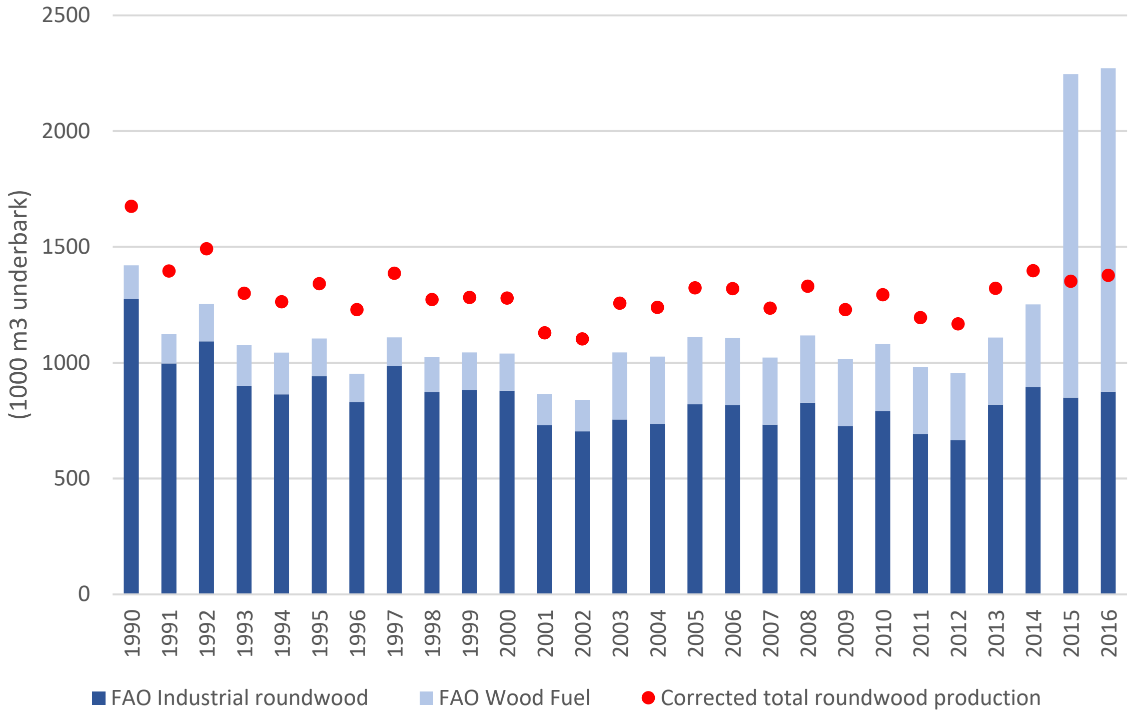

Figure A2.1. *Annual production of round wood in the Netherlands. Dark bars represent production of industrial roundwood from FAO statistics, light coloured bars represent the amount of wood fuel from FAO statistics. The two together are the total amount of roundwood from FAO statistics. The dots represent the corrected total roundwood production with application of the improved approach using NFI data.*

Since the wood balance from the forest inventories can only give an average total production, the estimated average harvest for wood fuel is the same over the whole period between de NFIs. However, because the wood harvested as industrial round adds to the HWP pool every year it would be important to maintain the annual variation in the reported FAO statistics for industrial roundwood. Therefore, for each year the average annual fuel wood production (i.e. 502,400 m^3) is added to the industrial roundwood production in that year as provided by the FAO statistics.

As long as no new information from forest inventories is available, the estimated average amount of wood fuel production is maintained from the period before.

Given the underestimate of Wood fuel harvested from the forest for the period 2003-2013, it seems likely that also the amount of Wood fuel for the period 1990-2002 is an underestimate. We lack an inventory with permanent sample plots for this entire period. Before 2000, the HOSP system was in use to provide roundwood production estimates, based on permanent sample plots that were re-measured every 5 years. Reporting was rather irregular, and there is no good documentation available of procedures to arrive at these estimates, and definitions of the figures it produced. A concise overview is given by the "Compendium voor de Leefomgeving" (CLO 2007), with numbers for annual roundwood felling in the forest for the years 1990, 1995, 1996, 1997, 1998, 199, 2002 and 2005. For each of these years we estimated the production of Wood fuel as described above. The value for 1990 yielded a negative amount of Wood fuel and was therefore discarded. Perhaps this is influenced by a large storm damage that occurred that year. We also omitted the year 2005 because that is already covered in the correction for the period 2003-2013. For the remaining years, we estimate an average amount of 399,000 m^3 Wood fuel (underbark) must have been produced, compared to a reported amount of 143,000 m^3.

