State Forest Service
Valstybinė miškų tarnyba

LIETUVOS RESPUBLIKOS APLINKOS MINISTERIJA

National Forestry Accounting Plan

by Lithuania

in line with the Regulation (EU) No 2018/841 of the European Parliament and of the Council

Vilnius, 2018

Contents

Summary

Lithuania's National Forestry Accounting Plan (NFAP) has been prepared according to requirement by LULUCF Regulation: Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU. Outline of the NFAP and information provided was prepared according to the guidelines prepared by the consortium of ICF Consulting Limited (ICF), International Institute for Applied System Analysis (IIASA), Aether (Forsell et al., 2018), taking into account Capacity Building Plan for Lithuania, developed by ICF Consulting Limited under the capacity building project, initiated by the European Commission and implemented by the association of ICF Consulting Limited, Aether Limited, International Institute for Applied System Analysis (IIASA), European Forestry Institute (EFI), Forest, Environmental Research and Services (FERS) Ltd.

Lithuanian National Forestry Accounting Plan for the period of 2021-2025 has been prepared by State Forest Service under the Ministry of Environment in cooperation with Environment Protection and Forest Department of the Ministry of the Environment and Aleksandras Stulginskis University.

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1. General Introduction

1.1 General description of the forest reference level for Lithuania

Forest reference level for Lithuania, determined according to the criteria set out in Annex IV of the LULUCF regulation (EU 2018/841), is -1,429 kt CO_2 eq., assuming instant oxidation (all harvest is removed and oxidized in current year). With the first-order decay function applied for harvested wood products, forest reference level for Lithuania is -2,272 kt CO_2 eq. for the compliance period of 2021 - 2025.

Table 1-1. Estimated carbon stock changes in pools, used for forest reference level estimation in Lithuania

Pools	Carbon stock change in pools 2021 - 2025, kt CO_2 eq.
Above-ground biomass	-1,426.10
Below-ground biomass	-364.99
Dead wood	-62.33
Organic soils	424.03
Harvested wood products	-842.84
Total + HWP IO	-1,429.40
Total + HWP first-order decay function	-2,272.24

Forest reference level was calculated for forest land remaining forest land only, while all forest land is considered managed in Lithuania. Land, classified as land converted to forest land during the reference period (2000 – 2009) was not included in the projections of carbon stock changes in above mentioned pools.

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

Consideration of the criteria set in Annex IV of the LULUCF regulation is explained in this chapter, accordingly to the list in paragraph A of the Annex.

A. Lithuania is projecting declining growing stock volume change (Figure 1-1), which is determined by the change of forest stand structure assuming stably increasing area of mature stands while volume drain due to harvest and mortality in forest stands is also larger comparing to the one observed in NFI (Table 1-2). Increasing drain (harvest and mortality) are related to aging forest and wood use by BAU scenario (used for forecasting) - more volume is available for wood supply when forests reach age suitable for final harvest, older stands also have a higher probability of natural mortality. Lithuanian forest reference level is consistent with the aim of achieving a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century due to the goal of sustainable forestry sector development goal set in National Forestry Sector Development programme (2012).

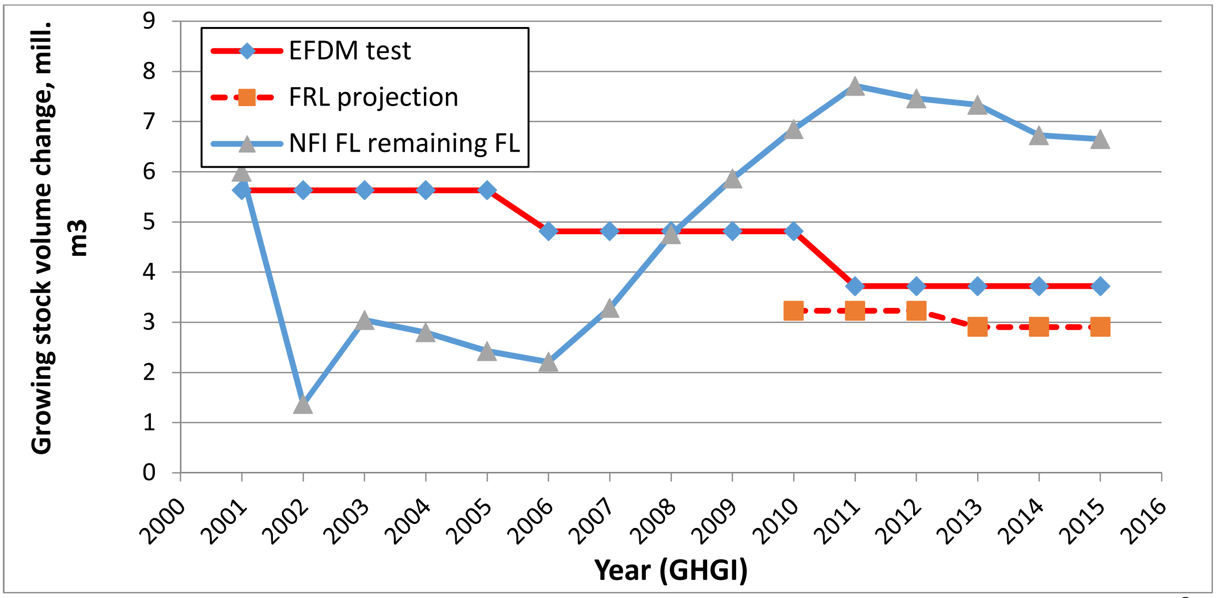

Figure 1-1. Reported in NIR 2018 and projected growing stock volume change in Lithuania's forests, mill. m^3

Table 1-2. Wood drain (harvest + mortality) by stem volume in Forest land remaining forest land, mill. m^3

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
NFI FL remaining FL	11.7	11.7	13.0	12.8	13.0	13.1	12.8	12.1	11.9	11.5	11.8	12.4	12.7	13.4	13.8
EFDM testing	11.3	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	13.9
Difference from NFI, %	-3.4	-2.6	-10.8	-7.8	-7.7	-6.9	-3.1	4.1	7.6	13	11.9	8.1	7.1	3.0	0.7
FRL projection										13.8	13.9	13.9	14.0	14.2	14.3
Difference from NFI, %										20.0	17.8	12.1	10.2	6.0	3.6

B. In its forest reference level estimation Lithuania has included only carbon stock changes in pools, calculated as a change between two stock volumes in different time steps provided by the EFDM model; remaining carbon stock in living biomass of forest land remaining forest land is excluded from calculation.

C. Biomass removed from forest is calculated under the assumption of instant oxidation, through the application of stock change method applied for living biomass and dead wood volume estimation both in National GHG Inventory and FRL projection. Carbon stock changes in harvested wood products pool are calculated applying first-order decay function for providing a comparison to assumption of instant oxidation, using the EFDM model provided felled stem volume estimate to calculate activity data for harvested wood pool stock change projection.

D. Carbon stock change in harvested wood products pool is included in the reference level, calculated both with assumption of instant oxidation and applying first-order decay function.

E. Ratio between forest biomass used for solid and energy production is assumed as in the reference (2000 - 2009) period, determining the change ratio between historical harvest and projected harvest provided by the EFDM model, applying estimated ratio to the harvested wood product commodities activity data (amounts of domestically produced and consumed products), obtained from FAO database, The Chronicle of Lithuanian Forests (Ministry of Environment, 2003) and Statistics Lithuania.

F. Lithuania's forest reference level is constructed based on historical forest management practices, as observed during NFI measurements in reference period and development of forest age classes, taking into account sustainable historical forest resource use. There are numerous protected areas, such as strict reserves, reserves, regional parks, national parks, established in forests in Lithuania with specific restrictions and limitations for forest resource use set in those areas, which ensure the needs of biodiversity protection.

G. Lithuania's FRL and reporting of national projections of greenhouse gas emissions by sources and removals by sinks under Regulation (EU) No 525/2013 is consistent with the FRL estimation documented as both approaches report all forest carbon pools (biomass, dead wood, litter, soil carbon), and also non-CO2 emissions, like those from drained organic soil, nitrogen fertilization and from controlled burning. However, method used to estimate forest reference level according to the LULUCF regulation (EU 2018/841) is different than in national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks reported under Regulation (EU) No 525/2013, since EFDM model was first time applied for projections of living biomass and dead wood carbon pool changes. National projections of anthropogenic greenhouse gas emissions by sources and removals by sinks will be updated accordingly.

H. The EFDM model used for forest reference level estimation is able to reproduce general trend of living biomass and dead wood carbon pool development, however, high interannual variations cannot be produced with the model. All the pools represented in National Greenhouse Gas inventory are included in the construction of projections for forest reference level and carbon stock changes in those pools are calculated applying the same methodology as for National GHG inventory report.

Table 1-3. Equivalence table for the NFAP for Lithuania.

Annex IVB. item	Elements of the national forestry accounting plan according to Annex IV B.	Chapter in the NFAP
(a)	A general description of the determination of the forest reference level.	Ch. 3.1
(a)	Description of how the criteria in LULUCF Regulation were taken into account.	Ch. 1, Annex I, Annex II, Annex III.
(b)	Identification of the carbon pools and greenhouse gases which have been included in the forest reference level.	Ch. 2.1
(b)	Reasons for omitting a carbon pool from the forest reference level determination.	Ch. 2.1
(b)	Demonstration of the consistency between the carbon pools included in the forest reference level.	Ch. 2.2
(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.	Ch. 3.3, Annex III
(c)	A description of documentary information on sustainable forest management practices and intensity.	3.2.2, Annex III
(c)	A description of adopted national policies.	Ch. 2.3.1
(d)	Information on how harvesting rates are expected to develop under different policy scenarios.	Ch. 2.3.2
(e)	A description of how the following element was considered in the determination of the forest reference level:	
(i)	• The area under forest management	Ch. 3.2.1
(ii)	• Emissions and removals from forests and harvested wood products as shown in greenhouse gas inventories and relevant historical data	Ch. 2.2, Ch. 4.2

(iii)	• Forest characteristics, including: - dynamic age-related forest characteristics - increments - rotation length and - other information on forest management activities under 'business as usual'	Ch. 3.2, Annex I, Annex II, Annex III
(iv)	• Historical and future harvesting rates disaggregated between energy and non-energy uses	Ch. 4.1

2. Preamble for the forest reference level

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

Carbon pools included in forest reference level is as reported in Greenhouse Gas Inventory Report of Lithuania 2018:

- Above and below-ground biomass carbon stock changes
- Dead wood carbon stock changes
- Harvested wood products pool carbon stock changes
- GHG emissions from soil (organic only) due to drainage

Carbon stock changes in mineral soils in forest land remaining forest land are not reported in Lithuania, since after the BioSoil project it was estimated that mineral soils are not a source of GHG emissions. The results of BioSoil project show small, but not significant increase in carbon stock pool in mineral forest soils in Lithuania from 1998 to 2006 (Armolaitis et al., 2001; Kuliesis et al., 2009):

Table 2-1. Mean carbon stock in forest land according to the soil monitoring in ICP-Forest sample plots *Level I* in 1998 and 2006

Year	Mean carbon stock in litter, g C/kg	Mean carbon stock in mineral soil (0-10 cm depth),g C/kg	Mean carbon stock in mineral soil (10-20 cm depth), g C/kg	Research activity
1998	370,69 ±12,8	29,1 ±4,4	15,6 ±2,8	Soil monitoring in IPC-Forests Level I sample plots (Armolaitis et al., 2001)
2006	399,0 ±96,6	29,9 ±18,2	15,8 ±11,6	Soil monitoring in IPC-Forests Level I sample plots during BioSoil project (Kuliešis et al., 2009)

Carbon stock changes in litter were not included in forest reference level estimation nor in annual greenhouse gas inventory report. Lithuania assumes that there are no changes in carbon stocks in litter in forest land remaining forest land, assuming that the amount of litter after the conversion period in forest remains stable with insignificant changes (Tier 1 method is applied).

