Ministry of Agriculture
Republic of Latvia

SILAVA

LATVIA'S NATIONAL FORESTRY ACCOUNTING PLAN AND PROPOSED FOREST REFERENCE LEVEL 2021-2025

2019

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ANNOTATION

Updated Latvia's National Forestry Accounting Plan (NFAP) is elaborated under the Regulation 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 (further in the text – LULUCF Regulation 2018/841) in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU. NFAP including a proposed Latvia's Forest Reference Level (FRL) is developed for submission in December 31, 2019 for the period from 2021 to 2025. Updated NFAP version takes in account technical recommendations provided in Assessment of the national forestry accounting plans, Compilation of Synthesis Reports Technical Assessment of National Forest Accounting Plans as requested by the LULUCF Regulation as well as qualitative and quantitative information until 2050 consistent with the long-term strategy required under Regulation (EU) 2018/1999 (*Compilation of Synthesis Reports Technical Assessment of National Forest Accounting Plans as requested by the LULUCF Regulation*, 2019; European Commission, 2019). Responses to the technical recommendations are summarized in Annex 1 and Annex 2 of this document.

The structure of Latvia's NFAP is based on the Annex IV of the LULUCF Regulation 2018/841 Latvia's NFAP takes in account unbalanced age structure of forest with the aim of maintaining or strengthening long-term carbon sink. The projected future sink is based on an extrapolation of forest management practices from a reference period (2000-2009) according to paragraph 5 of the Article 8 of the LULUCF Regulation 2018/841. Specific national circumstances and practices, such as ageing of forests and stand type changes during the reference period are taken into account.

The basis for the calculations of GHG projections are AGM (Forest growth model) and EPIM (Emissions Projections and Inventory Model) tools. Yasso07 model is used to calculate carbon stock changes in mineral soils. Modelling is done for 5 years periods which are later interpolated as annual data. The description of the applied methodologies is provided in the NFAP to demonstrate consistency between the methods and data used to determine the proposed Latvia's FRL in the NFAP and those used in the reporting for managed forest land.

This Latvia's NFAP for the period of 2021-2025 has been prepared in cooperation with Forest & Agriculture Departments of the Ministry of the Agriculture of Republic of Latvia.

Latvia's FRL calculations and explanations have been prepared by experts from LSFRI Silava – A. Lazdiņš, A. Lupiķis, A. Butlers, A. Bārdule, I. Kārkliņa, G. Šņepsts, J. Donis with support of Ministry of Agriculture of Republic of Latvia.

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1. GENERAL INTRODUCTION

1.1 General description of the construction of Latvia's FRL

According to LULUCF Regulation 2018/841 removals from managed forest land are accounted against a forward-looking forest reference level (FRL) including harvested wood products (HWP). The projected future removals by sinks are based on an extrapolation of forest management practices and intensity from a reference period. A decrease in a sink relative to the reference level is accounted for as debits.

This chapter provides a general description of the construction of the reference level and a description on how the criteria according to LULUCF Regulation 2018/841 were taken into account.

The estimated Latvia's FRL for period 2021-2025 is **-1709 kt CO_2 eq yr^{-1}**. The Latvia's FRL includes carbon stock changes and GHG emissions due to on-site incineration of biomass, forest fires, drainage, rewetting and forest fertilization that refers to managed forest lands (Table 1).

Projections are started with 2010 considering no land use changes after 2009, including those associated with completion of 20 years transition period in land converted to forest lands.

Latvia's FRL is based on the National forest inventory (NFI) data (implemented since 2004 by LSFRI Silava, Latvian State Forest Research Institute 'Silava', 2018) and stand-wise forest inventory data maintained by the State forest service. To be able to characterize forest management practices since 2000 forest inventory data in the NFI plots are calculated backwards using equations utilized in the AGM model (Šņepsts, Kārkliņa, et al., 2018), and the stand-wise forest inventory data characterizing thinning and forest regeneration during this period.

Table 1: Net GHG emissions and CO_2 removals from managed forests in Latvia in 2021-2025 and 2026-2030 (ktons CO_2 eq. in 5 years period)

Parameter		2021-2025	2026-2030
Living biomass	Managed forest land (3180 kha)	−11 633.02	−8 201.35
Ameliorated organic soils	Dead wood	−181.09	185.57
	Litter, Soil	10 194.80	11 168.61
Other soils	Dead wood	−1 494.27	1 702.39
	Litter, Soil	-	-
HWP	Total	−7 055.03	−6 621.46
	Sawn wood	−7 053.59	−6 619.27
	Wood panels	−1.44	−2.19
Biomass burning		1 624.22	1 597.08
TOTAL WITHOUT HWP		**−1 489.37**	**6 452.31**
TOTAL WITH HWP		**−8 544.41**	**−169.15**

The calculations of Latvia's FRL for managed forest land is based on simulations of the carbon stocks for period 2010–2025. The simulations of the forest management were implemented using AGM model (Šņepsts, Bārdule, & Lazdiņa, 2018; Šņepsts, Kārkliņa, et al., 2018), as well as documented forest management practices (stand-wise forest inventory data) in 2000-2009, including forestry and nature conservation measures. The harvest rate, that has been used in model, corresponds to the harvest rate (proportion of volume extracted and available for final felling in 2000-2009). Other emissions (due to forest fires) are based on activity data of the period 2000-2009 (applied as a proportion of forest area at the end of 2009) and projected area of ameliorated and rewetted organic soils in 2010–2025 and 2026-2030.

In the calculations the same plots of the National Forest Inventory were used as in reporting for LULUCF sector to the EU and the UNFCCC. The Latvia's FRL includes all carbon pools and other GHG emissions (on-site incineration of biomass, forest fires, drainage, rewetting and forest fertilization) that have been reported to the EU and UNFCCC. Mineral soils are excluded from calculation of carbon stock change as those are not a source of GHG emissions and will be included in the NFAP with technical corrections as soon as the improved methods will be implemented.

Forest definition in Latvia's NFAP and the National GHG inventory is harmonized. Transition period between land converted to forest land and forest land remaining forest land is set to **20 years** (Table 2).

Table 2: Forest definition in Latvia's NFAP

No	Parameter	Measurement unit	Value
1.	Minimal area of forest stand	ha	≥ 0.1
2.	Tree height at maturity age	m	≥ 5
3.	Basal area at maturity age	%	≥ 20
4.	Width of protective belts and other bands of trees	m	≥ 20
5.	Transition period between land converted to forest land and forest land remaining forest land (more details in chapter Projections of future climate conditions, page 54)	years	20

Instead of trends of implementation of management activities carried out during the period between 2000 to 2009 average values characteristic for this period are used in projections (the assumptions are provided in chapter Documentation of sustainable forest management practices as applied in the estimation of the forest reference level, page 38).

Characteristics of forest land in 2010-2020 are based on the modelling results using the same forest management assumptions as for calculation of projections of the GHG emissions in 2021-2030. Forest growth and production is calculated using AGM model, and EPIM model is used to transfer forest growth into CO_2 removals and GHG emissions (chapter Documentation of sustainable forest management practices as applied in the estimation of the forest reference level, page 38).

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

1.2.1 Balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of this century

The FRL is 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 sink.

The NFAP is contributing to the sustainable growth of managed forest lands to meet the growing need for harvested wood products. In regard to sustainable use of renewable resources, fellings are not exceeding the growth expressed as a gross annual increment.

The elements of Annex IV of the LULUCF Regulation 2018/841 used in elaborating Latvia's FRL and corresponding chapters of this report are included in chapter Consideration to the criteria as set in Annex IV of the LULUCF Regulation and Table 6.

The net GHG emissions in forest land remaining forest land in case of continuation of forest management practices as recorded in 2000-2009 are summarized in Figure 1. After 2050 forest land continuously is net sink of CO_2 removals.

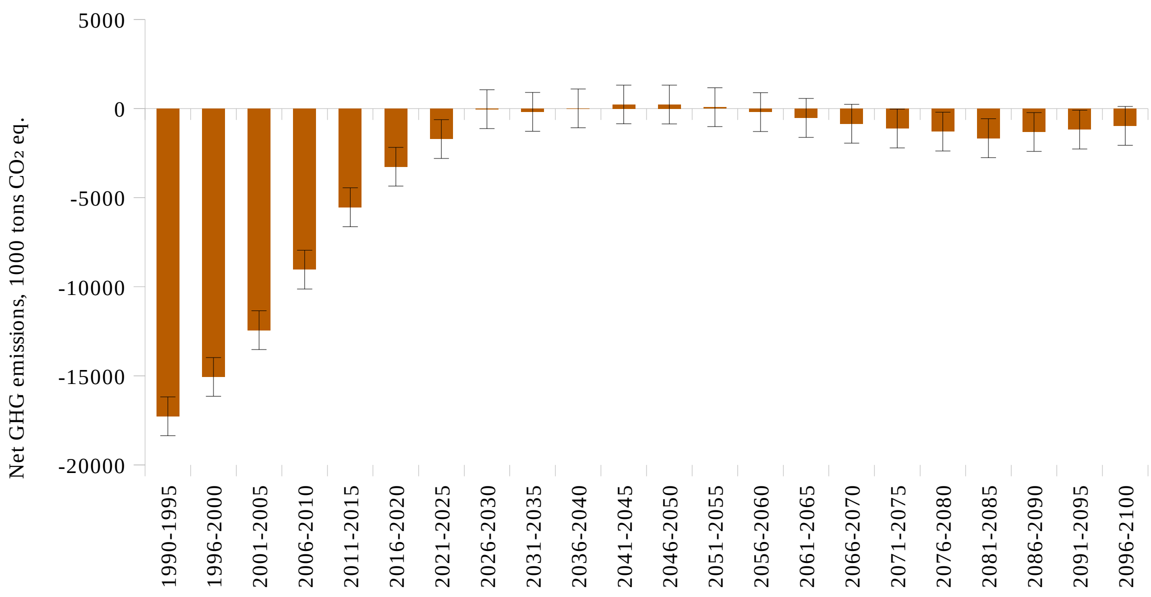

Figure 1: Projections of net GHG emissions in forest lands in case of continuation of forest management practices as recorded in 2000-2009 (FRL scenario)[1].

[1] Standard error of mean as the error bar.

1.2.2 Mere presence of carbon stocks is excluded from accounting

Latvia's FRL ensures that the mere presence of carbon stocks is excluded from accounting. This statement corresponds to Decision 16/CMP.1 under the Kyoto protocol. The principle requires to enlarge carbon stocks and the net carbon sinks, in addition to preservation of existing carbon stocks. Terrestrial vegetation of forest land does not contribute towards the reduction of atmospheric carbon. Therefore, FRL supports accounting for net changes in forest carbon stocks. To gain sustainable growth, an additional growth must be obtained, and emissions must be reduced in comparison to FRL.

1.2.3 Approaches applied to guarantee that emissions and removals resulting from biomass use are properly accounted

Latvia's FRL ensures a robust and credible accounting, to guarantee that emissions and removals resulting from biomass use are properly accounted for. To ensure properly accounting, Latvia's FRL includes the following carbon pools: living biomass, dead wood, litter, soil and harvested wood products. By elaborating Latvia's FRL, it is ensured that all carbon pools and GHG emissions are accounted. Off-site combustion of wood is accounted in energy sector; therefore harvest is assumed as a carbon emission from living biomass pool.

1.2.4 Inclusion of the carbon pool of harvested wood products

Latvia's FRL includes the carbon pool of harvested wood products (HWP), providing a comparison between assuming instantaneous oxidation and applying the first-order decay function and half-life values.

In the accounts provided pursuant to Articles 6(1) and 8(1) relating to HWP, emissions and removals resulting from changes in the pool of HWP falling within the following categories (paper, wood panels, sawn wood) using the first order decay function, the methodologies and the default half-life values specified in Annex V of the regulation. The methodologies are described in detail in the National GHG inventory report (Ministry of Environmental Protection and Regional Development, 2019). Approach B is used in calculation of the GHG emissions.

Net emissions due to production of the HWP are calculated according to methodology in the 2013 IPCC Kyoto Protocol Supplement (T. Hiraishi et al., 2013). CO_2 emissions due to roundwood production in forest land converted to other land uses are accounted using instantaneous oxidation method and are not included in the FRL estimates.

The net emissions from the HWP are calculated according to the methodology elaborated by Rüter, 2011 (refers to Approach B in CRF Reporter). The methodology corresponds to Tier 2 for HWP in the 2013 IPCC Kyoto Protocol Supplement for HWP. Three main HWP groups are used in calculations – sawnwood, wood based panels and paper and paperboard (according to Table 2.8.1 of the 2013 IPCC Kyoto Protocol Supplement).

The calculation is based on harvesting statistics collected by the State forest service, production statistics by the Forest industry association, FAO and EUROSTAT. Linkage with land area used in the commercial felling is ensured through the National Forest Inventory and stand wise inventory system collecting information on all forest management activities. Only domestically harvested wood is accounted.

If HWP is accounted using instant oxidation method, the FRL is **-298.60 kt CO_2 eq yr** for the period 2021-2025.

1.2.5 A constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009

When modelling FRL the ratio between raw materials of biomass from domestic forests and production of the product categories were constant in the Latvia's FRL scenario. Description of wood categories is provided in chapter 1.2.4 'Inclusion of the carbon pool of harvested wood products'. Species specific share of energy wood is used in calculation. Distribution of harvesting rate into energy and non-energy uses is calculated as proportion of total roundwood produced and energy wood assortment according to data provided by the Joint stock company "Latvia's state forests" on situation in 2000-2009. All values are applied over bark. Proportion of biofuel and harvested wood product production from local sources is calculated using the same methodology described in chapters 1.2.4 'Inclusion of the carbon pool of harvested wood products' and 2.2 'Demonstration of consistency between the pools included in the FRL'. Summary of input data applied in the forest reference scenario is provided in Figure 2.

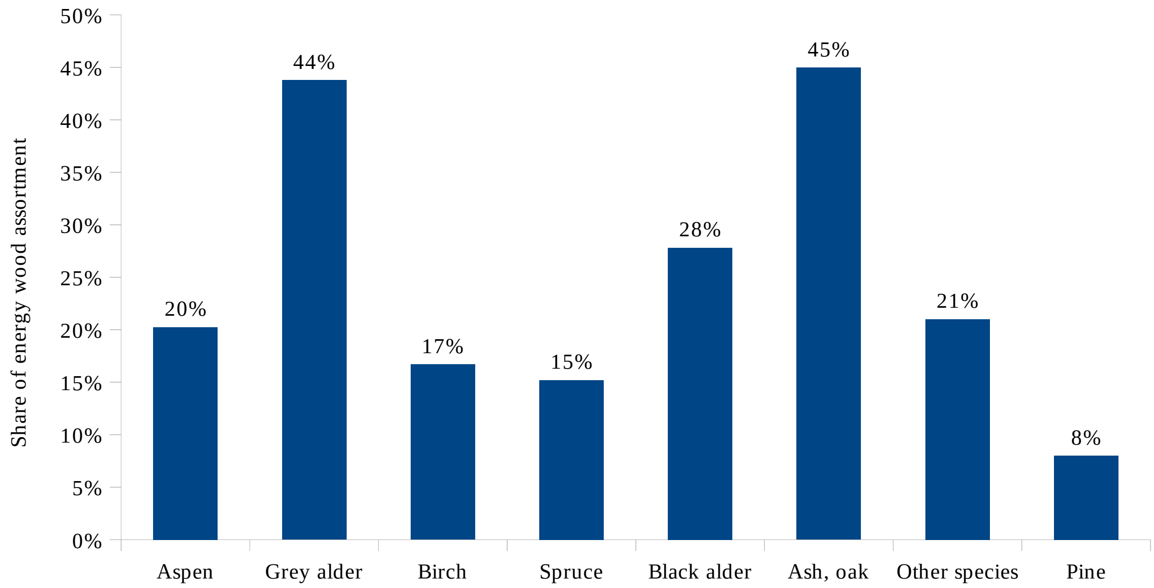

Figure 2: Proportion of energy wood assortment from roundwood produced.

Species specific proportion of energy wood is used due to changes in forest age structure in the commitment period – increase of mature stands of species with higher proportion of energy wood assortment, e.g. grey alder and aspen, leading to increase of output of energy wood assortment without changes in species specific assortment structure. Summarized impact of changes in age structure and species composition is shown in Figure 3.

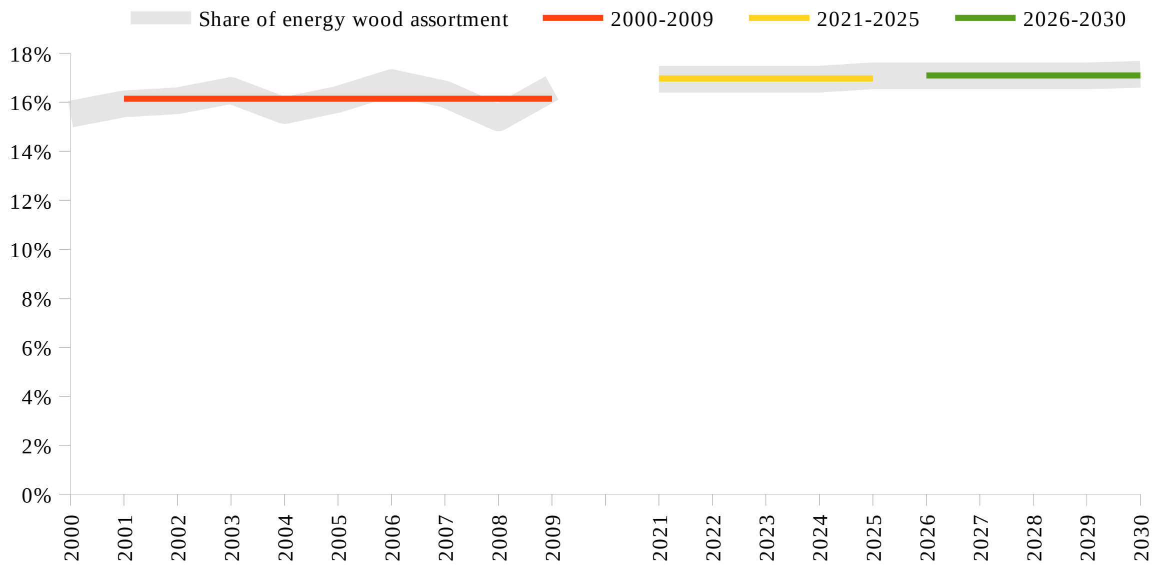

Figure 3: Proportion of energy wood assortment from roundwood produced.

1.2.6 Contribution to the conservation of biodiversity and the sustainable use of natural resources

Latvia as a member state of European Union contributes to implementation of European Union's policies in the field of biodiversity and sustainable use of natural resources. Particular targets and priorities both of EU biodiversity strategy to 2020 (European Commission, 2011) and EU Forest Strategy (European Commission, 2013) have been elaborated in national legislative acts and planning documents.

According to the highest national long-term development planning document Sustainable Development Strategy of Latvia until 2030 (Parliament of the Republic of Latvia, 2010) targets related to EU biodiversity strategy and EU Forest Strategy are:

- to maintain and restore diversity of ecosystems and their natural structures;
- to maintain and enable diversity of local wildlife species;
- to facilitate conservation of traditional landscape;
- to ensure sustainable use of natural resources;
- the capitalization of nature resources (investment funds of green economy, knowledge transfer).

National Development Plan of Latvia 2014-2020 is the highest medium-term development planning document in Latvia. In regard to sustainable use of natural resources, as well as forests, the strategic objective "Sustainable Management of Natural and Cultural Capital" is determined (Cross-Sectoral Coordination Centre, 2012). The objective also includes target related to biodiversity or forestry, for instance, to support the natural capital as the basis for sustainable economic growth and promote its sustainable uses while minimizing natural and human risks, as well as individual measures related to biodiversity and sustainable forestry:

- to promote the sustainable use and biological diversity of land and other natural resources through the application of environmental conservation technologies;
- to increase the value of forest resources by minimising the environmental impact and deploying conservation technologies.

Latvia's Forest Policy was adopted in 1998. Goal of the policy is to ensure a sustainable management of forests and forests lands. In Forest Policy likewise in EU Forest Strategy sustainable management is defined as administration of forests and forest lands in a way that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential ability to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems (Cabinet of Ministers of Republic of Latvia, 1998).

The economic aspects of Latvia's Forest Policy involve promoting various use of timber (EU Forest Strategy, priority 3.3.2) and social aspects – effort to balance the interests of society and forest owners regarding to forest values and labour relations (EU Forest Strategy, priority 3.3.1). Latvia's Forest Policy includes a range of ecological aspects, contributing to 2020 headline target of EU biodiversity strategy, for instance, estimation of forestry impact on environment, monitoring of forest stands, conservation of forest biotopes and species (EU biodiversity strategy, Target 2, Action 7, Cabinet of Ministers of Latvia, 1998).

Forest and Related Sectors Development Guidelines for 2015-2020 is a medium-term policy planning document that consists of the forest-based sector development medium-term strategic goals, guidelines of policy development, directions of actions to achieve these goals and results in policies (Ministry of Agriculture, 2015). The development goals of guidelines are:

- sustainable management of Latvia's forests (EU Forest Strategy, 2020 forest objective, priorities 3.3.1, 3.3.3; EU biodiversity strategy, 2020 headline target, Target 1, Action 1);
- forestry production of high added value (EU Forest Strategy, priority 3.3.2);
- potential of education and science corresponding to development of forest-based sector (EU biodiversity strategy, Target 1, Action 3).

In 2000 the National Programme on Biological Diversity was adopted by the Government of Latvia and by 2003 major part of activities listed in Action Plan of mentioned National Programme was implemented. Since the Government of Latvia adopted the Environmental Policy Concept 2014-2020 in 2014, the mentioned National Programme is considered out-of-date (Ministry of Environmental Protection and Regional Development, 2014). However, the Environmental Policy Concept 2014 - 2020 (EPC) also comprises biodiversity protection issues and is the actual environmental planning document in force (Ministry of Environmental Protection and Regional Development, 2014). EPC is general environmental planning document, which activities provide preconditions for incorporation of the biodiversity considerations into sectorial policies and land use plans (Ministry of Environmental Protection and Regional Development, 2014). The main goal is to provide ability of living in clean environment, by fulfilling actions towards sustainable development, maintaining the quality of environment and biological diversity (EU biodiversity strategy, 2020 headline target), ensuring sustainable use of natural resources, participation of society in making decisions and availability of information of environmental state (EU biodiversity strategy, Target 1, Action 3). In regard to sustainable use of natural resources a monitoring of forest resources and forest condition, as well as annual monitoring of GHG emission and GHG projections are defined as important measures in EPC (EU Forest Strategy, 2020 forest objective, priority 3.3.3).

Rural Development Programme 2014-2020 includes several targets that correspond to both EU biodiversity strategy to 2020 and EU Forest Strategy (Ministry of Agriculture, 2018). Goals of the Programme and measures that comply with the EU biodiversity strategy to 2020, are:

- to increase knowledge level of persons employed in agriculture, forestry and food industry (Target 1, Action 3);
- to restore, to protect and to improve ecosystems related to agriculture and forestry (2020 headline target and Target 3, Action 9);
- restoration of forest stands after natural disturbances (Target 1, Action 1).

Goals of the Programme and measures that comply with the EU Forest Strategy, are:

- to restore, to protect and to improve ecosystems related to agriculture and forestry (2020 forest objective, priority 3.3.4);
- to promote the development of innovative products for agriculture, food production and forestry (priority 3.3.2);
- to promote social incorporation, reduction of poverty and economic growth in rural areas (priority 3.3.1);
- to promote effective usage of resources and to support economics resistant to climate change with low emission level of carbon dioxide in agricultural, food and forestry sectors (priority 3.3.3);
- restoration of forest stands after natural disturbances (priorities 3.3.3 and 3.3.4);
- afforestation and improvement of stand quality in naturally afforested areas (priority 3.3.3);
- reconstruction and improvement of existing drainage systems in forest land (priority 3.3.3).

According to Target 3B of the EU Biodiversity Strategy by 2020 Member State’s all publicly owned forests as well as forest holdings above a certain size that receive funding under the EU Rural Development Policy require Forest Management Plans or equivalent instruments. In Latvia the elaboration of forest management plans is regulated with Law on Forests (Parliament of the Republic of Latvia, 2000a) and The Regulation of the Cabinet of Ministers, No.67 "Rules for Forest Management Plan" (Cabinet of Ministers of Latvia, 2014).

Action 12 (Target 3B) of the EU Biodiversity Strategy determines to integrate biodiversity measures in forest management plans. The Law on Forests determines that owner of forest must take into account the following (Parliament of the Republic of Latvia, 2000a):

- maximum equable and sustainable utilisation of timber resources;
- general requirements of nature protection, in order to:
  - ensure the preservation of the biological diversity;
  - preserve the ability of the forest to protect the soil from erosion;
  - protect surface water and underground water from pollution;
  - preserve the essential elements of cultural heritage in the forest.

In accordance with The Regulation of the Cabinet of Ministers, No.67 "Rules for Forest Management Plan", a forest management plan should contain information (number of) about registered specially protected nature territories, micro-reserves, specially protected biotopes and habitats of specially protected species, forest stands of genetic resources and cultural heritage. It is required that the forest management plan indicates impact of forest management practices on condition of forest resources and assessment rules of social and environmental spheres, as well as public participation in elaboration of state and municipal plans (Cabinet of Ministers of Latvia, 2014). The Regulation of the Cabinet of Ministers, No.936 "Rules for Forest Conservation in Forest Management" determines general nature protection requirements regarding to forest management and requirements in conservation of biologically significant forest elements (Cabinet of Ministers of Republic of Latvia, 2012a). The Regulation of the Cabinet of Ministers, No.935 "Rules for Tree Cutting in Forest" determines requirements for nature conservation referred to tree cutting and restrictions of clear cut (Cabinet of Ministers of Republic of Latvia, 2012c). All previously mentioned Regulations of the Cabinet of Ministers contribute to the objective of EU Forest Strategy – to ensure that all forests in the European Union are managed according to sustainable forest management principles, as well as priority 3.3.4 that refers to protecting forests and enhancing ecosystem services.

It should be noted that The Regulation of the Cabinet of Ministers, No.67 "Rules for Forest Management Plan" does not refer to specially protected nature territories (Cabinet of Ministers of Latvia, 2014). According to the Law On Specially Protected Nature Territories these areas are protected by general regulations on protection and use of protected territories, individual protection and use regulations and nature protection plans for the protected territories, including Natura 2000 territories (The Supreme Council of the Republic of Latvia, 1993). Action 1 (Target 1) of EU biodiversity strategy determines to establish of the Natura 2000 network and to ensure good management. In this context several legislative acts have been elaborated for specially protected nature territories – nature reserves, national parks and the North

Vidzeme Biosphere Reserve, thereby contributing to conservation of biodiversity (Ministry of Environmental Protection and Regional Development of the Republic of Latvia, n.d.).

The purpose of Law on the Conservation of Species and Biotopes is to ensure biodiversity by protection of species and biotopes, thereby it contributes to targets of EU biodiversity strategy related to halting the loss of biodiversity, ensuring the good management of Natura 2000 territories, as well as priority of EU Forest Strategy related to protecting forests and ecosystem services. Moreover the law indicates relevance of education and information, thereby it is related to Action 3 (Target 1) of EU biodiversity strategy – to increase stakeholder awareness and involvement (Parliament of the Republic of Latvia, 2000b). The aspects of environmental education and information are mentioned also in Law on Forests, Law On Specially Protected Nature Territories and Environmental Protection Law (Parliament of the Republic of Latvia, 2000a; The Supreme Council of the Republic of Latvia, 1993). The purpose of Environmental Protection Law is to promote the preservation and recovery of the quality of the environment and the sustainable use of nature resources (Parliament of the Republic of Latvia, 2006).

Target 5 of EU biodiversity strategy determines that invasive alien species and their pathways are identified and prioritised by 2020. The measures for restricting the spread of the invasive alien plant species regulates The Regulation of the Cabinet of Ministers, No.559 “Regulation Regarding Restricting the Spread of the Invasive Alien Plant Species – *Heracleum sosnowskyi* Manden” (Cabinet of Ministers of Republic of Latvia, 2008).

Law on Pollution determines requirement to increase removal of carbon dioxide, including forestry activities and to reduce greenhouse gas emissions from activities, including land, land use change and forestry activities – harvested wood products (Parliament of the Republic of Latvia, 2001). Thereby the law contributes to priority of EU Forest Strategy related to changing climate. Protection Zone Law determines Baltic Sea and Gulf of Riga coastal protection zone that preserves the protective functions of the forest and eliminates the development of erosion processes, protection zones around marshes to stabilise the regime of humidity in the zone of contiguity transition of the forest and marsh, as well as forest protection zones around cities (Parliament of the Republic of Latvia, 1997). That corresponds to priority 3.3.4 of EU Forest Strategy regarding to protecting forests and enhancing ecosystem services.

It should be noted that FRL complies with concept of sustainable use of natural resources in such a way that harvest rates does not exceed availability of wood resources. By developing FRL, one of the tasks was to keep constant share of mature forests.

In 2010 in total 212 kha of the productive forests have different nature conservation related management restrictions, including 92 kha of forests not considered for roundwood supplies considering considerable management restrictions.

1.2.7 Integrity with the national projections of anthropogenic GHG emissions by sources and removals by sinks reported under Regulation (EU) No. 525/2013

Latvia's FRL is consistent with the national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks reported under Regulation (EU) No 525/2013.

Latvia's reported projections includes following carbon pools – living biomass, dead wood, litter, organic soil and harvested wood products, as well as the GHG emissions due to forest fires and incineration of harvesting residues and forest drainage. The FRL considers the same carbon pools.

The most recent data representing period between 1990 and 2009 are used in elaboration of NFAP. The most significant difference between both estimates is more optimistic harvesting projections in the already elaborated projections based on the assumption of continuing trend of harvest rate until 2030. Comparison of FRL scenario and projections is provided in Figure 4. AGM model with 5 years calculation period and predefined harvest projections are used in both cases to project stock changes in forest. The difference between both models is not significant, however, distribution of the GHG emissions during the period is not equal, which is associated with different driving forces – economic drivers in the projections and management practices in FRL scenario.

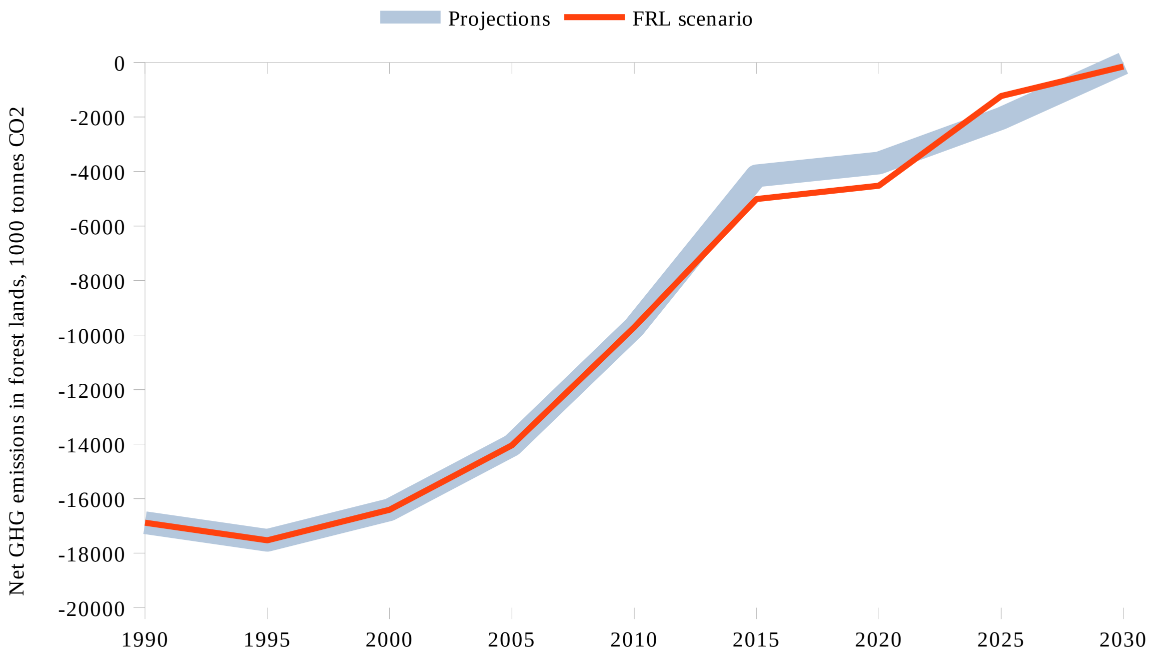

Figure 4: Net GHG emissions in forest lands remaining forest according to FRL scenario in the projection report.

1.2.8 Integrity of applied models with the historical data from the national GHG inventory

Reference level is consistent with Latvia's GHG inventory (Ministry of Environmental Protection and Regional Development, 2018) and relevant historical data and is based on transparent, complete, consistent, comparable and accurate information. In particular, the model used to construct the reference level is able to reproduce historical data from the national greenhouse gas inventory. The national forest growth prediction model AGM is used in projections of forest growth and impact of forest management. Description of the model is available in the research report (Šņepsts, Kārkliņa, et al., 2018). The results of modelling – mortality, increment and harvesting in forest lands summarized in previously established strata are fed into OASIS (Organization for the Advancement of Structured Information Standards) Open Document Format for Office Applications compatible spreadsheet file based EPIM model, which is used to transfer activity data into GHG emissions in land use, land use change and forestry sector and for reporting of activities listed in the Article 3.3 and 3.4 of the Kyoto protocol (Ministry of Environmental Protection and Regional Development, 2018).

The comparison of the GHG emissions in the most recent GHG inventory report and modelling results in forest land remaining forest land in the reference period is shown in Figure 5. The difference is not statistically significant using t-test.

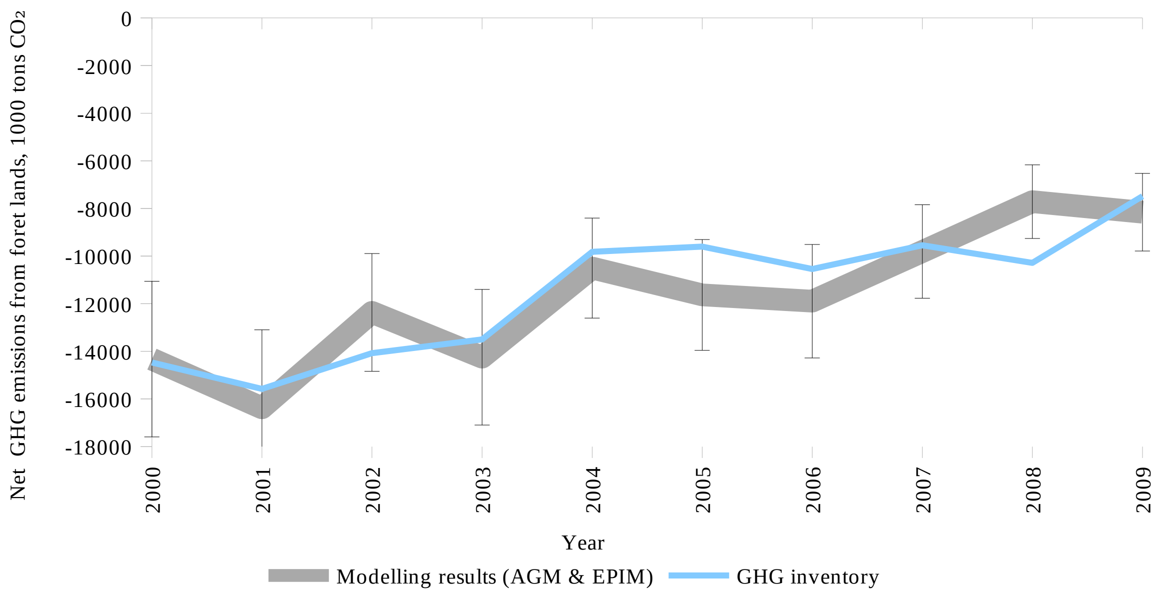

Figure 5: Comparison of the reported GHG emissions in the GHG inventory and modelling results.

To ensure consistent and complete reporting, the same definitions of carbon pools and the same sampling units are used in FRL, as well as in reporting of greenhouse gas inventories under EU and UNFCCC.

Information according to Annex IV, section B of the Regulation 2018/841:

(a) a description of how each of the following elements were considered in the determination of the Latvia's FRL:

   i. **the area under forest management** – the area of managed forest lands used in calculation of FRL is fixed since 2010. Impact of deforestation and land conversion to forest land between 2010 and 2017 and projections of deforestation and land conversion to forest in 2018-2030 is not considered in the Latvia's FRL, assuming that this impact will be included in FRL as technical corrections;

   ii. **emissions and removals from forests and HWP as shown in greenhouse gas inventories and relevant historical data** – emissions and removals from forests and harvested wood products as reported to the EU and the UNFCCC are similar to those reported in NFAP as it can be seen from Figure 4. The carbon stock changes reported to EU and to UNFCCC are updated with recent data before use in the FRL. The same NFI plots are used for estimating the FRL as for previous reporting. Carbon stock changes in HWP in the commitment period are provided in Table 3 reference period and time period between the reference and commitment period is presented in Table 4 and 5;

   iii. **forest characteristics, including dynamic age-related forest characteristics,** increments, rotation length and other information on forest management activities is interpreted as forest management practices during the time period 2000–2009. The projected age distribution is determined by situation in forests in 2010 and by the projected harvest rate. More information on the applied assumptions in FRL scenario is provided in chapter Detailed description of the modelling framework as applied in the estimation of the forest reference level;

   iv. **historical and future harvesting rates** (Figure 10) disaggregated between energy and non-energy uses (chapter A constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009).

Table 3: Carbon stock changes in HWP in the commitment period disaggregated by categories in 2021-2030

Category	HWP in use from domestic consumption	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total	HWP in use from domestic consumption, Gg C	24 373	24 774	25 167	25 552	25 929	26 297	26 673	27 042	27 403	27 757
	Gains, Gg C	925.72	925.72	925.72	925.72	924.09	939.84	939.84	939.84	939.84	939.15
	Losses, Gg C	−524.74	−532.83	−540.75	−548.50	−556.06	−563.65	−571.26	−578.70	−585.98	−593.09
	Annual changes in stock, Gg C	400.98	392.89	384.97	377.23	368.03	376.20	368.59	361.14	353.87	346.06
	HWP in use, Gg CO_2	−1470.26	−1440.59	−1411.57	−1383.16	−1349.45	−1379.39	−1351.48	−1324.19	−1297.51	−1268.89
Sawnwood	HWP in use from domestic consumption, Gg CO_2	−77 784	−79 164	−80 518	−81 845	−83 146	−84 416	−85 711	−86 980	−88 225	−89 445
	Gains, Gg C	800.37	800.37	800.37	800.37	798.96	812.58	812.58	812.58	812.58	811.98
	Losses, Gg C	−423.86	−431.25	−438.48	−445.58	−452.52	−459.45	−466.38	−473.17	−479.82	−486.34
	Annual changes in stock, kt C	376.51	369.13	361.89	354.79	346.44	353.13	346.21	339.42	332.76	325.64
	HWP in use, Gg CO_2	−1380.53	−1353.46	−1326.92	−1300.90	−1270.28	−1294.81	−1269.42	−1244.53	−1220.12	−1194.03
Platewood	HWP in use from domestic consumption, Gg CO_2	−11 435.12	−11 524.30	−11 611.05	−11 695.42	−11 777.49	−11 856.61	−11 940.40	−12 021.90	−12 101.17	−12 178.27
	Gains, Gg C	111.13	111.13	111.13	111.13	110.93	112.83	112.83	112.83	112.83	112.74
	Losses, Gg C	−86.81	−87.47	−88.12	−88.75	−89.36	−89.97	−90.60	−91.21	−91.80	−92.37
	Annual changes in stock, kt C	24.32	23.66	23.01	22.38	21.58	22.85	22.23	21.62	21.03	20.37
	HWP in use, Gg CO_2	−89.18	−86.75	−84.37	−82.07	−79.12	−83.79	−81.50	−79.27	−77.10	−74.69
Paper and paperboard	HWP in use from domestic consumption, Gg CO_2	−149	−149	−150	−150	−150	−150	−151	−151	−152	−152
	Gains, Gg C	14.22	14.22	14.22	14.22	14.20	14.44	14.44	14.44	14.44	14.43
	Losses, Gg C	−14.07	−14.12	−14.15	−14.17	−14.18	−14.22	−14.28	−14.33	−14.36	−14.38
	Annual changes in stock, kt C	0.15	0.10	0.07	0.05	0.02	0.22	0.15	0.11	0.08	0.04
	HWP in use, Gg CO_2	−0.54	−0.38	−0.27	−0.19	−0.06	−0.79	−0.56	−0.40	−0.28	−0.16

Table 4: Carbon stock changes in HWP in the commitment period disaggregated by categories in 2010-2020

Category	HWP in use from domestic consumption	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total	HWP in use from domestic consumption, Gg C	19 577	20 057	20 528	20 990	21 443	21 887	22 320	22 748	23 167	23 578
	Gains, Gg C	910.30	910.30	910.30	910.30	910.30	908.02	911.18	911.18	911.18	911.18
	Losses, Gg C	−430.36	−439.37	−448.39	−457.35	−466.23	−474.96	−483.57	−492.08	−500.45	−508.65
	Annual changes in stock, Gg C	479.94	470.93	461.91	452.95	444.07	433.06	427.61	419.10	410.74	402.53
	HWP in use, Gg CO_2	−1759.78	−1726.74	−1693.68	−1660.81	−1628.27	−1587.90	−1567.91	−1536.70	−1506.04	−1475.94
Sawnwood	HWP in use from domestic consumption, Gg CO_2	−61 248	−62 904	−64 528	−66 120	−67 681	−69 211	−70 704	−72 178	−73 623	−75 039
	Gains, Gg C	787.04	787.04	787.04	787.04	787.04	785.07	787.80	787.80	787.80	787.80
	Losses, Gg C	−335.30	−344.15	−352.84	−361.35	−369.70	−377.86	−385.88	−393.76	−401.48	−409.06
	Annual changes in stock, kt C	451.74	442.88	434.20	425.69	417.34	407.20	401.93	394.04	386.32	378.74
	HWP in use, Gg CO_2	−1656.39	−1623.91	−1592.07	−1560.85	−1530.24	−1493.08	−1473.73	−1444.83	−1416.50	−1388.72
Platewood	HWP in use from domestic consumption, Gg CO_2	−10 359.11	−10 471.03	−10 579.88	−10 685.76	−10 788.74	−10 888.90	−10 985.34	−11 080.51	−11 173.08	−11 263.12
	Gains, Gg C	109.28	109.28	109.28	109.28	109.28	109.00	109.38	109.38	109.38	109.38
	Losses, Gg C	−78.76	−79.59	−80.40	−81.19	−81.96	−82.70	−83.43	−84.14	−84.83	−85.50
	Annual changes in stock, kt C	30.52	29.69	28.88	28.09	27.32	26.30	25.96	25.25	24.56	23.88
	HWP in use, Gg CO_2	−111.91	−108.85	−105.88	−102.98	−100.17	−96.44	−95.17	−92.57	−90.04	−87.58
Paper and paperboard	HWP in use from domestic consumption, Gg CO_2	−177	−169	−162	−158	−155	−153	−151	−150	−150	−149
	Gains, Gg C	13.98	13.98	13.98	13.98	13.98	13.95	14.00	14.00	14.00	14.00
	Losses, Gg C	−16.31	−15.63	−15.15	−14.81	−14.56	−14.39	−14.27	−14.19	−14.13	−14.09
	Annual changes in stock, kt C	−2.32	−1.64	−1.16	−0.82	−0.58	−0.44	−0.27	−0.19	−0.14	−0.10
	HWP in use, Gg CO_2	8.52	6.03	4.26	3.01	2.13	1.62	0.99	0.70	0.50	0.35

Table 5: Carbon stock changes in HWP in the commitment period disaggregated by categories in 2000-2009

Category	HWP in use from domestic consumption	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	HWP in use from domestic consumption, Gg C	14 243	14 886	15 507	16 138	16 762	17 351	17 953	18 565	18 945	19 236
	Gains, Gg C	957.21	948.42	971.71	978.10	956.94	982.17	1006.49	785.27	705.36	762.68
	Losses, Gg C	−314.42	−327.19	−340.66	−354.57	−367.87	−380.52	−394.06	−405.78	−413.72	−421.54
	Annual changes in stock, Gg C	642.79	621.23	631.06	623.53	589.07	601.65	612.42	379.49	291.65	341.14
	HWP in use, Gg CO_2	−2356.89	−2277.84	−2313.87	−2286.29	−2159.94	−2206.05	−2245.56	−1391.46	−1069.37	−1250.85
Sawnwood	HWP in use from domestic consumption, Gg CO_2	−43 160	−45 494	−47 700	−49 932	−52 102	−54 140	−56 224	−58 310	−59 581	−60 361
	Gains, Gg C	875.80	853.40	872.33	867.61	842.71	866.31	878.28	665.14	536.58	570.18
	Losses, Gg C	−239.44	−251.70	−263.68	−275.57	−286.93	−298.06	−309.33	−318.39	−323.92	−328.42
	Annual changes in stock, kt C	636.36	601.70	608.64	592.04	555.77	568.25	568.95	346.75	212.66	241.76
	HWP in use, Gg CO_2	−2333.33	−2206.25	−2231.70	−2170.81	−2037.83	−2083.57	−2086.17	−1271.42	−779.74	−886.45
Platewood	HWP in use from domestic consumption, Gg CO_2	−8990.39	−9017.60	−9082.76	−9151.02	−9251.25	−9364.37	−9481.76	−9619.42	−9724.00	−10 008.82
	Gains, Gg C	75.51	86.21	87.56	96.91	101.23	103.27	109.76	101.66	152.29	172.55
	Losses, Gg C	−68.09	−68.44	−68.94	−69.58	−70.38	−71.26	−72.22	−73.14	−74.61	−77.01
	Annual changes in stock, kt C	7.42	17.77	18.62	27.33	30.85	32.02	37.54	28.52	77.68	95.53
	HWP in use, Gg CO_2	−27.21	−65.16	−68.26	−100.23	−113.12	−117.40	−137.65	−104.58	−284.82	−350.29
Paper and paperboard	HWP in use from domestic consumption, Gg CO_2	−75	−71	−78	−92	−107	−116	−121	−143	−158	−163
	Gains, Gg C	5.90	8.81	11.83	13.58	13.00	12.59	18.44	18.47	16.50	19.95
	Losses, Gg C	−6.90	−7.06	−8.04	−9.42	−10.55	−11.20	−12.52	−14.26	−15.19	−16.11
	Annual changes in stock, kt C	−1.00	1.75	3.79	4.16	2.45	1.39	5.93	4.22	1.31	3.85
	HWP in use, Gg CO_2	3.65	−6.43	−13.91	−15.25	−8.99	−5.08	−21.74	−15.46	−4.82	−14.11

Detailed information according to the Annex IV, section B of the Regulation 2018/841 is provided in following chapters. Summary of location of different elements is provided in Table 6.