Implementation in LULUCF reporting
For the period 1990-2002, the amount of Wood fuel produced as reported in the FAO statistics (149,000 m^3) will be replaced by the calibrated amount for the years where we have information (399,000 m3). For the period 2003-2013 we replace the amount of Wood fuel produced as reported in the FAO statistics (290,000 m^3) by the calibrated amount (520,000 m^3). We use this calibrated amount also for the years after 2013 as a preliminary estimate. After the completion of NFI7 in 2021, we will replace this estimate by the calibrated amount, that can be deduced in the same way as described above. See Table A2.1 for a comparison of the numbers reported in NIR 2018 and new corrected numbers.

Table A2.1. *Roundwood removals as used up to the NIR 2018 based on FAO statistics and the corrected amounts of wood fuel and total roundwood as will be used from the NIR 2019.*

	FAO roundwood			Corrected roundwood	
Year	Industrial	Wood Fuel	Total (m³ underbark)	Wood fuel	Total
1990	1275	145	1420	399(2	1674
1991	996	127	1123	399(2	1395
1992	1092	161	1253	399(2	1491
1993	900	175	1075	399(2	1299
1994	863	180	1043	399(2	1262
1995	941	163	1104	**399(2**	1340
1996	829	123	952	**399(2**	1228
1997	986	123	1109	**399(2**	1385
1998	873	150	1023	**399(2**	1272
1999	882	162	1044	**399(2**	1281
2000	879	160	1039	399(2	1278
2001	729	136	865	399(2	1128
2002	703	136	839	**399(2**	1102
2003	754	290	1044	**502(3**	1256
2004	736	290	1026	**502(3**	1238
2005	820	290	1110	**502(3**	1322
2006	817	290	1107	**502(3**	1319
2007	732	290	1022	**502(3**	1234
2008	827	290	1117	**502(3**	1330
2009	726	290	1016	**502(3**	1229
2010	791	290	1081	**502(3**	1293
2011	692	290	982	**502(3**	1194
2012	665	290	955	**502(3**	1167
2013	818	290	1108	**502(3**	1321
2014	894	357	1251	*502(3*	*1397*
2015	849	1397(1	2246	*502(3*	*1351*
2016	874	1397(1	2271	*502(3*	*1377*

1. Estimated using new method for determining FAO statistics
2. Calibrated based on the calibrated average for 1995-1999 and 2002 from CLO (2007) data. The years on which the average is based are provided in bold.
3. Average based in the wood balance from the forest inventories for 2003-2013. In bold the years on which the average was based. In italics the years that will be updated once the information of the next NFI (ongoing, expected by 2021) becomes available.

A2.4 Consequences of the new method

As indicated in sections A2.2. and A2.3 the FAO statistics from 2015 onwards include large amounts of wood fuel that are not exclusively based on wood from forest land, but also includes other wood sources. Additionally a comparison between the wood balance based on forest inventory data and the current FAO statistics indicate that FAO statistics up to 2015 underestimate the amount of harvested wood fuel. The new method provided in section A2.3 solves these issues. Below we provide the anticipated consequences of implementation of the new method.

Emissions and removals from (managed) forest land

1) The new method closes the gap in wood harvests that was observed between the FAO statistics and the wood balance calculated on the basis of the NFI-5 and NFI-6 forest inventories.
2) It has no effect on the net emissions or removals from forests as the amounts of carbon in the harvests are both added to the carbon stock gains and carbon stock losses. The net changes in carbon stocks in forest were already based on the observed changes from the NFIs. In this respect, in the new approach harvests are actually better aligned with the information from the forest inventories than in the old situation that likely underestimated gains and losses.
3) Because the added volumes in the new method are all in the energy wood category this change will neither have an effect on the carbon stock changes in the Harvested Wood Products pool that assumed that the use of wood energy results in instantaneous oxidation.