Two main greenhouse gases are included in the estimation of forest reference level: CO_2 (biomass carbon stock changes, dead wood carbon stock changes, harvested wood products, drainage of organic soils), N_2O (from drained organic soils). Methane emissions from drained organic forest soils are not included in the estimation of forest reference level due to the lack of default emission factors for the Tier1 method in the 2006 IPCC Guidelines, as applied for the National GHG Inventory.

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

All the carbon pools included in National Greenhouse gas inventory report are included in construction of forest reference level as described in the section above. Carbon stock changes in corresponding pools were estimated applying 2006 IPCC Guidelines and 2014 Kyoto Protocol Supplement as in National Greenhouse Gas Inventory. For the estimation of carbon stock changes in living biomass and dead wood pools the Tier 2 approach and method 2 (stock-change method) was applied. Soil carbon stock change (organic sols) and non-CO2 GHG emissions due to organic soil drainage were calculated using Tier 1 method from 2006 IPCC GL, as in NIR 2018. For estimation of carbon stock changes in harvested wood products pool, approach B (production approach) was applied.

Consistency of the development of carbon stock changes in certain pools can be seen from the table 2-2. Derivation from development of carbon stock changes in pools are determined by large interannual variations, which were partly caused by natural causes (i.e. removal of spruce dieback consequences), in addition to this, large interannual variations cannot be estimated by the model since average growing stock volume, felling (probability functions) and mortality rates of the whole period (2000 – 2015) is applied for model calibration and average of 2000 - 2009 is applied for modelling of growing stock volume, dead wood volume and felling volume for forest reference level estimation. Differences in area of forest land remaining forest land used for EFDM simulation for model calibration and reported in 2018 National GHG inventory can be explained in different aggregation of area data and increase in forest land area. The so called "plot center decision" is used to estimate area for National GHG Inventory, while growing stock volume is calculated for each sector of the sampling plot. In order to obtain the most accurate data of forest land remaining forest land, for the EFDM modelling area was aggregated from sampling plot sectors with their respective area. This resulted in underestimation of the area of forest land remaining forest land in NFI data used for EFDM compared to NFI data calculated for National GHG Inventory (some sampling plots were included as a forest land remaining forest with total area (400 ha) represented in GHGI, while for EFDM simulation only a part of that sampling plot was included as forest land remaining forest land). Constant forest land remaining forest land area from NFI 1998 - 2002 was applied for the whole modelling period (2001 - 2016), while forest land remaining forest land area is constantly increasing in Lithuania due to land converted to forest land becoming forest land remaining forest land after 20 years of conversion period.

Table 2-2. Results of model replicability testing (area, thous. ha and carbon stock change, kt CO_2 eq.), % from National Greenhouse Gas Inventory report 2018 (data of 1990 – 2016)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Area FL remaining FL	97.2	96.9	96.6	96.5	96.3	96.0	95.8	95.5	95.2	94.7	94.4	94.1	93.9	93.7	93.6	93.5
Above-ground biomass	107.2	137.9	190.2	212.5	257.5	248.9	160.0	105.4	82.0	66.8	46.4	47.9	48.6	53.1	55.5	29.4
Below-ground biomass	105.2	131.9	175.4	191.3	220.3	206.9	142.3	97.9	78.3	65.4	46.7	48.2	49.1	53.5	56.0	31.8
Dead wood	130.7	38.7	33.9	28.1	26.0	16.0	16.9	20.0	24.2	35.6	56.8	64.0	80.7	64.7	67.2	31.0
Organic soils	96.8	96.5	96.3	96.1	95.9	95.6	95.4	95.1	94.8	94.4	94.0	93.7	93.5	93.4	93.2	93.1
HWP	121.0	104.9	89.1	87.8	89.7	103.8	101.7	114.0	124.2	88.6	91.9	104.8	107.2	85.0	92.6	96.0
SUM	109.7	122.0	147.3	153.2	171.8	145.1	113.9	89.7	76.8	64.9	49.1	51.3	52.3	55.0	57.9	33.2

Results of EFDM model calibration with age class distribution starting as of 2000, according to 1st NFI cycle data and average forest management practice of 2000 - 2015 show differences in annual carbon stock changes, however, total carbon stock development is following the same trend (Figure 2-1, figure 2-2).

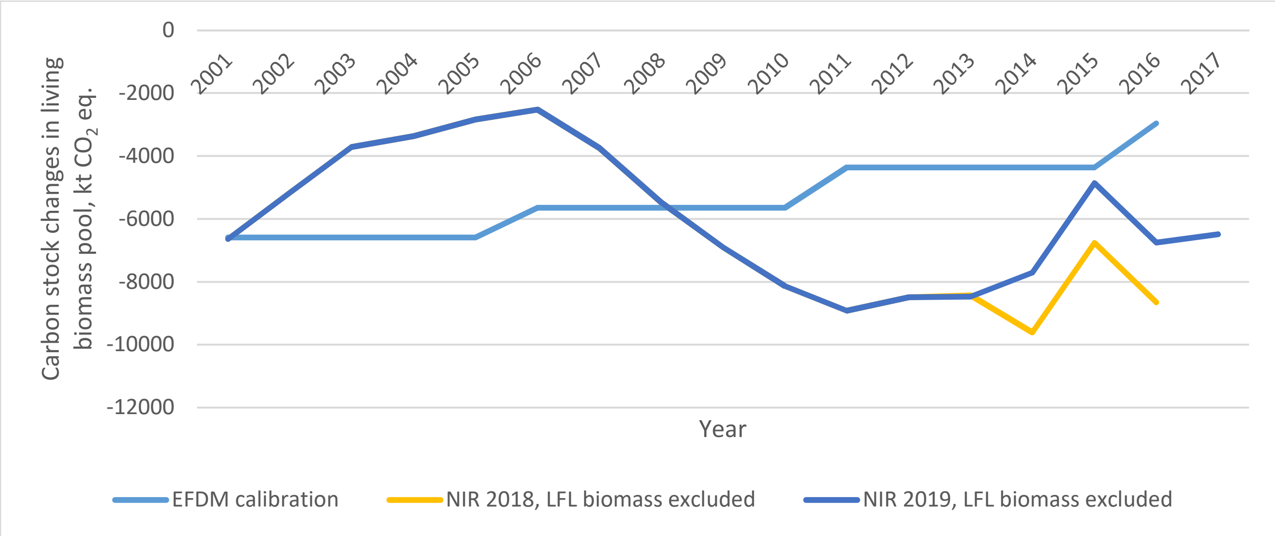

Figure 2-1. Carbon stock changes in living biomass in NIR and EFDM calibration, LFL - land converted to forest land

Two different variations of living biomass carbon stock changes are presented to explain the impact of interpolation-extrapolation tool applied for living biomass carbon stock estimation in National Greenhouse Gas inventory. Interpolation-extrapolation tool is used for more accurate growing stock volume changes representation, as well as to reduce inter-annual variations. Interpolation-extrapolation tool is used for annual change of growing stock volume: growing stock volume change between each permanent sampling group (remeasured every 5th year) between two remeasurements is calculated using linear interpolation. Estimation of annual growing stock volume change in two latest years is based on extrapolation of previous 5 years growing stock volume change and change factor between two latest inventory cycles (tendency of 10 years). After the actual measurement data is available (NFI measurement represents data of X-2 years, middle of cycle data), extrapolated values are changed for the actual ones. Due to the change of 2015 and 2016 extrapolated data in the 2019 National GHG inventory, significant difference in carbon stock changes is observed (Figure 2-1), which better conform with the results of EFDM replicability testing.

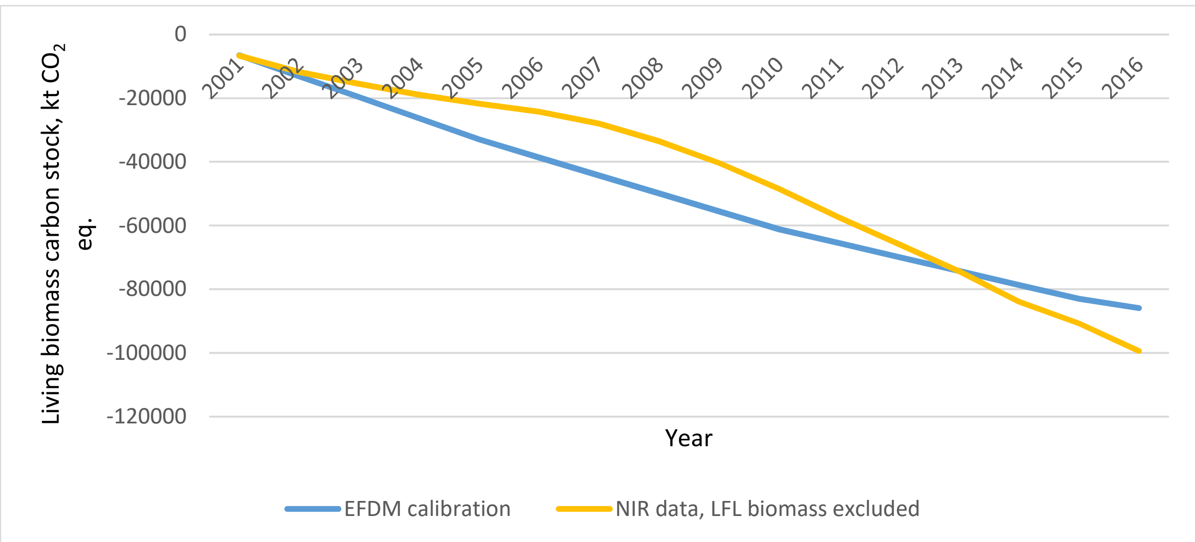

Figure 2-2. Living biomass carbon pool development according to NIR 2018 and EFDM calibration

Despite the differences in annual carbon stock changes, model is able to represent actual living biomass carbon stock development in forest land remaining forest land (Figure 2-2).

2.3: Description of the long-term forest strategy

Lithuania has adopted its main legal act, regarding forestry and sustainable forest management, Forest Law in 1994. The main aim of the Forest Law is to regulate forestry areas, such as forest regeneration, protection and resource use in a way to ensure sustainable development - providing the country with the greatest socio-economic benefits, ensuring biodiversity conservation, increasing forest productivity, landscape stability and environmental quality, the ability to perform ecological, economic and social functions now and in the future without harming other ecosystems.