Table 6: Consideration to Annex IV B. elements of the Regulation in the NFAP

Annex IV B paragraph item	Elements of the national forestry accounting plan according to Annex IV B.	Page number in the NFAP
(a)	A general description of the determination of the forest reference level	Page 5
(a)	Description of how the criteria in LULUCF Regulation were taken into account	Pages 7-21
(b)	Identification of the carbon pools and greenhouse gases which have been included in the forest reference level	Pages 22-23
(b)	Reasons for omitting a carbon pool from the forest reference level determination	Page 22
(b)	Demonstration of the consistency between the carbon pools included in the forest reference level	Page 23
(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	Page 35
(c)	A description of documentary information on sustainable forest management practices and intensity	Page 38
(c)	A description of adopted national policies	Pages 30-32
(d)	Information on how harvesting rates are expected to develop under different policy scenarios	Pages 32-34
(e)	A description of how the following element was considered in the determination of the forest reference level:	
(i)	• The area under forest management	Page 52
(ii)	• Emissions and removals from forests and harvested wood products as shown in greenhouse gas inventories and relevant historical data	Page 8
(iii)	• Forest characteristics, including: ○ dynamic age-related forest characteristics ○ increments ○ rotation length ○ other information on forest management activities under 'business as usual' scenario (continuation of forest management practices as documented in 2000-2009)	Pages 38, 23, 35, 33, 34
(iv)	• Historical and future harvesting rates disaggregated between energy and non-energy uses	Page 9

2. PREAMBLE FOR THE REFERENCE LEVEL

Following chapters contain information on identification of the carbon pools and greenhouse gases, which have been included in the reference level, reasons for omitting a carbon pool from the reference level construction, and demonstration of the consistency between the pools included in the reference level.

2.1 Carbon pools and GHG included in the FRL

Latvia's FRL includes changes in following carbon pools and GHG emissions:

- living biomass;
- dead wood;
- litter;
- soil organic carbon;
- harvested wood products;
- CH_4 and N_2O emissions from ameliorated and rewetted organic soil;
- CH_4, N_2O and CO_2 emissions due to biomass burning.

Emissions from forest fertilization and mineralization of organic matter in mineral soils are not included in the calculation due to the fact that forest fertilization was not used in 2000-2009. Mineralization of organic matter in mineral soils is not accounted because soil carbon is not a source of GHG emissions according to modelling exercises realized with Yasso model on the base of the results of AGM modelling data (Bārdulis, Lupiķis, & Stola, 2017).

Summary of the emissions by GHG is provided in Figure 6. Increase of the methane emissions is associated with depreciation of amelioration systems and rewetting of organic soils in forest lands. Activity data are based on the rate of reconstruction of old forest amelioration systems in 2000-2009. The methodology for calculation of GHG emissions from organic soils will be updated and introduced as technical corrections. Currently tier 1 method is applied.

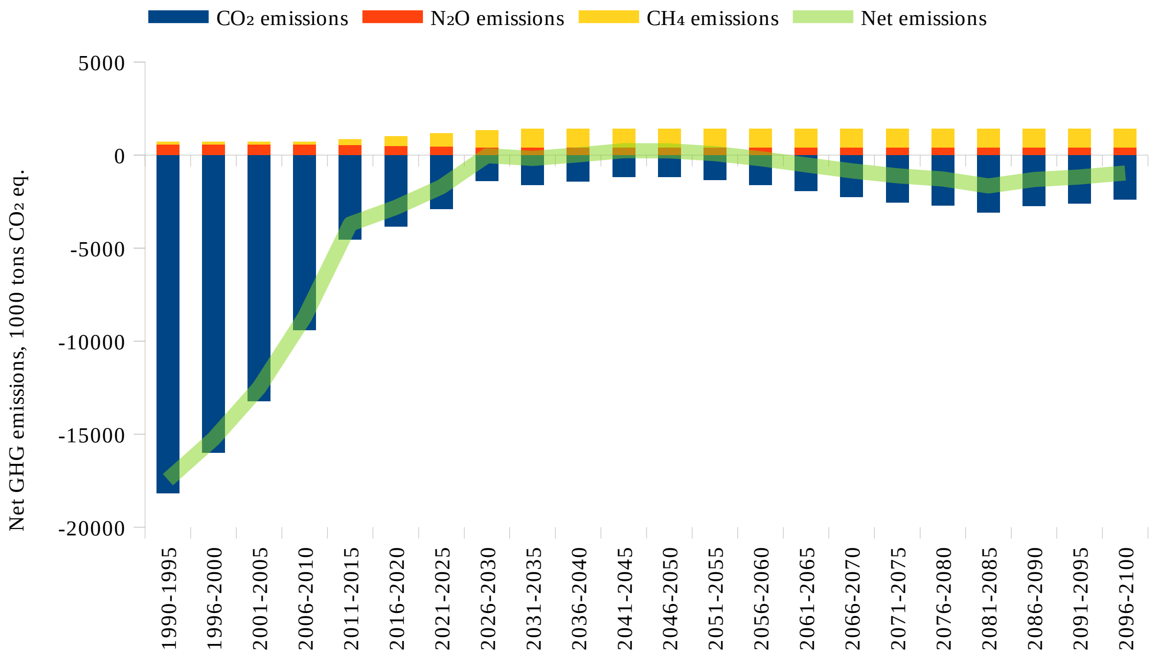

Figure 6: Historical data and projections of GHG emissions in forest land remaining forest land according to FRL scenario.

2.2 Demonstration of consistency between the pools included in the FRL

The methodology applied in elaboration of forest growth projections is described in the report on structure of the AGM model (Šņepsts, Kārkliņa, et al., 2018). Activity data and volume of trees is transformed into GHG emissions and CO2 removals using EPIM model, which is used in the 1990-2017 National GHG inventory (Ministry of Environmental Protection and Regional Development, 2019).

Forest land category includes emissions and removals resulting from carbon stock changes in living biomass, litter, dead wood, organic soils and GHG emissions from drainage and rewetting of organic soils, and GHG emissions due to biomass burning.

The NFI and research data are used to estimate time series for areas and gross increment[2]. Mortality data are calculated on the base of the NFI data and mortality rate (stratified data in AGM model for projections). Distinction between forest land remaining forest land and areas converted to forest land is made according to the age of dominant species in forests on afforested land – if age of dominant species was less than zero in 1990, it is considered as land converted to forest, in other cases it is considered as forest land remaining forest land. Land use changes and transition of land from afforested land category to the forest land category is considered for the period before 2010.

Carbon stock changes in above and below ground living and dead biomass are reported in the inventory. Decay factor for dead wood including harvesting residues not incinerated on-site is considered 20 years. In forest land remaining forest land,

[2] Summary of National Forest Inventory, source:http://www.silava.lv/userfiles/file/2010%20nov%20MRM_visi%20mezi_04-08g.xls

changes of organic carbon in litter and mineral soil organic matter in naturally dry soils are assumed to be zero according to the national research data on carbon stock in mineral forest soils (Lazdiņš et al., 2015).

Carbon stock changes are reported separately for ameliorated and rewetted organic soils in forest land. Soil type is considered organic as defined in the NFI: a soil is classified as organic if the organic layer (H horizon) is at least 20 cm deep. Conversion of forest stands on ameliorated mineral or organic soil to naturally wet conditions in forest land is accounted as rewetting. Rewetting is considered according to forest management practice in 2000-2009 using stand wise forest inventory data; respectively, if the drainage system is not restored before or after regenerative felling, it is considered as rewetted area, where growth of following generation of trees will continue according growth rates typical for naturally wet organic soils. Tier 1 methodology – CO_2-C according to Table 3.1 of the IPCC 2013 Wetlands supplement[3], CH_4-C emissions according to Table 3.3 of the IPCC 2013 Wetlands supplement[4].

The carbon stock change in living biomass is estimated with the Tier 2 method according to the 2006 IPCC Guidelines – carbon uptake and release of the living biomass correspond to the mean gross annual increment of forest growing stock, annual harvesting of trees and decay due to natural mortality.

The dynamics of carbon stock changes in living biomass are very much affected by commercial felling. The accessibility of forest resources was low at the beginning of the 1990s due to implementation of land reform; therefore, felling was also at a low level and the CO_2 sink of living biomass was high. The felling stock increased during 1990s with implementation of the land reform and reached top average in early 2000s.

Calculations of carbon stock changes and GHG emissions in forest lands are based on activity data provided by the NFI (area, living biomass and dead wood) and Level I forest monitoring data (soil organic carbon). Data from State forest service are used to estimate commercial felling related emissions and removals. The calculation of GHG emissions and CO_2 removals in historical forest lands is based mainly on research report "Elaboration of the model for calculation of the CO_2 removals and GHG emissions due to forest management" (Lazdiņš, Donis, & Strūve, 2012b, 2012a) and factors and coefficients elaborated within the scope of the research program on impact of forest management on GHG emissions and CO_2 removals (Lazdiņš et al., 2015).

Methodologies for estimation of carbon stock changes and GHG emissions are considerably improved during recent submissions; they are merged together into the "Emissions projection & inventory model (EPIM)" spreadsheet tool (basic structure in Figure 7).

[3] 2013 SUPPLEMENT, TABLE 3.1 DEFAULT EMISSION FACTORS (EF CO_2) FOR CO_2-C FROM REWETTED ORGANIC SOILS (temperate, rich).

[4] 2013 SUPPLEMENT, TABLE 3.3 DEFAULT EMISSION FACTORS FOR CH_4 FROM REWETTED ORGANIC SOILS (temperate, rich).

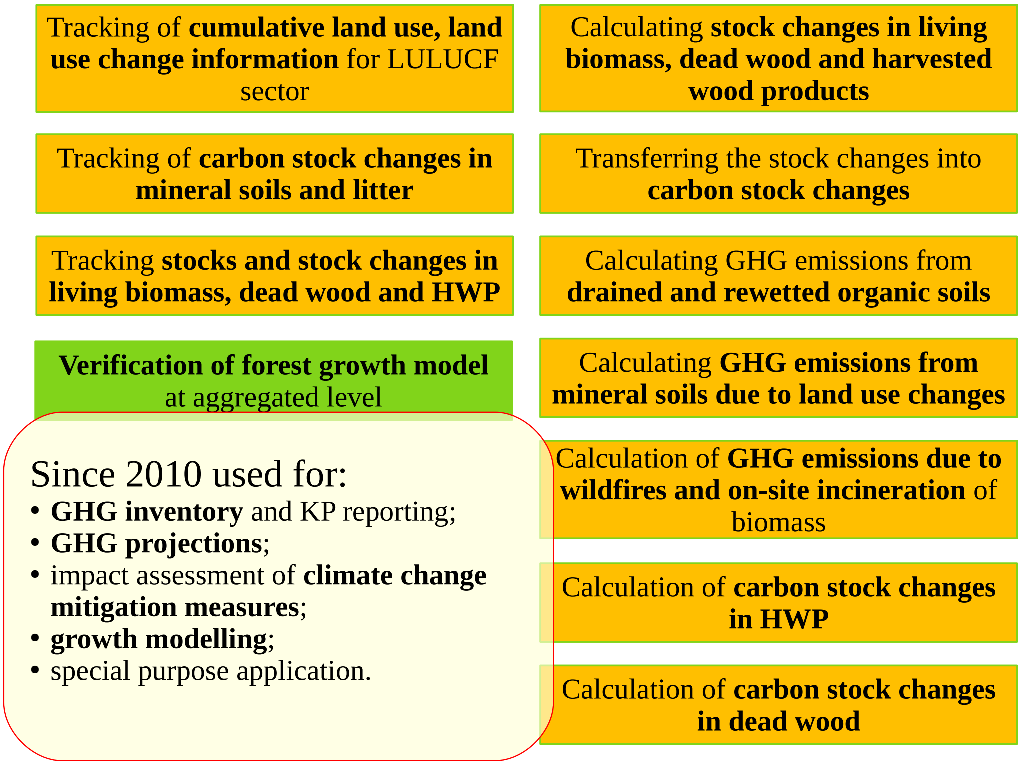

Figure 7: Structure of EPIM tool.

Commercial felling in the GHG inventory is evaluated using following approaches:

- dominant species specific harvesting data since 1970 (1990-2009 Central statistical bureau data updated by NFI data and in 1970-1989 according to research papers, Saliņš, 2002);
- decomposition of crown and underground biomass – 20 years; species specific wood densities and different biomass expansion factors (BEFs) for coniferous and deciduous trees according to national studies (Liepiņš, Lazdiņš, & Liepiņš, 2017; Liepiņš & Liepiņš, 2017).

The methodology for harvested wood products is based on Rüter, 2011. More detailed description is provided in chapter Inclusion of the carbon pool of harvested wood products in page 8.

Emissions from ameliorated soils are accounted – 0.52 tonnes C ha^{-1} (Lazdiņš, Butlers, & Lupiķis, 2014; Lazdiņš & Lupiķis, 2014; Lazdiņš, Lupiķis, & Okmanis, 2014; Lupiķis & Lazdins, 2017) and 2.8 kg N_2O-N ha^{-1} (Takahiro Hiraishi et al., 2013) annually from organic soils.

Area of organic soils in the forest lands is reported according to structure of distribution of the forest stand types. Total area of organic soils as well as total area of forests was updated according to research data on land use structure according to the NFI (Lazdiņš & Zariņš, 2010).

Ameliorated organic soil in forest land is source of CH_4 emissions. CH_4 emissions are calculated by equation 2.6 in the IPCC Wetlands Supplement. The CH_4 emission factor for organic soils of drained forest land (Table 2.3 and Table 2.4 in the IPCC Wetlands

Supplement) is 2.5 kg CH_4 ha^{-1} yr^{-1} and emission factor for drainage ditches is 217 kg CH_4 ha^{-1} yr^{-1}. Fraction of the total area of ameliorated organic soil which is occupied by ditches is 0.025 (Table 2.4 in the IPCC Wetlands Supplement).

GHG emissions from rewetted organic soils are estimated according to the Tier 1 methods. Emission factor for CO_2-C (0.5 tonnes CO_2-C ha^{-1} yr^{-1}) is taken from Table 3.1 of the IPCC Wetlands Supplement. N_2O emissions from rewetted organic soils according to the Tier 1 method are assumed to be negligible and are not estimated, CH_4 emissions are calculated applying Tier 1 method using equation 3.7 of the IPCC Wetlands Supplement. Default emission factor (216 kg CH_4-C ha^{-1} yr^{-1}) from Table 3.3 was used.

Rewetting is reported under forest land – conversion of forests on ameliorated organic soils to forest on naturally wet organic soil. The conversion is usually approved by changes in ground vegetation and groundwater table during the site visits. Rewetting takes place due to wearing of drainage systems. Rewetting projections for 2010-2030 are estimated according to proportion of regenerative felling sites in 2000-2009, where drainage systems are not restored before or after the felling and proportion of forests with old (more than 30 years) drainage systems in projections of regenerative fellings in 2010 to 2030.

Biomass burning includes GHG emissions (CO_2, CH_4, N_2O) from biomass on-site incineration in forest land comprising wildfires and controlled burning.

Taking into account that wetlands (bogs and fens) belong to forest land according to national land use definitions, emissions associated with wildfires in wetlands cannot be separated and are reported under forest lands remaining forests. The approach used in the Latvia's GHG inventory ensures that emissions from biomass burning in forest land and grassland are not overlapping.

The area statistics on forest wildfires in 2000-2009 are compiled by the State forest service and they are based on information given by the local units.

Emissions from biomass burning are represented by incineration of harvesting residues during forest logging operations. The activity data for this calculation was based on a research data (Lazdiņš & Zariņš, 2013). In recent decade results of the forest owners questionnaire on utilization of harvesting residues is applied (Lazdiņš & Lazdiņa, 2013). In case of on-site incineration of harvesting residues during commercial harvesting, all emissions also are applied to the forest land remaining forest land category, because no commercial felling takes place in young stands (younger than 20 years) on land converted to forest land and all cut trees are treated as dead wood laying in forest.

Tier 1 and 2 methods provided in the 2006 IPCC Guidelines were utilized for calculation of GHG emissions due to any type of fires. Amount of burned biomass is considered according to average growing stock of living biomass, dead wood and litter in a particular year. Combustion efficiency or fraction of biomass combusted (dimension-less) is considered 0.45 according to Table 2.6 of the 2006 IPCC

Guidelines[5]. Tier 2 method and default emission factors of calculation provided in the 2006 IPCC Guidelines was utilized to estimate emissions due to controlled incineration of harvesting residues. Emissions from controlled fires were calculated considering average stock of above-ground harvesting residues, which considerably increased due to increase of estimates of harvesting stock. The following assumptions have been made for burned harvesting residues calculation:

- 1990 to 2000 – 50% of harvesting residues are left for incineration and 67% of the left residues are incinerated, the rest are left to decay;
- 2001 to 2004 – 30% of harvesting residues are left for incineration and 67% of the left residues are incinerated, the rest are left to decay;
- 2005 to 2009 – 7% of harvesting residues are left for incineration and 100% of the left residues are incinerated; the rest of the residues are left for decay or extracted for bioenergy production.
- starting from 2010 – average value in 2000-2009 – 21% of harvesting residues are left for incineration and 67% of the left residues are incinerated, the rest are left to decay.

CO_2 emissions are calculated only from wildfires taking into account that carbon located in harvesting residues is already accounted as losses in living biomass. Incinerated residues are extracted from removals in dead wood. CO_2 emissions are reported using instant oxidation method and do not appear in the inventory as removals in dead wood.

Activity data consist of areas of land remaining in a land-use category and land converted to other land-use category on ameliorated organic soils. Default N_2O emission factors for ameliorated organic soils is applied (2.8 kg N_2O-N ha^{-1} yr^{-1}) according to Table 2.5 of the IPCC Wetlands Supplement.

2.3 Description of the long-term forest strategy

Long-term forest strategy in Latvia is determined by adopted national policies in forestry and related sectors like agriculture, energy and nature conservation. One of the most important and direct forest strategy documents is Latvian forest sector development is Forest and associated sectors development guidelines for 2015-2020 (Ministry of Agriculture, 2015). These guidelines are regularly updated and harmonized with related policies and new challenges of forest sector, particularly, the increase of the role of forest lands in climate change mitigation is highlighted in the current edition of the guidelines. In addition to Latvian forest sector development is Forest and associated sectors development guidelines for 2015-2020 there are other sectoral policies, like energy, nature conservation and agriculture, that play an important role in establishment of long-term forest development vision.

[5] Combustion factor values (proportion of prefire biomass consumed) for fires in a range of vegetation types.

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

According to Latvian Forest Law forest and forest land are separated. Forest is an ecosystem that consists of forest land that is covered by woody vegetation fulfilling certain criteria (listed in Table 2, page 6). Forest definition in national land register, GHG inventory report and calculation of Latvia's NFAP are harmonized. Forest land without woody vegetation meeting threshold values listed in Table 2 are forest infrastructure (roads, ditches, protective belts) or wetlands except water bodies outside forests.

According to the NFI in 2009 there were 3180 kha of forest stands. The total area of forest land according to national legislation, including wetlands and forest infrastructure, is 3575 ha. In total forest land equals to 55 % of the area of Latvia. 48% of forest land belongs to state and 52% are privately owned.

Area of forests with different management restrictions is 212 kha, including 92 kha of forests where management activities are completely or significantly prohibited (Figure 18, page 53). These areas are considered in the Latvia's FRL accounting as areas, where forest management will not take place.

Forest ageing is one of the issue identified during elaboration of the Latvia's FRL. 28% of forests (holding more than 50% of growing stock) are available for regenerative felling, including 19% of forest area being 1-20 years older than the threshold value for the egenerative felling age and 9% of over-mature forests, which are more than 20 years older than the threshold age criteria for final felling. The share of middle age stands, which will become available for final felling during following 10-20 years is 72%. The most of these forests are birch and pine stands, which have high commercial value and might be utilized to considerably higher extent.

Area of mature forests (forest stand available for regenerative felling by age) is continuously increasing in the FRL scenario until 2050 (Figure 8) and beyond, from 969 kha at the beginning of the reference period to 1109 kha in 2050. For aspen and grey alder more than 54-67% of forests are available for regenerative felling in the reference period, for other species – about 20-30% with clear trend to increase in following decades. In total share of mature stands increase from 31% of forest area at the beginning of reference period to 36% at 2030 and 2050 (Figure 9).

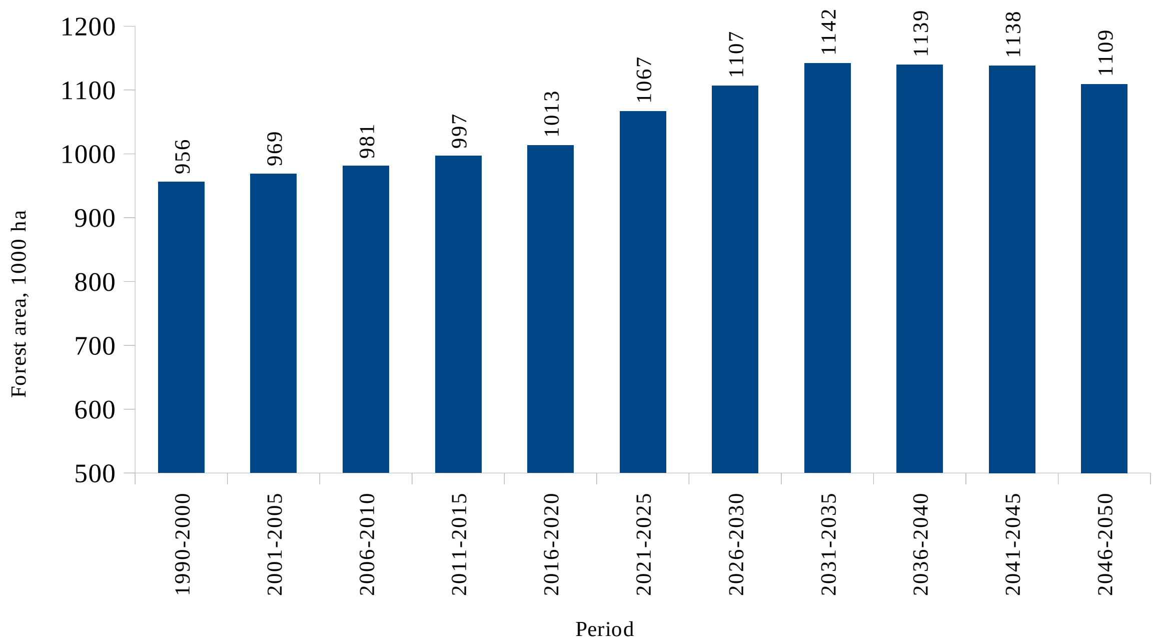

Figure 8: Mature forest area projections in FRL scenario.

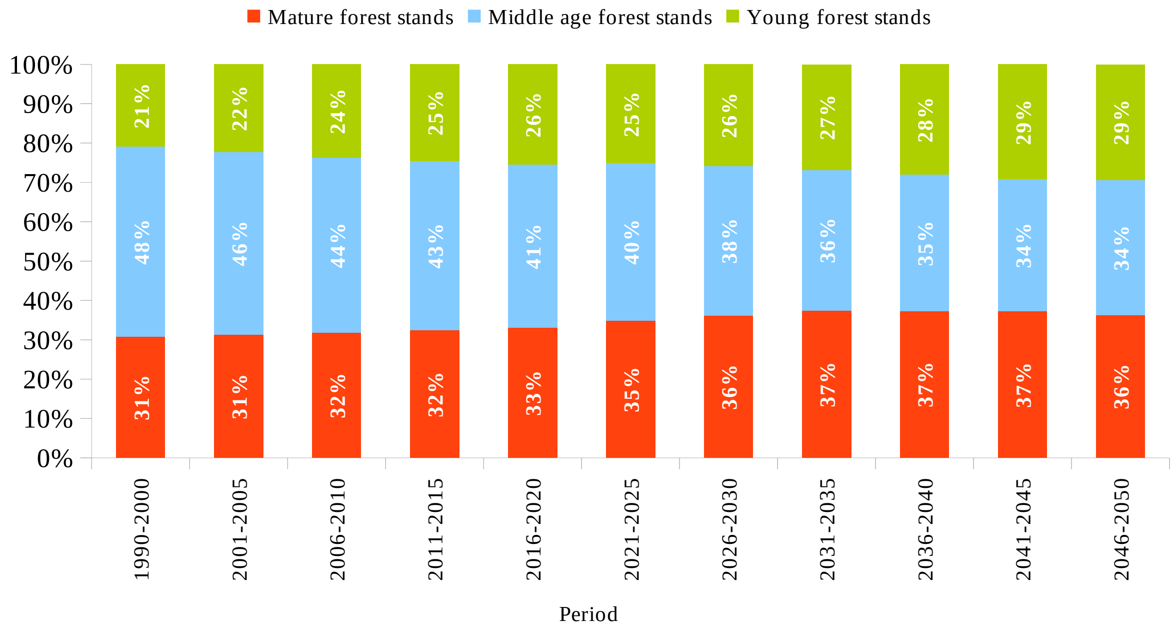

Figure 9: Projections of age structure in FRL scenario.

Growing stock in forests at the end of 2010 was about 669 mill. m^3 (extrapolated value on the basis of NFI data). It increased by 11% in comparison to 2000.

2.3.2 Information on adopted national policies

2.3.2.1 Forest sector

Latvia's Forest Policy has been elaborated to gain a compromise among all stakeholders of forestry. Latvia's Forest Policy targets are (Cabinet of Ministers of Latvia, 1998):

- to ensure a sustainable management of forests and forests lands;
- to generate favourable environment for development of economics;
- to conserve ecological functions of forest;
- to ensure social functions of forest.

The goals and directions of the Forest-based Sector Development Guidelines is to promote the achievement the Latvia's Forest Policy targets, for instance, sustainable management of Latvia's forests, forestry production of high added value, potential of education and science corresponding to development of forest-based sectors (Cabinet of Ministers of Latvia, 1998).

Law on Forests is the main forestry law in Latvia. The purpose of the law is to regulate sustainable management of all the forests, by guaranteeing equal rights and independence of economic activities, and determining equal obligations to all forest owners. The Law on Forests defines sustainable forest management as management and utilisation of forest and forest land in such a manner and at such a level as to maintain the biological diversity, productivity and vitality thereof, as well as regeneration ability and the ability to fulfil significant ecological, economic and social functions at the present time and in the future, on a local and global scale. The Law on Forests determines, when felling is permitted and prohibited, for instance, final felling is permitted, when forest stand has reached a certain final felling age that depends on dominant tree species, site index, and the final felling diameter (Parliament of the Republic of Latvia, 2000a).

The Parliament of Republic of Latvia adopted Law on Forests in 2000, since then there have been several amendments in the law (Parliament of the Republic of Latvia, 2000a). Particular environmental laws – Law on Specially Protected Nature Territories and Protection Zone Law have been adopted in 1993 and 1997, respectively (Parliament of the Republic of Latvia, 1997; The Supreme Council of the Republic of Latvia, 1993). While in the period 2000-2009 the following laws were adopted: Law on Pollution (2001), Environmental Protection Law (2006), as well as several laws on particular nature reserves and national parks (Parliament of the Republic of Latvia, 2001, 2006; The Supreme Council of the Republic of Latvia, 1993). There have been amendments in mentioned legacy acts, however, the laws with planning documents have formed a basis for sustainable forestry and conservation of biodiversity.

2.3.2.2 Energy sector

By 2050 European Union is moving to a competitive low-carbon economy. Currently Latvia elaborates the strategy to achieve climate neutrality by 2050 (Ministry of

Environmental Protection and Regional Development, 2017). In 2016 Latvia approved the Guidelines for Energy Sector Development 2016-2020 that is a sectoral planning document. The long-term targets of Latvia's energy policy are (Cabinet of Ministers of Latvia, 2016):

- to improve sustainability in energy sector that promotes sustainability in economic, social and environmental dimension. To fulfil the target it is planned to increase energy efficiency and to promote use of high-efficiency technologies and the usage of renewable energy sources;
- to increase security of energy distribution by minimising geopolitical threats, developing infrastructure and ensuring various energy sources.

The EU common target of at least a 40 % domestic reduction in economy-wide greenhouse gas emissions by 2030 compared to 1990 is set (European Parliament, Council of the European Union, 2018). According to the Directive (2009/28/EC) – to increase the use of renewable energy sources from 32,6% of gross final energy consumption in 2005 up to 40% in 2020 (European Parliament, Council of the European Union, 2009).

2.3.2.3 Agriculture

Rural Development Programme 2014-2020 is sectoral planning document. There main measures and priorities related to climate and forestry are (Ministry of Agriculture of Latvia, 2018):

- increase education level of persons that are employed in agriculture and forestry – a measure contributes to precise usage of fertilizers, protection of water quality and reduces soil erosion threats;
- reduction of GHG emissions in agriculture;
- restoration of drainage systems in agricultural lands and forest lands – the measure promotes CO_2 removals in soil;
- increasing CO_2 removals in forest lands;
- effective management of abandoned agricultural lands;
- conservation of biodiversity in agricultural lands and forest lands.

2.3.2.4 Nature conservation

By implementing EU biodiversity strategy, Latvia contributes to 2050 vision – biodiversity and the ecosystem services it provides, its natural capital, are protected, valued and appropriately restored, as well as 2020 headline target – Halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020. Nature conservation aspects are also discussed in chapter 'Contribution to the conservation of biodiversity and the sustainable use of natural resources'.

2.3.3 Description of future harvesting rates under different policy scenarios

Development of harvesting rates are evaluated for 2 scenarios – Latvia's FRL scenario and the scenario considering continuation of current (2013-2017) forest management practices as reported in the biannual report on the GHG emissions and projections. In the scenario considering continuation of current forest management practices roundwood and biofuel demand projections are compared with the recent harvest rates (2013–2017 average values). In the Latvia's FRL scenario average harvest rate in 2000-2009. In both scenarios harvest rate in regenerative felling is calculated as comparison of volume of extracted trees and growing trees available for final felling. Volume of trees extracted in thinning and selective felling is calculated using probability functions developed from harvesting statistics in 2000-2009 (Latvia's FRL scenario) and 2013-2017 ('continuation of current forest management practices' scenario).

2.3.3.1 Harvest projections under Latvia's FRL scenario

Primary assumptions applied to estimate harvesting intensity, like share of wood actually extracted in final felling in comparison to resources available for final felling and proportion of roundwood extracted in thinning is provided in Table 7 and Table 8. The values provided in the tables represent average conditions in 2000-2009.

Table 7: Assumptions for the final felling rate from available wood

No	Species	Average share of area (available volume) at regenerative felling age in the reference period (2000-2009)	Share of available volume extracted in regenerative felling during the reference period (2000-2009)
1.	Aspen	92.3%	1.5%
2.	Grey alder	92.1%	2.3%
3.	Birch	40.5%	4.6%
4.	Other species	25.8%	17.7%
5.	Spruce	37.7%	4.9%
6.	Black alder	34.2%	1.9%
7.	Ash, oak	36.9%	1.1%
8.	Pine	39.3%	3.7%

Table 8: Proportion of harvests outside final felling

No	Species	Share of harvests outside clear-cuts
1.	Aspen	6.3%
2.	Grey alder	11.3%
3.	Birch	22.9%
4.	Other species	26.6%
5.	Spruce	27.8%
6.	Black alder	18.1%
7.	Ash, oak	36.4%

No	Species	Share of harvests outside clear-cuts
8.	Pine	33.0%

Projections of harvest rates in comparison to growing stock are provided in Figure 10. According to the reference scenario carbon stock in living biomass will continue to increase till 2050 (Figure 21, page 56) and beyond.

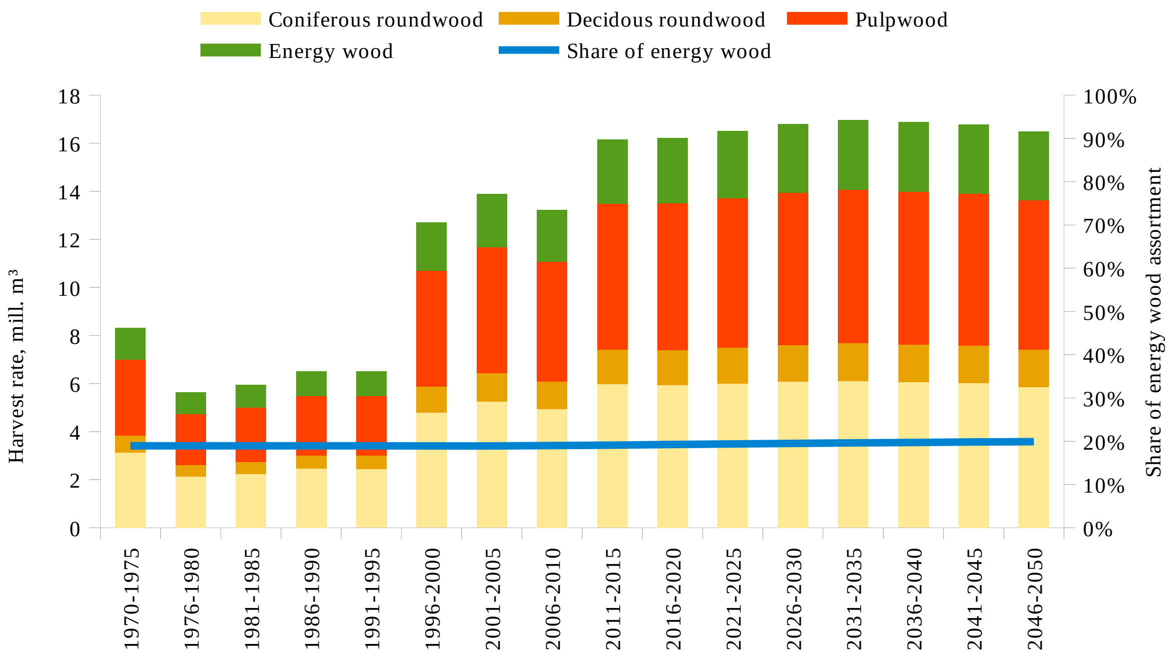

Figure 10: Projections of harvest rate in the Latvia's FRL scenario.

2.3.3.2 Harvest projections under 'continuation of current forest management practices' scenario

Assumptions applied to estimate harvesting intensity in 'continuation of current forest management practices' scenario, specifically, share of wood actually extracted in final felling in comparison to resources available for final felling and proportion of roundwood extracted in thinning is provided in Table 9 and Table 10. The values provided in the tables represent average conditions in 2013-2017. Age structure is considered in the 'continuation of current forest management practices' scenario as a limiting value determining accessibility of resources. Projections of harvest rate are market (demand) driven. Summary of harvest projections and historical data is shown in Figure 11. This scenario considers significantly higher share of energy wood due to more intense harvest in deciduous forests

Table 9: Assumptions for the final felling rate from available wood

No	Species	Average share of area (available volume) at regenerative felling age in 2013-2017	Share of available volume extracted in regenerative felling in 2013–2017
1.	Aspen	91.5%	3.3%
2.	Grey alder	91.0%	3.2%
3.	Birch	42.3%	6.5%

No	Species	Average share of area (available volume) at regenerative felling age in 2013-2017	Share of available volume extracted in regenerative felling in 2013–2017
4.	Other species	23.3%	0.1%
5.	Spruce	37.6%	7.7%
6.	Black alder	37.1%	2.1%
7.	Ash, oak	41.0%	1.5%
8.	Pine	40.7%	5.4%

Table 10: Proportion of harvests outside final felling

No	Species	Share of harvests
1.	Aspen	5.2%
2.	Grey alder	8.1%
3.	Birch	10.8%
4.	Other species	23.4%
5.	Spruce	29.7%
6.	Black alder	12.4%
7.	Ash, oak	15.5%
8.	Pine	19.3%

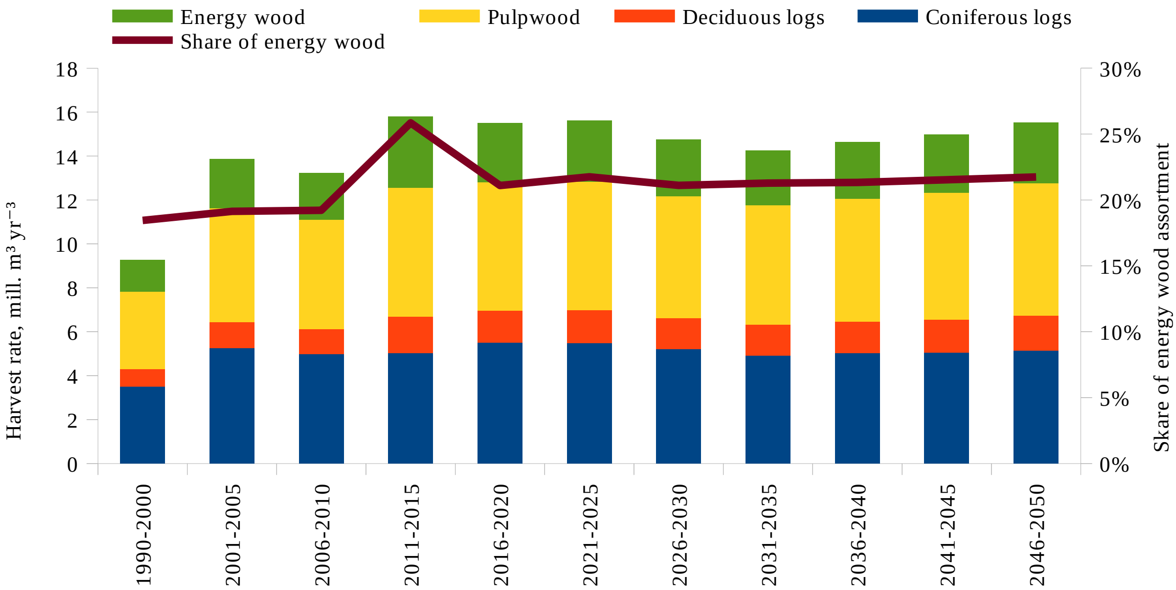

Figure 11: Projections of harvest rate in the 'continuation of current forest management practices' scenario.

3. DESCRIPTION OF MODELLING APPROACH

Following chapters contains description of approaches, methods and models, including quantitative information, used in the construction of Latvia's FRL, consistent with the most recently submitted National Inventory report and documentary information on sustainable forest management practices and intensity and adopted national policies.

The methods applied to calculate carbon stock changes and GHG emissions in forest lands are available in the 2019 National GHG inventory report (Ministry of Environmental Protection and Regional Development, 2019).

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

Latvia's FRL is the expected average annual net removals of greenhouse gases in 2021-2025, based on simulations of the carbon stocks and GHG emissions on managed forest land starting from 2010 assuming the continuation of forest management practices as observed 2000-2009.