Share solid vs energy use of wood

Because it is also applied to the historic period, the improved approach will increase the estimated amount of wood fuel in the reference period 2000-2009 that is relevant for setting the Forest Reference Level under the EU LULUCF regulation. For the purpose of projecting the HWP pool the regulation demands to use ‘a constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009’. Using the raw FAO data the share of wood fuel in total wood harvests would be 24%. Application of the improved approach results in a share of 38% of total harvests. As a result in the projections a larger share of the total projected wood production is allocated to wood fuel and a smaller share to solid use. In the overall FRL of the Netherlands, this difference only has a limited effect since the HWP pool only has a limited contribution to the FRL level (see Section 4.1)

Harvested Wood Products in the projections

The total harvest level and the share of conifers and broadleaves were taken directly from the EFISCEN Space output. For the calculation of Harvested Wood Products we scaled each years’ projected production values compared to the average over the period 2000-2009 (Table A2.2).. In the projections the actual numbers for import and export of the HWP categories have been used up to 2015, the last available year as used in the NIR 2018. From 2015 onwards the Imports and Export values for are kept the same as for 2015 (see Table A2.2).

Table A2.2*. Quantities for production (P), export (E) or import (I) for the HWP categories industrial roundwood (IRW), Pulpwood (Pulp), Sawnwood (SW), Paper and Panels) in m^3 or tonnes (t).*

year	IRW_P (m3)	IRW_E (m3)	IRW_I (m3)	Pulp_P (t)	Pulp_E (t)	Pulp_I (t)	SW_P (m3)	SW_E (m3)	SW_I (m3)	Paper_P (t)	Paper_E (t)	Paper_I (t)	Panels_P (m3)	Panels_E (m3)	Panels_I (m3)	Other_P (m3)
1990	1115000	480559	752972	190000	7800	607700	455000	412700	3450100	2770000	2098500	2420000	97000	140900	1621200	115000
1991	996000	558812	708035	175000	4700	577800	425000	461000	3149000	2862000	2135100	2547200	105000	154300	1589100	132000
1992	1092000	549004	629436	135000	19897	642462	405000	439800	3221513	2835000	2224471	2579479	111000	167446	1531591	95000
1993	900000	433000	543878	119000	75328	686618	389000	427000	3564000	2855000	2049814	2429258	107000	237000	1456000	77000
1994	863000	374000	497000	119000	160100	895000	383000	426000	3771000	3011000	2204000	2366000	110000	312000	1593000	100000
1995	941000	280000	463000	148000	226300	873000	426000	458000	3277000	2967000	2250000	2522000	114000	305000	1599000	75000
1996	829000	274600	409000	125000	256100	1037200	359000	389000	3322000	2987000	2438000	2797500	96000	318100	1531000	70000
1997	986000	308000	402000	138000	274400	1149000	401000	377000	3431000	3159000	2844000	3178000	101000	313000	1765000	59000
1998	873000	289600	526000	129000	321000	1312000	349000	415000	3534000	3180000	2809600	3523100	58900	299300	1813300	39000
1999	882000	262000	428000	117000	352000	1144000	362000	427000	3606000	3256000	2588000	3496000	60800	288000	2089000	92000
2000	879000	220000	383000	137000	363000	905000	390000	380000	3705000	3332000	3001000	3210000	61000	275000	1727000	110000
2001	729000	415700	435100	129500	282100	915600	268000	304500	3294200	3174000	2557500	3210600	20000	256900	1816200	84000
2002	703000	362300	505800	118000	159600	1055100	258000	355600	3021800	3346000	2818900	3306300	23000	254100	1630600	116000
2003	754000	480800	377900	124000	346800	1131800	269000	400100	3163400	3339000	3044000	3263700	10000	247400	1630000	126000
2004	735724	589600	274800	119000	369500	1259700	273000	387700	3174800	3459000	2956600	3055400	8000	308200	1597100	33107
2005	820000	460800	315900	117000	498900	1419200	278942	487900	3099500	3471000	3150700	3385700	11000	327200	1642500	44000
2006	816676	569800	389600	177000	508600	1242500	265269	554600	3398800	3367000	3168700	3367000	10000	362800	1870800	32393
2007	732046	661400	467300	139380	430268	1266929	273069	600700	3434300	3224000	3105700	3519100	17500	405300	1886100	20223
2008	827099	488700	353000	141559	623800	1360400	242690	422500	3100500	2977000	2374100	3413400	32950	411200	1894200	30637
2009	726133	388000	229300	71507	1528938	1883180	209959	291700	2574800	2609000	2007200	2922800	45700	301200	1494700	48031
2010	790593	477300	206500	96855	712600	1210400	231308	314100	2750000	2859000	2270100	3035600	50611	273700	1482600	52295
2011	691800	405364	343854	34000	943700	1567200	237700	321900	2710000	2748000	2484001	2874200	45700	295300	1679600	61400
2012	664700	406900	232300	39400	1088790	1560304	190400	431800	2556900	2761000	1941300	2569500	57500	329300	1431100	19600
2013	818200	425300	208100	40600	763771	1388900	235110	445800	2477200	2783645	2278800	2757600	20611	288011	1371200	55538
2014	894140	485700	265200	44000	630921	1208700	281372	508400	2506000	3331372	2268200	2789000	24667	289556	1403500	66466
2015	860323	426000	251700	44200	471531	891200	265688	477200	2661100	3145682	2140400	2411400	23292	243700	1522400	62761
2016	860323	426000	251700	44200	471531	891200	262966	477200	2661100	3113453	2140400	2411400	23054	243700	1522400	62118
2017	860323	426000	251700	44200	471531	891200	279142	477200	2661100	3304974	2140400	2411400	24472	243700	1522400	65939
2018	860323	426000	251700	44200	471531	891200	227222	477200	2661100	2690256	2140400	2411400	19920	243700	1522400	53674
2019	860323	426000	251700	44200	471531	891200	266653	477200	2661100	3157108	2140400	2411400	23377	243700	1522400	62989
2020	860323	426000	251700	44200	471531	891200	250904	477200	2661100	2970637	2140400	2411400	21996	243700	1522400	59268
2021	860323	426000	251700	44200	471531	891200	248777	477200	2661100	2945454	2140400	2411400	21810	243700	1522400	58766
2022	860323	426000	251700	44200	471531	891200	265279	477200	2661100	3140843	2140400	2411400	23256	243700	1522400	62664
2023	860323	426000	251700	44200	471531	891200	216193	477200	2661100	2559677	2140400	2411400	18953	243700	1522400	51069
2024	860323	426000	251700	44200	471531	891200	250953	477200	2661100	2971225	2140400	2411400	22000	243700	1522400	59280
2025	860323	426000	251700	44200	471531	891200	237669	477200	2661100	2813941	2140400	2411400	20836	243700	1522400	56142