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

State of Lithuanian forest resources up to the 1st January 2017 using data from the latest forest assessment is presented in this paragraph. Definition of forest land has not changed since the 1st Commitment Period in forest land category and is used as following: land area not less than 0.1 hectare in size covered with trees, the height of which in a natural site in the mature age is not less than 5 meters, other forest plants as well as thinned or temporary vegetation – lost forest due to the acts of nature or human activities (cutting areas, burnt areas, clearings). Tree lines up to 10 meters of width in fields, at roadsides, water bodies, in living areas and cemeteries or planted at the railway protection zones as well as single trees and bushes, parks planted and grown by man in urban and rural areas are not defined as forests. All forest land is considered as managed land in Lithuania.

Statistics are based on the state Standwise Forest Inventory (SFI) and National Forest Inventory (NFI) data. The SFI provides data on forest area. The National Forest Inventory presents more reliable data about growing stock volume and changes. According to this data, the total forest land area was 2,189,600 ha, covering 33.5% of the country's territory. Since the 1st January 2003, the forest land area has increased by 144,300 ha corresponding to 2.2% of the total forest cover. During the same period, forest stands expanded by 107,400 ha to 2,058,400 ha. occupying 1,145,100 ha, coniferous stands prevail in Lithuania, covering 55.6% of the forest area. They are followed by softwood deciduous forests (841,100 ha, 40.9%). Hardwood deciduous forests occupy 72,200 ha (3.5%). Although forests cover a large part of Lithuanian territory and constitute to 2,203.3 thous. ha which is more than 33% of the country, it is estimated and forecasted that Lithuanian forest area should account for at least 35% considering the needs of the nature frame and landscape. Despite the fact that forest land area has increased significantly and many new forests have been planted on private and State land the need for further enlargement of forest land still remains. According to the statistical data of National Land Service under Ministry of Agriculture, there was approximately 64 thous. ha of land that is not used for agriculture or is unsuitable for that in 2016 and part of it might already be covered with woody vegetation (natural afforestation has been started). In addition to this, a target in the General Plan for the territory of the Republic of Lithuania (2002) has been set to increase afforestation of such lands and as a conclusion country forest coverage could increase up to 37-38%. However, this process is slowed down by incomplete land reform, problems related to the transfer of free land from the state land fund to managers of state-owned forests for afforestation, as well as legal restrictions linked with afforestation of land that has relatively high productivity. Therefore, it is reasonable to increase forest coverage by harmonizing the scope with other land use needs.

The amount of prepared merchantable round wood increased by 4% since 2015 and amounted 7.0 million m³ in 2016. Changes in felling rates in state forests were insignificant over last five years. The amount of round wood harvested in state forests totalled 3.9 million m³ in 2016. The volume from the final felling in state forests was like in the previous year (2.7 million m³). The share of the final felling constituted 70% in the total harvest (72% in 2015). Amount of timber prepared in coniferous stands final felling totalled 1,294,000 m³ like in 2015. The roundwood volume from final felling decreased by 5% in spruce stands and increased by 6% in pine stands. Volume of prepared wood in these stands amounted to 631,000 m³ and 663,000 m³ respectively. For non-coniferous, the round wood volume from final felling decreased by 1%, to 1,436,000. Felling in birch stands grew up by 1% from 738,000 m³ to 747,000 m³. For aspen, the increase was 1% and removals grew up till 336,000 m³. The prepared wood volume in black alder stands decreased by 5% to 277,000 m³. For other species, the removed volumes and changes were as follows: 48,000 m³ grey alder (-3%); 7,400 m³ ash (-55%); and 12,000 m³ oak (-4%). The volume from intermediate felling increased by 4% to 1.2 million m³. Strongest storm bypassed Lithuania in June. He damaged forests from southern part till central regions of the country. Amount of selective sanitary felling increased by 14%, from 368,000 m³ in 2015 to 417,000 m³ in 2016. Other felling (mainly clear salvage felling in immature stands) increased from 90,000 m³ to 164,000 m³. The volume of wood prepared by commercial thinning decreased by 1% until 587,000 m³ and constituted to 15% in the total harvests. The felling rate in private forests increases to 3.1 million m³ (expert evaluation). Private forest owners received cutting permits for 2.4 million m³. Half of this (1.2 million m³) was issued to cut in coniferous stands. The allowable cut of pine stands increases from 545,000 m³ in 2015 to 583,000 m³ in 2016. The allowable cut in spruce stands increased by 5% to 607,000 m³. The amount of timber allowed to cut in the birch stands was similar like in 2015 (668,000 m³).

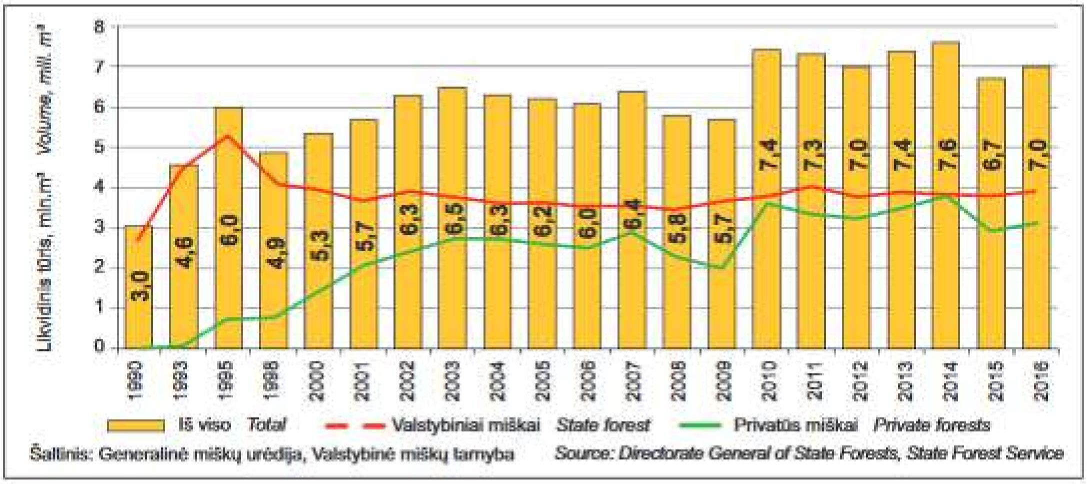

Figure 2-3. Development of fellings (by merchantable volume) in Lithuania

Forest resource use, management practices and overall forestry sector development is determined by several main legal documents adopted in Lithuania:

- Forest Law, No I-671, adopted November 22, 1994.

The Forest Law establishes the rights and duties of all forest managers, owners and users of the Republic of Lithuania in the use, restoration, cultivation and protection of forests, harmonises the interests of forest owners and the public, establishes the basic principles of forest management. The main aim of the Forest Law is to regulate forestry areas, such as forest regeneration, protection and resource use in a way to ensure sustainable development - providing the country with the greatest socio-economic benefits, ensuring biodiversity conservation, increasing forest productivity, landscape stability and environmental quality, the ability to perform ecological, economic and social functions now and in the future without harming other ecosystems.

- Governmental Resoultion of the Republic of Lithuania of 29th October 2002 No IX-1154 Concerning the approval of the General Plan for the Teritory of the Republic of Lithuania

Forestry development is planned accordingly to the long-term Lithuanian forestry policy goals: 1) ensuring multi-purpose and forest-friendly forest management by combining economic, social and ecological functions of forests; 2) Increasing the forest area of the country; 3) preserving biodiversity in forests and enhancing the recreational potential of forests; 4) Supply of wood to domestic industry and population. General plan sets different forest cover increase for specific regions of the country: it is valuable to afforest the most infertile lands of the country, by increasing the forest cover by 10-15% in the Central Samogitia, East Aukštaitija and Dzūkija zones. In terms of the ecological stability of the landscape, forests are most needed in poorly wooded areas of Central Samogitia, West Aukštaitija and Suvalkija. For the aim of forest expansion in these areas should be given priority. The mostly forested areas will remain in the eastern and southern part of Lithuania - Aukštaitija and Dzūkija - 54-62% . In the western part, Samogitia, forests will reach 38-39 percent, except for its most western part (29 percent). The least forested area will remain in Central Lithuania - 23–27 percent. Afforestation of infertile lands should increase forest cover to 37–38 percent. The creation of valuable forest stands is planned by regulating the species of planted trees and the extent of permitted forest felling. The balance between the growth and use of stands will be ensured by means of forest management, regulation of forest use and state control measures. It is planned that in Group II forests there will annually be 0.3–0.4 mln. m^3 of wood cut, and in the forest groups III and IV - 6.5-7.5 mln. m^3 of wood cut, or up to approx. 4.3 m^3 / ha of wood in wooded areas.

- Governmental Resolution of the Republic of Lithuania of 28th September 2011 No 1131 Concerning the approval of procedures of forest land conversion to other land use and compensation for forest land conversion to other land use and repealing some of the governmental resolutions

The Resolution sets the rules for limited cases of forest land conversion to other land uses and corresponding compensation mechanism of such conversion. It is explained that forest land can be converted to other land use only in exceptional cases and the conversion can either be compensated by the monetary payment to the State budget or by afforesting another land area, not smaller than the deforested area. Monetary compensation is calculated by the State Forest Service summing market value of forest land converted into other land, expenses of the forestry measures applied to reach the state of the forest being deforested and the value of the lost wood, which could be gained at the final felling age.

- Governmental Resolution of the Republic of Lithuania of 23rd May 2012 No 569 Concerning the approval of National Forestry Sector Development Programme for 2012 – 2020

The strategic objective of forestry development is to increase the diverse public benefits provided by forests, taking into account the long duration of forest growth and differences in forms of ownership, as well as ensuring the implementation of sustainable forest principles in all forests of the country. The goals to achieve the objective are: to preserve and increase Lithuanian forests and their resources; ensure rational use of Lithuanian forest resources and increase the productivity of stands; to increase the economic efficiency and competitiveness of forestry; to preserve and enhance the sustainability of forest ecosystems, taking into account their ecological and social role, the impact of climate change.

- Governmental Resolution of the Republic of Lithuania of 16th April 2015 No XII-1626 Concerning the approval of National Environment Protection Strategy for 2050

By 2050 Lithuanian Forests should reach certain features - a natural component of Lithuanian landscape characterized by health, biodiversity, productivity and sustainability, meeting all ecological, economic and social needs of society based on the principles of sustainable development. The aim is to increase the country's forest coverage to 35 percent of the territory of the country by 2030. This will help to secure the country's ecological balance, protect habitats of wild fauna and flora, prevent soil erosion, purify the air, reduce greenhouse gas emissions in the air and protect ground and surface waters. The potential of unutilized and unsuitable land for agriculture needs to be exploited to increase forest coverage; completed land reform, rational use of EU financial measures to promote new afforestation, smooth transfer of land from a free state land fund to state forest managers to create new forests, rationalized legal restrictions on afforestation of high productivity land, thus creating preconditions for increasing ecological stability in low-wooded areas. For securing rational forest resource use it must be ensured that the amount of timber harvested in all forest fellings does not exceed its increment in all forests in Lithuania, the scope of forest felling, sanitary and basic felling needs to be harmonized, the volume of small non-liquid wood and logging waste used for biofuel production increased, and the commercial forestry business updated in all measures to restore the ownership of forests in reserved forests, encourage measures to increase the economic efficiency and competitiveness of private forests. There is also a need to promote the sustainable development of national forest-based timber industries and renewable energies, the use of raw wood resources to create high value-added products.