In the calculations, the same sample plots from the NFI as in the reporting of the LULUCF sector to the EU and the UNFCCC have been used.

Latvia's FRL comprise all carbon pools currently reported to the EU and the UNFCCC (above-ground and below-ground living biomass, dead wood, litter and soil organic carbon), as well as other emissions associated to forest land included in these reports (emissions from ameliorated and rewetted organic soils and biomass burning).

Development of carbon stocks are simulated on plot level using AGM model developed by LSFRI Silava and verified by EFDM model. GHG emissions from ameliorated organic soils are estimated using Tier 2 emission factors and country specific activity data assuming that the area of ameliorated organic soils is reducing due to rewetting during the reporting period. Carbon pools in mineral soils are simulated using Yasso07 model. Other emissions are based on average emissions in 2000-2009 and the state of forests and areas at the beginning of 2010.

The development of carbon stocks has been simulated using the documented forest management practice in 2000-2009, including measures in forestry and environmental protection measures aimed at preserving biological diversity. The harvest level in the simulation is set to the intensities of felling by species in 2000-2009. On forest land formally set-aside for nature conservation no harvest is forecasted.

Area of forest land remaining forest land according to GHG projections for 2021-2025 in Latvia is 3180 kha; all of the forest areas are assumed as productive forests; 92 kha of productive forests are protected in a way which prohibits regular supply of wood resources. About 50% of productive forests are managed by Joint Stock Company "Latvia's state forests", the rest are managed by private companies, municipalities and individuals.

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

The assumptions in Latvia's FRL are based on the forest management variables provided by the National forest inventory (NFI) and Stand-wise forest inventory. Considering that the NFI started in 2004, the situation in Latvian forests is extrapolated to 2000 using the Stand-wise inventory, particularly, area of clear-felling, share of selective felling in final felling and area of commercial and pre-commercial thinning, as well as area of salvage logging is taken from the Stand-wise inventory and extrapolated to growing stock in mature stands and intensities of thinning identified during the 1st (2004-2008) and the 2nd (2009) cycle.

During the 1st cycle of the NFI all fresh (up to 5 years old) stumps were measured in all NFI plots in forest land providing opportunity to estimate intensity of commercial thinning and volumes extracted in different types of harvests. Country specific conversion factors were elaborated to recalculate stump diameter to diameter of trees at 1.3 m height (Liepins & Liepins, 2015). After calculation of diameter the standard NFI methodology was applied to estimate extracted volume. An important factor, which had to be determined in recalculation of historical data, was dominant species and stand age in previous generation of trees, if the final felling was done between 2000 and the 1st visit to the NFI plot in 2004-2008. In the most cases it was possible using stump measurement data; however, in some cases dominant species or age of stand or both parameters could not be identified. In such cases probability of distribution of dominant species in forest regeneration described in further chapters was used and the most common final felling age of the selected species was assumed. Harvested stock were extrapolated using the average values of growing stock at certain age decade depending from site type, site index and dominant species.

Different approach was used to estimate harvested stock in the period between 2004 and 2009. NFI data from the 2nd cycle (mortality and harvesting in NFI plots) were used to estimate volume of recently died and extracted trees. It was assumed that the half of the harvesting events observed in the NFI plots measured 1st time in 2004 and 2nd time – in 2009 took place before middle of 2006 and the rest – in the second half of 2006, 2007 and 2008.

After application of the harvesting estimates growing stock and other parameters of the stand in all NFI plots in forest lands were recalculated to 2000. The mortality rates were developed according to data obtained in comparison of the 1st and 2nd NFI plots. The mortality equations are dominant species, age, site index and basal area specific, respectively, changes in any of these parameters will affect mortality rate. Basic principles of the calculation are provided in Figure 12.

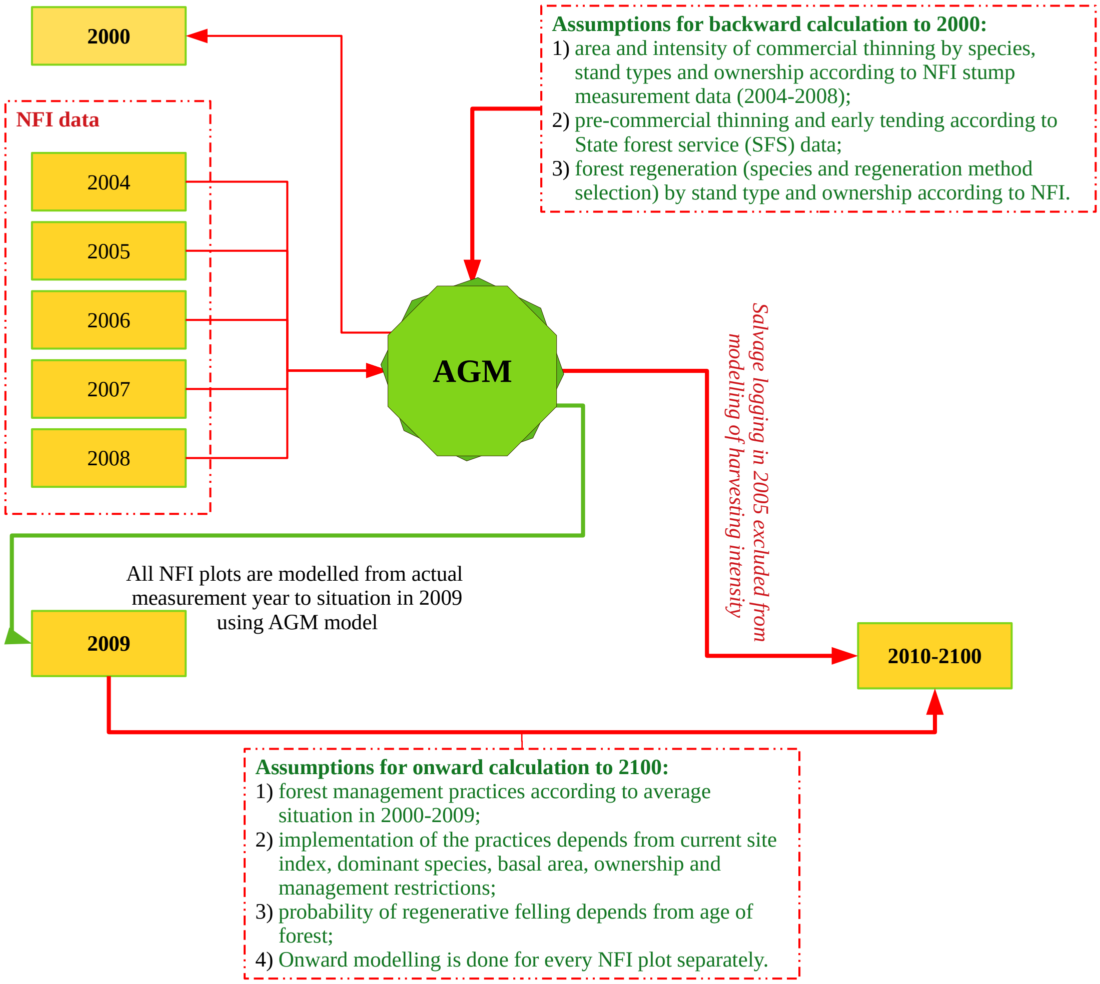

Figure 12: Basic principles for extrapolation of NFI data.

All forests are divided into 2 primary groups (strata) in the projections according to ownership structure – state and other forests, respectively it is assumed that ownership structure remains intact between 2010 and 2030. Calculations with AGM model are done at a single NFI plot level (about 8000 plots in total) using ownership structure dependant probabilities of forest management measures, e.g. selection of natural regeneration or planting, early thinning and commercial thinning. Forest management data are summarized before entering into EPIM model (Figure 7), which is doing calculations at the national level. Modelling framework elaborated for calculation of Latvia's FRL is provided in Figure 13.

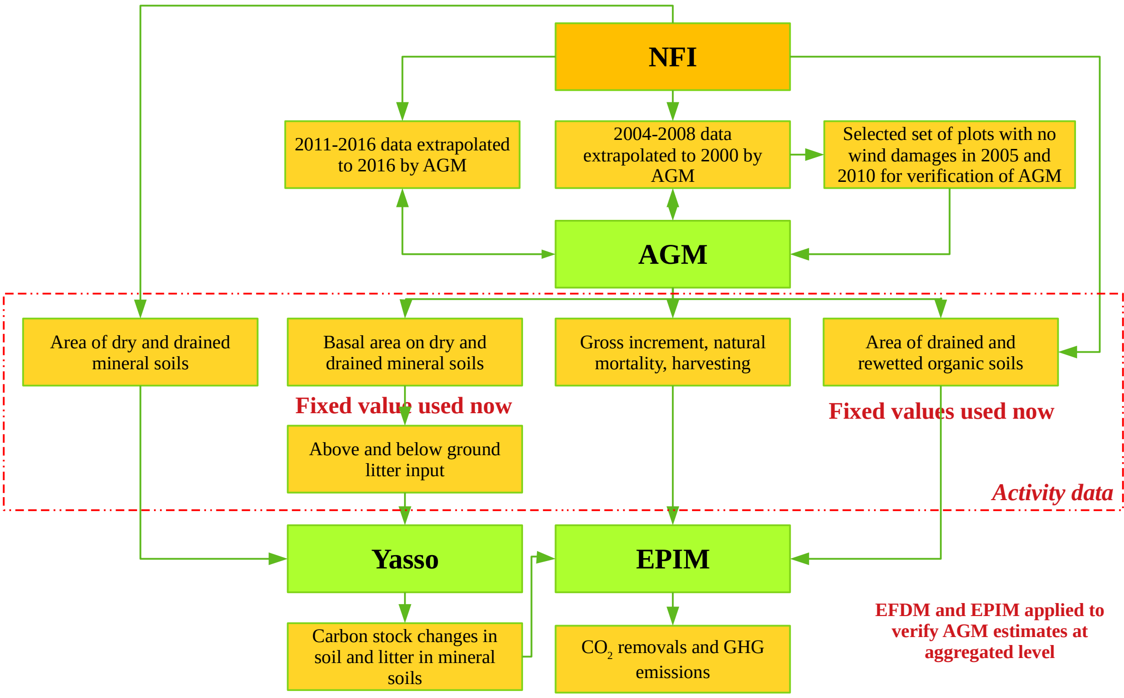

Figure 13: Modelling framework in calculation of FRL.

3.2.1 Documentation of stratification of the managed forest land

Ownership based stratification is used in the Latvia's National GHG inventory for LULUCF sector for the forest management projections, additionally stand type and management restrictions based correction factors are added to the probabilities. After calculation of stock changes in living and dead biomass, sample plots are categorized according to soil parent material and water regime to calculate soil carbon stock changes using Yasso07 model or fixed emission factors (in organic soils). All management assumptions are based on forest statistics in 2000-2009.

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

In modelling of Latvia's FRL the harvest level is set to species specific average of annual available stock on managed forest lands for wood supply (Table 7). In productive forests that are left for nature conservation no harvesting is allowed therefore in modelling their development is projected as continuous cover forestry without management activities. The harvests outside final felling are calculated as a proportion of those harvests by volume in comparison to final felling in 2000-2009 according to the State forest service data (Table 8). More detailed information of forest practices is provided in following chapter. Considered measures and probabilities are summarized in Figure 14. Directly age structure dependant forest management measures are regenerative felling and sanitary harvest probabilities; other measures depend from stand type, dominant species, basal area and tree height. In spite there is correlation between forest age and different types of thinning, these values differs by up to 3 decades depending from stand type and management history. For instance, the 1st commercial thinning in spruce stands can take place in 30-60 years, depending from management history (regeneration method, early tending and pre-commercial thinning). Use of averaged, age decade linked assumptions for early tending, pre-commercial and commercial thinning would lead to significant underestimation or overestimation of GHG emissions in calculation of the FRL in comparison to stand characteristics dependant modelling approach.

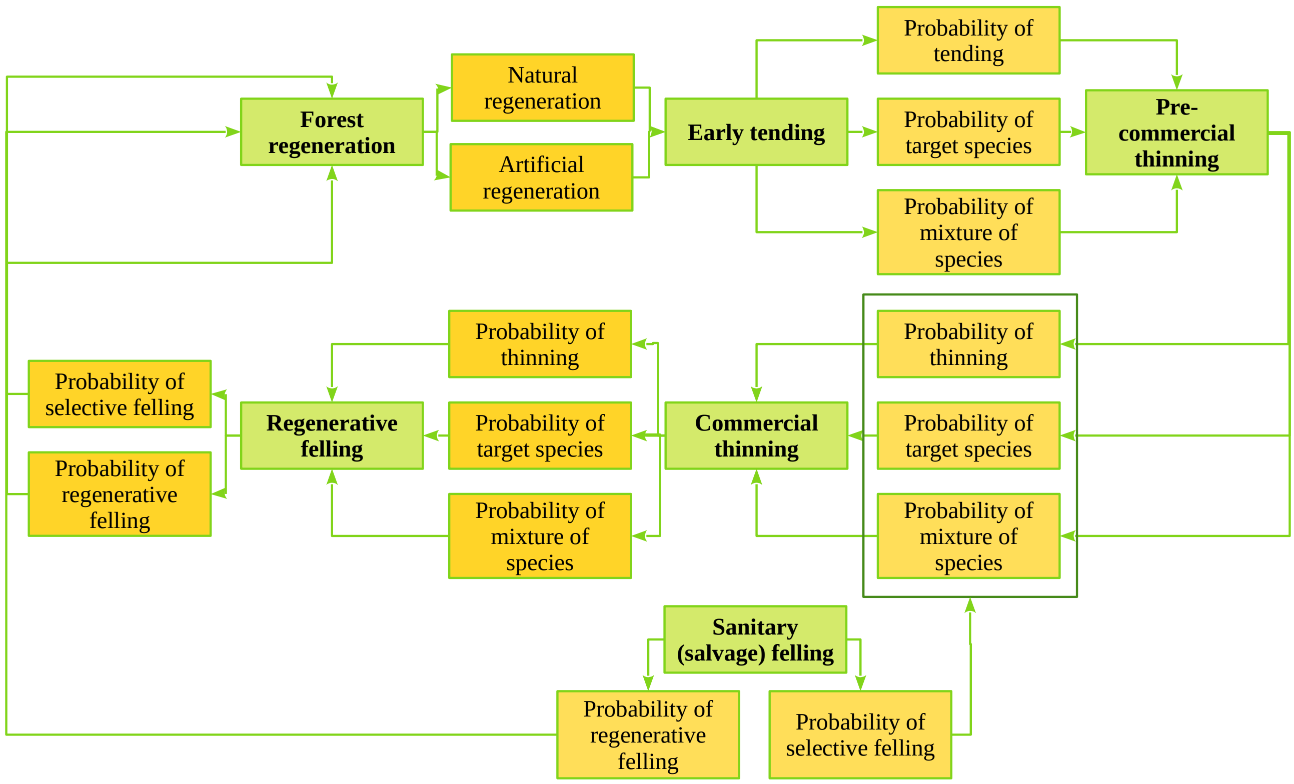

Figure 14: Forest management measures.

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

Latvia's FRL is elaborated using AGM model providing projections of growing stock, mortality, increment and harvests in forest land. The basic assumptions in AGM model are probabilities of forest regeneration method and dominant species depending from stand type and ownership, probability of early tending and pre-commercial thinning and target species depending from stand type, forest regeneration method, dominant species during the regeneration stage and ownership, probability and intensity of commercial thinning depending from stand type, dominant species and ownership, probability final felling depending from above-mentioned parameters and probability and type of sanitary felling (determined by above-mentioned parameters and age of forest stand). AGM is applied at a level of NFI plot or a sector (sector is part of a plot, if plot is split into pieces representing different land uses). Data on increments, mortality and harvests (5 years totals) obtained by AGM model are interpolated to annual values and feed into EPIM model, which transforms these data into carbon stock changes and GHG emissions.

3.3.1 Forest regeneration

Species suitable for the forest regeneration and corresponding minimal permitted number of trees in regenerated stands according to legal documents being in force in 2000 are shown in Table 11. These requirements apply, both to public and private forests.

Table 11: Tree species used in forest regeneration and corresponding minimal number of trees permitted in forest stands approved as regenerated

No	Species	Species ID	Minimal number of trees in regenerated stands
1.	Pine	1	3000
2.	Spruce	3	2000
3.	Birch	4	2000
4.	Alder	6	2000
5.	Aspen	8	2000
6.	Grey alder	9	2000
7.	Oak	10	1500
8.	Ash	11	1500
9.	Linden	12	2000
10.	Larch	13	2000
11.	Elm	16	1500
12.	Beech	17	1500
13.	Hornbeam	18	1500
14.	Poplar	19	2000
15.	Willow	20	2000
16.	Goat willow	21	2000
17.	Fir	23	2000
18.	Maple	24	1500
19.	Rowan	32	2000
20.	Cherry	56	2000

The probability of artificial forest regeneration is modelled separately for state and other forests according to data provided by the State forest service for the period between 2000 and 2009[6] (Table 13). The AGM model assumes that artificial regeneration takes place after final felling of pine, spruce, birch and aspen. Probability of regeneration with each species is modelled separately for different forest owners' groups (state and other forests) according to data provided by the State forest service for the period between 2000 and 2009[6] (Table 14).

[6] http://www.vmd.gov.lv/valsts-meza-dienests/statiskas-lapas/publikacijas-un-statistika/meza-statistikas-cd?nid=1809#jump

Table 12: Forest stand types in Latvian and Latin

Forest stand type in Latvian	Forest stand type in Latin	Code	Group of stand types	ID
Sils	Cladinoso-callunosa	Sl	Dry mineral soils  Higher fertility class	1
Mētrājs	Vacciniosa	Mr		2
Lāns	Myrtillosa	Ln		3
Damaksnis	Hylocomiosa	Dm		4
Vēris	Oxalidosa	Vr		5
Gārša	Aegipodiosa	Gr		6
Grīnis	Callunoso-sphagnosa	Gn	Wet mineral soils	7
Slapjais mētrājs	Vaccinioso-sphagnosa	Mrs		8
Slapjais damaksnis	Myrtilloso-sphagnosa	Dms		9
Slapjais vēris	Myrtillosoi-polytrichosa	Vrs		10
Slapjā gārša	Drypteriosa	Grs		11
Purvājs	Sphagnosa	Pv	Wet organic soils	12
Niedrājs	Caricoso-phragmitosa	Nd		14
Dumbrājs	Dryopterioso-caricosa	Db		15
Liekņa	Filipendulosa	Lk		16
Viršu ārenis	Callunosa mel.	Av	Ameliorated mineral soils	17
Mētru ārenis	Vacciniosa mel.	Am		18
Šaurlapju ārenis	Myrtillosa mel.	As		19
Platlapju ārenis	Mercurialosa mel.	Ap		21
Viršu kūdrenis	Callunosa turf. mel.	Kv	Ameliorated organic soils	22
Mētru kūdrenis	Vacciniosa turf. mel.	Km		23
Šaurlapju kūdrenis	Myrtillosa turf. mel.	Ks		24
Platlapju kūdrenis	Oxalidosa turf. mel.	Kp		25

Table 13: Probability of artificial forest regeneration depending from dominant tree species[6]

No.	Forest type	Other forests	State forests
1.	Cladinoso-callunosa	0.6686	0.7942
2.	Cladinosa-callunosa	0.4945	0.7603
3.	Vaccinosa	0.4679	0.8374
4.	Myrtillosa	0.2750	0.8867
5.	Hylocomiosa	0.1189	0.6437
6.	Oxalidosa	0.0596	0.2126
7.	Aegipodiosa	0.6860	0.5188
8.	Callunoso-sphagnosa	0.3580	0.7325
9.	Vaccinioso-sphagnosa	0.1434	0.6169
10.	Myrtilloso-sphagnosa	0.0609	0.3016
11.	Myrtillosoi-polytrichosa	0.0316	0.1173
12.	Drypteriosa	0.0500	0.0981

No.	Forest type	Other forests	State forests
13.	Sphagnosa	0.0565	0.1002
14.	Caricoso-phragmitosa	0.0410	0.0628
15.	Dryopterioso-caricosa	0.0500	0.0474
16.	Filipendulosa	0.7823	0.9153
17.	Callunosa mel.	0.5945	0.8797
18.	Vacciniosa mel.	0.2427	0.8074
19.	Myrtillosa mel.	0.0959	0.4188
20.	Mercurialosa mel.	0.1510	0.4686
21.	Callunosa turf. mel.	0.2520	0.7044
22.	Vacciniosa turf. mel.	0.1422	0.5580
23.	Cladinosa-callunosa	0.0878	0.3542

Table 14: Probability of dominant trees species in case of artificial forest regeneration by sowing or planting by forest type[6]

Forest type	State forests			Other forests			
	pine	spruce	birch	pine	spruce	birch	aspen
Cladinosa-callunosa	1			1			
Vaccinosa	1			1			
Myrtillosa	1			1			
Hylocomiosa	0.5026	0.4769	0.0205	0.2799	0.6752	0.0449	
Oxalidosa		0.9548	0.0452		0.9141	0.0571	0.0288
Aegipodiosa		0.8538	0.1462		0.8124	0.1155	0.0721
Callunoso-sphagnosa	1			1			
Vaccinioso-sphagnosa	1			1			
Myrtilloso-sphagnosa	0.5142	0.4502	0.0356	0.2438	0.6831	0.0731	
Myrtillosoi-polytrichosa	0.0142	0.8548	0.1310	0.0263	0.8956	0.0726	0.0055
Drypteriosa		0.9349	0.0651		1.0000		
Sphagnosa	1			1			
Caricoso-phragmitosa	0.5457	0.2530	0.2013	0.1860	0.5823	0.2317	
Dryopterioso-caricosa	0.0580	0.7191	0.2229	0.0239	0.7122	0.2639	
Filipendulosa		0.8113	0.1887	0.1139	0.8481	0.0380	
Callunosa mel.	1			1			
Vacciniosa mel.	1			1			
Myrtillosa mel.	0.4409	0.5162	0.0429	0.2845	0.6381	0.0774	
Mercurialosa mel.		0.9021	0.0979		0.7825	0.1792	0.0383
Callunosa turf. mel.	1			1			
Vacciniosa turf. mel.	1			1			
Myrtillosa turf. mel.	0.4521	0.4437	0.1042	0.1980	0.6322	0.1698	
Oxalidosa turf. mel.		0.7629	0.2371		0.7745	0.2060	0.0195

3.3.2 Forest thinning

The age and dominant tree height suitable for different types of thinning (tending, pre-commercial thinning and commercial thinning) are defined in the program for different species (Table 15). Ownership is not considered in this assumption, as this parameter is determined by regulations. The interval and intensity of thinning is also defined in the program using the NFI data.

Table 15: Threshold values limiting height of trees and age of stand limiting probability of different thinnings

Dominating tree species	Early tending				Pre-commercial thinning				Commercial thinning			
	H_{min}	H_{max}	A_{min}	A_{max}	H_{min}	H_{max}	A_{min}	A_{max}	H_{min}	H_{max}	A_{min}	A_{max}
Pine	0.1	1.9	1	5	2.0	11.9	6	40	12.0	-	-	80
Spruce	0.1	1.9	1	5	2.0	11.9	6	40	12.0	-	-	60
Birch	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Alder	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Aspen	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	30
Grey alder	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	30
Oak	0.1	1.9	1	5	2.0	11.9	6	40	12.0	-	-	80
Ash	0.1	1.9	1	5	2.0	11.9	6	40	12.0	-	-	60
Linden	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Larch	0.1	1.9	1	5	2.0	11.9	6	40	12.0	-	-	80
Elm	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Beech	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Hornbeam	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Poplar	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	30
Willow	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	30
Goat willow	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	30
Fir	0.1	1.9	1	5	2.0	11.9	6	40	12.0	-	-	60
Maple	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Rowan	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60
Cherry	0.1	1.9	1	5	2.0	11.9	6	20	12.0	-	-	60

3.3.2.1 Early tending

In addition to age and height restrictions (Table 15) it is possible to define how often the early tending is modelled sorting by property type (state and other forests), regeneration method (anthropogenically or naturally) and forest type (Table 16).

Table 16: Number of early tending by origin of the forest stand, ownership and forest stand type

Forest type	Naturally regenerated tree stands		Anthropogenically regenerated tree stands	
	state forests	other forests	state forests	other forests
Cladinoso-callunosa	2	0	3	2
Vacciniosa	2	0	3	2

Forest type	Naturally regenerated tree stands		Anthropogenically regenerated tree stands	
	state forests	other forests	state forests	other forests
Myrtillosa	2	0	3	2
Hylocomiosa	2	0	3	2
Oxalidosa	2	0	3	2
Aegipodiosa	2	0	3	2
Callunoso-sphagnosa	2	0	3	2
Vaccinioso-sphagnosa	2	0	3	2
Myrtilloso-sphagnosa	2	0	3	2
Myrtillosoi-polytrichosa	2	0	3	2
Drypteriosa	2	0	3	2
Sphagnosa	2	0	3	2
Caricoso-phragmitosa	2	0	3	2
Dryopterioso-caricosa	2	0	3	2
Filipendulosa	2	0	3	2
Callunosa mel.	2	0	3	2
Vacciniosa mel.	2	0	3	2
Myrtillosa mel.	2	0	3	2
Mercurialosa mel.	2	0	3	2
Callunosa turf. mel.	2	0	3	2
Vacciniosa turf. mel.	2	0	3	2
Myrtillosa turf. mel.	2	0	3	2
Oxalidosa turf. mel.	2	0	3	2

3.3.2.2 Pre-commercial thinning

It is possible to define what ranges of height and age of the dominating tree species of the 1st storey of the tree stand thinning is planned for (Table 15, Cabinet of Ministers of Republic of Latvia, 2012).

It is possible to define at what stand density the thinning is modelled for and proportionally how many stands are going to be thinned in the current five-year period in accordance with the criteria (Table 17). The stand density at which pre-commercial thinning is planned is determined according to the Joint Stock Company “Latvia's state forests” guidelines for the forest thinning.

Table 17: Indicators for planning pre-commercial thinning

Type of property	Density[7] at which pre-commercial thinning is planned	Proportion of stands to be thinned in the five year period	Maximum number of pre-commercial thinning
State forest	0.90	0.60	2
Other forests	0.90	0.40	1

7 Number of trees in the First story in comparison to normal number of trees.

The program assumes that after thinning there will be 100-125% of trees in comparison to optimal number of trees (AS 'Latvijas valsts meži', 2008).

The program allows for defining tree species suitable for the forest type as well as order them in preferable order of priority, therefore pre-commercial thinning will be modelled so as to achieve pure stands of high priority tree species. All tree and bush species can be separated into 3 groups (Table 18):

- tree species which can form a forest stand and can be target tree species:
  - tree species (priority code 1-8) which are defined in the priority tree species list,
  - tree species (11) which are not defined in the priority tree species list, but can be target, tree species where they already are the dominating tree species, however, if they are not the dominating tree species they are left in quantities that do not interfere with the growth of target tree species trees,
  - tree species (9) which can be target tree species in cases where species of the two former groups cannot form a forest stand ($N<N_{min}$),
- tree species (33) which cannot form a forest stand and cannot be target tree species, but are left in the forest stand in quantities that do not interfere with the growth of the target tree species,
- bush and tree species (22) which are removed completely in pre-commercial thinning.

Table 18: Target tree species priority groups[8] by forest type

Tree species	Forest stand type																						
	Cladinoso-callunosa	Vacciniosa	Myrtillosa	Hylocomiosa	Oxalidosa	Aegipodiosa	Callunoso-sphagnosa	Vaccinioso-sphagnosa	Myrtilloso-sphagnosa (9)	Myrtillosoi-polytrichosa (10)	Drypteriosa (11)	Sphagnosa	Caricoso-phragmitosa	Dryopterioso-caricosa	Filipendulosa	Callunosa mel.	Vacciniosa mel.	Myrtillosa mel.	Mercurialosa mel.	Callunosa turf. mel.	Vacciniosa turf. mel.	Myrtillosa turf. mel.	Oxalidosa turf. mel.
Pine	1	1	1	1	9	9	1	1	1	9	9	1	1	9	9	1	1	1	9	1	1	1	9
Spruce	9	9	9	2	1	1	9	9	2	1	1	9	3	9	9	9	9	2	1	9	9	2	1
Birch	9	9	9	3	3	3	9	9	3	3	3	2	2	1	2	9	9	3	2	9	9	3	2
Alder	9	9	9	9	4	4	9	9	9	4	4	9	9	2	1	9	9	4	4	9	9	4	4
Aspen	9	9	9	9	6	6	9	9	9	6	6	9	9	9	9	9	9	9	6	9	9	9	6
Grey alder	9	9	9	9	8	8	9	9	9	7	7	9	9	9	9	9	9	9	9	9	9	9	9

[8] 1-9 – Order of target tree species (1 – highest priority, 9 – lowest priority); 11 – if the species is the dominating one, then it is the target species, if it is not, then it is left in quantities that do not interfere with the growth of the target species; 22 – tree and bush species which are removed completely in pre-commercial thinning; 33 – tree species which are left in quantities that do not interfere with the growth of the target species.

Tree species	Forest stand type																						
	Cladinoso-callunosa	Vacciniosa	Myrtillosa	Hylocomiosa	Oxalidosa	Aegipodiosa	Callunoso-sphagnosa	Vaccinioso-sphagnosa	Myrtilloso-sphagnosa (9)	Myrtillosoi-polytrichosa (10)	Drypteriosa (11)	Sphagnosa	Caricoso-phragmitosa	Dryopterioso-caricosa	Filipendulosa	Callunosa mel.	Vacciniosa mel.	Myrtillosa mel.	Mercurialosa mel.	Callunosa turf. mel.	Vacciniosa turf. mel.	Myrtillosa turf. mel.	Oxalidosa turf. mel.
Oak	11	11	11	4	2	2	11	11	4	2	2	11	11	11	11	11	11	11	3	11	11	11	3
Ash	9	9	9	9	5	5	9	9	9	5	5	9	9	9	3	9	9	9	5	9	9	9	5
Linden	9	9	9	9	7	7	9	9	9	9	9	9	9	9	4	9	9	9	7	9	9	9	7
Elm	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Beech	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Hornbeam	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Poplar	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Willow	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Goat willow	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Cherry	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Maple	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Juniper	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Rowan	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Crab apple	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Hawthorn	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Other conifers	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Other broad leaved trees	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22

3.3.2.3 Commercial thinning

It is defined in the program at which stand density thinnings are modelled and what is proportion of stands conforming to criteria of stands suitable for thinning, which will be thinned during current 5 years period (Table 19).

Table 19: Indicators for planning of commercial thinning

Type of property	Density[9] at which thinning is planned	Proportion of stand thinned in current five year period	Maximum number of commercial thinning
State forests	0.85	0.60	3
Other forests	0.85	0.40	3

9 The proportion of basal area to a normal basal area in the 1st storey.

It is possible to define a range of basal area after thinning, in the default setting it is 100-125% of the minimum basal area listed in regulations (Cabinet of Ministers of Republic of Latvia, 2012c). The program allows to define various types of commercial thinning (NG; if neutral selection, then NG=1.0; if thinning from below, then NG>1.0; if thinning from top, then NG<1.0) and their proportion (Table 20). It is also possible to define the proportion of every type of thinning i.e. the area where every type of thinning is carried out on is proportional to the total area thinning is carried on. These indicators are sorted by type of property.

Table 20: Types and proportion of different types of commercial thinning

Type of property	Type of Commercial thinning	NG	Proportion
State forests	Top down	0.85	0.00
	Neutral	1.00	0.00
	Bottom up	1.15	1.00
Other forests	Top down	0.85	0.00
	Neutral	1.00	0.00
	Bottom up	1.15	1.00

It is possible to change the suitability of tree species to the forest type (Table 21), which directly impacts the proportion of species in the tree stand after commercial thinning.

Table 21: Priority group (suitability) of tree species according to forest type[10]

Forest type	Pine	Spruce	Birch	Alder	Aspen	Grey alder	Oak	Ash	Linden	Larch	Elm	Beech	Hornbeam	Poplar	Willow	Goat willow	Fir	Maple	Cherry	Other
Cladinoso-callunosa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vacciniosa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtillosa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylocomiosa	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Oxalidosa	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0
Aegipodiosa	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0
Callunoso-sphagnosa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinioso-sphagnosa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtilloso-sphagnosa	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Myrtillosoi-polytrichosa	0	1	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0
Drypteriosa	0	1	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0

10 1 – tree species suitable for forest type, 0 – tree species unsuitable for forest type.

Forest type	Pine	Spruce	Birch	Alder	Aspen	Grey alder	Oak	Ash	Linden	Larch	Elm	Beech	Hornbeam	Poplar	Willow	Goat willow	Fir	Maple	Cherry	Other
Sphagnosa	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caricoso-phragmitosa	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Dryopterioso-caricosa	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Filipendulosa	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Callunosa mel.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vacciniosa mel.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtillosa mel.	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Mercurialosa mel.	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0
Callunosa turf. mel.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vacciniosa turf. mel.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtillosa turf. mel.	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Oxalidosa turf. mel.	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0

3.3.3 Final felling

The program allows to define the final felling age and diameter. In the default setting the age and diameter at which final felling is carried out is set at values listed in current regulation (Table 22, Cabinet of Ministers of Latvia, 2012b; Parliament of the Republic of Latvia, 2000).

Table 22: Age and diameter of final felling

Tree species	Species ID	Final felling age (years) depending on site index			Final felling diameter (cm) depending on site index			
		0 and 1	2 and 3	4; 5 and 6	0	1	2	3
Pine	1	101	101	121	39	35	31	27
Spruce	3	81	81	81	31	29	29	27
Birch	4	71	71	51	31	27	25	22
Alder	6	71	71	71	999	999	999	999
Aspen	8	41	41	41	999	999	999	999
Grey alder	9	31	31	31	999	999	999	999
Oak	10	101	121	121	999	999	999	999
Ash	11	81	81	81	999	999	999	999
Linden	12	81	81	81	999	999	999	999
Larch	13	101	101	121	999	999	999	999

Tree species	Species ID	Final felling age (years) depending on site index			Final felling diameter (cm) depending on site index			
		0 and 1	2 and 3	4; 5 and 6	0	1	2	3
Other pines	14	101	101	121	999	999	999	999
Other spruces	15	81	81	81	999	999	999	999
Elm	16	81	81	81	999	999	999	999
Beech	17	81	81	81	999	999	999	999
Hornbeam	18	81	81	81	999	999	999	999
Poplar	19	41	41	41	999	999	999	999
Willow	20	31	31	31	999	999	999	999
Goat willow	21	31	31	31	999	999	999	999
Fir	23	81	81	81	999	999	999	999
Maple	24	81	81	81	999	999	999	999
Rowan	32	31	31	31	999	999	999	999
Cherry	56	81	81	81	999	999	999	999

The proportion of regenerative felling area is in accordance with the average values in 2000-2009[11] (Table 23). Intensity (actually extracted volume in comparison to resources available for final felling) is estimated using average rates in 2000-2009 (Table 7).

Table 23: Proportion of final felling area sorted by type of property and type of final felling

Type of felling	Other forests	State forest
Selective felling	0.1719	0.0647
Regenerative felling	0.8281	0.9353

3.3.4 Salvage (sanitary) felling

Due to windthrow in 2005 the share of salvage logging in the first half of the reference period is considerably bigger in comparison to the following period (2006-2009). To avoid overestimation of harvesting due to natural disturbances 2005 is excluded from calculation of projections of sanitary fellings.

Probability of sanitary felling in the tree stand is defined depending on the trees species and its decimal age group (Table 24). The program defines a proportion of selective and sanitary clear felling depending on the dominating tree species in the tree stand which in the default setting is in accordance with the last three years[12] (Table 25).

Table 24: Probability of sanitary felling depending on the dominating tree species in the tree stand and its decimal age group

Decimal age group	Pine	Spruce	Birch	Alder	Aspen	Ash	Other species
1	0	0	0	0	0	0	0

[11] State forest service statistics CD 2001-2009.

[12] State forest service statistics CD 2001-2009, excluding 2006.

Decimal age group	Pine	Spruce	Birch	Alder	Aspen	Ash	Other species
2	0.0002	0.0008	0.0004	0.0003	0.0004	0	0
3	0.0010	0.0067	0.0022	0.0010	0.0011	0	0
4	0.0033	0.0200	0.0053	0.0020	0.0020	0	0
5	0.0068	0.0347	0.0083	0.0028	0.0026	0	0
6	0.0108	0.0424	0.0098	0.0032	0.0028	0.0008	0
7	0.0143	0.0407	0.0095	0.0031	0.0026	0.0117	0
8	0.0165	0.0328	0.0079	0.0026	0.0022	0.0478	0
9	0.0173	0.0231	0.0059	0.0020	0.0017	0.0744	0
10	0.0167	0.0147	0.0041	0.0015	0.0013	0.0554	0
11	0.0151	0.0085	0.0026	0.0010	0.0009	0.0231	0
12	0.0129	0.0046	0.0016	0.0007	0.0006	0.0060	0
13	0.0105	0.0024	0.0009	0.0004	0.0004	0.0011	0
14	0.0083	0.0011	0.0005	0.0003	0.0003	0.0001	0
15	0.0063	0.0005	0.0003	0.0002	0.0002	0	0
16	0.0047	0.0002	0.0001	0.0001	-	0	0
17	0.0034	0.0001	0.0001	0.0001	-	0	0
18	0.0024	0	0	0	-	0	0
19	0.0016	0	0	0	-	0	0
20	0.0011	0	0	0	-	0	0
21	0.0007	0	0	0	-	0	0
22	0.0005	0	0	0	-	0	0
23	0.0003	0	0	0	-	0	0
24	0.0002	0	0	0	-	0	0
25	0.0001	0	0	0	-	0	0
26	0.0001	0	0	0	-	0	0
27	0.0001	0	0	0	-	0	0
28	0	0	0	0	-	0	0
29	0	0	0	0	-	0	0
30	0	0	0	0	-	0	0

Table 25: Proportion of selective and clear sanitary felling depending on the dominating tree species in the tree stand

Dominating tree species	Clear sanitary felling	Selective sanitary felling
Pine	0.0290	0.9710
Spruce	0.0545	0.9455
Birch	0.0590	0.9410
Alder	0.0718	0.9282
Aspen	0.0785	0.9215
Ash	0.3193	0.6807

4. FOREST REFERENCE LEVEL

Latvia's FRL is based on assumption of continuation of sustainable forest management practice according to situation in 2000-2009 as described in chapter Balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of this century (Table 7 and 8, page 32) and chapter Description of the general approach as applied for estimating the forest reference level, page 35.

Latvia's FRL is -1709 ktons CO_2 eq yr^{-1} with HWP and -298 ktons CO_2 eq yr^{-1} if instant oxidation of HWP method is applied to calculation (Figure 15 and 16).

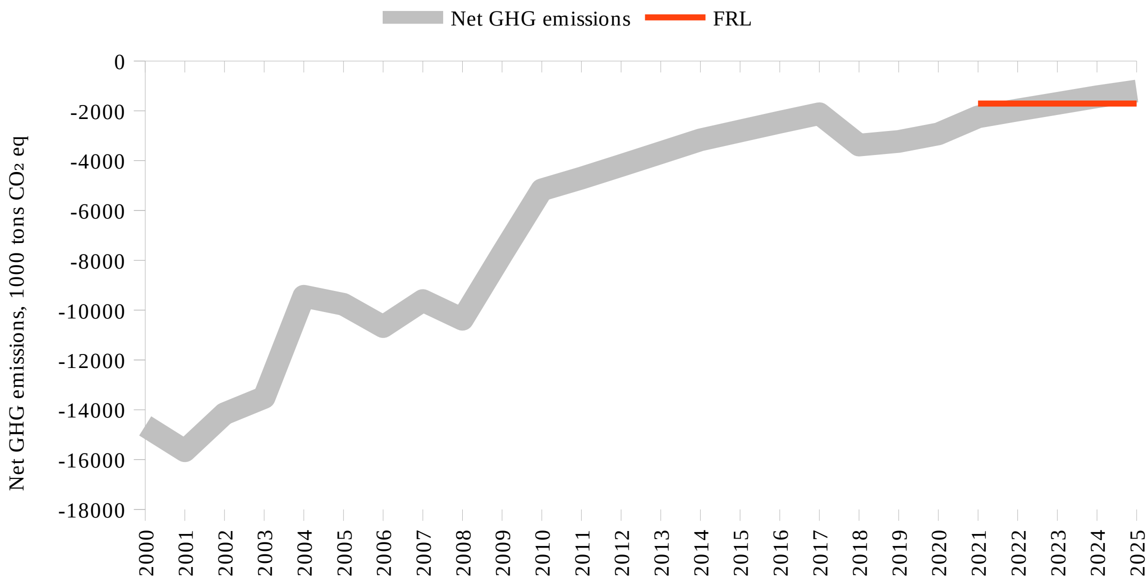

Figure 15: Forest reference level and projections of GHG emissions in forest land.

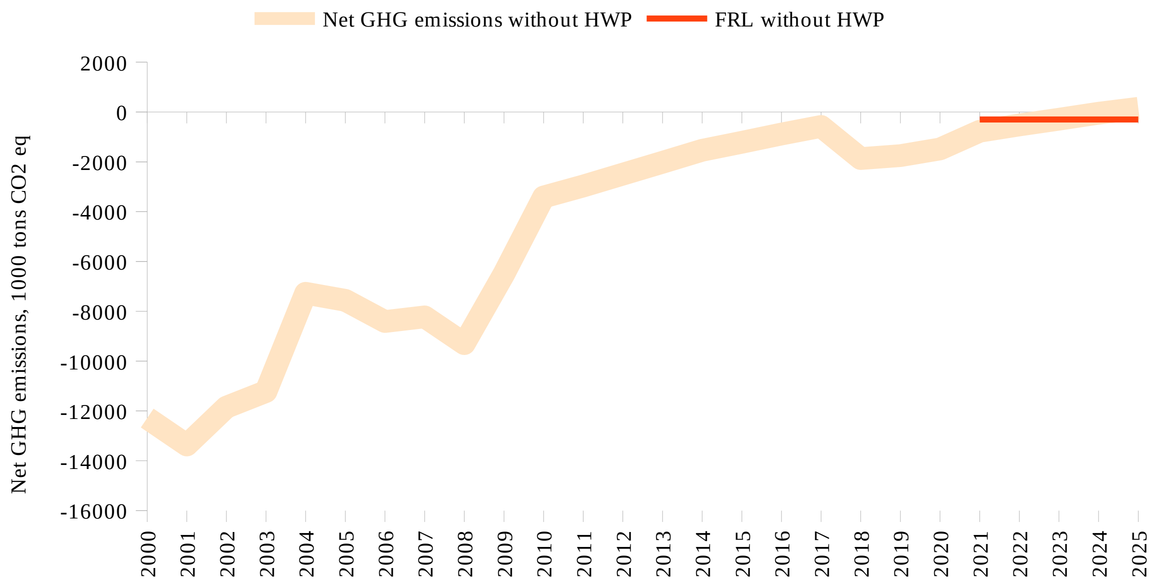

Figure 16: Forest reference level and projection of GHG emissions in forest land in case of instantaneous oxidation of HWP.