Appendix 3 – Response to the Technical Assessment

The Netherlands submitted its draft FRL and National Forestry Accounting Plan before 31 December 2018. In the spring of 2019, the European Commission, in consultation with experts and stakeholders from EU Member States (forming the LULUCF Expert Group – LULUCFEG), carried out a technical assessment of the submitted plans and FRLs from all Member States and made recommendations for revisions. The LULUCFEG reported on the technical assessment in a synthesis report. Based on this report and additional findings, on 18/6/2019 the European Commission published a working document on the assessment of the National Forestry Accounting Plans (SWD(2019) 213 final).

In this Appendix we briefly describe and refer to the revisions that have been made to increase transparency of the NFAP. The technical recommendations did not result in a revision of the value of the submitted Forest Reference Level.

Regarding Art 8(5) on general principles for the forest reference level no technical recommendations were made. Overview of our response to the technical recommendations related to Annex IV, section A criteria of the LULUCF regulation are provided in Table A3.1. The response to the technical recommendations related to Annex IV, section B criteria of the regulation are provided in Table A3.2.

***Table A3.1**. Global description of the response to each of the technical recommendations related to Annex IV, section A criteria and where its details can be found in the NFAP.*

Recommendation	Response	Section/page
a) Demonstrate how the goal of achieving a balance between anthropogenic emissions and removals will be achieved in the second half of the century. Provide qualitative and quantitative information until at least 2050 consistent with the long-term strategy required under Regulation (EU) 2018/1999.	In sections 1.2 (part on criterion a) and 2.3.1 we provide more information on the policy developments in the Netherlands related to the recently concluded National Climate Agreement, the national Climate Act and the Climate Plan that need to be developed. In its Climate Plan and consequently the long-term strategy The Netherlands aims at reducing emissions by 95% by 2050. Increasing removals in the land-use sector are an important component of this strategy. The agreed set of measures aim at preventing deforestation, increasing carbon removals in existing systems and expansion of forests and trees outside forests. Practical climate smart forest management principles aiming at increasing removals by managed forest land are being tested in a number of pilots. Eventually, depending on the outcomes, these pilots will be further scaled up.	Section 1.2, page 13 and Section 2.3.1, page 21.
e) Demonstrate how harvest statistics, information from the forest inventory, the ratio between energy and solid biomass use and HWP projection were considered in elaborating the NFAP.	Appendix 2 provided detailed information on how harvest statistics and information from forest inventories were used to calculate HWP effects. In section 1.2 (part on criterion e) we have now provided a summary on how harvest information from forest inventories and harvest statistics are used. The full description is still provided in Appendix 2. Also in section 1.2 (part on criterion e) we have now provided information on the calculation of the ratio of energy and solid biomass use of wood. Table	Section 1.2, Page 14. Appendix 2, page 67.