- The rules for forest harvest, as adopted by the order of the Minister of Environment, No 73 March 5, 1999.

Forest felling rules establish the basic biological, ecological and technological requirements of forest felling (logging, removal of harvested trees). Forest felling is divided into main, thinning, sanitary and special forest fellings. The rules sets the limitations for maximum clearcutting areas in different forest groups (accordingly to protection status), number of living and dead trees which should be left for biodiversity purposes, limitations of fellings around the nests of rare birds, limitations for forest felling area width, felling rotation periods for different felling practices, etc.

- Governmental Resolution of the Republic of Lithuania of 6th November 2012 No XI-2375 Concerning the approval of National Climate Change Management Policy

One of the aims of the strategy (same as in National Forestry Development Programme for 2012 – 2020) is to increase the forest cover of unutilized and unsuitable land for agriculture. According to the data of the National Land Service under the Ministry of Agriculture, on January 1 2011 in the country there were 168.3 thousand. ha land is not used and unsuitable for land use, of which 145.6 thous. ha not used for agriculture and 22.7 thousand. ha of damaged land. Afforestation of this land would increase the country's forests by about 3 percent. The program provides 7 times - from 70 thousand. m^3 to 500 thousand m^3 - increasing harvest of logging waste for biofuel production every year. The strategy sets the objective to increase the absorption of GHG emissions by increasing the country's forest cover and strengthening the natural framework (total annual absorbed emissions should be at least 3.7 million t CO_2e in 2020), which could be achieved by two abovementioned main goals: implementation of afforestation measures by planting unutilized land that is not suitable for agriculture; to implement a sustainable forestry policy by extending the scope of harvesting waste used for biofuel production.

- The rules for afforestation of non-forest land, as adopted by the order of the Minister of Agriculture and Minister of Environment No 3D-130/D1-144 29 March, 2004

The description of potential areas for afforestation activities is provided in the document. Moreover, the rules sets the limitations for afforestation in the most fertile lands in the country.

- The rules of inventory and registration of natural afforestation of non-forest land, as adopted by the Order of the Minister of Environment and Minister of Agriculture No D1-409/3D-331 8 May, 2012

The rules provide the definition of procedures for afforested/reforested area registration into State Forest Cadastre and Centre of Registers.

2.3.2: Description of future harvesting rates under different policy scenarios

State owned forests. According to data provided by State Forest Service (2017) harvest rates in State forests are rather stable, 10 percent changes may be projected according to the Ministry of Environment. The use may decrease due to proposal of restrictions for final fellings (prohibited clearcutting) in III forests group.

Harvest in State Forests are regulated by the order of the Minister of Environment for the approval of forest harvest rules (redactions from 1999 to 2010) and Government Resolution for annual final felling quota for state forests (2004 – 2008; 2009 – 2013; 2014 – 2018; 2019 – 2023). Maximum felling quota in State Forests are determined to use not more than 85 % of growing stock volume increment. For example, in 2004 - 2008 maximum felling quota was 2400 thous. m^3 of merchantable wood, in 2009 - 2013 - 2 800 thous. m3 of merchantable wood, 2014 – 2018: 11 168 ha, 3 145 thous. m^3 of merchantable wood, 2019 – 2023: 11 850 ha, 3 620 thous. m^3 of merchantable wood.

Private forests. Harvest in private forests are mostly related to wood price and economic situation. Harvest rate less stable than in State forests. Fluctuations between 3 mln. m^3 (minimum) of merchantable timber (in 2015) and 4 mln. m^3 (maximum) of merchantable timber (in 2014) are observed (State Forest Service, 2017).

Future development of taxes related to forest land. There is a proposal to change tax of wood production (5 % of income), which forest owners pay from the gain after selling wood. Change could be to less production related tax, which may also lead to changes in harvest rates in private forests, since the situation may become more profitable for owners. Forest land has no taxes in Lithuania, however there is a proposal to introduce forest land tax for owners as well as in other land uses, which may increase forest resource use in order to keep the land profitable to owners.

Strategical planning documents, having impact on forest harvest rates:

- National Environment Protection Strategy adopted by the Parliament in 2015.

Sets targets for forestry sector, however, not only related to harvest: increase forest coverage to 35 % of total country area until 2030; protect biodiversity in forests; promote of non-clear final fellings; resume commercial forestry practice in all forests reserved for restitution, promote measures to increase economic efficiency and competitiveness of private forests; promote renewable resources in energy sector. Planned measures may result in increase of harvest rates due to more beneficial economic situation and increased demand of biomass for energy sector.

- National Energy Strategy for 2050 adopted in 2018.

Biomass and wind energy are the main renewables in Lithuania. In 2016, solid biofuel amounted 82.5 % from total energy from renewables. However, it is planned that wind energy will become prevailing and in 2020 will consist 45 % of total energy from renewables, while biomass – 26 %. In 2030: planned that renewables (including biomass) will consist 45 % of total electricity and 90 % of total heating produced; wind energy – 55 %, solar energy – 25 %, energy from biomass - 9 % of electricity. In 2050: planned that renewables (including biomass) will consist not less than 80 % of total final energy produced (electricity, heating, transport). Planned targets may result in increase of harvest rates due to increased demand of biomass for energy sector.

- National Bioeconomy Strategy (Study on possibilities of Lithuanian bioeconomy development)

Aim to increase potential of forestry, as bioeconomy sector: promotion of sustainable biomass use from forests (including the residues from roundwood procurement and industry). Potential of bioenergy sector: main renewable source for energy due to price, availability of local resources and low GHG emission; has a limited potential to increase. According to the information provided in the study, harvest rates may not increase in the future due to limited potential of forestry and more sustainable use of residues from wood production industry.

3: Description of the modelling approach

For the estimation of carbon stock changes in living biomass and dead wood, European Forestry Development Model was used to provide growing stock volume development during the period of 2010 to 2025, taking into account age class structure estimated by NFI 2005 – 2009 and historical (average of 2000 – 2009 NFI data) management practice intensity. Calculation spreadsheets, used for carbon stock change and GHG emissions and removals estimation for National GHG Inventory, were used to calculate carbon stock changes from the EFDM model results for forest reference level estimation.

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

Forest reference level was estimated using EFDM - European Forestry Dynamics Model, which was adjusted for Lithuanian conditions. Development of growing stock volume as well as harvested and dead tree volume were estimated with EFDM model, using data of NFI measurements during 2005 - 2009, providing data of age class distribution and actual forest management practice intensity, which were estimated as probability functions. Carbon stock changes and GHG emissions/removals were afterwards calculated for above and below-ground biomass, dead wood and harvested wood products using calculation spreadsheets as in annual GHG inventory with national and default factors, using 2006 IPCC Guidelines for National Greenhouse Gas Inventories and 2014 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.

Table 3-1. Factors used in forest reference level estimation

	Coniferous	Deciduous
Basic wood density	0.41	0.47

Biomass expansion factors	1.221	1.178
Root-to-shoot ratio	0.26	0.19
Carbon fraction of dry matter, t C/ t d.m.	0.51	0.48
C loss due to the drainage, t C/ha	0.68	
N_2O emission factor, nutrient poor soils, kg N_2O-N/ha	0.1	
N_2O emission factor, nutrient rich soils, kg N_2O-N/ha	0.6	
Conversion factor from C to CO_2	-44/12	
Conversion factor from N_2O to CO_2	298	

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

Main data source used for Forest Reference Level estimation is National Forest Inventory, measurements executed during the period from 2005 to 2009 (remeasurements in pairs: 2000/2005, 2001/2006, 2002/2007, 2003/2008 and 2004/2009). National Forest Inventory measurements are presented in statistical yearbooks: Lietuvos miškų statistika. Nacionalinė miškų inventorizacija atrankiniu metodu *(Lithuanian Forest Statistics. National Forest Inventory by sampling method).*

Another data sources are Food and Agriculture Organization, Statistics Lithuania and Ministry of Environment (The Chronicle of Lithuanian Forests. XX century, 2003) data on forestry production and trade for harvested wood production carbon stock changes estimation, as used in annual GHG inventory.

3.2.1: Documentation of stratification of the managed forest land

Stratification is based on the data obtained from NFI, regarding forest management practices occurring in each stratum. Definition of stratum is based on several different aspects:

Forest management groups:

- I - strict nature reserves. No management is allowed, natural regeneration preferred.
- II - forests of special purpose - ecosystem protection forests. Management aims for protection and restoration of forest ecosystems. No clearcutting for final fellings is allowed.
- III - protective forests. Management aims to form productive forests that can perform soil, air, water protection functions. Clearcutting for final fellings is allowed.
- IV - commercial forests. Management aims to form productive forests for wood supply.

All Lithuanian forests are distributed into four functional groups. In the beginning of 2017, distribution of forests by functional groups was as follows: group I (strict nature reserves) – 24.9 thous. ha (1.1%); group II (ecosystems protection and recreational forests) – 260.8 thous. ha (11.9%); group III (protective forests) – 320.3 thous. ha (14.6%); and group IV (exploitable forests) – 1,583.5, thous. ha (72.3%) from total forest land category.

Group I contains strict reserves and account for 1.1% of all forests. No silvicultural practices are allowed. The main objective is to maintain the natural growth, development and enhanced biodiversity. Group II contains forests of special purpose. They are divided into two subgroups: IIA-ecosystem protection forests, occupy 9.0% and IIb – recreational forests occupy 2.9% of all forest Ecosystem protection forests are used to preserve and improve the recreational forest environment. In group II forest wood production is not the primary objective, harvesting is allowed at the age of natural maturity only and as a result wood quality is lower due to an absence of thinnings and selective cuttings. Group III contains protective forests: geological, geomorphological, hydrographical and cultural reserves, forests for soil, water, human living surroundings and infrastructure protection. Forests in group III occupy 15.7% of all country forests. The main objective is to form productive forest stands, capable to perform various protection functions. Group IV contains commercial forests, which occupy the main part of all forests (70.9%). The main objective is to form productive forest stands that continuously supply the industry and energy sectors with wood, while at the same time following environment protection requirements. According to the main objectives of each forest group and protection level, there are strict limitations for harvesting determined in each group (Table 3-2).