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

Forest land remaining forest land reported in the 2019 National GHG inventory in 2010, including ameliorated organic soils is considered in calculation of the FRL (Figure 17). The total area of forest land remaining forest land in the FRL calculation is smaller in comparison to the area reported in the GHG inventory report for the period between 2010 and 2018 due to completion of 20 years transition period in lands converted to forest land.

After 2010 area of forest land remaining forest land in FRL calculation is fixed. No land use changes like afforestation or deforestation are considered between 2010 and 2030 in the FRL scenario assuming that these changes can be calculated as technical corrections.

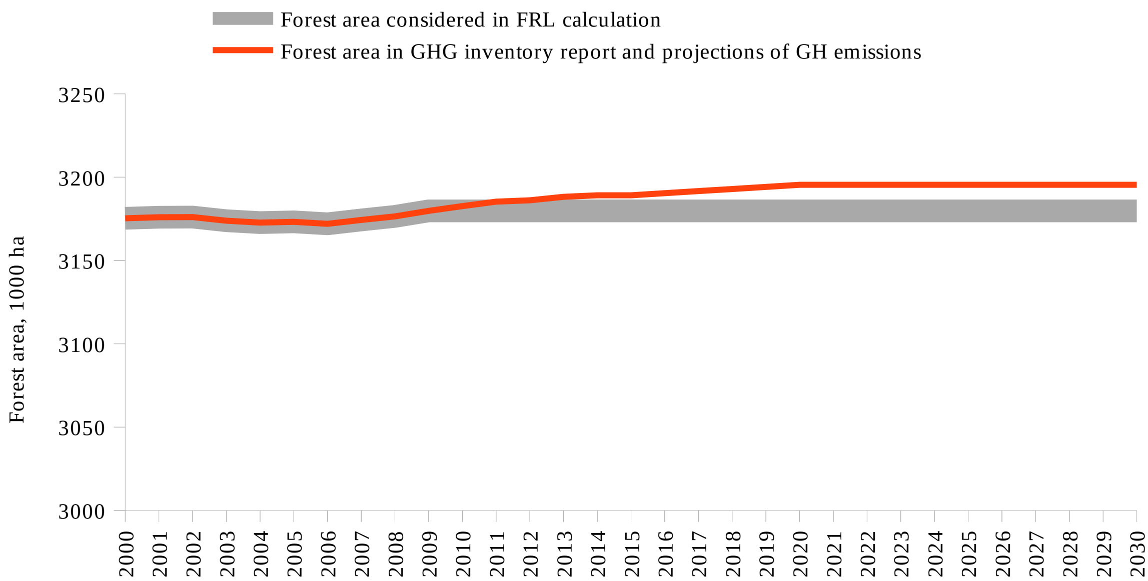

Figure 17: Area of forests considered in FRL calculation.

Nature conservation areas in forest land remaining forest land are considered in the FRL scenario by intersection of geospatial information of the NFI plots and nature conservation areas provided by the State forest service. Situation at the end of 2009 was used to compare with the NFI plots. Summary of distribution of the forest management restrictions is shown in Figure 18.

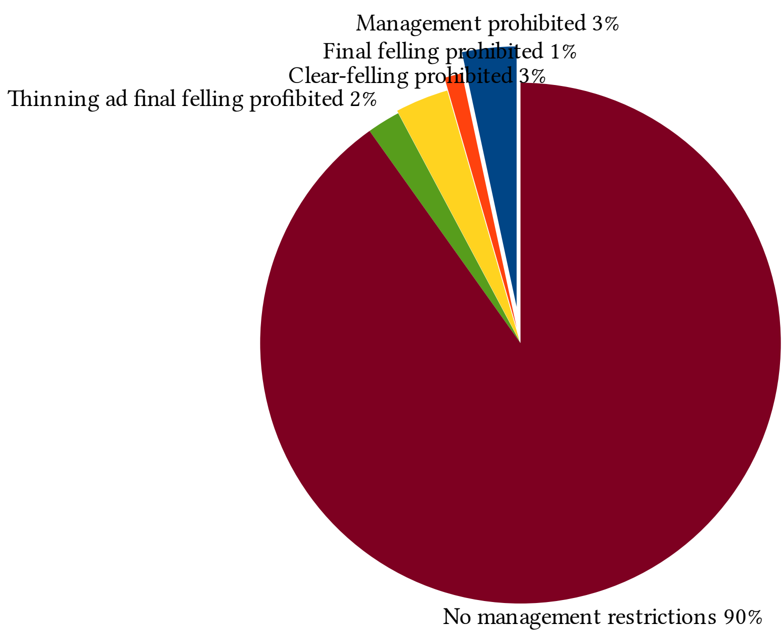

Figure 18: Summary of distribution of forest management restrictions[13].

[13] State forest service data on 2010.

Forest characteristics are stratified according to stand type, dominant species, ownership and age class, which are affected by management assumptions. For instance, increment potential is considerably higher in anthropogenically regenerated forests, where thinnings are done according to the good practice guidance. This means that modelled stocks, increments and mortalities may vary within the age class depending from the applied management assumptions. More detailed description of stand parameters is provided in description of AGM model (Šņepsts, Kārkliņa, et al., 2018) and chapter 'Detailed description of the modelling framework as applied in the estimation of the forest reference level'.

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

Emissions and removals from forests and HWP as shown in GHG inventories and relevant historical data are estimated using methods applied in the National GHG inventory including use of the same activity data and models. The EPIM model was used in both cases to transfer the activity data into GHG emissions and CO_2 removals.

The results of the model verification using selected number of the NFI sample plots are not affected by wind-blows in 2005 and 2010 are published in a research report available from the internet (Šņepsts, Bārdule, et al., 2018). Further information on forest management practices is provided in chapters 'Detailed description of the modelling framework as applied in the estimation of the forest reference level' and 'Inclusion of the carbon pool of harvested wood products'.

Comparison of modelled (AGM and EPIM models) and actual GHG emissions in forest lands remaining forest land in 2000-2009 is provided in Figure 5 (page 16). Test proved that the difference is not statistically significant ($p > 0.05$).

4.3 Projections of future climate conditions

Climate changes (increase of average temperature) are considered in calculations of soil carbon stock changes in mineral soils using Yasso07 model. The applied climate parameters (Figure 19) are published in earlier studies on evaluation of carbon stock changes in soil (Bārdulis et al., 2017).

Modelling results are used to demonstrate that mineral soils in forest lands are not a net source of GHG emissions (Figure 20), therefore the soil carbon pool, except ameliorated and rewetted organic soils, is not used in estimation of the Latvia's FRL. Forest growth assumptions (Chapter 'Description of the general approach as applied for estimating the forest reference level') and forest growth modelling results under Latvia's FRL scenario are used to determine soil carbon stack changes.

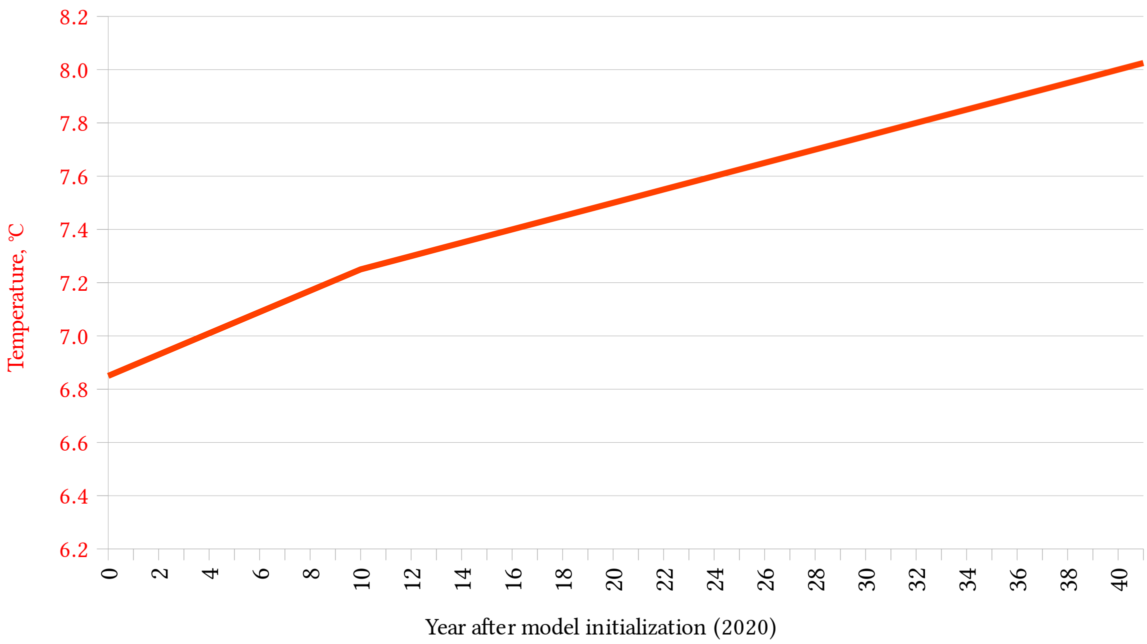

Figure 19: Average monthly temperature considered in soil carbon stock change modelling using Yasso model.

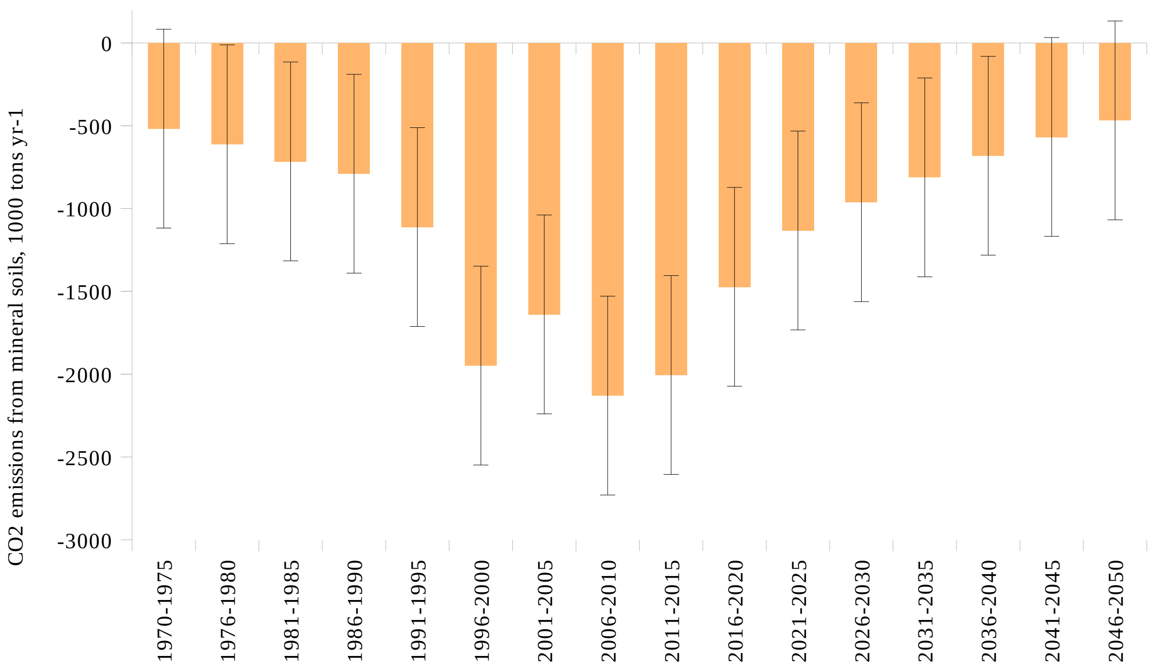

Figure 20: Projections of soil carbon stock changes in mineral soils under Latvia's FRL scenario.

The 20 years transition period is used for land use changes in afforested lands in calculation of the reference level, respectively, all areas afforested since 1990 are transferred from the category land converted to forest land to category forest land remaining forest land after reaching 20 years age. After 2010 no land use changes are considered. According to Yasso07 modelling results accumulation of carbon continuous for more than 30 years in birch, spruce and pine stands, which are the most common tree species in afforested areas. Initial carbon stock is assumed according to average conditions in grassland in Latvia (Bardule, Lupikis, Butlers, & Lazdins, 2017) and assumptions of structure of organic material from earlier studies in Finland (Palosuo, Heikkinen, & Regina, 2015). A 100 years calibration period is applied before afforestation assuming that initial land use is mature forest with average soil carbon stock characteristic for fertile soils (Bārdulis et al., 2017; Lazdiņš, Bārdule, Stola, & Krišāns, 2013). Thirty years transition period will be implemented later as technical corrections.

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

Latvia has proposed the 2021-2025 FRL of −1709 ktons CO_2 eq yr^{-1} applying the first-order decay function for HWP and −298 ktons CO_2 eq yr^{-1} assuming instantaneous oxidation of HWP. The proposed value consists of net GHG emissions per year from organic soils and forest fires and accumulations of CO2 eq. in dead wood, HWP and living biomass.

According to the Figure 21 implementation of the FRL scenario will lead to continuous increase of carbon stock in forest carbon pools, especially in dead wood and living biomass carbon pool.

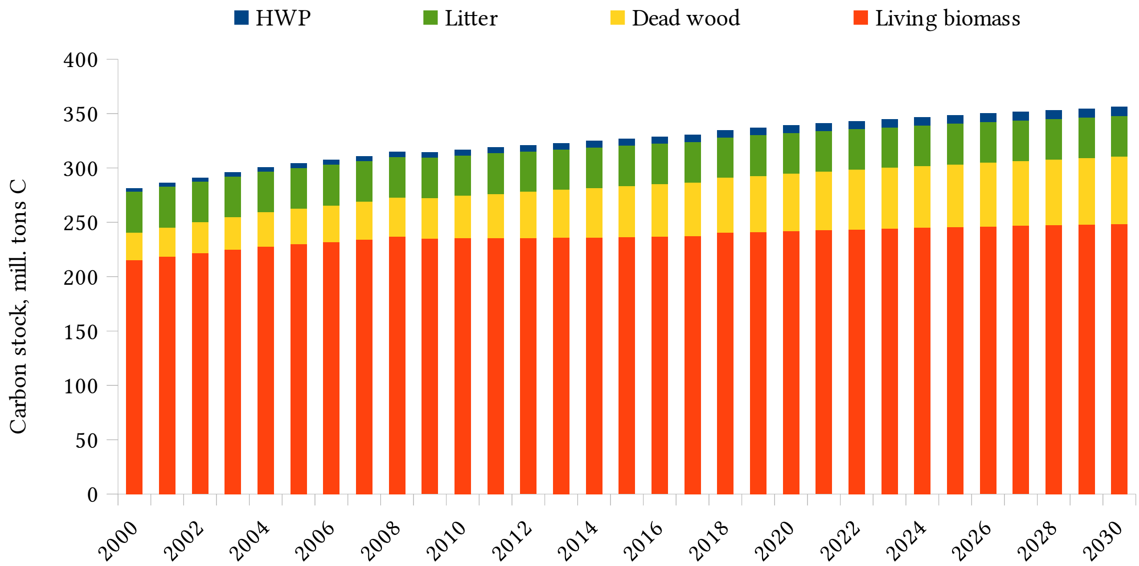

Figure 21: Projection of carbon stock in forest lands.

Projections of annual gross increment, mortality, harvest rate and growing stock values for the period between 2000 and 2050 in Figure 22 demonstrate continuous increase of growing stock in forests in spite of increase of harvest rate between 2010 and 2020.

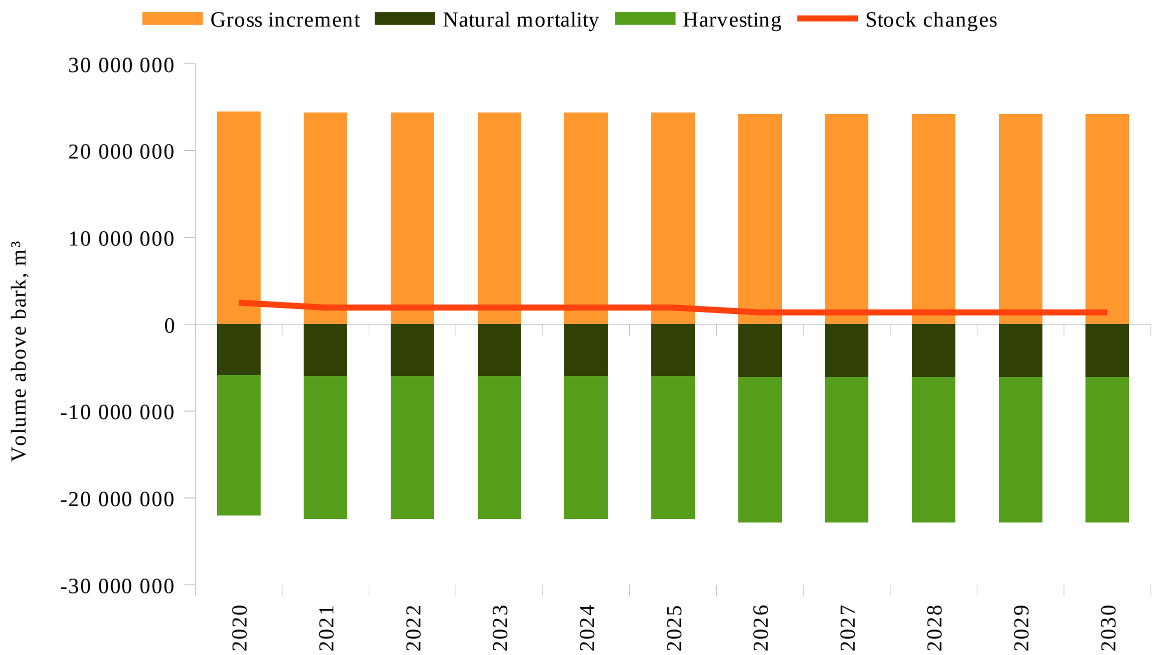

Figure 22: Projection of growing stock changes in forest lands.

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Annex 1 Responses to technical recommendations in the “Assessment of the National Forestry Accounting Plans”

RESPONSE TO TECHNICAL RECOMMENDATIONS IN ASSESSMENT OF THE NATIONAL FORESTRY ACCOUNTING PLANS

(1) Demonstrate how dynamic age-related forest characteristics have been taken into account and revise the FRL, if applicable. (2) Demonstrate that the FRL is based on the continuation of sustainable forest management practices from the reference period specifically for harvest rates. (3) Specifically, exclude policy assumptions from the FRL calculation. (4) Explain the change and indicate drivers for living biomass converting from a sink in the reference period to a source during the compliance period. (5) Indicate if data outside the reference period (2000-2009) were used, and if so, provide a justification.

1. *Age structure dependant variable in the AGM growth model is probability of regenerative felling; the rest of variables are determined by growth conditions (site index) and management practices, e.g. thinning intensity. Detailed description of the modelling approach is provided in research report by* Šņepsts et al. (2018), as well as in Annex 3 of this document. *Age structure of forests is shown in Figure 8 and 9 (page 29).*
2. *Projections of harvest rates are recalculated by exclusion of policies related impact. Projections of harvest rate is provided in chapter 'Harvest projections under Latvia's FRL scenario' (page 32).*
3. *Current version of NFAP is based on assumption that harvest rate follows to intensities documented in 2000-2009 and modelling is started from 2010 thus excluding impact of policies implemented after the reference period. Projections of harvest rate is provided in chapter 'Harvest projections under Latvia's FRL scenario' (page 32).*
4. *NFAP is supplemented with Figure 22 (page 57) demonstrating increments, mortality and harvest rate in forest lands remaining forest lands in 2010 according to the most recent inventory.*
5. *No data outside the reference period (2000-2009) are used in calculation of the Latvia's FRL.*

(1) Demonstrate how the goal of achieving a balance between anthropogenic emissions and removals will be achieved in the second half of the century. (2) Provide qualitative and quantitative information until at least 2050 consistent with the long-term strategy required under Regulation (EU) 2018/1999.

1. *The GHG projections are provided in NFAP in Figure 1 (page 7). The calculation period is extended to 2100 using updated information on harvest intensities.*
2. *Following to the previous response period of projections is extended to 2100; assumptions on forest management practices applied in the FRL scenario ensures*

that forest land remaining forest land is net sink of CO_2 removals in the second half of 21st century (2051-2100, Figure 1 in page 7).

(1) Provide a detailed description of forest management practices as documented in the reference period (2000-2009). (2) Exclude policy assumptions from the FRL calculation and revise the FRL accordingly.

1. *The information on forest management practices is provided in NFAP and sources of information listed in this document in chapters 'Description of future harvesting rates under different policy scenarios' (page 32) and 'Detailed description of the modelling framework as applied in the estimation of the forest reference level' (page 39). Detailed description of stand characteristics and age related probabilities of various forest management measures (Annex 3 'Description of the AGM model'). To simplify description of the measures number of strata is reduced in NFAP to 2 – state owned and other forests, including private and municipality owned forests (chapter 'Documentation of stratification of the managed forest land', page 38).*
2. *Policy assumptions are excluded from calculation of FRL in current version of NFAP by recalculation of harvest intensities in the reference period (chapter 'Harvest projections under Latvia's FRL scenario', page 32).*

(1) Demonstrate the consistency with the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013. (2) Provide explanations for possible differences between national projections and the proposed FRL.

1. *The consistency with the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013 is ensured by transferring calculations of land use changes to 20 years period. In both cases historical data sets until 2009, including it, are equal. Comparison of the projections and FRL scenario is provided in chapter 'Integrity with the national projections of anthropogenic GHG emissions by sources and removals by sinks reported under Regulation (EU) No. 525/2013' and Figure 14 in page 15.*
2. *The national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013 differs from modelling results in NFAP due to different forest management intensities applied in FRL scenario in 2010-2017 according to the intensities as documented in 2000-2009 and actual forest management characteristics, as well as due to different forest land remaining forest land area (Figure 17, page 53), which increased in the GHG inventory due to completion of 20 years transition period. Carbon stock changes and GHG emissions due to afforestation are accounted under forest lands within the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013, in NFAP afforestation is not accounted. Deforestation after 2009 is not considered in NFAP due to use of fixed land use approach, thus significantly affecting carbon stock changes and GHG emissions in the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013. Management practices including harvest rate*

in the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013 are considered according recent data (2013-2017) and market driven projections of wood demand. Forest management in 2000-2009 positioned as 'business as usual' according to LULUCF regulation represents outdated forest management practices, hardly comparable with actual forest management practices.

(1) Estimate the FRL based on the area under forest management as indicated in Annex IV, Section B (e) i. (2) Use the conversion period for Land converted to forest land (Afforested Land) consistent with the latest national GHG inventory. (3) Demonstrate the ability of the model used to construct the FRL to reproduce historical data from the national GHG inventory. (4) Demonstrate the consistency between historical data from the national GHG inventory and modelled data for estimating the FRL for the reference period.

1. *Area of forest land is recalculated using 20 years transition period for conversion of other land use categories to forest land; no land use changes are considered after beginning of 2010.*
2. *Land use changes are recalculated using 20 years transition period instead of 30 years; however, it is planned to apply 30 years transition period in GHG inventory and calculation of NFAP using technical corrections.*
3. *Ability of the model to recalculate historical data (2000-2009) is demonstrated in chapter 'Integrity of applied models with the historical data from the national GHG inventory', page 16. According to results summarized in Figure 5, page 16.*
4. *The most recent GHG inventory and the NFI data applied in the GHG inventory are used for calculation of the FRL.*

(1) Ensure consistency of values throughout the NFAP specifically between table 1 and the text, e.g. on page 6.

1. *Contents of NFAP is corrected accordingly to ensure consistency of text and tables.*

(1) Provide additional data on harvest assumptions, specifically on harvest intensity and harvest frequency. (2) Demonstrate the exclusive use of data from the reference period for modelling the FRL.

1. *Harvesting assumptions are provided in NFAP. The FRL scenario intensities of regenerative felling is determined by age of stands and probability (according to intensity tables, chapter 'Final felling', page 48). A figure demonstrating changes in growing stock available for regenerative felling since 1990 is included in NFAP to make information on harvest projections more transparent (Figure 22, page 57). To exclude policy assumptions the harvest intensities in the reference period are recalculated considering the intensities as documented in 2000-2009. Modelling is started from 2010.*
2. *It is mentioned in NFAP that only data characterizing forest management in the reference period (2000-2009) are used in calculation.*

(1) 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. (2) Given the use of the dynamic area approach, provide a detailed disaggregated calculation of the managed forest land area at annual time steps for the entire time series since, at least, year 2000. (3) Specifically, provide information on change in area for each age class using sufficiently disaggregated age-classes, e.g. 10-20 years.

1. *Land use is recalculated in NFAP using 20 years transition period ensuring consistency of land use with the most recent GHG inventory report (2019) until beginning of 2010. Land use changes including those determined by completion of transition period are avoided and will be included in NFAP with technical corrections.*

2. *Dynamic area approach is not any more used in calculation of FRL. Fixed area of forests is used staring with 2010. A figure demonstrating land use changes due to conversion of forest lands to other land uses and conversion of non-forest lands to forest lands from 2000 to 2017 will be added with technical corrections to NFAP.*

3. *A figure demonstrating species specific changes of distribution of age classes (young forests, middle age forest and mature forests) are provided in chapter 'Overall description of the forests and forest management in Latvia and the adopted national policies', page 28. According to the assumptions used in FRL scenario area of mature forests in Latvia continue to grow in the commitment period (Figure 8 and 9).*

(1) Provide detailed information on increments, age structure and harvesting rates for estimating the FRL. (2) Exclude policy assumptions on harvests in the reference period to balance age-structure. (3) Avoid contradictions in the NFAP such as between Figures 4 and 5 regarding reference period and harvesting rates or table 7 and Figure 4 regarding the share of harvest.

1. *Information is provided in description of AGM model in Annex 3 'Description of the AGM model'. Only regenerative felling is determined by age structure and probability models, other management activities are determined by stand characteristics and probability models.*

2. *Policy assumptions are excluded from calculation of the FRL by modelling of FRL from 2010 and by using of forest management intensities as documented in 2000-2009, including harvesting intensity.*

3. *Charts and tables are updated to ensure consistency of the projections in the FRL scenario.*

(1) Provide information about the future harvesting rates disaggregated between energy and non-energy uses. (2) Provide additional information on the assumptions used to allocate round wood to each HWP category.

1. *The future harvesting rates disaggregated between energy and non-energy uses is provided in Figure 10 (page 33). The disaggregation is done at species level,*

respectively, changes in species composition in harvest rate may change proportion of wood for energy wood and other assortments.

2. *Additional tables are included in chapter 'IIntegrity of applied models with the historical data from the national GHG inventory' (Table 3, 4 and 5) to demonstrate production of different types of HWP. No changes are considered in proportion of imported and exported roundwood at species level.*

Annex 2 Responses to comments in the "Synthesis Reports Technical Assessment of National Forest Accounting Plans as requested by the LULUCF Regulation"

Table 26 Compilation of Synthesis Reports Technical Assessment of National Forest Accounting Plans as requested by the LULUCF Regulation

Art. 8(5) General principles for forest reference level (FRL)	**LULUCFEG Conclusion**	**TI[14]**	**AI[15]**	**Response**
Paragraph 1. The forest reference level shall be based on the continuation of sustainable forest management practice, as documented in the period from 2000 to 2009 with regard to dynamic age-related forest characteristics in national forests, using the best available data.	The LULUCFEG noted that the **FRL includes policy assumptions**. The LULUCFEG suggests Latvia revises the FRL values using the management practices as documented in the reference period.	Yes	Yes	*Assumptions in calculation of harvest rate are changed according to proposal by the LULUCFEG; harvest rate in the projections (2010-2030) is set as proportion of volume extracted and available for final felling in 2000-2009 (page 6) and chapter 'Harvest projections under Latvia's FRL scenario' (page 32). Detailed information on modelling assumptions is provided in Annex 3; assumptions on forest regeneration in the FRL scenario are provided in chapter 'Forest regeneration' (page 40); assumptions on thinning – in chapter 'Forest thinning' (page 43); assumptions on regenerative felling – in chapter 'Final felling' (page 48), assumptions on salvage logging – in chapter 'Salvage (sanitary) felling' (page 49).*
Paragraph 2. Forest reference levels [...] shall take account of the future impact of dynamic age-related forest characteristics in order not to unduly constrain forest management intensity as a core element of sustainable forest management practice, with the aim of maintaining or strengthening long-term carbon sinks.	The LULUCFEG noted that the **FRL includes policy assumptions**. The LULUCFEG suggests Latvia revises the FRL values using the management practices as documented in the reference period.	Yes	Yes	*Assumptions in calculation of harvest rate are changed according to proposal by the LULUCFEG; harvest rate in the projections (2010-2030) is set as proportion of volume extracted and available for final felling in 2000-2009 (page 6) and chapter 'Harvest projections under Latvia's FRL scenario' (page 32).*
Annex IV Part A. Criteria and guidance for determining FRL	LULUCFEG Conclusion	-	-	-
(a) the reference level shall be consistent with the goal	The LULUCFEG noted that the NFAP includes	No	No	-

14 Transparency issues (TI) are defined as issues that will not impact on the values of the FRL, but relate to the transparency information included in the NFAP.

15 Accuracy issues (AI) are defined as issues that may impact on the values of the FRL.

Art. 8(5) General principles for forest reference level (FRL)	LULUCFEG Conclusion	TI	AI	Response
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;	transparent and complete information on how Latvia addresses Annex IV Part A(a).			
(b) the reference level shall ensure that the mere presence of carbon stocks is excluded from accounting;	The LULUCFEG noted that the NFAP includes transparent and complete information on how Latvia addresses Annex IV Part A(b).	No	No	-
(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;	The LULUCFEG noted that the **FRL includes policy assumptions**. The LULUCFEG suggests Latvia revises the FRL values using the management practices as documented in the reference period.	Yes	Yes	*Assumptions in calculation of harvest rate are changed according to proposal by the LULUCFEG; harvest rate in the projections (2010-2030) is set as proportion of volume extracted and available for final felling in 2000-2009 (page 6) and chapter 'Harvest projections under Latvia's FRL scenario' (page 32).*
(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 LULUCFEG suggests that Latvia check the **consistency of the values between Table 1 and the text in the NFAP**. The LULUCFEG suggests Latvia revises the NFAP if needed.	Yes	No	*Values in Table 1 and text in chapter 'General description of the construction of Latvia's FRL' (page 5) are harmonized.*
(e) a constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009 shall be assumed;	The LULUCFEG noted that the NFAP includes transparent and complete information on how Latvia addresses Annex IV Part A(e).	No	No	-
(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 LULUCFEG noted that the NFAP includes transparent and complete information on how Latvia addresses Annex IV Part A(f).	No	No	-
(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;	The LULUCFEG suggests that **Latvia checks the values submitted under Regulation 525/2013** and those presented in NFAP and provide a more extensive explanation for the differences observed.	Yes	No	*Overall consistency between the FRL and the national projections of anthropogenic greenhouse gas emissions is demonstrated in chapter 'Integrity with the national*

Art. 8(5) General principles for forest reference level (FRL)	LULUCFEG Conclusion	TI	AI	Response
				projections of anthropogenic GHG emissions by sources and removals by sinks reported under Regulation (EU) No. 525/2013', Figure 4 (page 15)
(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 LULUCFEG noted an inconsistency between the GHG Inventory and the FRL related to the **transition period for afforestation (20 years vs 30 years)** and suggests that Latvia ensures consistency. The LULUCFEG noted that necessary data for assessing the **overall consistency between the FRL and the GHG inventory** is not included in the NFAP. The LULUCFEG suggests Latvia explains how the consistency will be ensured.	Yes	Yes	*Transition period for land converted to forest land in the calculation is changed to 20 years to ensure consistency with the National GHG inventory report (chapter 'General description of the construction of Latvia's FRL', page 5; Table 2, page 6; chapter 'Forest reference level and detailed description of the development of the carbon pools', page 52). Overall consistency between the FRL and the GHG inventory is proved in chapter 'Consistency between the forest reference level and the latest national inventory report', Figure 5 (page 16).*
(a)-(e) All elements of the national forestry accounting plan relevant for setting the forest reference level summarised in one conclusion.	The LULUCFEG noted the following potential accuracy issue: - The LULUCFEG noted that the FRL includes policy assumptions. The LULUCFEG suggests Latvia revises the FRL values using the management practices as documented in the reference period. The LULUCFEG noted the following potential transparency issues: 1) Lack of **consistency between some tables and the text**, 2) Information on the impact of the change in **transition periods for afforestation from 20 to 30 years is not presented**, 3) Information provided for the estimation of the FRL on **increments, the age structure and harvesting rates on each stratum is not sufficient**, 4) Information on the assumptions on the	Yes	Yes	*Values in Table 1 and text in chapter 'General description of the construction of Latvia's FRL' (page 5) are harmonized. Transition period for land converted to forest land in the calculation is changed to 20 years to ensure consistency with the National GHG inventory report (chapter 'General description of the construction of Latvia's FRL', page 5; Table 2, page 6; chapter 'Forest reference level and detailed description of the development of the carbon pools', page 52). Number of strata in calculation is reduced to two – state owned and other forests. Detailed information on modelling assumptions is provided in Annex 3; assumptions on forest regeneration in the*

Art. 8(5) General principles for forest reference level (FRL)	LULUCFEG Conclusion	TI	AI	Response
	allocation of wood harvested per harvested wood product category is not provided. The LULUCFEG suggests that Latvia clarifies these issues and provide additional information.			*FRL scenario are provided in chapter 'Forest regeneration' (page 40); assumptions on thinning – in chapter 'Forest thinning' (page 43); assumptions on regenerative felling – in chapter 'Final felling' (page 48), assumptions on salvage logging – in chapter 'Salvage (sanitary) felling' (page 49). Historical and projected age structure of forests is provided in chapter 'Overall description of the forests and forest management in Latvia and the adopted national policies', Figure 8 and 9 (page 29). Allocation of wood harvested per harvested wood product category is provided Table 3 (page 18).*

Annex 3 Description of the AGM model

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TERMS AND DEFINITIONS

Listed below are terms and definitions which have been used when making the equations:

Tree	-	a perennial plant which usually forms one lignified trunk and a clearly defined crown.
The above- and below-ground part of the tree	-	Categorized according to the lined formed by the top layer of the soil/ground, the surface part consists of the lateral part of the tree and the crown, but the underground part of tree roots.
Trunk	-	The surface part of the main shoot with apical dominance. The trunk consists of a stump, stem (middle part) and top.
Height	-	The height of an individual tree from the base point to the tree top.
Circumference at breast height	-	The circumference of an individual tree 1.3 m above the base point.
Tree stand	-	A collection of trees within a forest stand.
Simple tree stand	-	A stand in which the trees are of similar height (the deviance does not exceed 20%).
Compound tree stand	-	A stand in which the trees are of two or more heights.
Pure stand	-	A stand in which the dominating tree species forms at least 95% of the stand.
Mixed stand	-	A stand in which the dominating tree species forms less than 95% of the stand.
Dominating tree species	-	A tree species which has the greatest wood stock (if the dominating species has a d≥10 cm or h≥12 m) or number of trees within the stand.
Dominating stand	-	Trees within the forest stand with the greatest wood stock and the height of which has a deviance of less than 10% from the average height of the group.
Forest stand	-	An area of forest with similar growing conditions, similar tree species and age structure which is different from the surrounding forest area.
Forest element	-	A collection of trees of the same species, generation, origin and development stage which interact in the same conditions in growth and development. Trees are of the same generation if their age differs by no more than 2 age groups. When modelling trees of the same species and height are considered a forest element.
Undergrowth	-	A collection of young trees under a stands older trees or in a clearing after the clearing of older trees which can later form a new stand and become a forestry object.
Kraft classes	-	Classification of trees to describe their social state: • class 1st – the tallest trees and trees with the greatest circumference with a well developed crown and the treetops of which rise above the crown of the surrounding trees; • Class II – form the main crown cover, the trunks are a little smaller than those of class 1st trees; • class III – the tree crowns are relatively less developed, less wide, placed in between class 1st and II tree crowns in the bottom part of the crown cover; • class IV – the crowns are smaller than those of class III trees. The treetops reach the bottom part of the crown cover. The trees noticeably fall behind class 1st – III trees. The trees are divided into 2 subclasses: IV a – trees with narrow, but consistent crowns and which reach into the crown cover; IV b subclass – the crown is on one side of the tree and the top does not reach the crown cover, and the bottom part of the crown is very shaded or dead; • class V – placed under the crown cover of the dominating stand. Trees with a small dying crown are classified as Va, but trees with a dead crown as class Vb.
Site index	-	A classification unit used to describe the productivity, of a forest stand, it is determined by the height of a tree at a certain age.
Biological or chronological age	-	Time from the sprouting of the seeds or blossoming of off-sping buds
Breast height age	-	The age of a forest element at 1.3 m from base point.
Site index at dominant height	-	A classification unit used to describe the productivity of a forest stand, determined by the dominant height of the dominating tree species at a certain

		age.
Density factor		The actual number of trees divided by a normal number of trees or the actual area of a basal divided by a normal basal area.
Density	-	The number of trees per ha
Stand of normal density	-	A stand with a basal area equal to a normal basal area
Square average diameter	-	The diameter at breast height of a tree with an average basal area.
Average diameter of the dominating stand	-	The square average diameter of the trees i the dominating stand.
Average height	-	A height of a forest element corresponding to the square average diameter according to the height curve.
Height of dominating stand	-	Tree height which corresponds to the square average diameter of the dominating trees.
Dominant height	-	A height which corresponds to the square average diameter of dominating trees.
Basal area	-	The sum (m^2) of the tree trunk basal areas at breast height (1.3 m from base point) of the trees in one hectare.
Wood stock	-	The volume of tree trunks of a forest element from stump to tree top. Can be determined with or without the bark of a tree.
Tree	-	a perennial plant which usually forms one lignified trunk and a clearly defined crown.
The above- and below-ground part of the tree	-	Categorized according to the lined formed by the top layer of the soil/ground, the surface part consists of the lateral part of the tree and the crown, but the underground part of tree roots.
Trunk	-	The surface part of the main shoot with apical dominance. The trunk consists of a stump, bole (middle part) and stem top.

ABBREVIATIONS

a_0	–	The biological age of a forest element, years
$a_{1.3}$	–	The age of a forest element at breast height, years
a_1	–	The age of a forest element at the height of 1.3 m in the beginning of the actualization period, years
a_2	–	The age of a forest element at the height of 1.3 m at the end of the actualisation period, years
Δa	–	The age difference between stump height and at 1.3 m (a_0-$a_{1.3}$), years
B	–	Orlov's site index
d_{ij}	–	average diameter of individual 1st floor trees at the height of 1.3 m , cm
d	–	average diameter of forest elements at the height of 1.3 m, cm
d_1	–	average diameter of forest elements at the height of 1.3 m in the beginning of actualization
d_2	–	average diameter of forest elements at the height if 1.3 m at the end of the actualization period, cm
g	–	basal area of a forest element, m^2ha^{-1}
G	–	basal area of a forest stand, m^2ha^{-1}
g_1	–	basal area of a forest element in the beginning of actualization period, m^2ha^{-1}
g_2	–	basal area of a forest stand at the end of actualization period, m^2ha^{-1}
$g`_2$	–	estimated basal area of an individual tree at the end of actualization period, m^2ha^{-1}
GL	–	sum of basal areas of forest elements which are the same or greater than the chosen forest element (if a forest element of the 1st floor, then a basal of the 1st floor, if a forest element of the II floor, then a sum of the basal areas of both the 1st and II floors) in the beginning of actualization period, m^2ha^{-1};
g_{max}	–	The greatest possible basal area of a forest element, m^2ha^{-1}
G_{max}	–	The greatest possible basal area of 1st storey, m^2ha^{-1}
g_{norm}	–	Normal basal of a forest element, m^2ha^{-1}
G_{norm}	–	Normal basal area of trees of 1st storey, m^2ha^{-1}
h	–	Average height of forest element, m
h_1	–	Average height of forest element in the beginning of actualization, m
h_2	–	Average height of forest element at the end of actualization, m
h_{dom}	–	Dominant height of forest element, m
h_{dom1}	–	Dominant height of forest element in the beginning of actualization, m
h_{dom2}	–	Dominant height of forest element at the end of actualization, m
$h_{20,50,100}$	–	Estimated height of forest element at a particular age at breast height (20, 50 or 100 years), m
k_{ij}	–	Composition coefficient of individual 1st storey forest element
m	–	Wood stock of a forest element, m^3ha^{-1}
M	–	Wood stock of a forest stand, m^3ha^{-1}
m_1	–	Wood stock of a forest element in the beginning of actualization period, m^3ha^{-1}
m_2	–	Wood stock of a forest element at the end of actualization period, m^3ha^{-1}
n	–	Number of trees in a forest element, ha^{-1}
N	–	Number of 1st floor trees in a forest stand, ha^{-1}
n_1	–	Number of trees in a forest element in the beginning of actualization period, ha^{-1}
n_2	–	Number of trees in a forest element at the end of actualization period, ha^{-1}
n_{max}	–	highest possible number of 1st floor trees in a forest element, ha^{-1}
N_{max}	–	highest possible number of 1st floor trees in a forest stand, ha^{-1}
RB	–	Relative density of 1st floor trees in a forest stand
SI	–	Site index of 100 highest trees in a forest stand, m
t	–	Duration of actualization period, years

BASIC PRINCIPLES APPLIED IN THE MODEL

This LVMI Silava forest research long-term prognosis model is developed as a simulation model.

In forest research modelling data from the National Forest inventory (NFI) database was used, but it is possible to use data from the State Forest Service (SFS) registry by changing the format according to the NFI data.

Changes to the forest stand in the programme are modelled on a forest element level where a collection of individuals of the same species, generation and level are considered a forest element. Changes in forest resources are modelled in five year periods.

The process of existing tree stand modelling is deterministic, but renewing and harvesting are stochastic processes. In modelling the growing process of tree stands growing process models developed by LVMI Silava were used (Donis et al, 2017).

The default forest resource long term prognosis model works according to current (last 5 years) management practice, but users are able to set a variety of management scenarios.

Changes in forest resources are modelled according to current forest management practice in the default setting, but it is possible to set a variety of management scenarios.

The process of forest resource prognosis consists of three stages:

1. creating a data table suitable for modelling;
2. defining a management scenario and criteria of suitable sectors;
3. modelling changes in forest resources for n periods in the future.