	A2.2. in Appendix 2 now provides the used values for production, import and export for the various HWP categories.	
g) Demonstrate the consistency with the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013. Provide explanations for possible differences between national projections and the proposed FRL.	In section 1.2 (part on criterion g) we have detailed how the FRL is only partly consistent with the submitted projections under regulation (EU) No 525/2013 up to 2019, but will be consistent with forthcoming similar projections as required under the governance regulation.	Section 1.2, page 15.
h) Estimate the FRL based on the area under forest management as indicated in Annex IV, Section B (e) i.	In section 1.2 (part on criterion h) we now explicitly provide the area of Managed Forest Land and relate this to the area of Forest Land remaining Forest Land as provided in the NIR2018	Section 1.2, page 17.

Table A3.2. *Global description of the response to each of the technical recommendations related to Annex IV, section B criteria and where its details can be found in the NFAP.*

Recommendation	Response	Section/page
c) Provide a justification for allocating 100% of "unknown management objective" to category "multifunctional"	We have added further explanation in section 3.2.3. When no subsidy scheme is present the management objectives are unknown. Because only in case of a Nature subsidy scheme there are legal restrictions on the harvest, for cases without a subsidy scheme and hence unknown management objective, a multifunctional objective is assumed. This also is the most common management objective in the Netherlands. We additionally corrected the final classifications in rows 5 and 12 of Table 3.2. This had no influence on the projections because the classifications were applied correctly in the analysis.	Section 3.2.3, page 31.
e) i Provide the area under forest management consistent with Table 4.A ("Forest land remaining Forest land") from the latest national GHG inventory using the year preceding the starting point of the projection	In section 1.2 (part on criterion h) we now explicitly provide the area of Managed Forest Land and relate this to the area of Forest Land remaining Forest Land as provided in the NIR2018. In section 3.1.2 the area was correct, but referred to the wrong starting date. This was corrected to 1 January 2009 instead of end of 2009. This is consistent with the area from Table 4.A. from the 2018 GHG inventory using the year preceding the starting point of the projection (i.e. 2008).	Section 3.1.2, page 28
e) iii Provide additional information on age-class structure and rotation length. Correct editorial changes such as in Table 3.2	We have added section 3.3.2 with information on size (age related) class structure of the starting situation based on data from the NFI6 for transparency reasons. The EFISCEN space model that we use for age dependent projections of forest structure, however, uses diameter classes, not age classes.	Section 3.3.3, page 38.

Recommendation	Response	Section/page
	Also the age dependent projections of forest structure and forest management practices are based on actual harvesting probabilities as derived from the National Forest Inventories. In section 3.3.5 we have now explicitly explained that the modelling approach does not include specific rotation lengths. Moreover, we have also explained why this is consistent with practice in Dutch forests. For a long time wood harvesting in Dutch forests was usually limited to thinnings and small group fellings without prescribed rotation lengths. Only more recently also larger regeneration fellings are applied, but since these have been highly criticised in public opinion, this practice was abandoned again. The modelling approach that is used in the EFISCEN space model is consistent with this practice. Harvesting is implemented as the removal of a certain fraction of trees of a certain species in a certain diameter class, where the annual harvesting probabilities were derived from NFI data. As a result neither information on rotation length is needed as an input, nor will it be possible to provide information on rotation lengths from the model output.	Section 3.3.5, page 45.
e) iv Provide explicit information on allocation of future harvest to specific HWP categories. Provide information on import and export of HWP	We have included a description in the allocation in section 3.3.10 and provide the information on production, import and export in Table A2.2 in Appendix 2.	Section 3.3.10, page 51 and Appendix 2, page 72.