Table 3-2. Description of legal restrictions for management of forests applied in reference period, clearcutting

Species	Min age of final fellings in forest groups			Intermediate fellings			Max clearcut area in forest groups, ha	
	IV (clearcut)	III (clearcut)	II (no clearcutting allowed)	Young stand formation	Thinning	Precommercial thinning	IV	III
Pine	101	111	170	8 – 21	21 – 41	>41	8	5
Spruce	71	81	120	8 –21	21 – 41	>41	8	5
Birch	61	61	90	8 – 21	21 – 41	>41	8	5
Aspen	41	41	60	6 – 21	21 – 31	>31	8	5
Black alder	61	61	90	6 – 21	21 – 31	>31	8	5
Grey alder	31	31	50	6 – 21	21 – 31	>31	8	5
Oak	121	141	200	8 – 21	21 – 41	>41	8	5
Ash	101	111	170	8 – 21	21 – 41	>41	8	5

Ownership type - state forests, private forests, forests reserved for restitution.

Main tree species:

- Pine *(Pinus sylvestris)*
- Spruce *(Picea abies)*
- Birch *(Betula pendula, Betula pubescens)*
- Aspen *(Populus tremula)*
- Black alder *(Alnus glutinosa)*
- Grey alder *(Alnus incana)*

- Oak *(Quercus robur)*
- Ash *(Fraxinus excelsior)*
- Others

It must be noted, that in order to reduce the number of strata, some of the strata were merged since the management practices applied in those strata are very similar. 3rd and 4th forest groups were merged together, distributed among 6 main species - pine, spruce, birch, aspen, black alder, grey alder and others merged into one group (oak, ash and other deciduous). Tree species in Ist and 2nd forest groups were merged into 2 groups: coniferous and deciduous, in addition to this, Ist forest group is only state owned. Aggregation of strata and areas, representing each strata, are provided in the table below:

Table 3-3. Distribution of managed forest land into strata

Stratum No	Code	Forest group	Ownership	Species	Area during reference period
1	1gr	1	All	All	26,446.21
2	2gr12ow1sp	2	State and private	Pine	100,067.11
3	2gr12ow2sp	2	State and private	Spruce	30,155.22
4	2gr12ow3-9	2	State and private	Birch Aspen Black alder Grey alder Oak Ash Others	81,382.53
5	2gr3ow1-9sp	2	Reserved for restitution	All	30,160.04
6	3gr12ow1sp	3	State and private	Pine	107,035.94
7	3gr12ow2sp	3	State and private	Spruce	33,527.35
8	3gr3ow12sp	3	Reserved for restitution	Pine and spruce	20,444.13
9	4gr1ow1sp	4	State	Pine	229,851.14
10	4gr2ow1sp	4	Private	Pine	155,934.59
11	4gr1ow2sp	4	State	Spruce	180,461.38
12	4gr2ow2sp	4	Private	Spruce	96,524.24
13	4gr3ow12sp	4	Reserved for restitution	Pine and spruce	55,431.47
14	34gr1ow3sp	3--4	State	Birch	157,996.20
15	34gr2ow3sp	3--4	Private	Birch	148,500.73
16	34gr3ow3sp	3--4	Reserved for restitution	Birch	50,583.71
17	34gr12ow4sp	3--4	State and private	Aspen	110,643.30
18	34gr12ow5sp	3--4	State and private	Black alder	140,666.06
19	34gr12ow6sp	3--4	State and private	Grey alder	76,073.49
20	34gr12ow7sp	3--4	State and private	Oak	38,016.99
21	34gr12ow89sp	3--4	State and private	Ash and others	48,852.10
22	34gr3ow4-9sp	3--4	Reserved for restitution	Aspen Black alder Grey alder Oak Ash Others	71,206.57

Total area of managed forest land during the reference period (2000 – 2009) and used for projection of forest reference level is 1,989.96 thous. ha.

Stratification of managed forest land was done using NFI 2005 - 2009 data, taking into account only those NFI plots where land use was defined as forest land remaining forest land. Forest land definition according to the Forest Law, as used in National GHG inventory: area of land, covered with trees or temporary without tree cover, with 30 % crown cover and 5 m height at maturity stage in natural site, not smaller than 0.1 ha.

As it is requested in LULUCF regulation (EU 2018/841), that forest reference level of a country shall contain description of forest characteristics, including dynamic age-related characteristics, age class distribution during the projection period (in time steps of 5 years) are provided in Annex I.

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

Forest management practices were set and described according to actual forest management activity applied for certain forest group, forest ownership and specie combination – accordingly to the division of forest into strata. Those management practices are as follows: clearcutting (FMP 1), all selective cuttings including shelterwood logging, thinning, sanitary cuttings and other temporary cuttings (FMP 2) or no management (FMP 3). The extent of each forest management activity applied in certain strata and age class were defined according to actual management practice detectability observed in sample measurements of NFI 2005 – 2009. Probabilities (expressed by logistic regression functions) for each of 3 management activities applied in strata were defined for 34 age classes (with 5 years' time step), 16 volume classes and summarized values are provided in Annex III. Description of practices in each stratum are described in the table below.

Table 3-4. Description of forest management practices applied for projection of forest reference level

Stratum No	Code	Average probability of management practice applied		
		Clearcutting	Selective cutting	No management
1	1gr	0.000	0.368	0.632
2	2gr12ow1sp	0.011	0.346	0.643
3	2gr12ow2sp	0.004	0.417	0.580
4	2gr12ow3-9	0.004	0.478	0.518
5	2gr3ow1-9sp	0.000	0.440	0.560
6	3gr12ow1sp	0.008	0.421	0.571
7	3gr12ow2sp	0.025	0.338	0.638
8	3gr3ow12sp	0.000	0.422	0.578
9	3gr3ow3-9sp	0.000	0.464	0.536
10	4gr1ow1sp	0.033	0.346	0.621
11	4gr2ow1sp	0.032	0.485	0.483
12	4gr1ow2sp	0.068	0.285	0.647
13	4gr2ow2sp	0.109	0.378	0.514
14	4gr3ow12sp	0.023	0.426	0.551
15	34gr1ow3sp	0.061	0.439	0.500
16	34gr2ow3sp	0.072	0.400	0.527
17	34gr3ow3sp	0.005	0.400	0.595

18	34gr12ow4sp	0.082	0.489	0.430
19	34gr12ow5sp	0.049	0.433	0.518
20	34gr12ow6sp	0.034	0.556	0.409
21	34gr12ow7sp	0.450	0.236	0.314
22	34gr12ow89sp	0.055	0.589	0.355
23	34gr3ow4-9sp	0.007	0.501	0.492

Management practice intensity (probability functions) for every age class in certain stratum are provided in Annex III. Description of legal restrictions for forest management, as observed in NFI measurements and included in development of probability functions for forest management practices, applied in 2000 - 2009 period is provided in the tables below. Actual management intensity for each management practice in strata are described in the Table 3-4.

Pursuance of sustainable forest management is fixed in the Forestry development programme for 2012 - 2020, adopted by the Government Resolution in 2012 as a measure to increase the overall benefit of forests: "Forest development strategic aim - increase benefit of forestry to society (..), ensuring the implementation of the principles of sustainable forest management in all forests of the country".

Protected areas. The strategic aim of sustainable forest management is being successfully implemented through various actions, such as forest division into 4 different management regime forest groups with certain restrictions for management, as described in section 3.2.1. Another implementation of sustainability is the establishment of special protected areas, which include forest land as well: national parks, regional parks, strict reserves, reserves and municipal reserves, biosphere polygons buffer zones around state parks, ets. These protected areas also include areas of international (European) importance: Special Protected Areas (SPA) of Natura 2000 network, Proposed Sites of Community Interest (pSCI) of Natura 2000 network. According to the data of State Forest Service (2010), all above mentioned protected areas cover more than 707 thous. ha of forests (33 % of total forest land), with dominant area in IV forest group (more than 40 % from total protected areas in forests), providing additional special limitations and restrictions for forest management in those areas. Forests in strict reserves make up to 13.8 thous. ha, forests in national parks - to 97.2 thous. ha, forests in regional parks - 224.0 thous. ha. Areas of Natura 2000 network covered 735.7 thous. ha in 2009, it composes 11.3% of the country's territory.

There also are specific limitations for forest management in forest stands with inventoried nests of rare birds – no management allowed in specific area around the nest (buffer zone), time limitations for logging and other activities, etc. According to the data of State Forest Service, there were 2040 nests of rare birds inventoried in 2009.

Lithuania has also inventoried Woodland Key Habitats in its forests, which cover more than 26.7 thous. ha of forest land in Lithuania.

Certification of sustainability. Lithuanian State Forests are certified under the FSC certification. FSC (Forest Stewardship Council) - international forest certification scheme, securing that certified product is produced from wood, harvested in sustainable managed forest. All units[1] (42) of State Forest Enterprise have the FSC certificate. In each of the State Forest Enterprise unit there are forest areas left to natural development which may make up 5.3 % from total forest land area in that unit, as

[1] Previously there were 42 separate State Forest Enterprises established in Lithuania. The reorganization took place in 2017 and 2018, continuously merging all separate enterprises into one State Forest Enterprise.

well as plan of environmental protection actions in the unit. Private forests. In 2017, the first group of private forests (73 private forest owners) achieved first group FSC certificate, covering approx. 31 thous. ha of forest.

Increment use of forests. As it is explained by European Environment Agency (2017), percentage of increment use for fellings must not exceed 70 %. According to the historical data of National Forest Inventory, harvest rates in Lithuania are significantly lower than total annual increment and constitute only half of it (Figure 3-1).