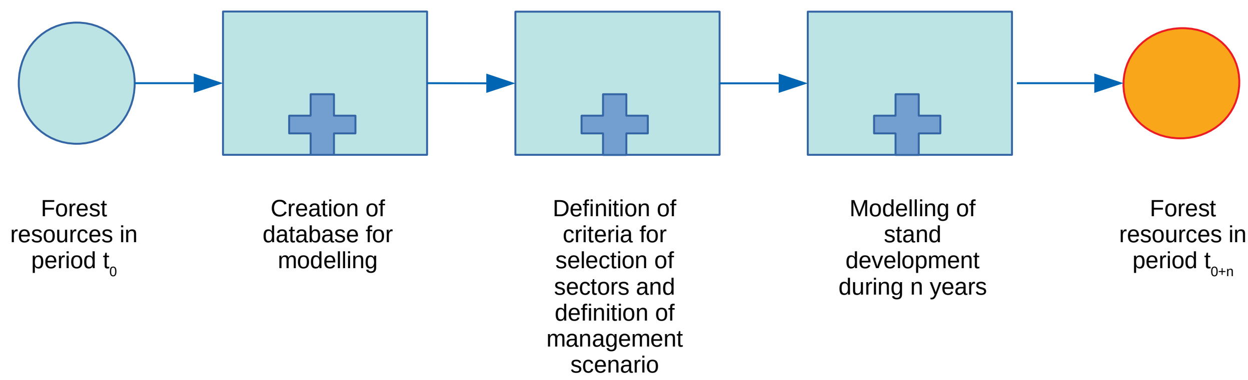

Figure 1: Scheme of the LVMI Silava changes in forest resources projections process based on NFI data.

DEVELOPING A DATABASE FOR MODELLING FOREST RESOURCES

A table suitable for modelling forest resources has been created from the NFI database and is updated every year. The table includes information about all sectors measured in the last five years. It includes relevant information about the sector (BIG FINAL) and information about some forest elements (if the sector has such elements) which sourced from the tree database or young forest stand inventory data. The data table used for modelling the forest stand is also regularly updated with the information available on economic activities happening after taking measurements of the sampling plot (Figure 2).

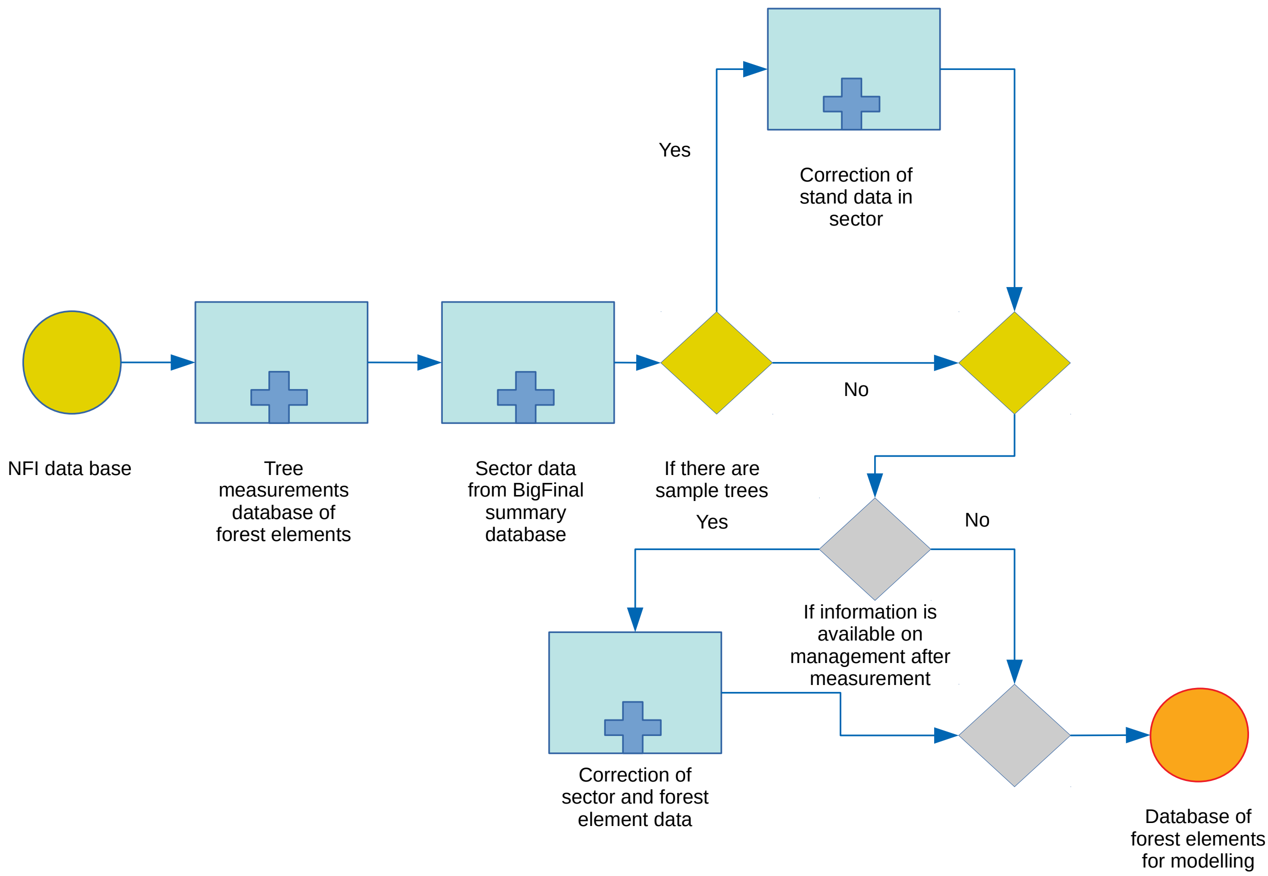

Figure 2: Scheme of developing the data table.

A data table (Table 1) is created for modelling forest resources which allows the user to add additional fields required for modelling by defining various management scenarios.

Table 1: Structure of the input data table[16]

Column name	Description	Unit of measurement
ID	Automatically generated number	
IbIPLID	Identifier of sampling plot	
SEKTNR	Name of sector	

[16] Orange fields are taken from the NFI database and the rest are calculated.

Column name	Description	Unit of measurement
IblSektID	IblPLID & SektNr	
DATUMS	PL date of measurement	dd.mm.yyyy
RAJONS	Regional code	
IPASUM	Property code according to NFI classification	
IEROB	Restriction code of economic activities from the NFI database	
AGM_CIKLA_GARUMS	Defined duration of one cycle (used in the second and all further iterations) which currently cannot exceed 5 years	years
AGM_CIKLS	*Iteration cycle of growing modelling (0 – measured data, 1 – calculated data for current year, 2 – 1/2 of defined cycle, 3 and more cycles). Should generate automatically.*	
ZEM_KAT	Land category according to NFI classification	
IZCELSM	Source code of the forest stand according to NFI classification	
MEZ_TIP	Forest type code	
PLATIBA	Land area of sector	m^2
VALD_IP	Coefficient of the content of dominating tree species in the sector	
VALD_SU	Code of the dominating tree species in the sector according to NFI classification	
VALD_VEC	Age of dominating tree species in the sector listed in the NFI database	years
VALD_VEC_0	Biological age of the dominating tree species in the sector	years
VALD_VEC_13	Age at breast height of the dominating tree species in the sector	years
VALD_BONIT	Site index of the dominating species (code 0.1.2.3.4.5.6)	
VALD_D_VID	Square average diameter of the dominating species at breast height	cm
VALD_H_VID	Height of a tree corresponding to the square average diameter at breast height of the dominating tree species	m
VALD_H_DOM	Average height of the 100 highest trees of the dominating species in the sector	m
VALD_G	basal area of the dominating tree species in the sector	m^2ha^{-1}
VALD_M	Wood stock of the dominating tree species in the sector	m^3ha^{-1}
VALD_N	Number of trees of the dominating tree species in the sector	ha^{-1}
G_KOP	Total basal area in the sector	m^2ha^{-1}
G_1_ST	basal area of the 1. storey of the sector	m^2ha^{-1}
G_2_ST	basal area of the 2. storey of the sector	m^2ha^{-1}
G_3_ST	basal area of the 3. storey of the sector	m^2ha^{-1}
M_KOP	Total wood stock in the forest stand in the sector	m^3ha^{-1}
M_1_ST	Wood stock in the 1. storey of the forest stand in the sector	m^3ha^{-1}
M_2_ST	Wood stock in the 2. storey of the forest stand in the sector	m^3ha^{-1}
M_3_ST	Wood stock in the 3. storey of the forest stand in the sector	m^3ha^{-1}
N_KOP	Total number of trees in the forest stand in the sector	ha^{-1}
N_1_ST	Number of trees in 1. storey of the forest stand in the sector	ha^{-1}
N_2_ST	Number of trees in 2. storey of the forest stand in the sector	ha^{-1}
N_3_ST	Number of trees in 3. storey of the forest stand in the sector	ha^{-1}

Column name	Description	Unit of measurement
N_MAX	Highest possible number of trees in the 1st storey of the forest stand in the sector	ha^{-1}
RB	Relative density of the 1st storey of the forest stand	
ELEM_IP	Content of forest elements	
ELEM_SU	Tree species code of the forest element according to NFI classification	
ELEM_ST	storey of the forest element	
ELEM_EKO	Generation of the forest element (if the ecological trees – 6, if charcteristic tree – 9, in other cases 1)	
ELEM_VEC	Age of the forest element listed in the NFI database	years
ELEM_VEC_0	Biological age of the forest element	years
ELEM_VEC_13	Age at breast height of the forest element	years
ELEM_BONIT	Site index of the forest element ((code 0.1.2.3.4.5.6)	
ELEM_D_VID	Square average diameter at breast height of the forest element	cm
ELEM_H_VID	Tree height corresponding to the square average diameter at breast height of the forest element	m
ELEM_H_DOM	Dominant height of the forest element	m
ELEM_G	Basal area of the forest element	m^2ha^{-1}
ELEM_M	Wood stock of the forest element	m^3ha^{-1}
ELEM_N	Number of trees in the forest element	ha^{-1}
ELEM_N_MAX	Theoretically possible highest number of trees in the forest element	ha^{-1}

Creating a table suitable for the modelling of forest stands consists of four stages (Figure 3):

- input of basic data on the forest element;
- input of descriptive information on the sector;
- calculations of the forest element data needed for modelling;
- calculations of the forest stand data needed for modelling.

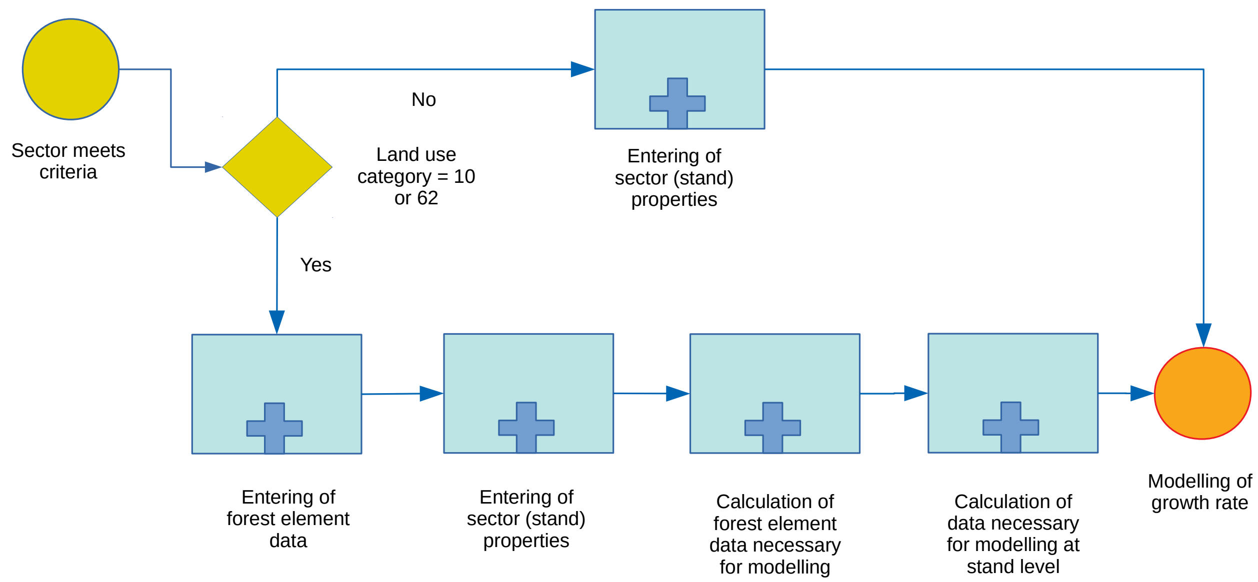

Figure 3: Data selection, input and calculations of forest element and forest stand data needed for the modelling of the growing process.

Input of basic taxation data of individual forest elements

There are several indicators NFI provides for the taxation of forest elements (Figure 4):

- tree species according to NFI classification;
- storey (1 – 3);
- generation (if the ecological trees – 6, if (characteristic tree) – 9, in other cases 1 or 2);
- age provided in the NFI database (1 – 500 years);
- square average diameter at breast height (0.1 – 100.0 cm);
- tree height corresponding with the square average diameter at breast height (0.1 – 45.0 m)
- number of trees (1 – 10 000 trees ha^{-1}).

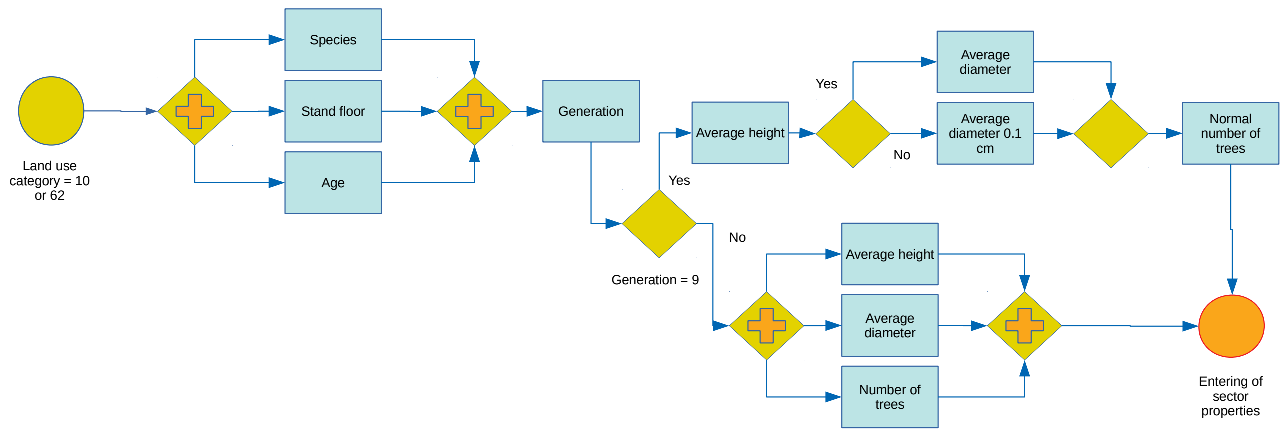

Figure 4: Scheme of data input for the taxation of individual forest element.

Input of NFI descriptive information of the sector

Descriptive information is selected from the NFI database and added for each forest element in the NFI sector

- identifier of the sampling plot;
- sector number;
- date of measuring the sampling plot;
- region code;
- property code according to NFI classification;
- forest type code;
- area of sector.

Calculations of taxation indicators for individual forest elements

A scheme of the taxation indicator calculations necessary for the modelling of growing processes of individual forest elements is shown in Figure 5.

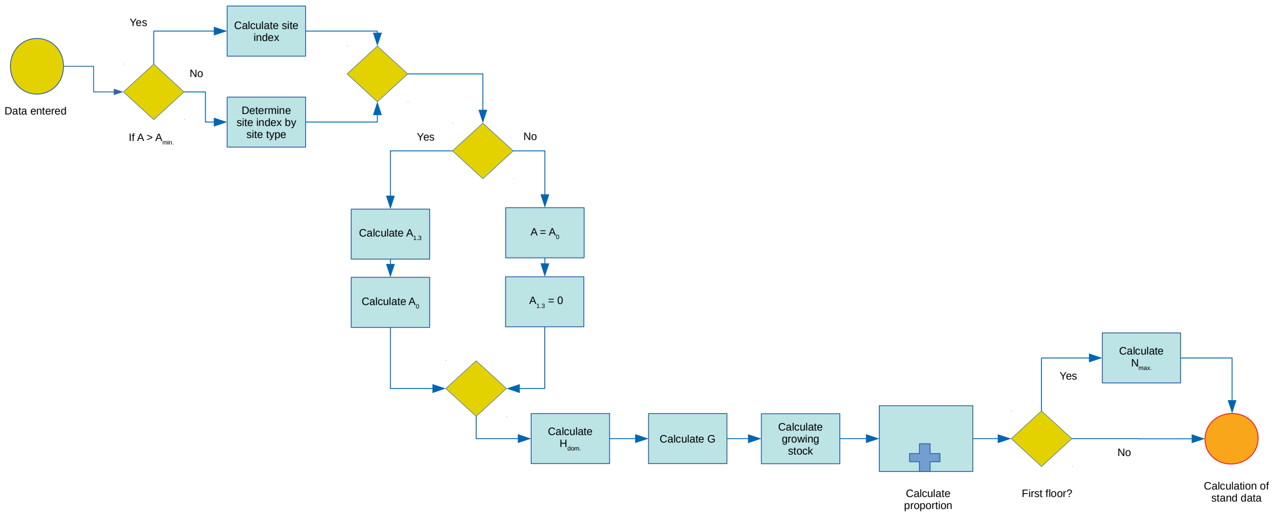

Figure 5: Scheme of the taxation data calculations necessary for the modelling of individual forest element growing

Site index of forest elements

The following equation was used in calculating the site index for every forest element:

$$B=\frac{h-(\alpha_1+\alpha_2*\ln(a_0)+\alpha_3*\ln(a_0)^2+\alpha_4*\ln(a_0)^3)}{\beta_1+\beta_2*\ln(a_0)+\beta_3*\ln(a_0)^2+\beta_4*\ln(a_0)^3}\ where \quad (1)$$

a_0 – biological age of forest element (in iteration 0 the age indicated by NFI, in further iterations the calculated biological age), years;
h – *average age of the forest element, m;*
$\alpha_i; \beta_i$ – *coefficients.*

The values obtained with the first equation are rounded to whole numbers, if the resulting site index value is negative, it is replaced with a 0, if the site index value is greater than 6, it is replaced with a site index of 6.

The equations are used for:

- high forest stands with an average age of 21 – 160 years:
    - *pine, spruce, oak, ash, lapel, other pines, other spruces, elm, beech, hornbeam, fir, maple, juniper;*
- coppice (except grey alder group) stands with an average age of 11 – 100 years:
    - *birch, alder, aspen, linden, poplar, goat willow, cherry, rowan;*
- grey alder and willow stands with an average age of 6 – 100 years:
    - *grey alder, willow, osier, buckthorn, alder buckthorn, hazels, bird cherries, hawthorn, crab apples, broad-leaved trees, unknown species;*

If the age of the dominating species is over the limit the highest limit value is used in calculations.

Table 2: Coefficient values for site index calculations of tree stands (Formula 1)

Tree species	Species code	α_1	α_2	α_3	α_4	β_1	β_2	β_3	β_4	A_{min}	A_{max}
Pine	1	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Spruce	3	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Birch	4	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Alder	6	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Aspen	8	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Grey alder	9	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Oak	10	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Ash	11	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Linden	12	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Larch	13	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Other pines	14	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Other spruces	15	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Elm	16	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Beech	17	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Hornbeam	18	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Poplar	19	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Willow	20	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Goat Willow	21	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Fir	23	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Maple	24	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Osier	30	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Juniper	31	70.64	−66.567	20.659	−1.7359	−2.02	2.294	−0.995	0.0897	21	160
Rowan	32	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100

Tree species	Species code	α_1	α_2	α_3	α_4	β_1	β_2	β_3	β_4	A_{min}	A_{max}
Alder Buckthorn	33	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Hazel	34	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Bird cherry	35	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Hawthorn	41	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Crab apple	51	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Broad leaved trees	53	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Unknown species	54	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100
Cherry	56	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	11	100
Buckthorn	57	29.38	−33.38	13.138	−1.2396	−5.264	5.855	−2.263	0.231	6	100

If the forest element is younger than the minimal limit, the site index is calculated according to the forest type (Table 3).

Table 3: Site index depending on the forest type and tree species

Tree species	Code	Forest type																						
		Sl (1)	Mr (2)	Ln (3)	Dm (4)	Vr (5)	Gr (6)	Gs (7)	Mrs (8)	Dms (9)	Vrs (10)	Grs (11)	Pv (12)	Nd (14)	Db (15)	Lk (16)	Av (17)	Am (18)	As (19)	Ap (21)	Kv (22)	Km (23)	Ks (24)	Kp (25)
Pine	1	4	3	2	1	1	1	5	4	3	2	2	5	4	3	2	4	3	2	1	3	2	1	1
Spruce	3	5	4	3	2	1	1	5	5	4	3	2	5	4	3	2	5	3	2	1	3	3	2	1
Birch	4	4	3	2	2	1	1	5	3	2	1	2	5	4	3	2	4	3	2	1	3	2	1	1
Alder	6	4	3	2	2	2	2	5	3	2	2	2	5	3	2	1	4	3	2	1	3	2	2	1
Aspen	8	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Grey alder	9	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Oak	10	5	4	3	3	2	2	5	5	3	2	2	5	4	3	2	5	3	3	2	3	3	3	2
Ash	11	4	3	2	2	2	1	5	3	2	2	1	5	4	2	1	4	3	2	1	3	2	2	1
Linden	12	4	3	2	2	1	1	5	3	2	1	2	5	4	3	2	4	3	2	1	3	2	1	1
Larch	13	4	3	2	1	1	1	5	4	3	2	2	5	4	3	2	4	3	2	1	3	2	1	1
Other pines	14	4	3	2	1	1	1	5	4	3	2	2	5	4	3	2	4	3	2	1	3	2	1	1
Other spruces	15	5	4	3	2	1	1	5	5	4	3	2	5	4	3	2	5	3	2	1	3	3	2	1
Elm	16	4	3	2	2	2	1	5	3	2	2	1	5	4	2	1	4	3	2	1	3	2	2	1
Beech	17	4	3	2	2	2	1	5	3	2	2	1	5	4	2	1	4	3	2	1	3	2	2	1
Hornbeam	18	4	3	2	2	2	1	5	3	2	2	1	5	4	2	1	4	3	2	1	3	2	2	1
Poplar	19	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Willow	20	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Goat willow	21	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Fir	23	5	4	3	2	1	1	5	5	4	3	2	5	4	3	2	5	3	2	1	3	3	2	1
Maple	24	4	3	2	2	2	1	5	3	2	2	1	5	4	2	1	4	3	2	1	3	2	2	1
Osier	30	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1

Tree species	Code	Forest type																						
		Sl (1)	Mr (2)	Ln (3)	Dm (4)	Vr (5)	Gr (6)	Gs (7)	Mrs (8)	Dms (9)	Vrs (10)	Grs (11)	Pv (12)	Nd (14)	Db (15)	Lk (16)	Av (17)	Am (18)	As (19)	Ap (21)	Kv (22)	Km (23)	Ks (24)	Kp (25)
Juniper	31	5	4	3	2	1	1	5	5	4	3	2	5	4	3	2	5	3	2	1	3	3	2	1
Rowan	32	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Alder buckthorn	33	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Hazel	34	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Bird cherry	35	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Hawthorn	41	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Crab apple	51	4	3	2	2	1	1	5	3	2	1	2	5	4	2	1	4	3	2	1	3	2	1	1
Broad leaved trees	53	4	3	2	2	1	1	5	3	2	1	2	5	4	3	2	4	3	2	1	3	2	1	1
Unknown species	54	4	3	2	2	1	1	5	3	2	1	2	5	4	3	2	4	3	2	1	3	2	1	1
Cherry	56	4	3	2	2	1	1	5	3	2	1	2	5	4	3	2	4	3	2	1	3	2	1	1
Buckthorn	57	4	3	2	2	1	1	5	3	2	1	2	5	4	3	2	4	3	2	1	3	2	1	1

Biological and breast height age of a forest element

If the forest *element* is *taller than 1.3 m*

If the average height is greater than 1.3 m, the age at breast height is calculated by subtracting a number specific to the tree species:

$$a_{1.3} = a - \Delta a_0, where \tag{2}$$

$a_{1.3}$ – Age of the forest element at chest height, years;
a – Age of forest element listed in the NFI database, years;
Δa_0 – Difference between biological and chest height age given in the NFI database, years.

Table 4: Age difference between biological and breast height age given in the NFI database (formula 2)

Tree species	Tree species code	Δa_0
Pine	1	7
Spruce	3	7
Birch	4	3
Alder	6	3
Aspen	8	2
Grey alder	9	2
Oak	10	5
Ash	11	3
Linden	12	3
Larch	13	7
Other pines	14	7
Other spruces	15	7
Elm	16	5
Beech	17	2
Hornbeam	18	2
Poplar	19	2
Willow	20	2
Goat willow	21	2
Fir	23	7
Maple	24	3
Osier	30	2
Juniper	31	7
Rowan	32	2
Alder buckthorn	33	2
Hazel	34	2
Bird cherry	35	2
Hawthorn	41	2
Crab apple	51	2

Tree species	Tree species code	Δa_0
Broad leaved trees	53	2
Unknown species	54	2
Cherry	56	2
Buckthorn	57	2

To calculate the biological age, a number specific to the tree species and site index is added to the calculated age at breast height:

$$a_0 = a_{1.3} + \Delta a, where \quad (3)$$

a_0 – Biological age of the forest element, years;
$a_{1.3}$ – Age at chest height of the forest element, years;
Δa – Biological and age at chest height difference for the tree species and site quality, years.

Table 5: Biological and breast high age difference for the tree species and site index (for use in formula 3)

Tree species	Tree species code	Site index						
		0	1	2	3	4	5	6
Pine	1	4	5	7	9	12	17	22
Spruce	3	6	8	10	12	14	18	22
Birch	4	3	3	4	4	5	5	5
Alder	6	3	3	4	4	5	5	5
Aspen	8	2	2	2	2	2	2	2
Grey alder	9	2	2	2	2	2	2	2
Oak	10							
Ash	11							
Linden	12	3	3	4	4	5	5	5
Larch	13	4	5	7	9	12	17	22
Other pines	14	4	5	7	9	12	17	22
Other spruces	15	6	8	10	12	14	18	22
Elm	16							
Beech	17							
Hornbeam	18							
Poplar	19	2	2	2	2	2	2	2
Willow	20	2	2	2	2	2	2	2
Goat willow	21	2	2	2	2	2	2	2
Fir	23	6	8	10-	12	14	18	22
Maple	24	3	3	4	4	5	5	5
Osier	30	2	2	2	2	2	2	2
Juniper	31	6	8	10	12	14	18	22
Rowan	32	3	3	4	4	5	5	5
Alder buckthorn	33	2	2	2	2	2	2	2

Tree species	Tree species code	Site index						
		0	1	2	3	4	5	6
Hazel	34	2	2	2	2	2	2	2
Bird cherry	35	2	2	2	2	2	2	2
Hawthorn	41	3	3	4	4	5	5	5
Crab apple	51	3	3	4	4	5	5	5
Broad leaved trees	53	3	3	4	4	5	5	5
Unknown species	54	3	3	4	4	5	5	5
Cherry	56	3	3	4	4	5	5	5
Buckthorn	57	3	3	4	4	5	5	5

If the forest element height is below 1.3 m

The biological age for forest elements with a height up to 1.3 m is already listed in the NFI database, therefore for column _VEC_0 the values are equal with value in column _VEC_, however the age at breast height (_VEC_13) is 0 for these elements.

Dominant height of the forest element

To calculate the dominant height of the dominating tree species of an individual forest element of the sector he following equation is used:

$$h_{dom} = \left(\frac{h}{\alpha_1 * n^{\alpha_3}} \right)^{\left[\frac{1}{\alpha_2}\right]} where \quad (4)$$

h_{dom} – Dominant height of the forest element, m;
h – Average height of the forest element, m;
n – Number of trees in the forest element, ha^{-1};
α_{1-3} – *Coefficients* (*Table* 2.3.5).

If the number of trees in the forest element is below 120 per ha, the dominant height is equal to the average height.

Table 6: Coefficient values corresponding between the average height and dominant height of the forest element (formula 4)

Tree species	Tree species code	α_1	α_2	α_3
Pine	1	1.0935	1.0279	−0.0395
Spruce	3	1.1756	1.0285	−0.0558
Birch	4	1.1962	1.0242	−0.0553
Alder	6	1.1590	1.0100	−0.0390
Aspen	8	1.0446	1.0438	−0.0408
Grey alder	9	1.1684	1.0107	−0.0410
Oak	10	1.0935	1.0279	−0.0395
Ash	11	1.1756	1.0285	−0.0558
Linden	12	1.1962	1.0242	−0.0553
Larch	13	1.0935	1.0279	−0.0395
Other pines	14	1.0935	1.0279	−0.0395

Tree species	Tree species code	α_1	α_2	α_3
Other spruces	15	1.1756	1.0285	−0.0558
Elm	16	1.1962	1.0242	−0.0553
Beech	17	1.1756	1.0285	−0.0558
Hornbeam	18	1.1684	1.0107	−0.0410
Poplar	19	1.0446	1.0438	−0.0408
Willow	20	1.0446	1.0438	−0.0408
Goat willow	21	1.0446	1.0438	−0.0408
Fir	23	1.1756	1.0285	−0.0558
Maple	24	1.1962	1.0242	−0.0553
Osier	30	1.1684	1.0107	−0.0410
Juniper	31	1.1756	1.0285	−0.0558
Rowan	32	1.1684	1.0107	−0.0410
Alder buckthorn	33	1.1684	1.0107	−0.0410
Hazel	34	1.1684	1.0107	−0.0410
Bird cherry	35	1.1684	1.0107	−0.0410
Hawthorn	41	1.1684	1.0107	−0.0410
Crab apple	51	1.1684	1.0107	−0.0410
Broad leaved trees	53	1.1962	1.0242	−0.0553
Unknown species	54	1.1962	1.0242	−0.0553
Cherry	56	1.1962	1.0242	−0.0553
Buckthorn	57	1.1962	1.0242	−0.0553

basal are of forest elements

The forest element basal area if the height is below 1.3 m is 0 m^2ha^{-1}, but if the average height is greater than 1.3 m the basal area is determined by the number of trees and the average diameter:

$$g = \frac{pi() * d^2 * n}{40000} \quad (5)$$

g – cross-section area of the forest element, $m^2 ha^{-1}$;
d – average diameter a chest height of the forest element, cm;
n – number of trees in the forest element, ha^{-1}.

Wood stock of a forest element

To determine the wood stock of a forest element the I. Liepa formula (Liepa, 1996) for individual tree volume is used as well as the number of trees, the average height and square average diameter:

$$m=\psi*h^{\alpha}*d^{\beta*\log10(h)+\varphi}*n, where \quad (6)$$

m – Wood stock of the forest element, $m^3 ha^{-1}$;
h – Average height of the forest element, m;
d – Average diameter at chest height of the forest element, cm;
n – Number of trees in the forest element, ha^{-1};
$\psi; \alpha; \beta; \phi$ – Coefficients.

Table 7: Coefficients for determining the wood stock of a forest element (formula 6)

Tree species	Tree species code	ψ	α	β	ϕ
Pine	1	0.00016 541	0.56582	0.25924	1.59689
Spruce	3	0.00023 106	0.78193	0.34175	1.18811
Birch	4	0.00009 090	0.71677	0.16692	1.75701
Alder	6	0.00007 950	0.77095	0.13505	1.80715
Aspen	8	0.00005 020	0.92625	0.02221	1.95538
Grey alder	9	0.00007 450	0.81295	0.06935	1.85346
Oak	10	0.00013 818	0.56512	0.14732	1.81336
Ash	11	0.00008 530	0.73077	0.06820	1.91124
Linden	12	0.00009 090	0.71677	0.16692	1.75701
Larch	13	0.00023 106	0.78193	0.34175	1.18811
Other pines	14	0.00016 541	0.56582	0.25924	1.59689
Other spruces	15	0.00023 106	0.78193	0.34175	1.18811
Elm	16	0.00008 530	0.73077	0.06820	1.91124
Beech	17	0.00013 818	0.56512	0.14732	1.81336
Hornbeam	18	0.00013 818	0.56512	0.14732	1.81336
Poplar	19	0.00005 020	0.92625	0.02221	1.95538
Willow	20	0.00005 020	0.92625	0.02221	1.95538
Goat willow	21	0.00005 020	0.92625	0.02221	1.95538
Fir	23	0.00023 106	0.78193	0.34175	1.18811
Maple	24	0.00009 090	0.71677	0.16692	1.75701
Osier	30	0.00007 450	0.81295	0.06935	1.85346
Juniper	31	0.00023 106	0.78193	0.34175	1.18811
Rowan	32	0.00007 450	0.81295	0.06935	1.85346
Alder buckthorn	33	0.00007 450	0.81295	0.06935	1.85346
Hazel	34	0.00007 450	0.81295	0.06935	1.85346
Bird cherry	35	0.00007 450	0.81295	0.06935	1.85346
Hawthorn	41	0.00007 450	0.81295	0.06935	1.85346
Crab apple	51	0.00007 450	0.81295	0.06935	1.85346
Broad leaved trees	53	0.00007 450	0.81295	0.06935	1.85346
Unknown species	54	0.00007 450	0.81295	0.06935	1.85346
Cherry	56	0.00009 090	0.71677	0.16692	1.75701
Buckthorn	57	0.00009 090	0.71677	0.16692	1.75701

Proportion of a forest element

The proportion of the forest element is calculated separately for each storey.

For the 1st and 2nd storey of the tree stand of the forest element the proportion is calculated by either wood stock or number of trees.

If the smallest forest element of the storey in the tree stand has an average diameter of at least 9.5 cm or the smallest forest element has an average height of at least 11.5 m the proportion is calculated by wood stock:

$$ip = \frac{m}{M}, where \tag{7}$$

ip – Proportion of the forest element;
m – Wood stock of forest element, $m^3 ha^{-1}$;
M – Current total wood stock of the forest element in the story, $m^3 ha^{-1}$.

If the average diameter of the tree stand storey smallest element is less than 9.5 cm and the average height of the smallest forest element is less than 11.5 m then the proportion is calculated by number of trees:

$$ip = \frac{n}{N} \tag{8}$$

ip – Proportion of the forest element;
n – Number of trees in the forest element, ha^{-1};
N – Current total number of trees in the forest element in the story, ha^{-1}.

The proportion of the forest element in the 3rd storey of the tree stand is calculated by the number of trees regardless of the average diameter of the storey.

Maximum number of trees in the forest element

The maximum number of trees in the forest element is calculated only for forest elements on the 1st storey.

To calculate the maximum number of trees for individual forest elements of the 1st storey the following formula is used:

$$n_{max} = \alpha_1 * d^{\alpha_1} * h^{\alpha_1} * ip, where \tag{9}$$

n_{max} – Maximum number of trees in forest element, ha^{-1};
h – Average height of forest element, m;
ip – Content of the forest element;
α_{1-3} – Coefficients.

Table 8: Coefficient values for the calculation of maximum number of trees in the forest element (to use in formula 9)

Tree species	Tree species code	α_1	α_2	α_3
Pine	1	83 570	−1.366	−0.069
Spruce	3	103 106	−1.381	−0.103
Birch	4	144 400	−1.357	−0.302
Alder	6	197 511	−1.314	−0.339
Aspen	8	197 511	−1.314	−0.339

Tree species	Tree species code	α_1	α_2	α_3
Grey alder	9	197 511	−1.314	−0.339
Oak	10	83 570	−1.366	−0.069
Ash	11	103 106	−1.381	−0.103
Linden	12	144 400	−1.357	−0.302
Larch	13	103 106	−1.381	−0.103
Other pines	14	83 570	−1.366	−0.069
Other spruces	15	103 106	−1.381	−0.103
Elm	16	144 400	−1.357	−0.302
Beech	17	103 106	−1.381	−0.103
Hornbeam	18	197 511	−1.314	−0.339
Poplar	19	197 511	−1.314	−0.339
Willow	20	197 511	−1.314	−0.339
Goat willow	21	197 511	−1.314	−0.339
Fir	23	103 106	−1.381	−0.103
Maple	24	144 400	−1.357	−0.302
Osier	30	197 511	−1.314	−0.339
Juniper	31	103 106	−1.381	−0.103
Rowan	32	197 511	−1.314	−0.339
Alder buckthorn	33	197 511	−1.314	−0.339
Hazel	34	197 511	−1.314	−0.339
Bird cherry	35	197 511	−1.314	−0.339
Hawthorn	41	197 511	−1.314	−0.339
Crab apple	51	197 511	−1.314	−0.339
Broad leaved trees	53	144 400	−1.357	−0.302
Unknown species	54	144 400	−1.357	−0.302
Cherry	56	144 400	−1.357	−0.302
Buckthorn	57	144 400	−1.357	−0.302

Calculating taxation indicators of tree stands

Dominating forest element

The dominating forest element is determined separately for each storey. The forest element with the greatest content is considered the dominating one. If the content of the forest elements is equal the one with the lowest tree species code according to NFI classification is considered to be the dominating one.

Taxation indicators of the dominating tree species

To each forest element the following are added:

- ✓ Taxation indicators for the 1st storey dominating forest element:
    - content;

- tree species code;
- biological age;
- age at breast height;
- site index;
- average diameter;
- average height;
- dominant height;
- basal area;
- number of trees;
- wood stock;

✓ Taxation indicators for the 2^{nd} storey dominating forest element:

- tree species code;
- average diameter;
- average height;
- basal area;
- number of trees;
- wood stock.

Taxation indicators of a tree stand

The basal area, wood stock and number of trees of all forest elements of the 1^{st} storey is summed for each storey of the tree stand.

Total basal area, wood stock and number of trees is also calculated for the whole tree stand as a sum of the corresponding taxation indicators of all three storeys.

Relative density of the 1^{st} storey of the tree stand

The relative density of the 1^{st} storey of the tree stand can be calculated as division of the number of trees in the 1st storey and the calculated highest possible number of trees:

$$RB = \frac{N}{N_{max}}, where \tag{10}$$

RB – Relative density of the I storey of the tree stand;
N – Number of trees in the I storey of the tree stand, ha^{-1};
N_{max} – Highest possible number of trees in the I story of the tree stand, ha^{-1}.

The highest possible number of trees in the tree stand is the sum of the maximum number of trees in all the forest elements of the 1st storey.

Correction of the NFI descriptive information on forest elements and sectors

The information in the NFI table on sectors in which (characteristic trees) were measured is replaced with the information in the NFI table on young forest stands: dominating species in the tree stand, number of trees, average diameter, average height. The information on species content is modelled similarly to planning forest regeneration (chapter 'Forest regeneration')

The information on the sector is corrected if information on economic activity after measuring the sampling plot (final felling, thinning etc.), is available.

- if there has been a clear felling or a sanitary felling after measuring the sampling plot, the sector is modelled as a clearing,
- if a selective felling is done, the sector is considered a young tree stand up to date on regulations. (chapter 'Selective felling'),
- if after measuring the sampling plot thinning or selective sanitary felling is performed the basal area of the 1st storey of the tree stand is considered to be 2 units above the regulations' lower limit and the other taxation indicators are calculated accordingly with the method for treatment felling (chapter 'Thinning').

DEFINING A MANAGEMENT SCENARIO

Forest regeneration

The users are able to define tree species suitable for forest regeneration and growing so that the forest stand is considered regenerated. In the default setting these criteria are defined accordingly with current regulations (Cabinet of Ministers of Republic of Latvia, 2012; Table 9).

Table 9: Tree species suitable for forest regeneration and their respective minimal number of trees in a tree stand for the forest stand to be considered regenerated

Tree species	Tree species code	Min number of trees
Pine	1	3000
Spruce	3	2000
Birch	4	2000
Alder	6	2000
Aspen	8	2000
Grey alder	9	2000
Oak	10	1500
Ash	11	1500
Linden	12	2000
Larch	13	2000
Elm	16	1500
Beech	17	1500
Hornbeam	18	1500
Poplar	19	2000
Willow	20	2000
Goat willow	21	2000
Fir	23	2000
Maple	24	1500
Rowan	32	2000
Cherry	56	2000

Proportion of anthropogenically regenerated area depends from type and owner (state and other forests). The default setting models the probability of regenerated clearings sorting by property groups (state and other forests) accordingly with the arithmetic average proportion of anthropogenically regenerated forest stands in 2013-2016[17] (Table 10).

The default setting allows for pine, spruce, birch, alder and oak to be planted after felling, but the user can define other tree species. Every tree species option is modelled sorting by property group (state and other) and forest type accordingly with the

[17] SFS statistikas CD 2013-2016 (Forestry statistics CD 2013-2016).

arithmetic average proportion of anthropogenically regenerated forest stands in 2013-2016 (Table 11).

Table 10: Probability of anthropogenically regenerated forests by forest type[18]

Forest type	Other forests	State forests
Cladinoso-callunosa	0.4789	0.6626
Cladinosa-callunosa	0.6801	0.6877
Vaccinosa	0.5767	0.8321
Myrtillosa	0.2108	0.7869
Hylocomiosa	0.1197	0.3943
Oxalidosa	0.0750	0.1385
Aegipodiosa	0.0000	1.0000
Callunoso-sphagnosa	0.4297	0.7622
Vaccinioso-sphagnosa	0.1599	0.4593
Myrtilloso-sphagnosa	0.0783	0.1477
Myrtillosoi-polytrichosa	0.0851	0.0435
Drypteriosa	0.0230	0.0675
Sphagnosa	0.0347	0.0928
Caricoso-phragmitosa	0.0827	0.0452
Dryopterioso-caricosa	0.0232	0.0508
Filipendulosa	1.0000	0.9642
Callunosa mel.	0.6729	0.9349
Vacciniosa mel.	0.2643	0.7151
Myrtillosa mel.	0.0884	0.2016
Mercurialosa mel.	0.1770	0.7633
Callunosa turf. mel.	0.3582	0.7783
Vacciniosa turf. mel.	0.1925	0.4976
Cladinosa-callunosa	0.1396	0.2380

Table 11: Probability of regenerated trees species when sowing or planting by forest type[19]

Forest type	State forests					Other forests			
	pine	spruce	birch	black alder	oak	pine	spruce	birch	black alder
Cladinosa-callunosa	1.000					1.0000			
Vaccinosa	1.000					1.0000			
Myrtillosa	1.000					1.0000			
Hylocomiosa	0.552	0.3998	0.0470		0.0004	0.2549	0.7110	0.0340	
Oxalidosa	0.0266	0.8003	0.1578	0.0062	0.0090	0.0169	0.9163	0.0595	0.0073
Aegipodiosa		0.4069	0.5289	0.0271	0.0371		0.8751	0.0742	0.0507
Callunoso-sphagnosa	1.0000					1.0000			

18 Arithmetic average proportion of anthropogenically regenerated forests from in 2013-2016 in the data published by SFS.