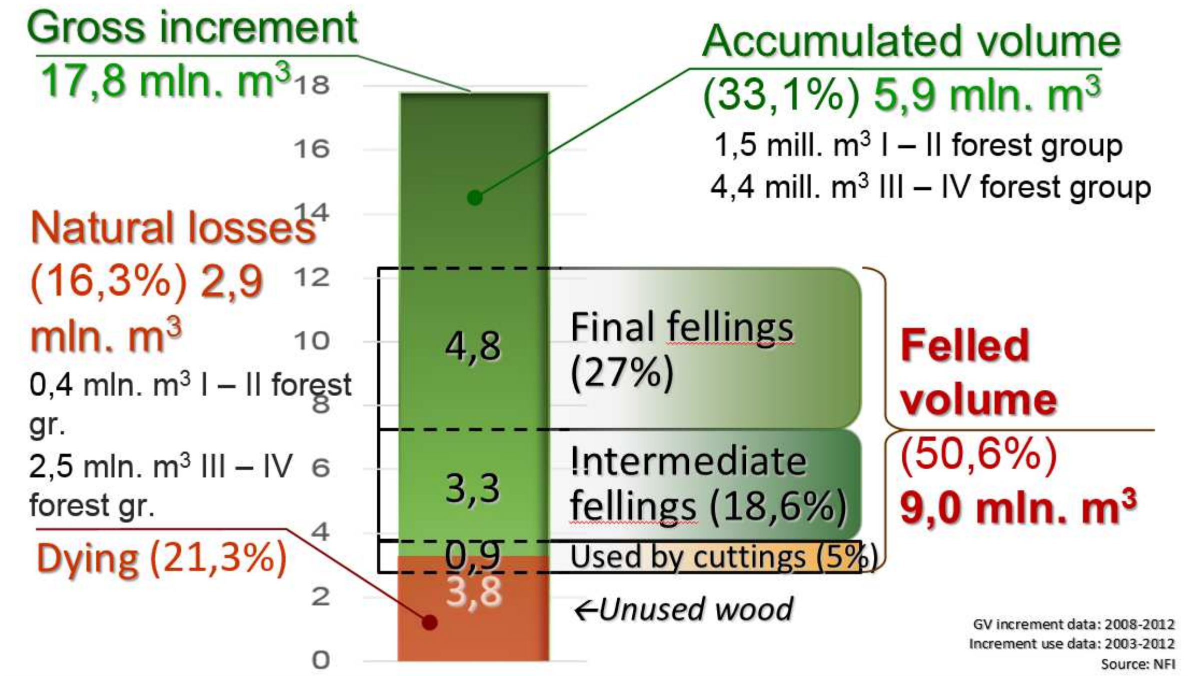

Figure 3-1. Use of growing stock volume increment in Lithuania

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

Description of EFDM modelling framework used for forest reference level estimation. European forestry dynamics model (EFDM) is an open code Markov Chain modelling solution used for simulations based on data from sampling plot measurements in national forest inventories, which simulates the development of unit areas of forest land according to probabilities indicating transitions due to natural processes or management actions (Vauhkonen, Packalen, 2017). EFDM modelling results are provided as a forest area in certain class with corresponding characterics - growing stock volume, felled volume, volume reduced due to mortality and dead wood. The distribution of the forest land, is presented as a matrix defined by a stratification factors (forest group, ownership type, tree species). The cell values of the matrix represent areas in each step of modelling. As explained in the original documents of the EFDM (Sirkiä, 2007; Packalen et al. 2017) a simulation step is obtained as transition of certain stratum state (growing stock volume in age classes) affected by forest management practices and their probabilities. Consequently, the basic output from an EFDM simulation is a sequence of areas in their state after each of requested number of time steps.

The modelling was done by 3 stages. First of all, the growing stock volume and total volume drain due to harvest and mortality were predicted. During second stage drain prediction separated into harvest and mortality predictions. During the last stage the dead volume prediction was modelled taking into account the relationship between growing stock volume and accumulated in stand dead volume.

Input data preparation. Modelling of growing stock volume, dead wood and fellings was carried out with all sampling plots sectors representing forest land remaining forest land from 2005 - 2009 NFI measurements (remeasurement of 2000 - 2004 NFI measurements). This data source was used for description of 3 forest management practices and initial state of the forest in strata defined.

For the definition of initial forest state 2 dynamic factors - volume (16 classes), age (34 classes) and 4 static factors - forest group (4 classes), ownership (3 classes), main tree species (9 classes) and site productivity class (2 classes). Boundaries of volume classes were defined using NFI growing stock volume data in all stands as well as clear cutting areas (temporary unstocked stands), separating them into equal groups (up to 10th group) and increasing the intervals of classes by 10 % in every class after 10th class.

Table 3-5. Values of class parameters used in all analyses

Volume class	Lower limit of volume class	Upper limit of volume class	Mean value of volume class	Age class	Lower limit of age class	Upper limit of age class
1	0	22,194	3	0	0	0
2	22,194	60,661	41.4275	1	1	5
3	60,661	99,128	79.8945	2	6	10
4	99,128	137,595	118.3615	3	11	15
5	137,595	176,062	156.8285	4	16	20
6	176,062	214,529	195.2955	5	21	25
7	214,529	252,996	233.7625	6	26	30
8	252,996	291,463	272.2295	7	31	35
9	291,463	329,93	310.6965	8	36	40
10	329,93	368,397	349.1635	9	41	45
11	368,397	412,6341	390.5155	10	46	50
12	412,6341	463,5067	438.0704	11	51	55
13	463,5067	522,0102	492.7584	12	56	60
14	522,0102	589,2892	555.6497	13	61	65
15	589,2892	666,6601	627.9746	14	66	70
16	666,6601	and more	795	15	71	75
				16	76	80
				17	81	85
				18	86	90
				19	91	95
				20	96	100
				21	101	105
				22	106	110
				23	111	115
				24	116	120
				25	121	125
				26	126	130
				27	131	135
				28	136	140
				29	141	145
				30	146	150
				31	151	155

				32	156	160
				33	161	and more

There were 34 age classes defined with first class name “0”, representing areas with temporarily unstocked stands, the age class “1” represents stands where age has not yet reached 5 years. Age classes from 1 to 33 represent forest land remaining forest land with forest stands in 5-year age steps.

Probability functions of forest management practices (clearcutting - FMP1, non-clearcutting - FMP2 and no management - FMP3) were defined suing NFI 2000 - 2009 measurement pairs. Probability of each management practice were set in every age/volume class for separate or aggregated forest group, ownership and species, as defined in forest land remaining forest land stratification step. Using the data of NFI measurements probability model was developed via multiple logistic regression.

Estimation of probability functions. Development of probability functions of forest management practices was done using historical NFI measurement data from 2000 to 2009 for calculation of empirical probabilities for each of the management practice in certain stratum and age class.

Logistical regression was applied for the modelling of forest management practice and probability models for each management practice were created using dynamic (age class, volume class) and static (forest group, ownership and species) factors’ values as independent variables. Modelling was carried out with STATISTICA 10 software, using ***Hooke-Jeeves and quasi-Newton*** or ***Rosenbrock and quasi-Newton*** methods from ***Nonlinear estimation – Quick Logit regression*** module. Logistic regression models were developed accordingly to stratification criteria defined in Chapter 3 of this document.

Logistic regression model:

$$EXP(X_0+X_1*Vol+X_2*Age+X_3*Productivity)/(1+EXP(X_0+X_1*Vol+X_2*Age+X_3*Productivity))$$

Where: X_0, X_1, X_2, X_3 – model factors,

Vol – volume class at time *t*,

Age – age class at time *t*,

Productivity – productivity class at time *t*.

After the development of logistic regression model of probabilities, probabilities for each management practice in certain stratum and age class were adjusted to equal the sum of probabilities to 1.

4: Forest reference level

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

Forest reference level for Lithuania, determined according to the criteria set out in Annex IV of the LULUCF regulation (EU 2018/841), is -1,429 kt CO_2 eq., assuming instant oxidation (all harvest is removed and oxidized in current year). With the first-order decay function applied for harvested wood products, forest reference level for Lithuania is -2,272 kt CO_2 eq. for the compliance period of 2021 – 2025, as explained in Chapter 1.1.

Lithuania is reporting changes in all carbon pools in its National Greenhouse Gas Inventory, except for mineral soils and litter in forest land remaining forest land:

- Above-ground biomass carbon stock changes;
- Below-ground biomass carbon stock changes;
- Dead wood carbon stock changes (consists of dead wood stems inventoried in forests and stumps of harvested trees which where inventoried as living in previous NFI);
- Organic soils carbon stock changes (carbon loss due to the drainage of organic soils);
- Harvested wood products.

As it was described in previous chapters, initial data source for the development of carbon stock changes in pools was National Forest Inventory, as executed in 2005 – 2009.

Above-ground biomass. EFDM model provided projection of growing stock volume for every 5 year modelling step. Growing stock volume change was calculated annually from model results (Table 4-1).

Table 4-1.Growing stock volume change in forest land remaining forest land, calculated from model results

Growing stock volume change, mill. m^3	2010 - 2012	2013 - 2017	2018 - 2022	2023 - 2025
Total	3.227	2.905	2.076	0.814
Coniferous	2.408	2.200	1.744	0.370
Deciduous	0.819	0.705	0.332	0.444

Above ground biomass refers to all living biomass above the soil including stem, stump, bark, branches, seeds and foliage. Calculation of above-ground biomass is based on volume of living trees stems with bark, basic wood density and biomass expansion factor. However, *2006 IPCC Guidelines* requires to use biomass conversion and expansion factor (BCEF), which is based on country specific data, but while Lithuania has no country specific values we are using previous methodology to estimate above and below ground biomass. Above-ground biomass is calculated by employing slightly modified eq. 2.8, (p. 2.12 of *2006 IPCC Guidelines*):

$$\Delta AGB = (\Delta GS) \cdot WD \cdot BEF$$

where:
ΔAGB – above-ground biomass change, t d. m.;
ΔGS – change of tree stems volume with bark, m^3;
WD – basic wood density, t d. m. m^{-3};
BEF – biomass expansion factor.

Basic wood density (WD) was estimated on the basis of data provided in Table 4.14 (p. 4.71 of *2006 IPCC Guidelines*). Density values for coniferous and deciduous were calculated as weighted average values related to growing stock volume (Table 4-2).

Table 4-2. Total growing stock volume and average basic wood density values

Species	**Total growing stock volume (mill m^3). Average 2002-2009**	**Basic wood density, tonnes d. m. m^{-3}**	
		By species	**Weighted average**
Pine	190.6	0.42	
Spruce	76.4	0.40	
Total coniferous	**267.0**		**0.41**
Birch	83.2	0.51	
Aspen	34.0	0.35	
Black alder	41.2	0.45	
Grey alder	21.6	0.45	
Oak	11.2	0.58	

Ash	9.0	0.57	
Total deciduous	**200.1**		**0.47**
Overall total	**467.1**		**0.44**

Default values of biomass expansion factor (BEF) for conversion of tree stems volume with bark to above-ground tree biomass were estimated using NFI data of stems volume (NFI 2003 - 2007), national tables of merchantable wood volume (for branches) and leaves-needles biomass data by Usolcev (Усольцев, В. А. 2001; 2002; 2003[2]). Rate of BEF for coniferous was estimated to be 1.221 and 1.178 for deciduous. The rates of BEF estimated for Lithuania are very close to the rates presented in Table 34.5 (p. 4.50 of *2006 IPCC Guidelines*), what is showing the consistency between the chosen methods.

Below-ground biomass. Calculated from above-ground biomass carbon stock change, estimated in first step (EFDM, as measured in NFI and used in National GHG Inventory, provided data of stem volume (above-ground volume)).

Below ground biomass refers to all living biomass of live roots. Below-ground biomass is calculated by using modified eq. 2.8 (p. 2.12 of *2006 IPCC Guidelines*) which requires data for above-ground biomass and root-to-shoot ratio. Default values of root-to-shoot ratios R were estimated using data of Usolcev[3] and Table 4.4 (p. 4.49 of *2006 IPCC*): for coniferous – 0.26, for deciduous – 0.19.

$$\Delta BGB = \Delta AGB \cdot R$$

where:
ΔBGB – below-ground biomass change, t d. m.;
ΔAGB – above-ground biomass change, t d. m.;
R – root-to-shoot ratio, dimensionless.

Dead wood. For the estimation of carbon stock changes in dead wood, EFDM modelling results of dead tree stems and felled volume was used as an activity data (Table 4-3).