19 Arithmetic average share of anthropogenically regenerated areas in 2013-2016 in SFS data.

Forest type	State forests					Other forests			
	pine	spruce	birch	black alder	oak	pine	spruce	birch	black alder
Vaccinioso-sphagnosa	1.0000					1.0000			
Myrtilloso-sphagnosa	0.6268	0.2832	0.0873	0.0027		0.2498	0.7061	0.0354	0.0087
Myrtillosoi-polytrichosa	0.0695	0.6534	0.2570	0.0201		0.0264	0.7613	0.1480	0.0644
Drypteriosa		0.5504	0.4496				0.7820	0.1833	0.0346
Sphagnosa	1.0000					0.4821	0.5179		
Caricoso-phragmitosa	0.6641	0.1808	0.1478	0.0073		0.1963	0.4782	0.2351	0.0905
Dryopterioso-caricosa	0.1906	0.4647	0.2267	0.1179		0.0333	0.5109	0.1738	0.2820
Filipendulosa		0.6093	0.3907				0.4423		0.5577
Callunosa mel.	1.0000					1.0000			
Vacciniosa mel.	1.0000					1.0000			
Myrtillosa mel.	0.4990	0.3786	0.1200	0.0024		0.3709	0.5561	0.0558	0.0172
Mercurialosa mel.		0.6759	0.2856	0.0280	0.0106		0.7882	0.1378	0.0740
Callunosa turf. mel.	1.0000					1.0000			
Vacciniosa turf. mel.	1.0000					1.0000			
Myrtillosa turf. mel.	0.5062	0.2610	0.2113	0.0215		0.3791	0.4000	0.1859	0.0349
Oxalidosa turf. mel.		0.4101	0.5490	0.0374	0.0035		0.6103	0.2691	0.1206

Thinning of forest stand

The user can define the height and age at which early tending, pre-commercial and commercial thinning is performed (Table 12).

Table 12: Various height and age regulations for thinning

Dominating tree species	Early tending				Pre-commercial thinning				Commercial thinning			
	Hmin	Hmax	Amin	Amax	Hmin	Hmax	Amin	Amax	Hmin	Hmax	Amin	Amax
Pine	0.1	1.9	1	5	2.0	11.9	6	40	12.0	——	——	80
Spruce	0.1	1.9	1	5	2.0	11.9	6	40	12.0	——	——	60
Birch	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Alder	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Aspen	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	30
Grey alder	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	30
Oak	0.1	1.9	1	5	2.0	11.9	6	40	12.0	——	——	80
Ash	0.1	1.9	1	5	2.0	11.9	6	40	12.0	——	——	60
Linden	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Larch	0.1	1.9	1	5	2.0	11.9	6	40	12.0	——	——	80
Elm	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60

Dominating tree species	Early tending				Pre-commercial thinning				Commercial thinning			
	Hmin	Hmax	Amin	Amax	Hmin	Hmax	Amin	Amax	Hmin	Hmax	Amin	Amax
Beech	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Hornbeam	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Poplar	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	30
Willow	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	30
Goat willow	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	30
Fir	0.1	1.9	1	5	2.0	11.9	6	40	12.0	——	——	60
Maple	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Rowan	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60
Cherry	0.1	1.9	1	5	2.0	11.9	6	20	12.0	——	——	60

The user can also define in more detail how often, by what tree stand criteria and with what intensity the thinning is performed.

Early tending

In addition to age and height restrictions (Table 12) the user can define how often the early tending is modelled sorting by property type (state and other forests), regeneration method (anthropogenically or naturally) and forest type (Table 13).

Table 13: Number of early tending by origin of tree stand, property type and forest type

Forest type	Naturally regenerated tree stands		Anthropogenically regenerated tree stands	
	State forests	Other forests	State forests	Other forests
Sl	2	0	3	2
Mr	2	0	3	2
Ln	2	0	3	2
Dm	2	0	3	2
Vr	2	0	3	2
Gr	2	0	3	2
Gs	2	0	3	2
Mrs	2	0	3	2
Dms	2	0	3	2
Vrs	2	0	3	2
Grs	2	0	3	2
Pv	2	0	3	2
Nd	2	0	3	2
Db	2	0	3	2
Lk	2	0	3	2
Av	2	0	3	2
Am	2	0	3	2
As	2	0	3	2
Ap	2	0	3	2

Forest type	Naturally regenerated tree stands		Anthropogenically regenerated tree stands	
	State forests	Other forests	State forests	Other forests
Kv	2	0	3	2
Km	2	0	3	2
Ks	2	0	3	2
Kp	2	0	3	2

Pre-commercial or young tree stand thinning

The user can define what ranges of height and age of the dominating tree species of the 1st storey of the tree stand thinning is planned for (Table 12).

The user can also define what stand density the thinning is modelled for and proportionally how many stands are to be thinned in the current five year period in accordance with the criteria (Table 14).

Table 14: Indicators for planning pre-commercial thinning

Type of property	Density[20] at which pre-commercial thinning is planned	Proportion of stands to be thinned in the five year period	Maximum number of pre-commercial thinning
State forest	0.90	0.60	2
Other forests	0.90	0.40	1

Density is calculated with the number of trees in the 1st storey in proportion to the normal number of trees listed in regulations[21] which is calculated with the formula 25 in accordance with the dominating species in the 1st storey.

No more than two instances of thinning are modelled in state forests, but in other forests no more than one pre-commercial thinning, however the user may change this number.

The user can define what number f trees will be left after the pre-commercial thinning. In the default setting 100-125% of the optimal number of trees is modelled to remain[22], which can be calculated with formula 27. The user can set the minimal number of trees listed in regulations as a reference point as well[23] which can be calculated with formula 28. The distribution range of remaining number of trees can be changed as well.

The program allows for defining tree species suitable for the forest type, as well as order them in preferable order of priority, therefore pre-commercial thinning is modelled so as to achieve pure stands of high priority tree species. All tree and bush species can be separated into 3 groups (Table 15):

- ✓ tree species which can form a forest stand and can be target tree species:
    - o tree species (priority code 1-8) which are defined in the priority tree species list,

[20] Number of trees in the First story in comparison to normal number of trees (Formula 25).
[21] Meža inventarizācijas un Meža valsts reģistra informācijas aprites noteikumi: Ministru kabineta 2016. gada 21. jūnija noteikumi Nr.384.
[22] Kopšanas cieršu rokasgrāmata. LVM, 2012
[23] Noteikumi par koku ciršanu mežā: Ministru kabineta 2012.gada 18.decembra noteikumi Nr.935.

- o tree species (11) which are not defined in the priority tree species list but can be target, tree species where they already are the dominating tree species, however, if they are not the dominating tree species they are left in quantities that do not interfere with the growth of target tree species trees,
- o tree species (9) which can be target tree species in cases where species of the two former groups cannot form a forest stand (N<Nmin),

✓ tree species (33) which cannot form a forest stand and cannot be target tree species, but are left in the forest stand in quantities that do not interfere with the growth of the target tree species,

✓ bush and tree species (22) which are removed completely in pre-commercial thinning.

Table 15: Target tree species priority groups [24] by forest type

Tree species	Forest site type																						
	Sl	Mr	Ln	Dm	Vr	Gr	Gs	Mrs	Dms (9)	Vrs (10)	Grs (11)	Pv	Nd	Db	Lk	Av	Am	As	Ap	Kv	Km	Ks	Kp
Pine	1	1	1	1	9	9	1	1	1	9	9	1	1	9	9	1	1	1	9	1	1	1	9
Spruce	9	9	9	2	1	1	9	9	2	1	1	9	3	9	9	9	9	2	1	9	9	2	1
Birch	9	9	9	3	3	3	9	9	3	3	3	2	2	1	2	9	9	3	2	9	9	3	2
Alder	9	9	9	9	4	4	9	9	9	4	4	9	9	2	1	9	9	4	4	9	9	4	4
Aspen	9	9	9	9	6	6	9	9	9	6	6	9	9	9	9	9	9	9	6	9	9	9	6
Grey alder	9	9	9	9	8	8	9	9	9	7	7	9	9	9	9	9	9	9	9	9	9	9	9
Oak	11	11	11	4	2	2	11	11	4	2	2	11	11	11	11	11	11	11	3	11	11	11	3
Ash	9	9	9	9	5	5	9	9	9	5	5	9	9	9	3	9	9	9	5	9	9	9	5
Linden	9	9	9	9	7	7	9	9	9	9	9	9	9	9	4	9	9	9	7	9	9	9	7
Elm	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Beech	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Hornbeam	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Poplar	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Willow	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Goat willow	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Cherry	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Maple	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Juniper	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Rowan	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Crab apple	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Hawthorn	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33

[24] 1-9 – Order of target tree species (1 – highest priority, 9 – lowest priority); 11 – if the specias is the dominating one, then it is the target species, if it is not, then it is left in quantities that do not interfere with the growth of the target species; 22 – tree and bush species which are removed completely in pre-commercial thinning; 33 – tree species which are left in quantities that do not interfere with the growth of the target species.

Tree species	Forest site type																					
	Sl	Mr	Ln	Dm	Vr	Gr	Gs	Mrs	Dms (9)	Vrs (10)	Grs (11)	Pv	Nd	Db	Lk	Av	Am	As	Ap	Kv	Km	Ks	Kp
Other conifers	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Other broad leaved trees	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22

Commercial thinning

The users are able to define the minimal height and maximum age at which commercial thinning is planned in the 1st storey of the tree stand (Table 12).

The user can define what stand density commercial thinning is modelled for and how many stands will be thinned in the current five-year period according to the criteria (Table 16).

Table 16: Indicators of commercial thinning planning

Type of property	Density[25] at which thinning is planned	Proportion of stand thinned in current five year period	Maximum number of commercial thinning
State forests	0.85	0.60	3
Other forests	0.85	0.40	3

The user can define a range of basal area after thinning, in the default setting it is 100-125% of the minimum basal area listed in regulations[26] which in the program is calculated with formula 36. When modelling changes in forest resources it is possible to change this reference point (minimal basal area) by modifying this formula or replacing it with another formula in the program.

The program allows the user to define various types of commercial thinning (NG; if neutral selection, then NG=1.0; if thinning from the bottom up, then NG>1.0; if thinning from the top down, then NG<1.0) and their proportion (Table 17). It is also possible to define the proportion of every type of thinning i.e. the area every type of thinning is carried out on in proportion to the total area thinning is carried out on. Theses indicators are sorted by type of property.

Table 17: Type and proportion of commercial thinning

Type of property	Type of Commercial thinning	NG	Proportion
State forests	Top down	0.85	0.00
	Neutral	1.00	0.00
	Bottom up	1.15	1.00
Other forests	Top down	0.85	0.00
	Neutral	1.00	0.00

25 The proportion of basal area to a normal basal area in the 1st storey (formula 34).
26 Noteikumi par koku ciršanu mežā: Ministru kabineta 2012.gada 18.decembra noteikumi Nr.935.

Type of property	Type of Commercial thinning	NG	Proportion
	Bottom up	1.15	1.00

The user can change the suitability of tree species to the forest type (Table 18) Which directly impacts the proportion of species in the tree stand after commercial thinning.

Table 18: Priority group (suitability) of tree species according to forest type[27]

Forest type	Pine	Spruce	Birch	Alder	Aspen	Grey alder	Oak	Ash	Linden	Larch	Elm	Beech	Hornbeam	Poplar	Willow	Goat willow	Fir	Maple	Cherry	Other
Sl	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mr	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ln	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dm	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Vr	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0
Gr	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0
Gs	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mrs	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dms	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Vrs	0	1	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0
Grs	0	1	1	1	1	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0
Pv	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nd	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Db	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Lk	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Av	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Am	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Ap	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0
Kv	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Km	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ks	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Kv	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0

Regenerative felling

The program allows the user to define the final felling age and diameter. In the default setting the age and diameter at which final felling is carried out is set at values listed in current regulation[28, 29] (Table 19).

27 1 –tree species suitable for forest type, 0 – tree species unsuitable for forest type.
28 Noteikumi par koku ciršanu mežā: Ministru kabineta 2012.gada 18.decembra noteikumi Nr.935.
29 Meža likums. LR likums (2000).

Table 19: Age and diameter of final felling

Tree species	Tree species code	Final felling age (years) depending on site index			Final felling diameter (cm) depending on site index			
		0 and 1	2 and 3	4; 5 and 6	0	1	2	3
Pine	1	101	101	121	39	35	31	27
Spruce	3	81	81	81	31	29	29	27
Birch	4	71	71	51	31	27	25	22
Alder	6	71	71	71	999	999	999	999
Aspen	8	41	41	41	999	999	999	999
Grey alder	9	31	31	31	999	999	999	999
Oak	10	101	121	121	999	999	999	999
Ash	11	81	81	81	999	999	999	999
Linden	12	81	81	81	999	999	999	999
Larch	13	101	101	121	999	999	999	999
Other pines	14	101	101	121	999	999	999	999
Other spruces	15	81	81	81	999	999	999	999
Elm	16	81	81	81	999	999	999	999
Beech	17	81	81	81	999	999	999	999
Hornbeam	18	81	81	81	999	999	999	999
Poplar	19	41	41	41	999	999	999	999
Willow	20	31	31	31	999	999	999	999
Goat willow	21	31	31	31	999	999	999	999
Fir	23	81	81	81	999	999	999	999
Maple	24	81	81	81	999	999	999	999
Rowan	32	31	31	31	999	999	999	999
Cherry	56	81	81	81	999	999	999	999

The user will also be able to define the final felling wood stack and area sorted by type of property. In the default setting the final felling is modelled for the same volume felled in the last five years (Table 20).

Table 20: Volume of final felling

Species	State forests				Other forests	
	proposed area of felling		final felling in the last 5 years		final felling in the last 5 years	
	area, 10^3 ha	wood stock, 10^6 m^3	area, 10^3 ha	wood stock, 10^6 m^3	area, 10^3 ha	wood stock, 10^6 m^3
Pine	33.982	8.7133	34.563	9.3605	27.669	5.7461
Spruce	10.919	3.0493	9.395	2.5685	18.693	3.8388
Birch	37.475	8.8073	25.675	6.8589	44.284	8.2789
Alder	3.208	0.7591	1.126	0.3189	2.993	0.5740
Aspen	6.170	1.7973	6.479	2.0330	12.626	2.4510
Grey alder			0.734	0.1407	32.221	4.6901

Species	State forests				Other forests	
	proposed area of felling		final felling in the last 5 years		final felling in the last 5 years	
	area, 10^3 ha	wood stock, 10^6 m^3	area, 10^3 ha	wood stock, 10^6 m^3	area, 10^3 ha	wood stock, 10^6 m^3
Oak	0.054	0.0109	0.001	0.0004	0.227	0.0321
Ash	0.255	0.0564	0.164	0.0218	0.607	0.0966
Other species			0.014	0.0033	0.249	0.0301
Total	92.063	23.1937	78.151	21.3060	139.570	25.7377

The user is able to define the proportion of the area sorted by type of final felling (clear felling, selective felling) and type of property (state and other forests). In the default setting the proportion of final felling area is in accordance with the last 5 years[30] (Table 21).

Table 21: Proportion of final felling area sorted by type of property and type of final felling

Type of felling	Other forests	State forest
Selective felling	0.1715	0.0560
Clear felling	0.8285	0.9440

Sanitary felling

The user can depending on the trees species and its decimal age group define a probability of sanitary felling in the tree stand (Table 22). The program allows to define a proportion of selective and sanitary clear felling depending on the dominating tree species in the tree stand which in the default setting is in accordance with the last three years[31] (Table 23).

Table 22: Probability of sanitary felling depending on the dominating tree species in the tree stand and its decimal age group

Decimal age group	Pine	Spruce	Birch	Alder	Aspen	Ash	Other species
1	0	0	0	0	0	0	0
2	0.0002	0.0008	0.0004	0.0003	0.0004	0	0
3	0.0010	0.0067	0.0022	0.0010	0.0011	0	0
4	0.0033	0.0200	0.0053	0.0020	0.0020	0	0
5	0.0068	0.0347	0.0083	0.0028	0.0026	0	0
6	0.0108	0.0424	0.0098	0.0032	0.0028	0.0008	0
7	0.0143	0.0407	0.0095	0.0031	0.0026	0.0117	0
8	0.0165	0.0328	0.0079	0.0026	0.0022	0.0478	0
9	0.0173	0.0231	0.0059	0.0020	0.0017	0.0744	0
10	0.0167	0.0147	0.0041	0.0015	0.0013	0.0554	0
11	0.0151	0.0085	0.0026	0.0010	0.0009	0.0231	0
12	0.0129	0.0046	0.0016	0.0007	0.0006	0.0060	0

30 SFS statistics CD 2013-2016.

31 SFS statistics CD 2015-2017

Decimal age group	Pine	Spruce	Birch	Alder	Aspen	Ash	Other species
13	0.0105	0.0024	0.0009	0.0004	0.0004	0.0011	0
14	0.0083	0.0011	0.0005	0.0003	0.0003	0.0001	0
15	0.0063	0.0005	0.0003	0.0002	0.0002	0	0
16	0.0047	0.0002	0.0001	0.0001	-	0	0
17	0.0034	0.0001	0.0001	0.0001	-	0	0
18	0.0024	0	0	0	-	0	0
19	0.0016	0	0	0	-	0	0
20	0.0011	0	0	0	-	0	0
21	0.0007	0	0	0	-	0	0
22	0.0005	0	0	0	-	0	0
23	0.0003	0	0	0	-	0	0
24	0.0002	0	0	0	-	0	0
25	0.0001	0	0	0	-	0	0
26	0.0001	0	0	0	-	0	0
27	0.0001	0	0	0	-	0	0
28	0	0	0	0	-	0	0
29	0	0	0	0	-	0	0
30	0	0	0	0	-	0	0

Table 23: Proportion of selective and clear sanitary felling depending on the dominating tree species in the tree stand

Dominating tree species	Clear sanitary felling	Selective sanitary felling
Pine	0.0290	0.9710
Spruce	0.0545	0.9455
Birch	0.0590	0.9410
Alder	0.0718	0.9282
Aspen	0.0785	0.9215
Ash	0.3193	0.6807

MODELLING OF CHANGES IN WOOD RESOURCES

The growing if an individual forest element is modelled in two ways depending on their height:

- forest elements up to the height of 1.3 m;
- forest element s taller than 1.3 m.

The 2 options are different in the order of calculations of taxation indicators of individual forest elements (Figures 6 and 7).

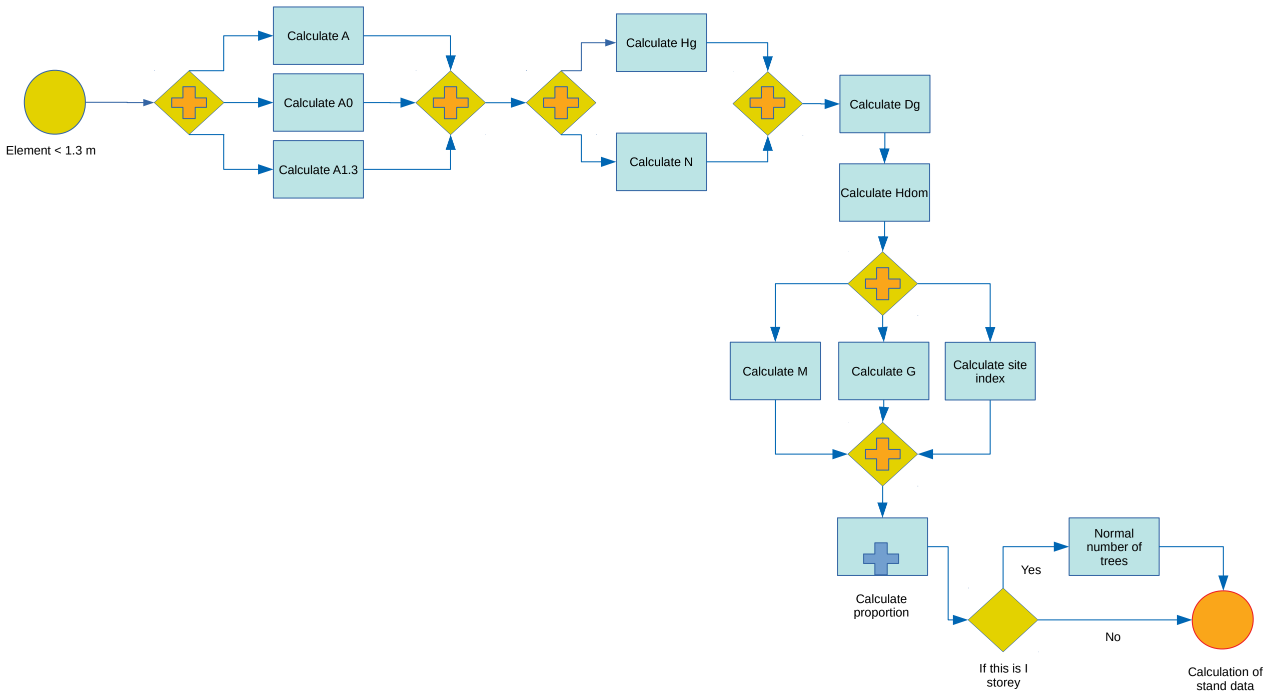

Figure 6: Scheme of the modelling of growth of individual forest elements of a forest stand before reaching a height of 1.3 m.

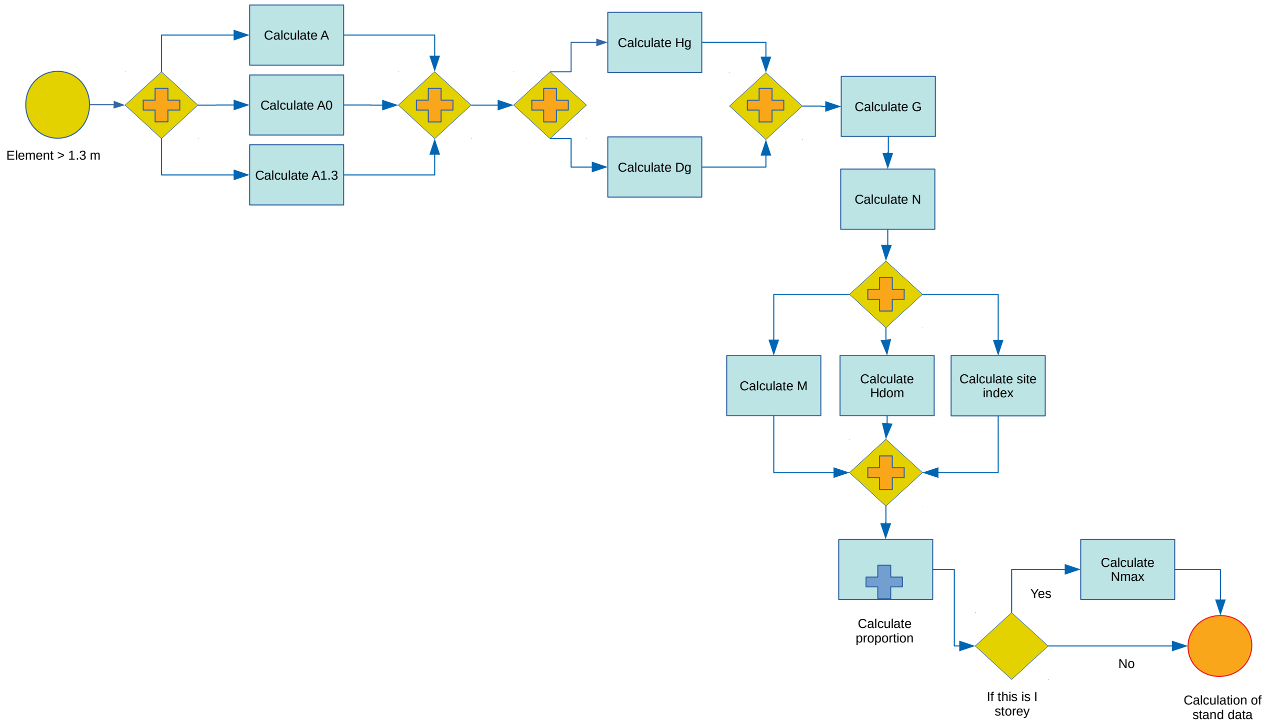

Figure 7: Scheme of the modelling of growth of individual forest elements of a forest stand after reaching a height of 1.3 m.

Height

If height of forest element is below 1.3 m

The increase in height is modelled after a site index corresponding with the forest type (Table 3). If information on the site index of previous stands is available height increase is modelled using this information.

Prognosis model average height increase of a forest element in Microsoft Excel format:

$$h_2 = h_1 + \left[\left(\alpha_1 + \frac{\alpha_2 * B^{\alpha_3}}{\alpha_4^{\alpha_3} + B^{\alpha_3}} \right) * \frac{\Delta t}{\Delta a + 5} \right], \quad (11)$$

h_2 – Average height of the forest element in the end of the actualisation period, m;
h_1 – Average height of the forest element at the beginning of the actualisation period, m;
B – Site index code (0–6);
Δt – Duration of the actualisation period, years
Δa – Difference between biological and chest height age of the forest element, years;
α_{1-3} – Coefficients.

Table 24: Coefficient values for the prognosis of height increase of forest element below the height of 1.3 m (formula No. 11)

Tree species	Tree species code	α_1	α_2	α_3	α_4
Pine	1	4.71974	−5.35203	0.99450	4.87410
Spruce	3	3.71000	−3.40971	1.00456	3.52752
Birch	4	4.33958	−5.50837	0.94706	6.16190

Tree species	Tree species code	α_1	α_2	α_3	α_4
Alder	6	5.03930	−6.88795	0.97118	6.49472
Aspen	8	5.02983	−7.69748	0.99068	8.22900
Grey alder	9	4.88003	−11.24780	0.99298	15.12452
Oak (regular)	10	4.71974	−5.35203	0.99450	4.87410
Ash	11	3.71000	−3.40971	1.00456	3.52752
Linden	12	4.33958	−5.50837	0.94706	6.16190
Larch	13	3.71000	−3.40971	1.00456	3.52752
Other pines	14	4.71974	−5.35203	0.99450	4.87410
Other spruces	15	3.71000	−3.40971	1.00456	3.52752
Elm	16	4.33958	−5.50837	0.94706	6.16190
Beech	17	3.71000	−3.40971	1.00456	3.52752
Hornbeam	18	4.88003	−11.24780	0.99298	15.12452
Poplar	19	5.02983	−7.69748	0.99068	8.22900
Willow	20	5.02983	−7.69748	0.99068	8.22900
Goat willow	21	5.02983	−7.69748	0.99068	8.22900
Fir	23	3.71000	−3.40971	1.00456	3.52752
Maple	24	4.33958	−5.50837	0.94706	6.16190
Osier	30	4.88003	−11.24780	0.99298	15.12452
Juniper	31	3.71000	−3.40971	1.00456	3.52752
Rowam	32	4.88003	−11.24780	0.99298	15.12452
Alder buckthorn	33	4.88003	−11.24780	0.99298	15.12452
Hazel	34	4.88003	−11.24780	0.99298	15.12452
Bird Cherry	35	4.88003	−11.24780	0.99298	15.12452
Hawthorn	41	4.88003	−11.24780	0.99298	15.12452
Crab apple	51	4.88003	−11.24780	0.99298	15.12452
Broad leaved trees	53	4.33958	−5.50837	0.94706	6.16190
Unknown species	54	4.33958	−5.50837	0.94706	6.16190
Cherry	56	4.33958	−5.50837	0.94706	6.16190
Buckthorn	57	4.33958	−5.50837	0.94706	6.16190

If the forest element is taller than 1.3 m

Prognosis model of the average height increase in Microsoft excel format:

$$h_2 = 1.3 + \frac{a_2^{\alpha_1}}{\alpha_2 + \alpha_3 * 100 * \left[\frac{\frac{a_1^{\alpha_1}}{h_1 - 1.3} - \alpha_2}{\alpha_3 * 100 + a_1^{\alpha_1}}\right] + \left[\frac{\frac{a_1^{\alpha_1}}{h_1 - 1.3} - \alpha_2}{\alpha_3 * 100 + a_1^{\alpha_1}}\right] * a_2^{\alpha_1}}, where \quad (12)$$

h_2 – Average height of the forest element at the calculation period, m;
h_1 – Average height of the forest element in the beginning of the period, m;
a_1 – Age at chest height of the forest element in the beginning of the period, years;
a_2 – Age at chest height of the forest element at the end of the period, years;
α_{1-3} – Coefficients.

Table 25: Coefficient values for the prognosis model of the increase of average height of forest elements with a height greater than 1.3 m (Formula No. 12)

Tree species	Tree species code	1st storey			II and III storey			H_{max}
		α_1	α_2	α_3	α_1	α_2	α_3	
Pine	1	1.18111	−42.59724	21.10918	1.18111	−42.59724	21.10918	45
Spruce	3	1.29005	−38.14248	20.15906	1.20905	−34.00184	12.99559	45
Birch	4	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	39
Alder	6	1.13922	−32.09572	15.97676	1.13922	−32.09572	15.97676	39
Aspen	8	1.32442	−26.07775	15.64465	1.32442	−26.07775	15.64465	45
Grey alder	9	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	30
Oak	10	1.18111	−42.59724	21.10918	1.18111	−42.59724	21.10918	39
Ash	11	1.29005	−38.14248	20.15906	1.29005	−38.14248	20.15906	39
Linden	12	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	39
Larch	13	1.29005	−38.14248	20.15906	1.20905	−34.00184	12.99559	45
Other pines	14	1.18111	−42.59724	21.10918	1.18111	−42.59724	21.10918	45
Other spruces	15	1.29005	−38.14248	20.15906	1.20905	−34.00184	12.99559	45
Elm	16	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	39
Beech	17	1.29005	−38.14248	20.15906	1.20905	−34.00184	12.99559	39
Hornbeam	18	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	39
Poplar	19	1.32442	−26.07775	15.64465	1.32442	−26.07775	15.64465	39
Willow	20	1.32442	−26.07775	15.64465	1.32442	−26.07775	15.64465	27
Goat willow	21	1.32442	−26.07775	15.64465	1.32442	−26.07775	15.64465	27
Fir	23	1.29005	−38.14248	20.15906	1.20905	−34.00184	12.99559	45
Maple	24	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	39
Osier	30	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	12
Juniper	31	1.29005	−38.14248	20.15906	1.20905	−34.00184	12.99559	9
Rowan	32	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	24
Alder buckthorn	33	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	9
Hazel	34	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	12
Bird cherry	35	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	24

Tree species	Tree species code	1st storey			II and III storey			H_{max}
		α_1	α_2	α_3	α_1	α_2	α_3	
Hawthorn	41	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	12
Crab apple	51	1.32873	−23.04796	7.32721	1.32873	−23.04796	7.32721	24
Broad leaved trees	53	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	39
Unknown species	54	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	39
Cherry	56	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	30
Buckthorn	57	1.33418	−35.78521	16.11630	1.33418	−35.78521	16.11630	10

Forest element height is updated until it reaches the forest element's corresponding maximum height (Table 25). If the forest element has reached maximum height it is considered the height remains the same.

Dominant height

The dominant height of the forest element is calculated as a secondary value regardless of the forest element height using formula 4 and depends on the projected forest element average height and number of trees.

Diameter

If the forest element height is smaller than 1.3 m

The average diameter at breast height is modelled as a secondary value using the average height with an accepted proportion $\frac{H}{D}$ of 1.2.

Model for the calculation of the average diameter of the forest element:

$$d = \frac{h}{1.2}, where \tag{13}$$

d – Average diameter at chest height of the forest element, cm;
h – Average height of forest element, m.

If the forest element height is greater than 1.3 m

The average diameter at breast height is modelled depending on the starting average diameter, age and relative density of the 1st storey.

Model for the calculation of average diameter of forest element:

$$d_2 = 1.3 + \frac{a_2^{\alpha_1}}{\alpha_2 * RB + \alpha_3 * 100 * \left[\frac{\left(\frac{a_1^{\alpha_1}}{d_1 - 1.3}\right) - \alpha_2 * RB}{\alpha_3 * 100 + a_1^{\alpha_1}}\right] + \left[\frac{\left(\frac{a_1^{\alpha_1}}{d_1 - 1.3}\right) - \alpha_2 * RB}{\alpha_3 * 100 + a_1^{\alpha_1}}\right] * a_2^{\alpha_1}}, where \quad (14)$$

d_2 – Average diameter of the forest element at the end of the actualization period, cm;
d_1 – Average diameter of the forest element in the beginning of the actualization period, cm;
a_1 – Age of the forest element at the height of 1.3 m in the beginning of the calcullation period, years;
a_2 – Age of the forest element at the height of 1.3 m at the end of the calculation period, years;
RB – Relative density of the I storey of the forest stand;
α_{1-3} – Coefficients.

Table 26: Coefficient values for the prognosis model of average diameter increase for forest elements with a height greater than 1.3 m (formula 14)

Tree species	Tree species code	α_1	α_2	α_3
Pine	1	1.06700	−9.98500	5.03500
Spruce	3	1.08900	−5.69800	4.61700
Birch	4	1.04300	−7.79300	3.65200
Alder	6	0.91200	−1.44400	1.38800
Aspen	8	1.29000	−13.95300	9.78600
Grey alder	9	0.92400	−8.15200	2.78100
Oak (regular)	10	1.06700	−9.98500	5.03500
Ash	11	1.08900	−5.69800	4.61700
Linden	12	1.04300	−7.79300	3.65200
Larch	13	1.08900	−5.69800	4.61700
Other pines	14	1.06700	−9.98500	5.03500
Other spruces	15	1.08900	−5.69800	4.61700
Elm	16	1.04300	−7.79300	3.65200
Beech	17	1.08900	−5.69800	4.61700
Hornbeam	18	0.92400	−8.15200	2.78100
Poplar	19	1.29000	−13.95300	9.78600
Willow	20	1.29000	−13.95300	9.78600
Goat willow	21	1.29000	−13.95300	9.78600
Fir	23	1.08900	−5.69800	4.61700
Maple	24	1.04300	−7.79300	3.65200
Osier	30	0.92400	−8.15200	2.78100
Juniper	31	1.08900	−5.69800	4.61700
Rowan	32	0.92400	−8.15200	2.78100

Tree species	Tree species code	α_1	α_2	α_3
Alder buckthorn	33	0.92400	−8.15200	2.78100
Hazel	34	0.92400	−8.15200	2.78100
Bird cherry	35	0.92400	−8.15200	2.78100
Hawthorn	41	0.92400	−8.15200	2.78100
Crab apple	51	0.92400	−8.15200	2.78100
Broad leaved trees	53	1.04300	−7.79300	3.65200
Unknown species	54	1.04300	−7.79300	3.65200
Cherry	56	1.04300	−7.79300	3.65200
Buckthorn	57	1.04300	−7.79300	3.65200

Number of trees

If the height of the forest element is below 1.3 m

The number of trees in forest elements with a height below 1.3 m has a projected natural mortality of 1%.

Model of changes in number if trees in the forest element:

$$n_2 = (1 - 0.01 * t) * n_{1,} \, where \tag{15}$$

n_2 – Number of trees in the forest element at the end of the actualization period, ha^{-1};
n_1 – Number of trees in the forest element in the beginning of the actualization period, ha^{-1}.

If the height of the forest element id greater than 1.3 m

The number of trees in the forest element is calculated as a secondary value depending on the projected basal area and diameter.

Algorithm for the calculation model of number of trees in the forest element:

$$n = 40000 * \left(\frac{\frac{g}{pi()}}{d^2} \right), where \tag{16}$$

n – Number of trees in the forest element, ha^{-1};
g – Cross-section are of the forest element, $m^2 ha^{-1}$;
d – Average diameter at chest height of the forest element, cm.

Basal area

If the height of the forest element is below 1.3 m

The basal area of the forest stand (forest element) up to the height of 1.3 m is considered to be 0 m^2ha^{-1}, but after reaching a height of 1.3 m the basal area is calculated depending on the projected number of trees and diameter (formula No. 5).

If the height of the forest element is above 1.3 m

Changes in the basal area of the forest element depend on the projected basal area difference and maximum basal area.

The calculation of the difference of basal area of the forest element depends on the duration of the projection period, basal area and age of the forest element. If the basal area of the forest element is below 10 m^2ha^{-1} or the age at breast height is greater than the age limit from Table 27 (A_{lim}), or the duration of actualization exceeds 20 years, formula No. 18 is used, in other cases formula No. 17 is used.

Model of basal area difference:

$$g_2 = g_1 + \left(\alpha_0 + \frac{\alpha_1 * a_1}{100} + \frac{\alpha_2}{\left(\frac{a_1}{10}\right)^2} + \frac{\alpha_3 * g_1}{a_1} + \frac{\alpha_4 * GL}{a_1} + \frac{\alpha_5 * SI}{a_1} \right) * (a_2 - a_1), where \quad (17)$$

g_2 – Projected cross-section area of the forest element at the end of actualization period, m^2ha^{-1};
g_1 – Projected cross-section area of the forest element in the beginning of actualization period, m^2ha^{-1};
a_1 – Age of forest element at the height of 1.3 m in the beginning of the actualization period, years;
a_2 – Age of forest element at the height of 1.3 m at the end of the actualization period, years;
GL – Sum of cross-section areas of forest elements with equal or greater cross-section areas than the chosen forest element (if forest element of the I storey, then cross-section are of the I storey, if forest element of the II storey, then a sum of the cross-section areas of the I and II stories, if a forest element of the III storey, then the total cross-section area of the tree stand), m^2ha^{-1};
SI – Projected height of the forest element (formula 13) at a specific chest height age, m;
$\alpha_i; \beta_i$ – Coefficients.

$$g_2 = g_1 + g_1 * (\alpha_0 + \frac{\alpha_1 * a_1}{100} + \frac{\alpha_2}{a_1^2}) * (a_2 - a_1), where \quad (18)$$

g_2 – Projected cross-section area of the forest element at the end of actualization period, m^2ha^{-1};
g_1 – Projected cross-section area of the forest element in the beginning of actualization period, m^2ha^{-1};
a_1 – Age of forest element at the height of 1.3 m in the beginning of the actualization period, years;
a_2 – Age of forest element at the height of 1.3 m at the end of the actualization period, years;
$\alpha_i; \beta_i$ – Coefficients.

Table 27: Coefficient values for formula No. 17 for the difference models of forest element basal areas for forest elements with a height greater than 1.3 m

Tree species	Tree species code	α_0	α_1	α_2	α_3	α_4	α_5
Pine	1	0.12790	−0.05718	0.02512	0.83096	−0.36719	0.15517

Tree species	Tree species code	α_0	α_1	α_2	α_3	α_4	α_5
Spruce	3	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Birch	4	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Alder	6	0.19929	−0.23874	−0.08695	0.84685	−0.18952	0.07761
Aspen	8	0.45672	−0.46009	0.24801	0.96946	−0.23032	0.00000
Grey alder	9	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Oak	10	0.12790	−0.05718	0.02512	0.83096	−0.36719	0.15517
Ash	11	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Linden	12	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Larch	13	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Other pines	14	0.12790	−0.05718	0.02512	0.83096	−0.36719	0.15517
Other spruces	15	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Elm	16	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Beech	17	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Hornbeam	18	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Poplar	19	0.45672	−0.46009	0.24801	0.96946	−0.23032	0.00000
Willow	20	0.45672	−0.46009	0.24801	0.96946	−0.23032	0.00000
Goat willow	21	0.45672	−0.46009	0.24801	0.96946	−0.23032	0.00000
Fir	23	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Maple	24	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Osier	30	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Juniper	31	0.19233	−0.11625	0.04781	0.82474	−0.23711	0.12125
Rowan	32	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Alder buckthorn	33	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Hazel	34	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Bird cherry	35	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Hawthorn	41	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Crab apple	51	0.66125	−1.72237	0.05124	0.96525	−0.46311	0.12640
Broad leaved trees	53	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Unknown species	54	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Cherry	56	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372
Buckthorn	57	0.23598	−0.25059	−0.06415	0.60903	−0.24720	0.16372

Table 28: Coefficient and age values for basal difference models for forest elements with a height above 1.3 m (formula 18) [32]

Tree species	Tree species	α_0	α_1	α_2	A_{lim}	A_{SI}
Pine	1	0.01800	−0.01139	12.01519	120	100
Spruce	3	0.02787	−0.02145	12.57435	100	100
Birch	4	0.05146	−0.06896	8.81694	80	50

32 A_{lim} – border age at breast height values needed to choose the basal difference equation, A_{SI} – breast height age for which the tree stand productivity height is calculated.

Tree species	Tree species	α_0	α_1	α_2	A_{lim}	A_{SI}
Alder	6	0.05924	−0.08500	3.36282	80	50
Aspen	8	0.05660	−0.06663	12.13606	80	50
Grey alder	9	0.06862	−0.16547	6.29221	50	20
Oak (regular)	10	0.01800	−0.01139	12.01519	120	100
Ash	11	0.02787	−0.02145	12.57435	100	100
Linden	12	0.05146	−0.06896	8.81694	80	50
Larch	13	0.02787	−0.02145	12.57435	100	100
Other pines	14	0.01800	−0.01139	12.01519	120	100
Other spruces	15	0.02787	−0.02145	12.57435	100	100
Elm	16	0.05146	−0.06896	8.81694	80	100
Beech	17	0.02787	−0.02145	12.57435	100	100
Hornbeam	18	0.06862	−0.16547	6.29221	50	100
Poplar	19	0.05660	−0.06663	12.13606	80	50
Willow	20	0.05660	−0.06663	12.13606	80	20
Goat willow	21	0.05660	−0.06663	12.13606	80	50
Fir	23	0.02787	−0.02145	12.57435	100	100
Maple	24	0.05146	−0.06896	8.81694	80	50
Osier	30	0.06862	−0.16547	6.29221	50	20
Juniper	31	0.02787	−0.02145	12.57435	100	100
Rowan	32	0.06862	−0.16547	6.29221	50	50
Alder buckthorn	33	0.06862	−0.16547	6.29221	50	20
Hazel	34	0.06862	−0.16547	6.29221	50	20
Bird cherry	35	0.06862	−0.16547	6.29221	50	20
Hawthorn	41	0.06862	−0.16547	6.29221	50	20
Crab apple	51	0.06862	−0.16547	6.29221	50	20
Broad leaved trees	53	0.05146	−0.06896	8.81694	80	50
Unknown species	54	0.05146	−0.06896	8.81694	80	50
Cherry	56	0.05146	−0.06896	8.81694	80	50
Buckthorn	57	0.05146	−0.06896	8.81694	80	50

Formulas 19 and 20 are used to project the potential basal area of the forest element, however it may not exceed the maximum theoretically possible basal area.