Table 4-3. Activity for dead wood carbon stock estimation, provided by EFDM

Volume, mill. m^3	2010 - 2012	2013 - 2017	2018 - 2022	2023 - 2025
Dead coniferous stems	0.066	0.057	0.038	0.018
Dead deciduous stems	0.013	0.007	-0.008	-0.023
Felled volume, total	10.557	10.734	11.193	11.669

Annual change in carbon stocks in dead organic matter in Forest Land remaining Forest Land is calculated following the summarizing equation for calculation of changes in dead organic matter carbon pools which is equal to the sum of carbons stock in dead wood (measured available dead wood) and carbon stock in dead wood that is left on site after fellings (BGB). Dead wood that is left on site after fellings is assumed to be below-ground biomass which is roots. It is assumed that BGB decays in equal parts in 5 years. Modified eq. 2.17 (p. 2.21) of *2006 IPCC Guidelines* has been used to calculate carbon stock change in dead organic matter:

[2] Усольцев В.А. 2001. *Фитомасса лесов Северной Евразии.База данных и география*. 707с., Екатеринбург.
Усольцев В.А. 2002. *Фитомасса лесов Северной Евразии. Нормативы и элементы географии*. 762с. Екатеринбург.
[3] Усольцев В.А. 2001. *Фитомасса лесов Северной Евразии.База данных и география*. 707с., Екатеринбург.
Усольцев В.А. 2002. *Фитомасса лесов Северной Евразии. Нормативы и элементы географии*. 762с. Екатеринбург

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{DWH}$$

where:
ΔC_{DOM} – annual change in carbon stocks in dead organic matter, t C yr^{-1};
ΔC_{DW} – change in carbon stocks in dead wood (measured dead stems), t C yr^{-1};
ΔC_{DWH} – change in carbon stocks in dead wood (BGB left on site after fellings), t C yr^{-1}.

Annual change of biomass of dead trees stems is calculated by using stock change method and employing equation 2.19 (p. 2.23) of *2006 IPCC Guidelines*:

$$\Delta C_{FF_{DW}} = \left[\frac{A \cdot \left(B_{t_2} - B_{t_1}\right)}{T}\right] \cdot CF$$

where:
ΔC_{FFDW} – annual change in carbon stocks in dead wood in forest land remaining forest land, t C yr^{-1};
A – area of managed forest land remaining forest land, ha;
B_{t1} – dead wood stock at time t_1 for managed forest land remaining forest land, t d. m. ha^{-1};
B_{t2} – dead wood stock at time t_2 (the second time) for managed forest land remaining forest land, t d. m. ha^{-1};
T (= t_2 - t_1) – time period between time of the second stock estimate and the first stock estimate, yr.;
CF – carbon fraction in dry biomass matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)$^{-1}$ (*2006 IPCC Guidelines*, Table 4.3, p. 4.48).

$$\Delta C_{FF_{DW}} = \frac{\Delta B}{T} \cdot CF$$

where:
ΔC_{FFDW} – annual change in carbon stocks in dead wood in forest land remaining forest land, t C yr^{-1};
ΔB – dead wood stock change for managed forest land remaining forest land, t d. m. ha^{-1};
T (= t_2 – t_1) – time period between time of the second stock estimate and the first stock estimate, yr.;
CF – carbon fraction in dry biomass matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)-1 (*2006 IPCC Guidelines*, Table 4.3, p. 4.48).

$$\Delta B = B_{t_2} - B_{t_1}$$

where:
ΔB – dead wood stock change for managed forest land remaining forest land, t d. m. ha^{-1};
B_{t1} – dead wood stock at time t_1 for managed forest land remaining forest land, t d. m. ha^{-1};
B_{t2} – dead wood stock at time t_2 (the second time) for managed forest land remaining forest land, t d. m. ha^{-1}.

$$B_t = AGB + BGB$$

where:
AGB – above-ground biomass in dead wood stems, t d. m.;
BGB – below-ground biomass (dead wood biomass left after fellings - roots), t d. m.

$$AGB = V_{dw} \cdot WD \cdot BEF$$

where:
V_{dw} – available dead wood volume, m^3;

WD – basic wood density, t d. m. m^{-3};
BEF – biomass expansion factor.

Available dead wood volume consists of volume of dead stems and roots left after fellings. Carbon stock changes in dead stems are calculated similarly to living biomass carbon stock change. Dead wood left on site after fellings is estimated from the data of felled volume – below-ground biomass carbon stock change included in this estimation. According to the IPCC 2003 Guidelines for LULUCF, p. 3.38, dead wood left on site after fellings (roots) decay in 5 years, therefore for the calculation of changes in below-ground biomass of dead wood left on site after fellings, for each of the sequent years after harvesting below-ground biomass is reduced by 1/5.

$$BGB = AGB \cdot R$$

where:
AGB – above-ground biomass, t d. m.;
R – root-to-shoot ratio, dimensionless.

Organic soils. Area of forest land remaining forest land was used straight for the estimation of carbon loss due to drainage of organic soils. Total area of forest land remaining forest land, as estimated during the reference period, was multiplied with the percentage of drained organic forest soil. According to *NFI*[4] data, area of mineral soils amounts to 84.3% and area of organic soils – 15.7% of the total forest area. Drained organic forest soils constitute to 7.9% of the total forest land. This area consists of 2.6% infertile and 5.3% of fertile drained organic forest soils. Area of lands converted to Forest land was also included into estimations.

Drained organic soil area was multiplied with emission factor for carbon loss (equation 2.26, p. 2.35 of *2006 IPCC Guidelines*):

$$L_{Organic} = A_{Drainage} \cdot EF_{Drainage}$$

where:
$L_{Organic}$ – carbon loss from drained organic forest soils, t C yr^{-1};
$A_{Drainage}$ – area of drained organic forest soils, ha;
$EF_{Drainage}$ – emission factor for CO_2 from temperate climate zone forest soils, t C ha^{-1} yr^{-1}.

Default value of emission factor for drained organic soils in managed forests provided in Table 4.6 (p. 4.53 of *2006 IPCC Guidelines*) was used in calculations. Default $EF_{Drainage}$ for temperate forests is 0.68 tonnes C ha^{-1} yr^{-1}.

For the estimation of non-CO_2 emissions from drained forest soils default *Tier 1* method was used, as in National Greenhouse Gas Inventory. *Tier 1* eq. 11.1 (p. 11.7 of *2006 IPCC, which is equal to equation 2.26 p.2.35 of 2006 IPCC Guidelines*) is applied with a simple disaggregation of drained forest soils into *nutrient rich* and *nutrient poor* areas and default emission factors are used.

$$N_2O_{emissions_{FF}} = \sum\left(\left(A_{FF_{organic\,IJK}} \cdot EF_{FF_{drainage,\ organic\,IJK}}\right) + \left(A_{FF_{mineral}} \cdot EF_{FF_{drainage,\ mineral}}\right)\right) \cdot \frac{44}{28}$$

[4] Lithuanian National Forest Inventory 2003 – 2007. Forest resources and their dynamics

where:
N_2O emissions $_{FF}$ – annual emissions of N_2O from managed organic soils, kg N_2O yr^{-1};
$A_{FF_{organic}}$ – area of drained forest organic soils, ha;
$A_{FF_{mineral}}$ – area of drained forest mineral soils, ha;
$EF_{FF_{drainage, organic}}$ – emission factor for drained forest organic soils, kg N_2O-N ha^{-1} yr^{-1};
$EF_{FF\ drainage,\ mineral}$ – emission factor for drained forest mineral soils, kg N_2O-N ha^{-1} yr^{-1};
IJK – soil type, climate zone, intensity of drainage, etc. (depends on the level of disaggregation).

Lithuania is using default emission factors from *2006 IPCC Guidelines* (Table 11.1, p. 11.11, Ch. 11.2 of *2006 IPCC Guidelines*) for N_2O emission estimation due to the drainage of organic soils:

$EF_{FF_{drainage, organic}}$ for nutrient rich forest soils - 0.6 kg N_2O-N ha^{-1} yr^{-1}

$EF_{FF_{drainage, organic}}$ for nutrient poor forest soils - 0.1 kg N_2O-N ha^{-1} yr^{-1}

However, currently due to the lack of data and sufficient knowledge to provide default equations for *Tier 1* method of other non-CO_2 greenhouse gases emission, only N_2O emissions were accounted.

Harvested wood products. EFDM model provided projected data of felled volume. In order to apply the same ratio of harvest used for energy and solid use, the ratio between historical (2000 – 2009) and projected felled volume was calculated. This calculated ratio of projected felled volume to historical felled volume was applied to calculate projection of activity data for harvested wood products carbon stock change estimation: solid wood, wood-based panels, paper and paperboard.

Table 4-4. Ratio of projected felled volume to historical felled volume for HWP stock changes estimation

2010 - 2012	2013 - 2017	2018 - 2022	2023 - 2025
1.1552142	1.205935796	1.250769	1.285078

Emissions and removals from harvested wood products are estimated using stock change method, and only HWP in use are considered, obtaining the information from FAO database on harvested wood production from domestic harvest (historical activity data used for projection for forest reference level estimation).

The worksheet provided in *2006 IPCC Guidelines* is a tool for estimating annual carbon balance under any of the proposed HWP approaches and was used for estimation of harvested wood products in use in Lithuania. The model consists of two elements: solid wood products and paper products. Both variables have different half-life values. Greenhouse gas accounting for HWP pool in the worksheet is based on first order decay function with default half-life values (eq. 2.8.5, p. 2.120 of *2013 IPCC Revised Guidelines*).

$$C \cdot (i+1) = e^{-k} \cdot C_{(i)} + \left[\frac{(1-e^{-k})}{k}\right] \cdot inflow(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

where:
i – year;
C(*i*) – the carbon stock in the particular HWP category at the beginning of year *i*, kt C;

k – decay constant of FOD for each HWP category (HWP_j) given in units yr^{-1} ($k = \ln(2)/HL$, where HL is half-life of the HWP pool in years);
Inflow(*i*) – the inflow to the particular HWP category (HWP) during year *i*, kt C yr^{-1};
ΔC(*i*) – carbon stock change of the HWP category during year *i*, kt C yr^{-1}.

Annual change in carbon stock in "products in use" where wood came from harvest in the reporting country, including export, was estimated using Equation 12.3 (Ch. 12.2, p. 12.12 of 2006 IPCC Guidelines).

$$\mathrm{InflowDH} = P \times \left[\frac{\mathrm{IRWH}}{\mathrm{IRWH} + \mathrm{IRWIM} - \mathrm{IRWEX} + \mathrm{WCHIM} - \mathrm{WCHEX} + \mathrm{WRIM} - \mathrm{WREX}}\right]$$

Where:
InflowDH - carbon in annual production of solid wood or paper products that came from wood harvested in the reporting country (that is, from domestic harvest), Gg C yr^{-1};
P - carbon in annual production of solid wood or paper products in the reporting country, Gg C yr^{-1}.
IRW_H - industrial roundwood harvest in the reporting country, Gg C yr^{-1};
IRW_{IM} , IRW_{EX} - industrial roundwood imports and exports, respectively, Gg C yr^{-1};
WCH_{IM}, WCH_{EX} - wood chip imports and exports, respectively, Gg C yr^{-1};
WR_{IM}, WR_{EX} = wood residues from wood products mills imports and exports, respectively Gg C yr^{-1}.

The HWP contribution to the total LULUCF sector emissions/removals was estimated separately for HWP produced and consumed domestically and HWP produced and exported. The annual carbon stock change was subdivided into these two groups by the proportion of exported products and total production for HWP categories, according to the data provided in FAO database:

$$C_{EXP} = C_{TOTAL} \times \frac{P_{EXP}}{P_{TOTAL}}$$

$$C_{DOM} = C_{TOTAL} \times (1 - \frac{P_{EXP}}{P_{TOTAL}})$$

Where:
C_{EXP} - carbon stock change in HWP produced and exported;
C_{DOM} - carbon stock change in HWP produced and consumed domestically;
C_{TOTAL} - total carbon stock change in HWP category;
P_{EXP} - quantity of HWP exported;
P_{DOM} - quantity of HWP consumed domestically

Lithuania uses default half-life values for „products in use“ carbon pools and associated fraction retained each year listed in the Table 3-10 (Table 2.8.2, p. 2.123 of *2013 KP-Supplement*). As Lithuania is using *Tier 1* methodology for carbon stock changes estimation in Harvested Wood Products pool, therefore default factors to convert from production units to carbon, provided in KP Supplement (2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol) (Table 2.8.1 of KP Supplement, Ch. 2.8.3.1, p. 2.122) is used. Default conversion factors used in Lithuanian Harvested Wood Product carbon stock change evaluation are provided in Table 4-5.

Table 4-5. Default half-life values for „products in use“ carbon pools and associated fraction retained each year

	Sawn wood	**Wood-based panels**	**Paper and paper-board**

Half-life (years)	35	25	2
Carbon factor (per air dry volume)	0.229 Mg (t) C m^{-3}	0.269 Mg (t) C m^{-3}	0.368 Mg (t) C Mg $(t)^{-1}$ (per air dry tonne)

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

Consistency between the forest reference level and latest national Greenhouse Gas Inventory Report is maintained due to the estimation of carbon stock changes in the same pools and same methodological approach applied (approach 2, stock change method applied both for National Greenhouse Gas Inventory and forest reference level estimation).

Differences between actual carbon stock changes values reported in latest (2018) National Greenhouse Gas Inventory and projected for forest reference level estimation are presented in the Figures below.

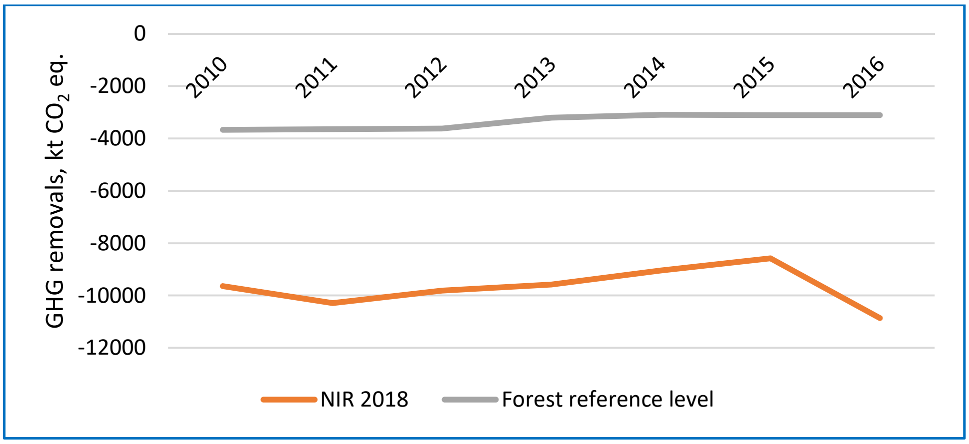

Figure 4-1. Difference between reported GHG removals in forest land remaining forest land and forest reference level

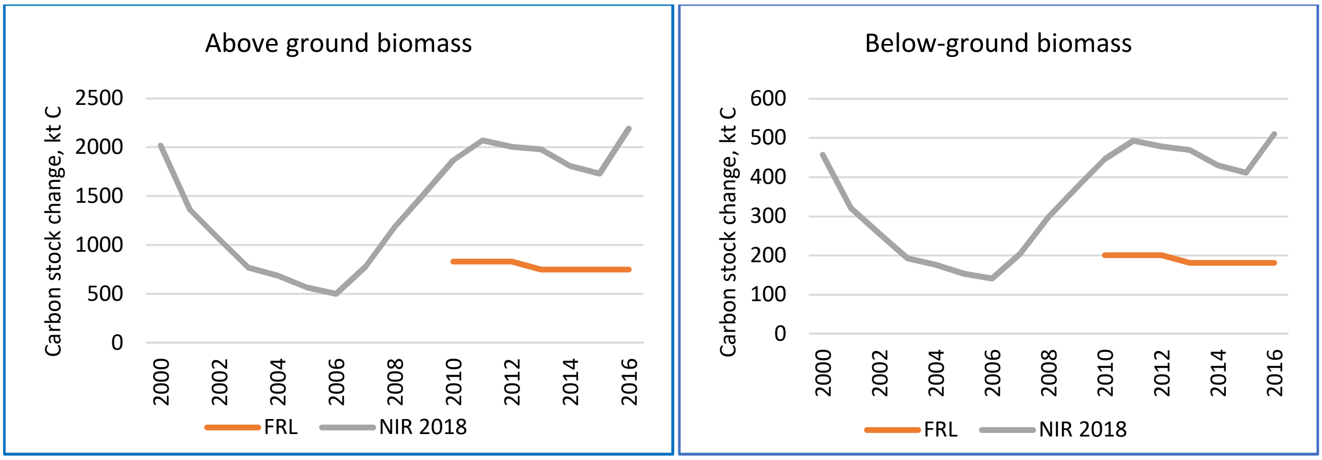

Figure 4-2. Difference between reported carbon stock change in above and below ground biomass pools in forest land remaining forest land and projected for forest reference level

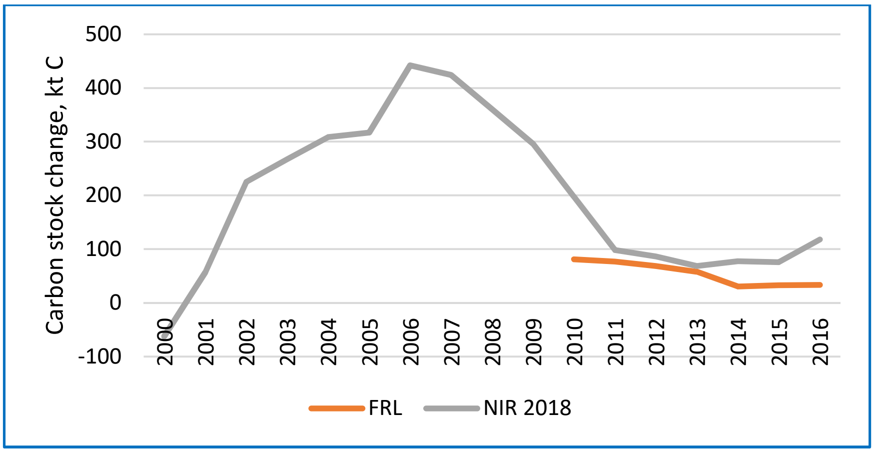

Figure 4-3. Difference between reported carbon stock change in dead wood pool in forest land remaining forest land and projected for forest reference level

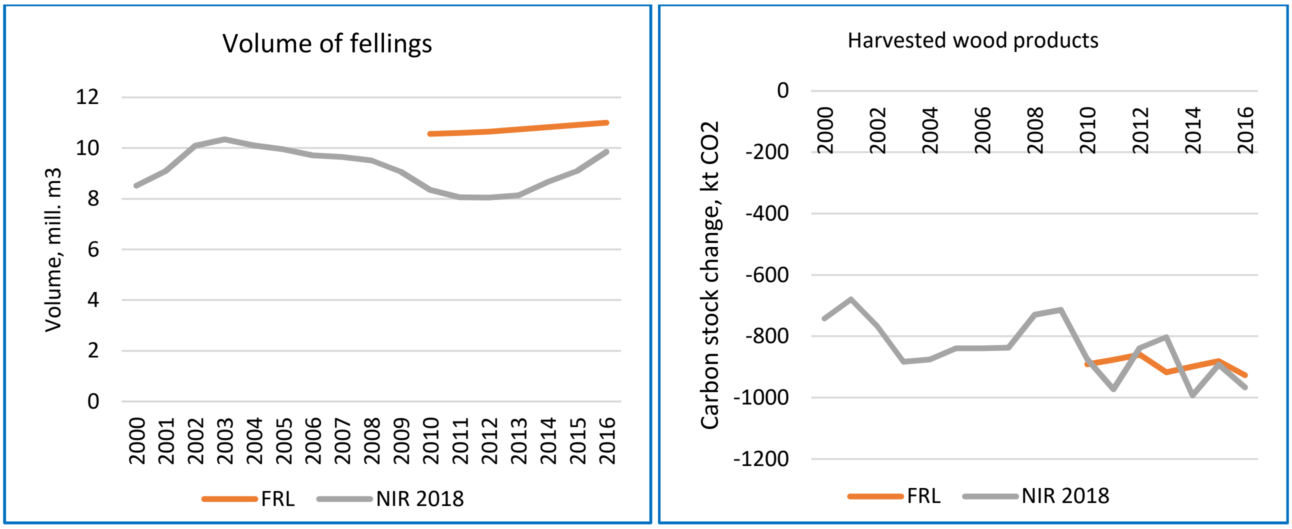

Figure 4-4. Difference between reported carbon stock change in harvested wood products pool and felled volume in forest land remaining forest land and projected for forest reference level

The causes of differences in total GHG removals reported in National GHG Inventory 2018 and forest reference level projection are explained in Chapter 2 (similar reasons fit for explanation of differences between model calibration and National GHG Inventory 2018, as well as forest reference level calculation and National GHG Inventory 2018). The main reasons of differences in carbon stock changes between reported in National GHG Inventory Report 2018 and projected for FRL estimation are: larger intern-annual variations during the whole 2000 – 2016 period which cannot be represented in modelled results due to the average management intensity applied, natural causes of tree diebacks, which are also hard to capture in model, increase in harvest of living and dead trees due to the economic conditions, etc.

4.3: Calculated carbon pools and greenhouse gases for the forest reference level

Results of calculations described in Chapter 4.2 are provided in the Table 4-6.

Table 4-6. Calculated carbon stock changes in carbon pools, kt CO_2 eq.

Carbon stock changes, kt CO_2 eq.	2021	2022	2023	2024	2025
Above-ground biomass	-1956.11	-1956.11	-1072.77	-1072.77	-1072.77
Below-ground biomass	-485.95	-485.95	-284.35	-284.35	-284.35

Dead wood	-87.81	-87.81	-47.16	-45.18	-43.70
Organic soils	424.03	424.03	424.03	424.03	424.03
HWP	-880.61	-861.27	-842.39	-823.96	-805.96
SUM with HWP (first-order decay function applied)	-2986.45	-2967.11	-1822.64	-1802.23	-1782.75
SUM with HWP (Instantaneous Oxidation applied)	-2105.84	-2105.84	-980.247	-978.272	-976.791

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