Model of the maximum basal area of a forest element:

$$g_{max}=\frac{\alpha_1}{1+\left(\frac{d}{\alpha_2}\right)^{\alpha_3}}*ip\text{, where}$$

g_{max} – Maximum cross-section area of the forest element, $m^2 ha^{-1}$; (19)
d – Projected average diameter of the forest element at chest height, cm;
h – Projected average height of the forest element, m;
ip – Proportion of the forest element;
$\alpha_i; \beta_i$ – coefficients.

$$g_{max}=\beta_1*(1-\exp(-\beta_2*h))*ip\text{, where}$$

g_{max} – maximal basa area of forest element, $m^2 ha^{-1}$;
d – projected diameter of forest element at breast height, cm; (20)
h – projected average height of forest element, m;
ip – share of forest element;
$\alpha_i; \beta_i$ – coefficients.

Formula No. 19 is used for forest stands which have been thinned in the last 18-22 (5 iteration) years, if there has been no thinning for a prolonged period of time, then the maximum basal area is calculated using formula No. 20.

Table 29: Coefficient values for maximum basal area models (formulas 19 and 20) of forest elements with a height above 1.3

Tree species	Tree species code	α_1	α_2	α_3	β_1	β_2
Pine	1	63.45877	13.46633	−1.51447	37.34807	0.07615
Spruce	3	56.98437	9.33710	−1.70296	38.74357	0.07334
Birch	4	44.21425	6.02039	−1.37711	43.54122	0.03710
Alder	6	50.01593	9.26982	−1.87173	39.56055	0.06983
Aspen	8	55.63098	5.97114	−1.49469	43.24735	0.04973
Grey alder	9	39.01299	3.96501	−2.04227	37.40094	0.07388
Oak	10	63.45877	13.46633	−1.51447	37.34807	0.07615
Ash	11	56.98437	9.33710	−1.70296	38.74357	0.07334
Linden	12	44.21425	6.02039	−1.37711	43.54122	0.03710
Larch	13	56.98437	9.33710	−1.70296	38.74357	0.07334
Other pines	14	63.45877	13.46633	−1.51447	37.34807	0.07615
Other spruces	15	56.98437	9.33710	−1.70296	38.74357	0.07334
Elm	16	44.21425	6.02039	−1.37711	43.54122	0.03710
Beech	17	56.98437	9.33710	−1.70296	38.74357	0.07334
Hornbeam	18	39.01299	3.96501	−2.04227	37.40094	0.07388
Poplar	19	55.63098	5.97114	−1.49469	43.24735	0.04973
Willow	20	55.63098	5.97114	−1.49469	43.24735	0.04973
Goat willow	21	55.63098	5.97114	−1.49469	43.24735	0.04973
Fir	23	56.98437	9.33710	−1.70296	38.74357	0.07334
Maple	24	44.21425	6.02039	−1.37711	43.54122	0.03710
Osier	30	39.01299	3.96501	−2.04227	37.40094	0.07388

Tree species	Tree species code	α_1	α_2	α_3	β_1	β_2
Juniper	31	56.98437	9.33710	−1.70296	38.74357	0.07334
Rowan	32	39.01299	3.96501	−2.04227	37.40094	0.07388
Alder buckthorn	33	39.01299	3.96501	−2.04227	37.40094	0.07388
Hazel	34	39.01299	3.96501	−2.04227	37.40094	0.07388
Bird cherry	35	39.01299	3.96501	−2.04227	37.40094	0.07388
Hawthorn	41	39.01299	3.96501	−2.04227	37.40094	0.07388
Crab apple	51	39.01299	3.96501	−2.04227	37.40094	0.07388
Broad leaved trees	53	44.21425	6.02039	−1.37711	43.54122	0.03710
Unknown species	54	44.21425	6.02039	−1.37711	43.54122	0.03710
Cherry	56	44.21425	6.02039	−1.37711	43.54122	0.03710
Buckthorn	57	44.21425	6.02039	−1.37711	43.54122	0.03710

The basal area of individual forest elements is projected as the minimal basal area of the projected potential basal area of the forest element and calculated maximum basal area of the forest element:

$$g_2 = min(g_2; g_{max}), where \tag{21}$$

g_2 – Cross-section area of the forest element at the end of the period, $m^2 ha^{-1}$;

g_2 – Projected cross-section area of the forest element at the end of the period (formula 19 or 20), $m^2 ha^{-1}$;

g_{max} – Maximum cross-section area of the forest element (formula 21 or 22), $m^2 ha^{-1}$.

Wood stock

The wood stock of the forest element is considered to be 2 $m^3 ha^{-1}$ until the forest stand reaches a height of 2 m (height of the dominating tree species of the 1st storey), but the wood stock of individual elements is calculated depending on their proportion:

$$m = 2 * ip, where \tag{22}$$

m – Wood stock of the forest element, $m^3 ha^{-1}$;

ip – Proportion of the forest element.

After reaching a height of 2 m I Liepa formula of individual tree volume (Liepa, 1996) is used to calculate the wood stock, using number of trees, average tree height and square average diameter (formula No. 6).

Modelling of the growing process of the previous generation of forest elements

Changes in dominant height, diameter and number of trees are modelled for the previous generation of forest elements, other taxation indicators are calculated from these values.

Height

The average height is considered to be the same as the dominant height.

Dominant height

Formula No. 12 and coefficient values from Table 30 are used in modelling the dominant height.

Table 30: Coefficient values for the projection model (formula No. 12) of the increase of the dominant height of the forest element

Tree species	Tree species code	α_1	α_2	α_3	Hmax
Pine	1	1.18637	−49.99697	25.76125	45
Spruce	3	1.25770	−50.61810	24.59717	45
Birch	4	1.31953	−51.58704	23.52032	39
Alder	6	1.46445	−53.96222	19.69977	39
Aspen	8	1.28130	−49.96142	26.03085	45
Grey alder	9	1.36976	−56.11828	17.84767	30
Oak	10	1.18637	−49.99697	25.76125	39
Ash	11	1.25770	−50.61810	24.59717	39
Linden	12	1.31953	−51.58704	23.52032	39
Larch	13	1.25770	−50.61810	24.59717	45
Other pines	14	1.18637	−49.99697	25.76125	45
Other spruces	15	1.25770	−50.61810	24.59717	45
Elm	16	1.31953	−51.58704	23.52032	39
Beech	17	1.25770	−50.61810	24.59717	39
Hornbeam	18	1.36976	−56.11828	17.84767	39
Poplar	19	1.28130	−49.96142	26.03085	39
Willow	20	1.28130	−49.96142	26.03085	27
Goat willow	21	1.28130	−49.96142	26.03085	27
Fir	23	1.25770	−50.61810	24.59717	45
Maple	24	1.31953	−51.58704	23.52032	39
Osier	30	1.36976	−56.11828	17.84767	12
Juniper	31	1.25770	−50.61810	24.59717	9
Rowan	32	1.36976	−56.11828	17.84767	24
Alder buckthorn	33	1.36976	−56.11828	17.84767	9
Hazel	34	1.36976	−56.11828	17.84767	12
Bird cherry	35	1.36976	−56.11828	17.84767	24
Hawthorn	41	1.36976	−56.11828	17.84767	12
Crab apple	51	1.36976	−56.11828	17.84767	24
Broad leaved trees	53	1.31953	−51.58704	23.52032	39
Unknown species	54	1.31953	−51.58704	23.52032	39
Cherry	56	1.31953	−51.58704	23.52032	30
Buckthorn	57	1.31953	−51.58704	23.52032	10

Diameter

Formula No. 14 is used in modelling the average diameter with an accepted relative density of 0.60.

Number of trees

A specific natural mortality decreased in number of trees is accepted for the previous generation of forest elements depending on the tree species (Table 31).

Table 31: Natural mortality percentage of the previous forest element generation in a 5 year period

Tree species	Tree species code	Natural mortality	Amax
Pine	1	0.04	500
Spruce	3	0.06	350
Birch	4	0.12	200
Alder	6	0.12	200
Aspen	8	0.14	150
Grey alder	9	0.22	100
Oak (regular)	10	0.04	500
Ash	11	0.06	350
Linden	12	0.06	350
Larch	13	0.04	500
Other pines	14	0.04	500
Other spruces	15	0.06	350
Elm	16	0.06	350
Beech	17	0.06	350
Hornbeam	18	0.06	350
Poplar	19	0.14	150
Willow	20	0.22	100
Goat willow	21	0.22	100
Fir	23	0.06	350
Maple	24	0.06	350
Osier	30	0.28	60
Juniper	31	0.06	350
Rowan	32	0.12	200
Alder buckthorn	33	0.28	60
Hazel	34	0.28	60
Bird cherry	35	0.28	60
Hawthorn	41	0.12	200
Crab apple	51	0.12	200
Broad leaved trees	53	0.22	100
Unknown species	54	0.22	100

Tree species	Tree species code	Natural mortality	Amax
Cherry	56	0.12	200
Buckthorn	57	0.28	60

Cross section area

The cross section area is determined in accordance with the projected number of trees and diameter (formula 5).

Wood stock

I. Liepa equation of individual tree volume (Liepa, 1996) to determine the wood stock using the number of trees, average tree height and square average diameter (formula No. 6).

MODELLING OF FOREST MANAGEMENT

Commercial activities included in modelling the growing process are:

- ✓ forest regeneration;
  - o natural forest regeneration,
  - o anthropogenic forest regeneration;
- ✓ all thinning;
  - o early tending,
  - o pre-commercial thinning,
  - o commercial thinning;
- ✓ all final felling;
  - o clear felling,
  - o selective and gradual felling;
- ✓ sanitary felling.

Forest regeneration

Forest regeneration after clear felling

Figure 8 shows a scheme of calculating taxation indicators of regeneration and regenerating forest elements.

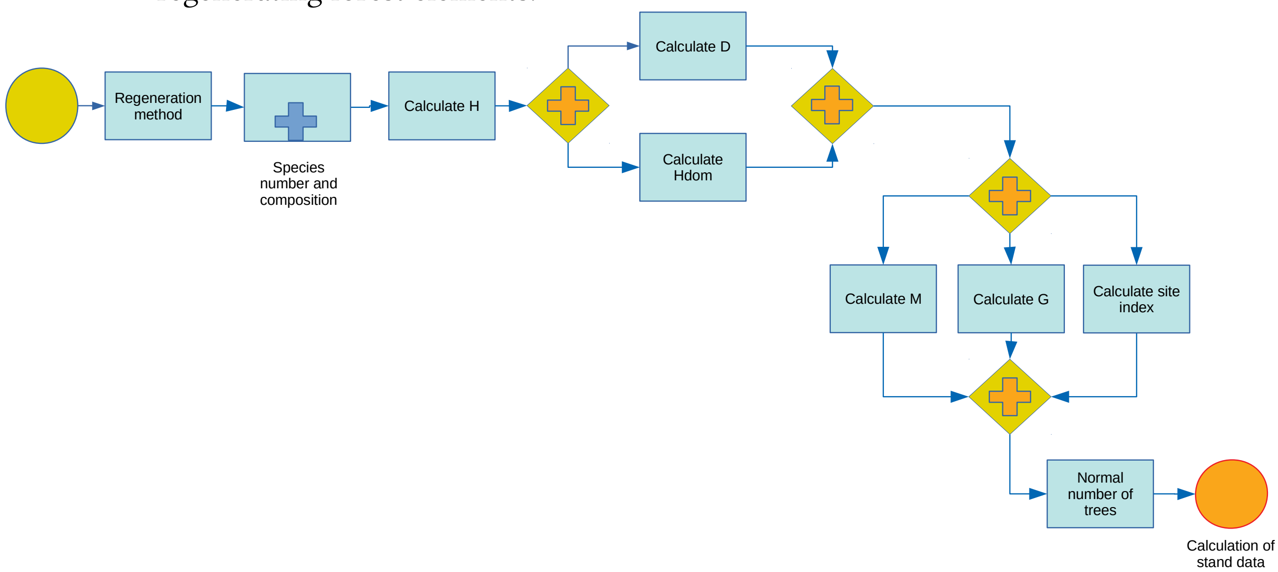

Figure 8: Scheme of regenerating model after clear felling.

Method of regeneration

The user can define the number of clearings to be regenerated naturally or anthropogenically as well as change the proportion of regeneration method by property type (state, other and all) and forest type. In the default setting the probability of anthropogenically regenerated forests is modelled sorting by property group (state and other) in accordance with the arithmetic average proportion of anthropogenically regenerated forest stand areas in 2013-2016 (Table 9).

Duration of regeneration

The program projects clearing to be regenerated in the following five years. The age of the tree stand at the end of the five years is between one and five years in both naturally and anthropogenically regenerated stands.

Soil scarification

In the default setting soil scarification is only used for anthropogenically regenerated clearing (the program allows the user to choose soil scarification as one of the factors encouraging natural regeneration).

Species' proportion and number

The content and number of regenerating species as well as the order of calculation changes depending on whether the forest stand is regenerated naturally or anthropogenically (Table 9).

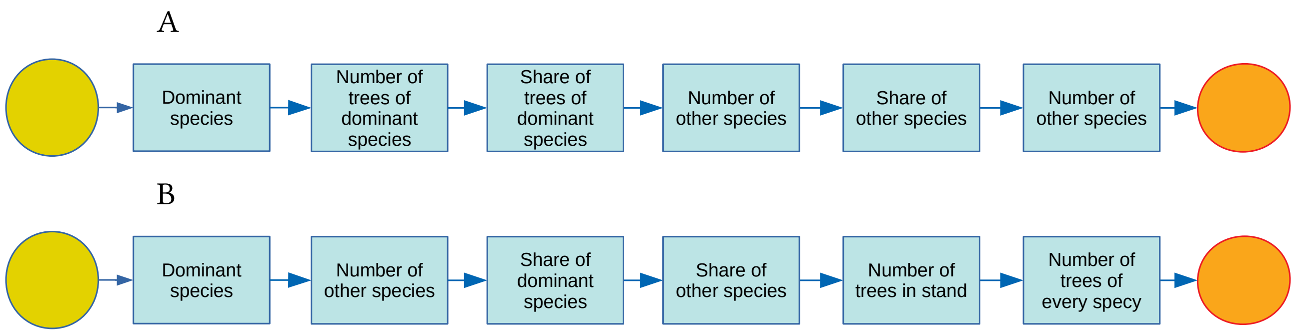

Figure 9: Scheme of species content and number in a forest stand after clear felling.

The dominating tree species in the forest stand is one of the tree species to be used for forest regeneration and afforestation as listed in regulations (Table 10).

In the program forest regeneration is modelled sorting by property group: state forests and other forests. In the default setting tree species suited for anthropogenic regeneration are pine, spruce and birch, however in small areas (with a small probability) anthropogenic regeneration is possible for other species as well (Table 11). In state forests regeneration is modelled with small areas of alder or oak, in private forests with alder.

Anthropogenically regenerated forest stands are planned with the minimal number of trees set in regulations as the number of trees in the stand (Table 10)

For other tree species the total number of trees is 0-25% of number of trees of anthropogenically regenerated tree species, the number changes depending on the forest type (Tables 32 and 33).

Table 32: Proportion of dominating tree species and other species according to forest type in anthropogenically regenerated areas

Forest type	Forest type code	Proportion of dominating tree species		Number of other species	
		Min	Max	Min	Max
Cladinoso-callunosa	1	0.95	1.00	0	2
Vacciniosa	2	0.85	1.00	0	3
Myrtillosa	3	0.75	0.95	1	3
Hylocomiosa	4	0.75	0.90	1	4
Oxalidosa	5	0.75	0.85	2	5
Aegipodiosa	6	0.75	0.80	2	5
Callunoso-sphagnosa	7	0.75	1.00	0	2
Slapjais Vacciniosa	8	0.75	0.95	0	3
Myrtilloso-sphagnosa	9	0.75	0.90	1	4
Myrtillosoi-polytrichosa	10	0.75	0.85	2	5
Drypteriosa	11	0.75	0.80	2	5
Sphagnosa	12	0.75	0.95	0	2
Caricoso-phragmitosa	14	0.75	0.90	1	3
Dryopterioso-caricosa	15	0.75	0.85	2	4
Filipendulosa	16	0.75	0.80	2	5
Callunosa mel.	17	0.85	1.00	0	2
Vacciniosa mel.	18	0.75	0.95	1	3
Myrtillosa mel.	19	0.75	0.90	2	4
Mercurialosa mel.	21	0.75	0.85	2	5
Callunosa turf. mel.	22	0.85	0.95	0	2
Vacciniosa turf. mel.	23	0.75	0.90	1	3
Myrtillosa turf. mel.	24	0.75	0.85	2	4
Oxalidosa turf. mel.	25	0.75	0.80	2	5

Table 33: Probability of other tree species[33] sorted by forest type

Forest type	Probability of other species													
	Pine	Spruce	Birch	Alder	A spen	Gr Alder	Oak	Ash	Lin	Elm	Elm	G Willow	Osi	Br leaf trees
Sl	0.961	0.097	0.353	0.008	0.003	0.003	0.006						0.006	
Mr	0.911	0.560	0.499	0.033	0.058	0.016	0.032	0.001	0.003	0.002	0.001	0.020	0.006	0.007
Ln	0.911	0.560	0.499	0.033	0.058	0.016	0.032	0.001	0.003	0.002	0.001	0.020	0.006	0.007
Dm	0.501	0.718	0.724	0.150	0.219	0.185	0.120	0.028	0.020	0.008	0.006	0.129	0.039	0.038
Vr	0.091	0.529	0.657	0.191	0.312	0.461	0.116	0.091	0.049	0.033	0.025	0.240	0.107	0.048

33 Proportion of tree species in NFI data

Forest type	Probability of other species													
	Pine	Spruce	Birch	Alder	A spen	Gr Alder	Oak	Ash	Lin	Elm	Elm	G Willow	Osi	Br leaf trees
Gr	0.069	0.579	0.671	0.346	0.243	0.439	0.182	0.262	0.131	0.114	0.027	0.162	0.171	0.046
Gs	0.961	0.097	0.353	0.008	0.003	0.003	0.006						0.006	
Mrs	0.911	0.560	0.499	0.033	0.058	0.016	0.032	0.001	0.003	0.002	0.001	0.020	0.006	0.007
Dms	0.501	0.718	0.724	0.150	0.219	0.185	0.120	0.028	0.020	0.008	0.006	0.129	0.039	0.038
Vrs	0.091	0.529	0.657	0.191	0.312	0.461	0.116	0.091	0.049	0.033	0.025	0.240	0.107	0.048
Grs	0.069	0.579	0.671	0.346	0.243	0.439	0.182	0.262	0.131	0.114	0.027	0.162	0.171	0.046
Pv	0.837	0.430	0.681	0.161	0.051	0.018	0.007	0.006	0.001		0.001	0.018	0.002	0.007
Nd	0.837	0.430	0.681	0.161	0.051	0.018	0.007	0.006	0.001		0.001	0.018	0.002	0.007
Db	0.135	0.556	0.785	0.625	0.089	0.229	0.024	0.053	0.004	0.007	0.029	0.086	0.023	0.036
Lk	0.135	0.556	0.785	0.625	0.089	0.229	0.024	0.053	0.004	0.007	0.029	0.086	0.023	0.036
Av	0.961	0.097	0.353	0.008	0.003	0.003	0.006						0.006	
Am	0.911	0.560	0.499	0.033	0.058	0.016	0.032	0.001	0.003	0.002	0.001	0.020	0.006	0.007
As	0.501	0.718	0.724	0.150	0.219	0.185	0.120	0.028	0.020	0.008	0.006	0.129	0.039	0.038
Ap	0.091	0.529	0.657	0.191	0.312	0.461	0.116	0.091	0.049	0.033	0.025	0.240	0.107	0.048
Kv	0.961	0.097	0.353	0.008	0.003	0.003	0.006						0.006	
Km	0.911	0.560	0.499	0.033	0.058	0.016	0.032	0.001	0.003	0.002	0.001	0.020	0.006	0.007
Ks	0.501	0.718	0.724	0.150	0.219	0.185	0.120	0.028	0.020	0.008	0.006	0.129	0.039	0.038
Kp	0.069	0.579	0.671	0.346	0.243	0.439	0.182	0.262	0.131	0.114	0.027	0.162	0.171	0.046

The projected total number of trees in naturally regenerated stands is between 2000 and 18 000 trees per hectare which is calculated using the Weibull equation:

$$N = \alpha_1 - \alpha_2 * \exp(-\alpha_3 * rand() * \alpha_4), where \tag{23}$$

N – Total number of naturally regenerated trees, ha^{-1};
α_i – Coefficients α_1=41088; α_2=38964; α_3=0.5039; α_4=3.1247.

Similar to anthropogenically regenerated stands, the dominating tree species is determined in naturally regenerated tree stands as well. The dominating tree species depends on the forest type. The dominating tree species is determined to be the one with the highest calculated probability which is calculated for each tree species with the following equation:

$$p = p_{MT} * rand(), where \tag{24}$$

p – The probability for the tree species to be the dominating one in the sector;
p_{MT} – Probability of the tree species being the dominating one according to forest type (Table 6.1.3).

Table 34: Probability of dominating tree species[34] in naturally regenerated stand sorted by forest type

Forest type	Tree species						
	pine	spruce	birch	alder	aspen	grey alder	other species
Cladinoso-callunosa	1.000						
Vacciniosa	1.000						
Myrtillosa	0.975		0.025				
Hylocomiosa	0.050	0.080	0.520		0.265	0.075	0.010
Oxalidosa		0.030	0.215	0.005	0.405	0.340	0.005
Aegipodiosa			0.190	0.020	0.505	0.280	0.005
Callunoso-sphagnosa	1.000						
Slapjais Vacciniosa	0.895		0.105				
Myrtilloso-sphagnosa	0.040	0.055	0.700	0.040	0.115	0.050	
Myrtillosoi-polytrichosa		0.025	0.360	0.115	0.220	0.280	
Drypteriosa		0.010	0.320	0.175	0.265	0.220	0.010
Sphagnosa	0.385		0.615				
Caricoso-phragmitosa	0.045	0.075	0.790	0.060	0.015	0.015	
Dryopterioso-caricosa		0.035	0.450	0.410	0.050	0.055	
Filipendulosa			0.325	0.575		0.100	
Callunosa mel.	1.000						
Vacciniosa mel.	0.855		0.145				
Myrtillosa mel.	0.035	0.060	0.560	0.025	0.245	0.075	
Mercurialosa mel.		0.015	0.295	0.080	0.335	0.270	0.005
Callunosa turf. mel.	0.650		0.350				
Vacciniosa turf. mel.	0.565		0.435				
Myrtillosa turf. mel.	0.020	0.070	0.775	0.025	0.090	0.020	
Oxalidosa turf. mel.		0.040	0.525	0.225	0.130	0.075	0.005

In naturally regenerated stands the content and proportion of other species depends on the forest type (Table 35). If the number of other species is modelled as zero, the share of the dominating species is automatically 100%.

Table 35: The proportion of the dominating tree species and number of other species depending on forest type in naturally regenerated forest stands

Forest type	Forest type code	Proportion of dominating tree species		Number of other tree species	
		Min	Max	Min	Max
Cladinoso-callunosa	1	0.95	1.00	0	2
Vacciniosa	2	0.85	1.00	0	3
Myrtillosa	3	0.75	0.95	1	3

34 arithmetic average proportion of naturally regenerated areas in 2013 – 2016 according to SFS data

Forest type	Forest type code	Proportion of dominating tree species		Number of other tree species	
		Min	Max	Min	Max
Hylocomiosa	4	0.65	0.90	1	4
Oxalidosa	5	0.55	0.85	2	5
Aegipodiosa	6	0.55	0.80	2	5
Callunoso-sphagnosa	7	0.75	1.00	0	2
Slapjais Vacciniosa	8	0.65	0.95	0	3
Myrtilloso-sphagnosa	9	0.55	0.90	1	4
Myrtillosoi-polytrichosa	10	0.55	0.85	2	5
Drypteriosa	11	0.55	0.80	2	5
Sphagnosa	12	0.55	0.95	0	2
Caricoso-phragmitosa	14	0.55	0.90	1	3
Dryopterioso-caricosa	15	0.55	0.85	2	4
Filipendulosa	16	0.55	0.80	2	5
Callunosa mel.	17	0.85	1.00	0	2
Vacciniosa mel.	18	0.75	0.95	1	3
Myrtillosa mel.	19	0.65	0.90	2	4
Mercurialosa mel.	21	0.55	0.85	2	5
Callunosa turf. mel.	22	0.85	0.95	0	2
Vacciniosa turf. mel.	23	0.75	0.90	1	3
Myrtillosa turf. mel.	24	0.65	0.85	2	4
Oxalidosa turf. mel.	25	0.55	0.80	2	5

Height

Tree height is calculated using equation 11 where the starting height (h_1) is zero and the duration of the actualization period is equal to the age of the tree stand.

If the area is regenerated anthropogenically, the site index 1st taken to be one unit higher than the site index corresponding the specific forest type (Table 3). Calculations are similar for naturally regenerated areas if soil scarification is projected.

If information is available on the site index of previous forest elements in the tree stand, equal site index is used for new forest elements which are similar to the previous generation.

Dominant height

Regardless of the forest element height the dominant height is calculated as a secondary parameter using formula 4 and depends on the projected average height and number of trees in the forest element.

Diameter

The average diameter at breast height is modelled as a secondary parameter and depends on the average height, taking the proportion H/D to be 1.2. The Diameter is calculated using formula 13.

Cross section area

The cross section area of forest stand with a height up to 1.3 m is 0 m^2ha^{-1} , but after reaching 1.3 m the cross section area is determined accordingly with the projected number of trees and diameter (formula No. 5).

Wood stock

The wood stock of forest stands with a height up to 2 m (height of the dominating tree species of the 1st storey) is taken to be 2 m^3ha^{-1}, but the wood stock of individual forest elements is calculated depending on its proportion (formula No. 22).

After reaching a height of 2 m the 1st. Liepa formula of individual tree volume is used (Liepa, 1996) using the number of trees, average height and square average diameter (formula No. 6).

Forest regeneration after selective felling

Forest regeneration after selective felling is modelled according to methodology described in previous chapter.

Thinning

The program includes three kinds of thinning:

- ✓ early tending;
- ✓ pre-commercial thinning;
- ✓ commercial thinning.

Early tending

Early tending is not projected directly but its effects are indirect in modelling. It is supposed that after early tending of forest regeneration a specific species content and tree number will be left and within three years of early tending optimal growing conditions will be secured for the trees, preventing mass tree mortality.

Pre-commercial or young stand thinning

Pre-commercial thinning is projected in stands which match the height and age range listed in Table 10. Pre-commercial thinning is also planned in stands where forestry activities and thinning are not prohibited.

Pre-commercial thinning not only optimises the number of trees in the forest stand but also aims to achieve pure stands suitable to the forest type.

A general scheme of pre-commercial thinning and tree data updating is given in Figure 10.

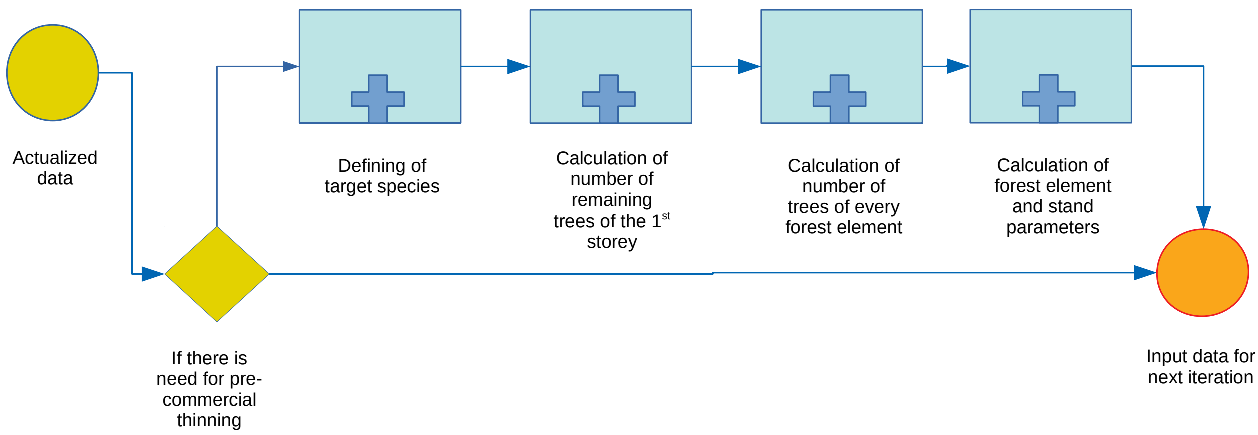

Figure 10: Scheme of pre-commercial thinning.

If multiple instances of pre-commercial thinning are planned no less than 10 years are between them (2 modelling cycles).

Stands in which pre-commercial thinning is done

Pre-commercial thinning is planned for a specific share of stands which corresponds the defined tree density (proportion of number of trees to normal number of trees) at which the stand is included in the planning of pre-commercial thinning (Table 14).

The number of trees in the 1st storey of the forest stand is calculated from the average height of the dominating forest element of the 1st storey:

$$N_{norm} = \alpha_1 - \alpha_2 * \exp(-\alpha_3 * H^{\alpha_4}), where \tag{25}$$

N_{norm} – Normal number of trees in the I storey of a forest stand, ha^{-1};
H – Average height of the dominating tree species of the forest stand, m;
α_i – Coefficients.

Table 36: Coefficients for the normal (formula No. 25) and minimal (formula No. 28) number of trees in the 1st storey of the forest stand

Tree species	Tree species code	N_{norm}				N_{min}		
		α_1	α_2	α_3	α_4	α_1	α_2	α_3
Pine	1	4002.555	2524.838	733.344	−2.875	3042.445	0.977	−0.345
Spruce	3	3203.495	708.040	666.674	−2.860	1983.232	0.992	−0.199
Birch	4	3203.434	6116.740	108.632	−1.602	1882.020	1.030	−0.341
Alder	6	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Aspen	8	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Grey alder	9	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Oak	10	2002.025	447.004	1 513 809.808	−6.807	1500	1	0
Ash	11	2002.025	447.004	1 513 809.808	−6.807	1500	1	0
Linden	12	3203.434	6116.740	108.632	−1.602	1882.020	1.030	−0.341
Larch	13	3203.495	708.040	666.674	−2.860	1983.232	0.992	−0.199
Other pines	14	4002.555	2524.838	733.344	−2.875	3042.445	0.977	−0.345
Other spruces	15	3203.495	708.040	666.674	−2.860	1983.232	0.992	−0.199
Elm	16	2002.025	447.004	1 513 809.808	−6.807	1500	1	0

Tree species	Tree species code	N_{norm}				N_{min}		
		α_1	α_2	α_3	α_4	α_1	α_2	α_3
Beech	17	2002.025	447.004	1 513 809.808	−6.807	1500	1	0
Hornbeam	18	2002.025	447.004	1 513 809.808	−6.807	1500	1	0
Poplar	19	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Willow	20	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Goat willow	21	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Fir	23	3203.495	708.040	666.674	−2.860	1983.232	0.992	−0.199
Maple	24	2002.025	447.004	1 513 809.808	−6.807	1500	1	0
Osier	30	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Juniper	31	3203.495	708.040	666.674	−2.860	1983.232	0.992	−0.199
Rowan	32	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Alder buckthorn	33	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Hazel	34	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Bird cherry	35	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Hawthorn	41	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Crab apple	51	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Broad leaved trees	53	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Unknown species	54	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Cherry	56	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229
Buckthorn	57	3206.086	2190.034	377.110	−2.586	1958.762	0.981	−0.229

Removed and remaining tree species in the forest stand after pre-commercial thinning

In pre-commercial thinning the goal is to create pure stands of target tree species suitable to the forest type. Up to a height of 12 m tree stand in which at least 75% of the total number of trees in the 1st storey are trees of the dominating tree species

All tree and bush species can be categorized into 3 groups (Table 15):

- ✓ tree species which can form a forest stand and can be the dominating tree species:
  - o tree species (priority code 1-8) which are defined in an order of priority of target tree species,
  - o tree species (11) which are not defined in an order of priority of target tree species, but which can be target tree species when they are already the dominating tree species, however, if they are not the target tree species, are left in quantities that will not interfere with the growing of the target tree species,
  - o tree species (9) which can be target tree species in cases where tree species of the two previous groups cannot form a forest stand (N<Nmin),

- ✓ tree species (33) which cannot form a forest stand and cannot be target tree species, but are left in quantities that do not interfere with the growth of the target tree species,
- ✓ bush and tree species (22) which are removed completely during thinning.

The target species of the 1st storey is defined depending on the method of regeneration, dominating tree species and number of trees in individual forest elements (Figure 11):

I. in anthropogenically regenerated plots the target species is the anthropogenically regenerated tree species,

II. in naturally regenerated plots:

   a. if one of the tree species is of priority group 11, it is the target species,

   b. if one of the tree species of priority groups 1-8 has a share of at least 80% of the optimal number of trees for the species, it is the target species of the highest priority,

   c. if none of priority group 1 – 8 tree species has a share of at least 80% of the optimal number of trees for that species, the tree species with the greatest number of trees is the target species, in the case of equal number of trees the species with the higher priority is the target species.

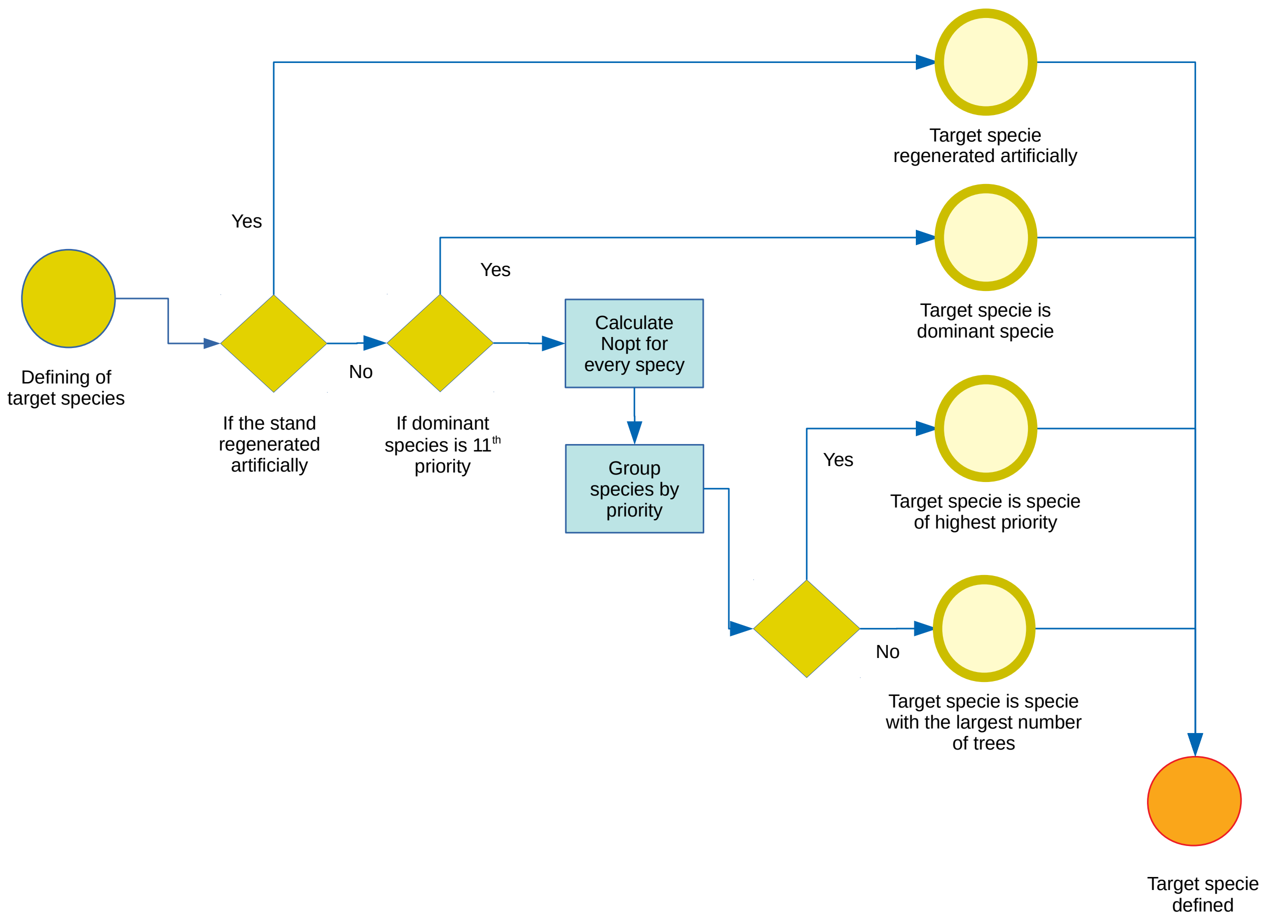

Figure 11: Scheme of determining the target species of the 1st storey of the forest stand.

Number of removed and remaining trees in forest stands after pre-commercial thinning

The number of tree remaining in the 1st storey after pre-commercial thinning is calculated according to the optimal number of trees for the target species of the 1st storey:

$$N_{pecSKC} = k * N_{opt}, where \quad (26)$$

N_{pecSKC} – Number of trees remaining in the I storey after pre-commercial thinning, ha^{-1};
N_{opt} – Minimal number of trees listed in regulation for the target tree species of the I storey, ha^{-1};
k – Coefficient of intensity for pre-commercial thinning (1.00 – 1.25).

If multiple target species are planned in the stand after pre-commercial thinning, the remaining number of trees is calculated by the dominating tree species (with the highest priority).

The optimal number of trees in the 1st storey of the tree stand is calculated using the following equation:

$$N_{opt} = \frac{\alpha_1}{1 + \alpha_2 * \exp(-\alpha_3 * H)}, where \quad (27)$$

N_{opt} – Optimal number for the target species of the I storey, ha^{-1};
H – Average height of the target species of the I storey, m;
α_i – Coefficients.

Table 37: Coefficients for the determining of the optimal number of trees in the 1st storey of the tree stand (formula 27, 28 and 29)

Tree species	α_1	α_2	α_3
Pine	1232.220	−0.727	0.211
Other tree species	1051.817	−0.520	0.114

After pre-commercial thinning the number of trees in the 1st storey of the tree stand may not be below the minimal number of trees or greater than the normal number of trees set in regulations (formula 25). The minimal number of trees in 1st storey of the tree stand is calculated using the equation below:

$$N_{min} = \alpha_1 * \alpha_2^H * H^{\alpha_3}, where \quad (28)$$

N_{min} – Minimal number of trees in the I storey, ha^{-1};
H – Average height of the dominating tree species of the I storey, m;
α_i – Coefficients.

Calculating taxation indicators of individual forest elements and tree stands after pre-commercial thinning

Scheme of taxation indicators of individual forest elements after pre-commercial thinning is shown in Figure 12.

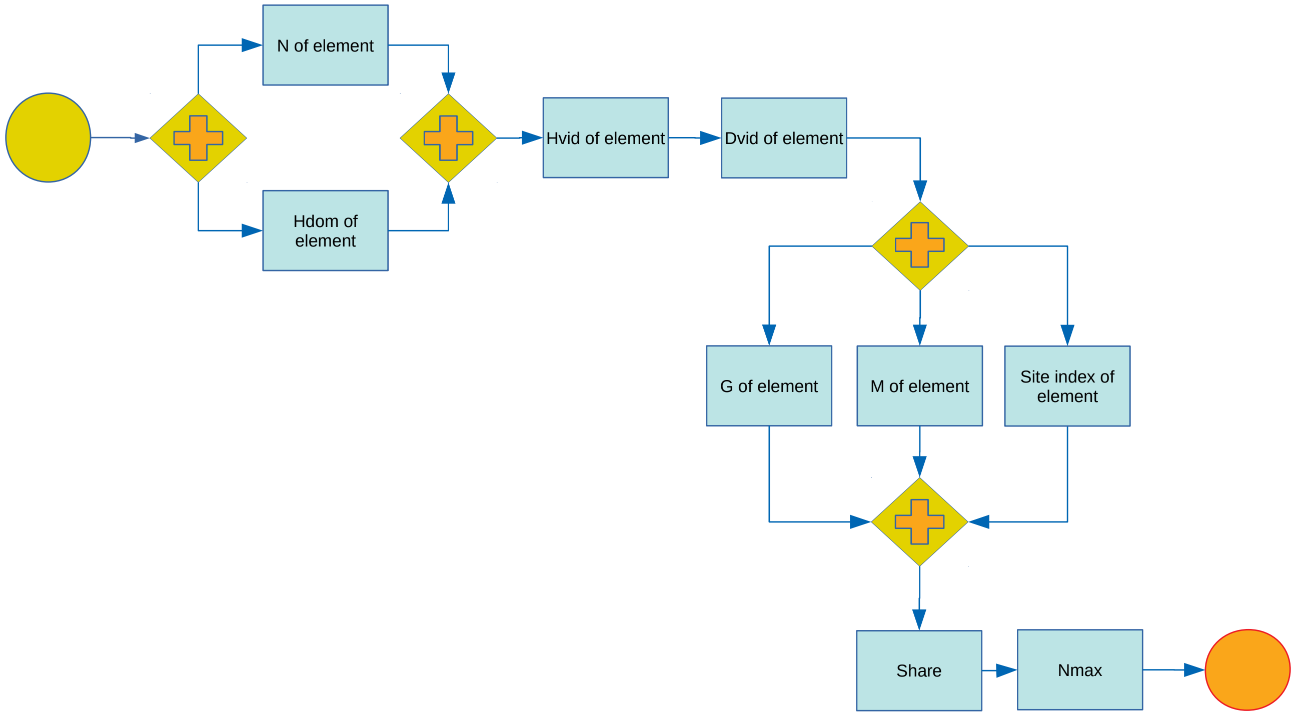

Figure 12: Scheme of calculations of taxation data of individual forest elements of the 1st storey after pre-commercial thinning.

Average height

The average height after pre-commercial thinning is calculated from the dominant height and number of remaining trees:

$$h = \alpha_1 * h_{dom}^{\alpha_2} * n^{\alpha_3}, where \tag{29}$$

h – Average height of the forest element, m;
h_{dom} – Dominant height of the forest element, m;
n – Number of trees in the forest element after pre-commercial thinning, ha^{-1};
α_{1-3} – Coefficients.

Dominant height

The dominant height of forest elements does not change after pre-commercial thinning.

Average diameter

The average diameter after pre-commercial thinning is calculated using a modification of the height curve equation:

$$d_{pec} = \frac{\alpha_1 * d_{pirms} + \alpha_2}{\frac{\alpha_1 * \alpha_2}{d_{pirms}} + \ln\left(\frac{h_{pec} - 1.3}{h_{pirms} - 1.3}\right)}, where \tag{30}$$

d_{pec} – Average diameter after thinning, cm;
d_{pirms} – Average diameter before thinning, cm;
h_{pec} – Average height after thinning, m;
h_{pirms} – Average height before thinning, m;
α_{1-3} – Coefficients.

Table 38: Coefficients for the average diameter of a forest element after thinning (formula No. 30)

Tree species	Tree species code	α1	α2
Pine	1	0.127	4.743
Spruce	3	0.146	7.094
Birch	4	0.179	3.815
Alder	6	0.137	3.007
Aspen	8	0.137	3.418
Grey alder	9	0.230	1.982
Oak	10	0.179	3.815
Ash	11	0.179	3.815
Linden	12	0.179	3.815
Larch	13	0.127	4.743
Other pines	14	0.127	4.743
Other spruces	15	0.146	7.094
Elm	16	0.179	3.815
Beech	17	0.179	3.815
Hornbeam	18	0.179	3.815
Poplar	19	0.137	3.418
Willow	20	0.230	1.982
Goat willow	21	0.230	1.982
Fir	23	0.146	7.094
Maple	24	0.179	3.815
Osier	30	0.230	1.982
Juniper	31	0.230	1.982
Rowan	32	0.230	1.982
Alder buckthorn	33	0.230	1.982
Hazel	34	0.230	1.982
Bird cherry	35	0.230	1.982
Hawthorn	41	0.230	1.982
Crab apple	51	0.230	1.982
Broad leaved trees	53	0.230	1.982
Unknown species	54	0.230	1.982
Cherry	56	0.230	1.982
Buckthorn	57	0.230	1.982

Basal area

The basal area after pre-commercial thinning is calculated by subtracting the removed basal area from the basal area before thinning:

$$g_{pec} = g_{pirms} - g_{izc}, where$$

g_{pec} – Cross-section area of forest element after thinning, $m^2 ha^{-1}$;

g_{pirms} – Cross-section area of forest element before thinning, $m^2 ha^{-1}$; (31)

g_{izc} – Cross-section area of forest element removed during thinning, $m^2 ha^{-1}$.

The removed basal area is calculated with the basal area before thinning and number removed trees, as well as the type of thinning:

$$g_{izc} = rg * g_{kop}\, general, where$$

g_{izc} – Removed cross-section area, $m^2 ha^{-1}$;

rg – Thinning intensity;

g_{pirms} – Cross-section area before thinning, $m^2 ha^{-1}$; (32)

ng – Type of thinning, 1.25;

n_{izc} – Number of removed trees, trees ha^{-1};

n_{kop} – Number of trees before thinning, trees ha^{-1}.

Number of trees

Number of trees in the 1st storey of a forest element. The calculation of the total number of trees in the 1st storey of a forest element was described previously (formula 22). In the calculation of number of trees in individual forest elements number and content of trees of the target and other species is used:

- The number of trees of the target species is 95% of the initial number of trees, but does not exceed 90% of remaining number of trees after pre-commercial thinning, except for cases where the number of other tree species cannot form the 10% of other trees after pre-commercial thinning and the remainder is added from the target species.
- If the 1st storey of the tree stand contains tree species of the priority group 11, which are not target species and tree species of priority group 33, then their share is 95% of the initial number of trees, but the total share is no more than 5% of remaining trees after pre-commercial thinning.
- Other tree species are added in order of priority, adding trees of other species until the needed number of trees is achieved. If the needed number of trees is less than 95% of the number of trees in the particular forest element, the specific needed number of trees is added.

Tree species of priority group 22 are removed completely in the 1st storey.

Number of trees in the II and III storey of a forest element. Tree species of priority groups 1-8, 11 and 33 are modelled to remain in numbers under 10% of the initial number of trees in forest elements of II and III stories of tree stands, but other species of the storey are removed completely.

Wood stock

To calculate the wood stock, I. Liepa formula of individual tree volume is used (Liepa, 1996), using number of trees, average height of trees and square average diameter (formula 6).

Commercial thinning

Commercial thinning is intended for stands which exceed minimal height, but not the maximum age given in Table 12. Commercial thinning is also planned for stands in which forestry activities are not prohibited and in which thinning is not prohibited.

The projected scale of commercial thinning depends on the tree species, forest type (suitability of tree species to the forest type) and storey for each forest element.

A scheme of commercial thinning updates is given in Figure 13.

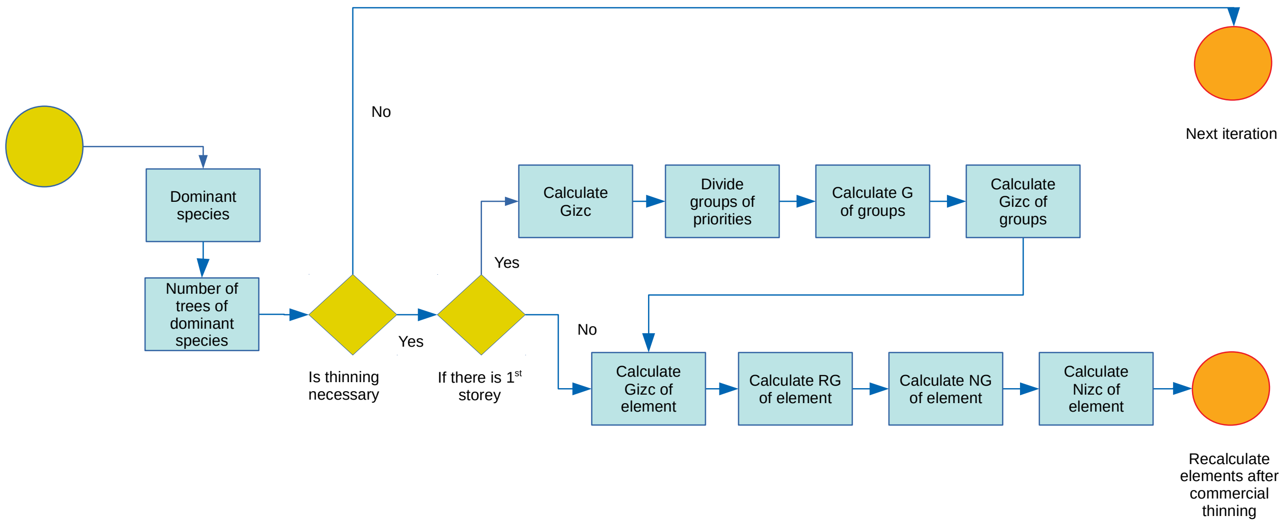

Figure 13: Scheme of modelling commercial thinning.

Stands in which commercial thinning is done

Commercial thinning is planned for a specific share of stand which match the defined density (proportion of the basal area of the stand to normal basal area) at which stands are to be included in the planning (Table 16). The program does not plan for more than three commercial thinning instances and plans at least 10 years (2 modelling cycles) between two commercial thinning instances.

The normal basal area of the 1st storey of a stand is calculated as the sum of cross section areas of individual forest elements of the 1st storey.

$$G_{norm} = \sum (g_{norm}), \quad (33)$$

G_{norm} – Normal cross-section area for the I storey of a tree stand, $m^2 ha^{-1}$;
g_{norm} – Normal cross-section of individual forest elements of the I storey of a tree stand, $m^2 ha^{-1}$.

The normal basal area of an individual forest elements of the 1st storey is calculated using the following equation:

$$g_{norm} = ip * \alpha_1 * \alpha_2^h * h^{\alpha_3}, where \quad (34)$$

g_{norm} – Normal corss-section of individual forest elements of the I storey of a tree stand, $m^2 ha^{-1}$;
h – Average height of a forest element, m;
ip – Proportion of the forest element;
α_i – Coefficients.

Table 39: Coefficients for equation of normal basal of individual forest elements (formula No. 34) and the minimum basal area (formula No. 36)

Tree species	Tree species code	G_{norm}			G_{min}		
		α_1	α_2	α_3	α_1	α_2	α_3
Pine	1	9.90686	0.99015	0.48135	23.05347	9.33540	0.20327
Spruce	3	6.28821	1.00308	0.53391	33.53064	13.43785	0.15027
Birch	4	3.01668	0.99796	0.72995	23.08551	7.53172	0.11702
Alder	6	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Aspen	8	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Grey alder	9	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Oak	10	3.19604	0.99548	0.75766	24.79793	10.06490	0.14140
Ash	11	0.72374	0.95709	1.46528	16.67566	14.95010	0.19405
Linden	12	3.01668	0.99796	0.72995	23.08551	7.53172	0.11702
Larch	13	6.28821	1.00308	0.53391	33.53064	13.43785	0.15027
Other pines	14	9.90686	0.99015	0.48135	23.05347	9.33540	0.20327
Other spruces	15	6.28821	1.00308	0.53391	33.53064	13.43785	0.15027
Elm	16	3.19604	0.99548	0.75766	24.79793	10.06490	0.14140
Beech	17	3.19604	0.99548	0.75766	24.79793	10.06490	0.14140
Hornbeam	18	3.19604	0.99548	0.75766	24.79793	10.06490	0.14140
Poplar	19	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Willow	20	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Goat willow	21	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Fir	23	6.28821	1.00308	0.53391	33.53064	13.43785	0.15027
Maple	24	3.19604	0.99548	0.75766	24.79793	10.06490	0.14140
Osier	30	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Juniper	31	6.28821	1.00308	0.53391	33.53064	13.43785	0.15027
Rowan	32	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Alder buckthorn	33	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Hazel	34	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Bird cherry	35	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Hawthorn	41	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Crab apple	51	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Broad leaved trees	53	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Unknown species	54	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Cherry	56	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124
Buckthorn	57	3.65344	0.99972	0.71034	32.66422	7.63357	0.09124

Removed and remaining basal area of tree stand after commercial thinning

The basal area of the 1st storey of a tree stand after commercial thinning is calculated according to the minimum basal area listed in regulations of the dominating species of the storey:

$$G_{pecKKC}=k*G_{min}, where$$

G_{pecKKC} – Remaining cross-section area of the I storey of the tree stand after commercial thinning, $m^2 ha^{-1}$;

G_{min} – Minimum cross-section area of the dominating tree species of the storey listed in regulations, $m^2 ha^{-1}$; (35)

k – Coefficients of intensity of commercial thinning (1.05-1.15).

The minimum basal area of the 1st storey if a tree stand is calculated using the following equation:

$$G_{min}=\frac{\alpha_1}{1+\alpha_2*\exp(-\alpha_3*H)}, where$$

G_{min} – Minimum cross-section area of the dominating tree species of the I storey listed in regulations, $m^2 ha^{-1}$; (36)

H – Average height of the dominating tree species of the I storey, m;

α_i – Coefficients.

Forest elements of the 1st and 2nd storey of the tree stands are modelled with a remaining 20% of the initial basal area after commercial thinning.

The intensity of commercial thinning in the 1st storey of a tree stand changes for some tree species depending on the priority (suitability to forest type) group (Table 18). The share of the removed basal area (intensity of thinning) of the forest element is different for each priority group.

- ✓ if the sum of the basal areas of forest elements of group 0 is greater than the projected removed basal area, then the removed basal area of group 0 is 80% of the removed basal area, but the removed basal area of group 1 elements is 20% of the removed basal area;
- ✓ if the sum of basal areas of forest elements of group 0 does not greater than the projected removed basal area, then the removed basal area of group 0 is 80% of the removed basal area, but the removed basal area of group1 is the difference between the projected removed cross section area and the removed group 0 cross section area.

Method and intensity of commercial thinning

Not only N and G, but also D and H exchange as a result of thinning is modelled, allowing for "simulation":

1. neutral selection, where average D and average H remain unchanged, G and N are decreased;
2. thinning bottom up, where average H and average D grow, G and N are decreased;
3. thinning top down, where average H, average D, G and N are decreased.
4. combination of 1st and 2nd 1) entry roads (no more than 20% of the area) and 2) other area (this approach cannot be used for NFI sampling plot data).

The following indicators are used for describing the type and intensity of thinning (Von Gadow & Hui, 1999):

scale of thinning:

$$rG = \frac{G_{izc}}{G_{kop}}, where \qquad (37)$$

rG – Intensity of thinning;

G_{izc} – Removed cross-section area, $m^2 ha^{-1}$;

G_{kop} – Total cross-section area, $m^2 ha^{-1}$.

type of thinning:

$$NG = \frac{\frac{N_{izc}}{N_{kop}}}{rG} \qquad (38)$$

NG – type of thinning (for neutral selection NG = 1.0; for thinning bottom up NG >1.0; for thinning top down NG<1.0);

rG – Intensity of thinning;

N_{izc} – Number of removed trees, trees ha^{-1};

N_{kop} – Total number of trees, trees ha^{-1}.

The type of commercial thinning (NG) and the corresponding share is defined by management scenario (Table 17).

By modifying formula No. 26 removed number of trees can be calculated:

$$N_{izc} = N_{kop} * rG * NG, where \qquad (39)$$

NG – type of thinning (for neutral selection NG = 1.0; for thinning bottom up NG >1.0; for thinning top down NG < 1.0);

rG – Intensity of thinning;

N_{izc} – Number of removed trees, trees ha^{-1};

N_{kop} – Total number of trees, trees ha^{-1}.

Updating taxation indicators of forest elements after thinning

Taxation data is updated after the calculation of thinning indicators and removed amount (Figure 14).

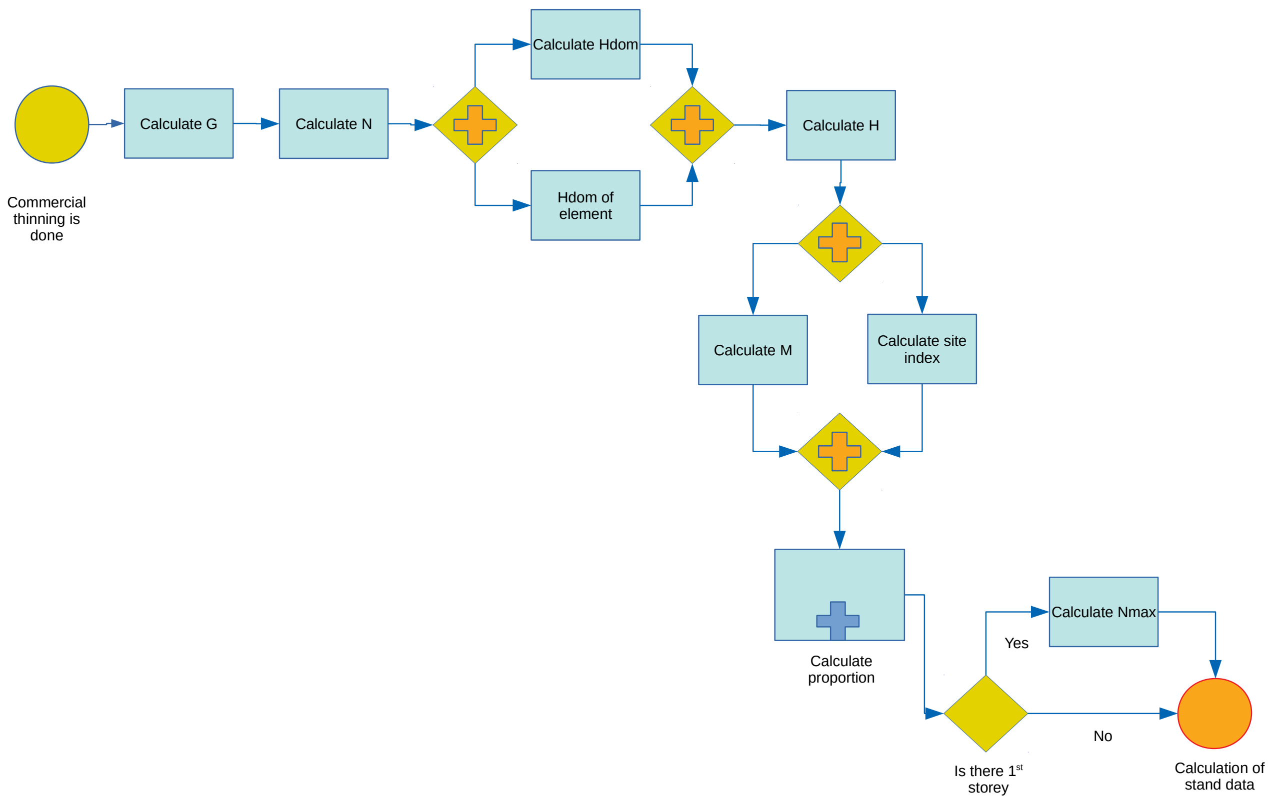

Figure 14: Calculation of taxation data of forest elements after commercial thinning

The basal area of forest elements is calculated as the difference between the initial basal area and projected removed basal area:

$$g_{pec} = g_{pirms} - g_{izc}, where \tag{40}$$

g_{pec} – Cross-section area of forest element after commercial thinning, $m^2 ha^{-1}$;
g_{pirms} – Cross-section area of forest element before commercial thinning, $m^2 ha^{-1}$;
g_{izc} – Cross-section area removed durinf commercial thinning, $m^2 ha^{-1}$.

The number of trees in a forest element is calculated as the difference between initial number of trees and projected removed number of trees:

$$n_{pec} = n_{pirms} - n_{izc}, where \tag{41}$$

n_{pec} – Number of trees in forest element after commercial thinning, ha^{-1};
n_{pirms} – Number of trees in forest element before commercial thinning, ha^{-1};
n_{izc} – Number of trees removed during commercial thinning, ha^{-1}.

The following equation is used to calculate the average diameter of the forest element after thinning:

$$d = \sqrt{40000 * \frac{\frac{g_{pec}}{pi()}}{n_{pec}}}, where \tag{42}$$

d – Average diameter after thinning, cm;
g_{pec} – Cross-section area of forest element after commercial thinning, $m^2 ha^{-1}$;
n_{pec} – Number of trees in forest element after commercial thinning, ha^{-1}.

The dominant height (h_{dom}) does not change after commercial thinning.

The average height of a forest element after commercial thinning is calculated using the dominant height and number of trees in the forest element:

$$h = \alpha_1 * h_{dom}^{\alpha_2} * n^{\alpha_3}, where \quad (43)$$

h – Average height of the forest element, m;
h_{dom} – Dominant height of the forest element, m;
n – Number of trees in the forest element after commercial thinning, ha^{-1};
α_{1-3} – Coefficients.

I. Liepa formula of individual tree volume (Liepa, 1996) is used to calculate wood stock with the average height and square average diameter of the trees (formula No. 6)

The calculation of site index is described in chapter 'Site index of forest elements', the calculation of the proportion of the forest element is described in chapter 'Proportion of a forest element', the calculation of the maximum number of trees is described in chapter 'Maximum number of trees in the forest element'.

The calculation of taxation indicators of stand is described in chapter 'Calculating taxation indicators of tree stands'.

For the time being additional wood stock increase after commercial thinning is not being modelled for height or diameter. Small additional increase of diameter is caused by the decrease in density (approximately 10-15% in 10 years).

Final felling

The planning of final felling includes sampling plots where forestry activity is not prohibited (commercial activity restriction code 1), final felling and thinning are not prohibited (2) and final felling is not prohibited (3).

Final felling is planned in plots where the trees of the dominating species of the 1st storey have reached the age or diameter of final felling (Table 19).

The maximum scale of final felling is determined for the area and wood stock sorted by the dominating tree species of the 1st storey and property type (Table 20).

Two types of final felling are modelled: clear felling and selective felling. The probability depends on the forest property type (Table 21).

Clear felling

Clear-fellings are planned in stands where forest management is not prohibited (management restriction code 1), regenerative felling and thinning is not prohibited (management restriction code 2), regenerative felling is not forbidden (management restriction code 3) and clear-felling is not forbidden (management restriction code 4). Clear-fellings are not planned in areas, where dominant species are Oak, Linden, Maple, Elm or Hornbeam.

If clear felling is planned in the sector, the whole tree stand is felled, keeping:

- twelve living and five dry ecological trees per hectare in state forests,
- six living and five dry ecological trees per hectare in other forests.

The dimensionally largest trees are left as living ecological trees:

- the average height of living ecological trees is 5% higher than the average height before felling,
- the average diameter of living ecological trees is 10% greater than the average diameter before felling.

Trees of the highest priority species (Table 40) are left as 2/3 of living ecological trees (in state forests 8 trees, in other forests 4 trees), the others being trees of the dominating tree species. If the sector does not contain any priority group trees, all remaining trees are of the dominating tree species.

Table 40: Priority ecological tree species after clear felling by forest type

Forest type	Forest type code	Priority group					
		1	2	3	4	5	6
Cladinoso-callunosa	1	Pine					
Vacciniosa	2	Pine					
Myrtillosa	3	Pine	Oak				
Hylocomiosa	4	Pine	Oak	Birch			
Oxalidosa	5	Oak	Linden	Ash	Elm	Maple	Aspen
Aegipodiosa	6	Oak	Linden	Ash	Elm	Maple	Alder
Callunoso-sphagnosa	7	Pine					
Slapjais Vacciniosa	8	Pine					
Myrtilloso-sphagnosa	9	Pine	Oak	Birch			
Myrtillosoi-polytrichosa	10	Oak	Linden	Ash	Elm	Alder	Aspen
Drypteriosa	11	Oak	Linden	Ash	Elm	Alder	Alder
Sphagnosa	12	Pine	Birch				
Caricoso-phragmitosa	14	Pine	Birch				
Dryopterioso-caricosa	15	Pine	Alder	Birch			
Filipendulosa	16	Alder	Ash				
Callunosa mel.	17	Pine					
Vacciniosa mel.	18	Pine	Oak				
Myrtillosa mel.	19	Pine	Oak	Birch			
Mercurialosa mel.	21	Oak	Linden	Ash	Elm	Maple	Aspen
Callunosa turf. mel.	22	Pine					
Vacciniosa turf. mel.	23	Pine	Oak				
Myrtillosa turf. mel.	24	Pine	Oak	Birch			
Oxalidosa turf. mel.	25	Oak	Linden	Ash	Elm	Maple	Aspen

Undergrowth of species suitable to the forest type up to two meters in height is kept at 80% of initial number after clear felling.

Selective felling

The program considers that selective felling is continuous selective felling or group selective felling, but selective felling in the classical sense is not modelled.

Selective felling is planned for sampling plots in which forestry activity (commercial activity restriction code 1) is not prohibited, final felling and thinning is not prohibited (2) and final felling is not prohibited (3).

Selective felling is mostly modelled for state forest sectors where clear felling is prohibited.

In gradual felling the mother stand is removed in the space of 10 years. Two or three felling periods are planned. If two periods are planned for gradual felling, they are spaced ten years apart, but in the case of three periods they are spaced five years apart.

First felling period

Regardless of whether there are two or three felling periods, the remaining basal area after the first period is calculated using the following equation:

$$G_{pec} = k * G_{krit}, where \tag{44}$$

G_{pec} – Cross-section area of tree stand after gradual thinning, $m^2 ha^{-1}$;
G_{krit} – Critical cross-section area of the tree stand, $m^2 ha^{-1}$;
k – Coefficient between 1.55 and 1.65.

The following equation is used to calculate the critical basal area of the tree stand:

$$G_{krit} = \alpha_1 * H^{\alpha_2}, where \tag{45}$$

G_{krit} – Critical cross-section area of the tree stand, $m^2 ha^{-1}$;
H – Average height of the dominating tree species of the I storey of the tree stand, m;
α_i – Coefficients.

Table 41: Coefficients for the critical basal area of a tree stand (formula No. 45)

Tree species	α_1	α_2
Pine	4.078	0.245
Spruce and other coniferous trees	1.470	0.575
Birch, linden	0.867	0.666
Alder, aspen, grey alder and other deciduous trees	0.926	0.701
Oak, elm, maple, beech, hornbeam	1.053	0.635
Ash	0.962	0.604

Second felling period

The second felling period is performed only if three periods are planned. In this period the remaining basal area of the mother stand is decreased to the critical basal area (formula No. 45)

The last felling period

In the last felling period the mother stand is felled completely, leaving only ecological trees. The criteria of leaving ecological trees and number of trees left is the same as after clear felling.

In sectors where clear felling is prohibited the final felling period is only planned if the height of the young stand is at least 12 meters and the basal area is greater than the minimal basal area (formula No. 35). In other sectors wherever selective felling is modelled the final felling period is planned 10 years after the first felling period.

After the last felling period ecological trees are kept same as after clear felling (Chapter ‘Clear felling’).

Sanitary felling

Sanitary clear felling is similar to clear felling and sanitary selective felling is similar to commercial thinning, but in the species suitability table spruce and bush species are marked as unsuitable species (group 0) and other species as suitable (group 1).

MODELLING OF DEAD WOOD

Deadwood taxation parameters are calculated for each forest element at each projection cycle. In every next cycle the amount of deadwood is updated accounting for decomposition. When updating the amount of deadwood average diameter and height (theses may have to be reduced by a specific % as well) remain the same, but other taxation indicators are recalculated.

Decomposition time of deadwood

All tree species are sorted into four groups depending on their decomposition time, which are 20, 30, 40 and 50 years (Table 42).

Table 42: Decomposition time of deadwood, coefficients of diameter, height decrease

Tree species	Tree species code	Decomposition time	Diameter	Height
Pine	1	50	0.89	0.85
Spruce	3	40	0.86	0.82
Birch	4	30	0.81	0.76
Alder	6	30	0.81	0.76
Aspen	8	20	0.71	0.64
Grey alder	9	20	0.71	0.64
Oak	10	50	0.89	0.85
Ash	11	50	0.89	0.85
Linden	12	40	0.86	0.82
Larch	13	40	0.86	0.82
Other pines	14	50	0.89	0.85
Other spruces	15	40	0.86	0.82
Elm	16	50	0.89	0.85
Beech	17	50	0.89	0.85
Hornbeam	18	50	0.89	0.85
Poplar	19	20	0.71	0.64
Willow	20	20	0.71	0.64
Goat willow	21	20	0.71	0.64
Fir	23	40	0.86	0.82
Maple	24	50	0.89	0.85
Osier	30	20	0.71	0.64
Juniper	31	50	0.89	0.85
Rowan	32	30	0.81	0.76
Alder buckthorn	33	20	0.71	0.64
Hazel	34	20	0.71	0.64
Bird cherry	35	20	0.71	0.64
Hawthorn	41	30	0.81	0.76
Crab apple	51	30	0.81	0.76

Tree species	Tree species code	Decomposition time	Diameter	Height
Broad leaved trees	53	20	0.71	0.64
Unknown species	54	20	0.71	0.64
Cherry	56	30	0.81	0.76
Buckthorn	57	20	0.71	0.64

A matrix is created for each previously made group to depict how deadwood divides into decomposition groups (new, medium, old and decomposed wood) and into five year periods of update projections (Table 43).

Table 43: Division of deadwood into decomposition groups and 5 year periods of updated projections sorted by decomposition time

Decomposition time, years	Projection period	Deadwood, %			
		new	medium	old	decomposed
50	1	20	80	0	0
	2	0	82	18	0
	3	0	52	48	0
	4	0	22	74	4
	5	0	1	80	19
	6	0	0	66	34
	7	0	0	51	49
	8	0	0	36	64
	9	0	0	21	79
	10	0	0	6	94
40	1	20	79	0	0
	2	0	72	28	0
	3	0	37	63	0
	4	0	5	83	12
	5	0	0	68	32
	6	0	0	48	52
	7	0	0	28	72
	8	0	0	8	92
30	1	20	78	2	0
	2	0	64	36	0
	3	0	19	66	15
	4	0	0	60	40
	5	0	0	35	65
	6	0	0	10	90
20	1	20	77	3	0
	2	0	44	49	7
	3	0	0	56	44
	4	0	0	16	84

Calculation of deadwood taxation parameters

Principles of calculation of dead wood stock by species and quality classes is shown in Figure 15 and 16.

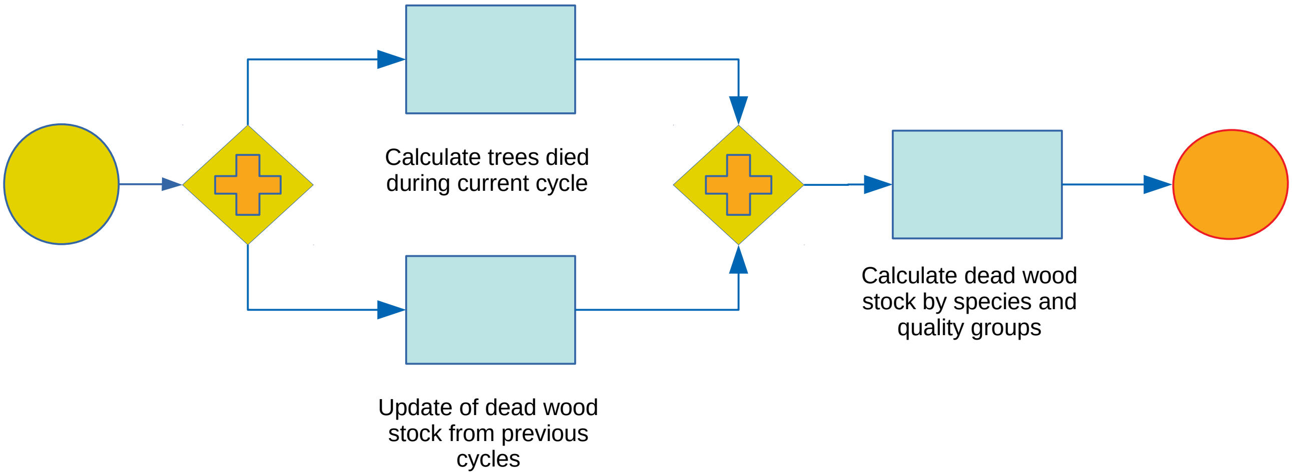

Figure 15: General scheme of deadwood calculations.

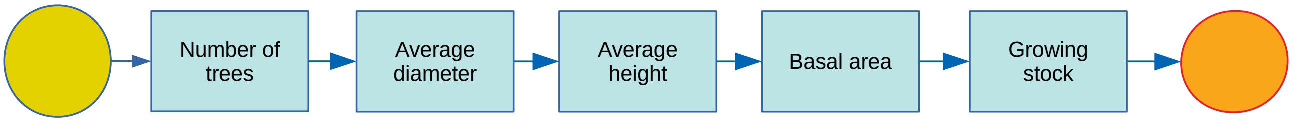

Figure 16: Scheme of deadwood taxation indicator calculation.

The general equation of a height curve is used in calculation of the average height of deadwood every update period of a forest element:

$$h_{atm} = 1.3 + (h_1 - 1.3) * \exp\left(\alpha_1 * \left(1 + \frac{d_1}{d_{atm}}\right) + \alpha_2\left(\frac{1}{d_1} - \frac{1}{d_{atm}}\right)\right), where \tag{46}$$

d_1 – average diameter at the beginning of projection period, cm;

d_{atm} – average diameter of deadwood, cm;

h_1 – average height height in the end of projection period, m;

h_{atm} – average height of deadwood, m;

α_{1-2} – coefficients.

The average height of deadwood formed in previous years is calculated as follows:

$$h_{atm2} = h_{atm1} * \alpha, where \tag{47}$$

h_{atm1} – Average height of deadwood in the previous update period, m;

h_{atm2} – Average height of deadwood in the current update period, m;

α – coefficient.

For each forest element average diameter of dead trees is calculated depending from initial diameter and age of forest element:

$$d_{atm} = d_1 * (\alpha_1 * a_1 + \alpha_2), where \tag{48}$$

d_{atm} – average diameter of dead trees, cm;

d_1 – average diameter of forest element at the beginning of the period, cm;

a_1 – age of forest element at the beginning of the period, years;

α_{1-2} – coefficients.

Table 44: Coefficients for calculation of average diameter of dead trees in formulas No. 47 and 48

Tree species	Species ID	First floor		Second floor	
		α_1	α_2	α_1	α_2
Pine	1	0.00030	0.81310	0.00114	0.92958
Spruce	3	0.00009	0.95758	0.00078	0.99369
Birch	4	0.00098	0.81725	0.00251	0.88205
Alder	6	0.00098	0.81725	0.00251	0.88205
Aspen	8	0.00098	0.81725	0.00251	0.88205
Grey alder	9	0.00196	0.85705	0.00204	0.90027
Oak	10	0.00042	0.92545	0.00047	0.95589
Ash	11	0.00042	0.92545	0.00047	0.95589
Linden	12	0.00042	0.92545	0.00047	0.95589
Larch	13	0.00009	0.95758	0.00078	0.99369
Other pines	14	0.00030	0.81310	0.00114	0.92958
Other spruces	15	0.00009	0.95758	0.00078	0.99369
Elm	16	0.00042	0.92545	0.00047	0.95589
Beech	17	0.00042	0.92545	0.00047	0.95589
Hornbeam	18	0.00042	0.92545	0.00047	0.95589
Poplar	19	0.00098	0.81725	0.00251	0.88205
Willow	20	0.00196	0.85705	0.00204	0.90027
Goat willow	21	0.00196	0.85705	0.00204	0.90027
Fir	23	0.00009	0.95758	0.00078	0.99369
Maple	24	0.00042	0.92545	0.00047	0.95589
Osier	30	0.00196	0.85705	0.00204	0.90027
Juniper	31	0.00009	0.95758	0.00078	0.99369
Rowan	32	0.00098	0.81725	0.00251	0.88205
Alder buckthorn	33	0.00196	0.85705	0.00204	0.90027
Hazel	34	0.00196	0.85705	0.00204	0.90027
Bird cherry	35	0.00196	0.85705	0.00204	0.90027
Hawthorn	41	0.00098	0.81725	0.00251	0.88205
Crab apple	51	0.00098	0.81725	0.00251	0.88205
Cherry	56	0.00098	0.81725	0.00251	0.88205
Buckthorn	57	0.00196	0.85705	0.00204	0.90027

Average diameter of trees which died in previous years are calculated using following equation:

$$d_{atm2} = d_{atm1} * \alpha, where \quad (49)$$

d_{atm1} – average diameter of dead wood in previous calculation period, cm;
d_{atm2} – average diameter of dead wood in current calculation period, cm;
α – coefficients (Table 6.2.1.).

Number of trees in each forest element is calculated as difference between number of trees at the beginning the period and projected number of trees:

$$n_{atm} = n_1 - n_2, where$$

n_{atm} – meža elementa atmirušo koku skaits, ha^{-1};

n_1 – meža elementa koku skaits prognožu perioda sākumā, ha^{-1}; (50)

n_2 – meža elementa prognozētais koku skaits, ha^{-1}.

Basal area of dead wood is calculated for informative purposes according to number of trees and average diameter of trees using equation No. 5.

Stock of dead wood is calculated using equations elaborated by I. Liepa (Liepa, 1996) using number of trees, average height and diameter in formula No. 6.

OUTPUT DATA

The output data is saved in Microsoft excel format and the structure is the same as the input data. The forest resource summary table are prepared in the same way at the end of the defined modelling period and of every five year growing modelling period. The summary table contain information about forest indicators (for example, area, wood stock, height etc.) sorted by forest type, age groups of the dominating species of the 1st storey, site index etc.

In the summary table the forest stands are grouped by property type and dominating tree species of the 1st storey and/or groups of them (Table 45).

Table 45: Property and dominating tree species of the 1st storey groups used in summary table

Parameter	Categories
Property type	1. State forests 2. Other forests, 3. All forest.
Origin	1. Natural, 2. Anthropogenic, 3. All.
Dominating tree species of the 1st storey	4. Pine, 5. Spruce, 6. Birch, 7. Alder, 8. Aspen, 9. Grey alder, 10. Oak, 11. Ash, 12. Other species 13. All coniferous trees, 14. All broad leaved trees, 15. Soft broad leaved trees, 16. Hard broad leaved trees, 17. All species.

Evaluation of stand area parameters and variations thereof

The share of each land category is calculated as follows:

$$P_m = \frac{K_m}{K}, where \qquad (51)$$

P_m – Share of land category;
K_m – Area of sampling plots or their parts that fit the corresponding land category, m^2;
K – Total area of sampling plots within the country, m^2.

The standard error (P_{Qm}) of the category area is calculated with the following formula:

$$P_{Qm} = \left(\frac{1 - P_m}{(K-1) * Pm} \right)^{0.5} * 100, where$$

P_{Qm} – Standard error of the category, %; (52)

P_m – Share of the land category;

K – Total are of sampling plots within the country, $m^{2.}$

Considering the standard area of a sampling plot is 500 m^2, but it is separated into smaller sampling plots and sectors of different size, evaluating the average indicators and their variation, the weighted mean average calculation method must be used.

Initially plot indicators are calculated for one hectare. The average indicator of a stand and dispersion are calculated as follows:

$$\ddot{Y} = \frac{\sum (Y_i * p_i)}{\sum (p_i)}, where$$

$\ddot{Y}$ – Average stand indicator for 1 ha; (53)

Y_i – Stand parameter value for 1 ha in i sampling plot unit (formula 50);

p_i – Share of sampling plot (formula 51);

$\sigma^2_{\hat{Y}}$ – Dispersion of stand indicator.

$$\sigma^2_{\hat{Y}} = \frac{\sum ((Y_i - \ddot{Y})^2 * p_i)}{\sum (p_i)}, where$$

$\ddot{Y}$ – Average stand indicator for 1 ha; (54)

Y_i – Stand parameter value for 1 ha in i sampling plot unit (formula 50);

p_i – Share of sampling plot (formula 51);

$\sigma^2_{\hat{Y}}$ – Dispersion of stand indicator.

Stand parameter value for 1 ha in i sampling plot unit is calculated as follows:

$$Y_i = \frac{y_i}{x_i}, where$$

Y_i – Stand parameter value for 1 ha in i sampling plot unit; (55)

y_i – Value of parameter in i units;

x_i – Area of sampling plot unit, $m^{2.}$

Share of sampling plot is calculated as a proportion of a sampling plot unit to sampling plot area:

$$p_i = \frac{x_i}{q}, where$$

p_i – Share of sampling plot; (56)

q – Are of sampling plot $(500\, m^2)$;

x_i – Area of a sampling plot unit, m^2.

The dispersion, standard error and standard error in percent of the average indicator are calculated as follows:

$$\sigma_{\ddot{Y}}^{2}=\frac{\sigma_{\hat{Y}}^{2}}{n}, where \tag{57}$$

$\sigma_{\ddot{Y}}^{2}$ – Dispersion of stand parameter per 1 ha;
$\sigma_{\hat{Y}}^{2}$ – Dispersion of the stand indicator;
$\sigma_{\ddot{Y}}$ – Standard error of stand parameter per 1 ha;
$P_{\ddot{Y}}$ – Standard error of stand parameter in percen;
$\ddot{Y}$ – Average stand indicator per 1 ha;
n – Number of sampling plot units (sampling plots, sectors).

$$\sigma_{\ddot{Y}}=\left(\sigma_{\ddot{Y}}^{2}\right)^{0.5}, where \tag{58}$$

$\sigma_{\ddot{Y}}^{2}$ – Dispersion of stand parameter per 1 ha;
$\sigma_{\hat{Y}}^{2}$ – Dispersion of the stand indicator;
$\sigma_{\ddot{Y}}$ – Standard error of stand parameter per 1 ha;
$P_{\ddot{Y}}$ – Standard error of stand parameter in percen;
$\ddot{Y}$ – Average stand indicator per 1 ha;
n – Number of sampling plot units (sampling plots, sectors).

$$P_{\ddot{Y}}=\frac{\sigma_{\ddot{Y}}}{\ddot{Y}}*100, where \tag{59}$$

$\sigma_{\ddot{Y}}^{2}$ – Dispersion of stand parameter per 1 ha;
$\sigma_{\hat{Y}}^{2}$ – Dispersion of the stand indicator;
$\sigma_{\ddot{Y}}$ – Standard error of stand parameter per 1 ha;
$P_{\ddot{Y}}$ – Standard error of stand parameter in percen;
$\ddot{Y}$ – Average stand indicator per 1 ha;
n – Number of sampling plot units (sampling plots, sectors).

Wood stock, increase and number is calculated by multiplying these indicator units per ha with an appropriate number of stand groups (strata):

$$Y_i=\ddot{Y}_i*Q_i, where \tag{60}$$

Y_i – Stand parameter value per 1 ha in sampling plot i units;
$\ddot{Y}$ – Value of i stand group inventory indicator;
Q_i – Area of the stand group i, ha.

The standard error of wood stock and their number in the area is determined using the following formula:

$$P_{Ti}=\left(P_{\ddot{Y}i}^{2}+P_{Qi}^{2}\right)^{0.5}, where \tag{61}$$

P_{Ti} – Standard error of the parameter in whole area;
$P_{\ddot{Y}i}$ – Standard error of stand group i inventory, %;
P_{Qi} – Error of stand group i area, %.

Description of forest resources depending from forest stand inventory data

Following parameters are used to characterize forest resources:

a) total area (ha 10^3) and error (% and ha 10^3),

b) total wood stock (m^3 10^6) and error (% and m^3 10^6),

c) arithmetic average wood stock (m^3ha^{-1}) and error (% and m^3ha^{-1}),

d) arithmetic average wood stock of the 1st storey of the tree stand (m^3ha^{-1}) and error (% and m^3ha^{-1}),

e) arithmetic average height of the dominating tree species of the 1st storey (m) and error (% and m),

f) arithmetic average diameter of the dominating tree species of the 1st storey of the tree stand (cm) and error (% and cm),

g) arithmetic average basal area of the tree stand (m^2ha^{-1}) and error (% and m^2ha^{-1}),

h) arithmetic average basal of the 1st storey of the tree stand (m^2ha^{-1}) and error (% and m^2ha^{-1}),

i) sum of wood stock increase (m^3 10^6)and error (% and m^3 10^6),

j) arithmetic average wood stock increase of the tree stand (m^3ha^{-1}) and error (% and m^3ha^{-1}),

k) arithmetic average increase of the 1st storey of the tree stand (m^3ha^{-1}) and error (% and m^3ha^{-1}).

Each of the taxation indicators listed above is given a summary table sorted by:

- age decade groups of the dominating tree species of the 1st storey of the tree stand (Table 46),
- site index of the dominating tree species of the 1st storey of the tree stand (Table 47),
- Forest type (Table 48).

Table 46: Forest resources by age decade group of the dominating species of the 1st storey of the tree stand

AGM period	Property type	Species	Parameter	Age group													Total
				1_10	11_20	21_30	31_40	41_50	51_60	61_70	71_80	81_90	91_100	101_110	111_120	120>	

Table 47: Forest resources by site index of dominating tree species of the 1st storey of the tree stand

AGM cycle	Property type	Species	Parameter	Site index								Total
				Ia and higher	1st	II	III	IV	V	Va	Vb and lower	

Table 48: Forest resources by forest type

AGM cycle	Property type	Species	Parameter	Forest type																							Total
				Sl	Mr	Ln	Dm	Vr	Gr	Gs	Mrs	Dms	Vrs	Grs	Pv	Nd	Db	Lk	Av	Am	As	Ap	Kv	Km	Ks	Kp	

Annex 4 National forest inventory methodology

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INTRODUCTION

Based on Forest monitoring guidelines (Latvijas Valsts mežzinātnes institūta Silava'', 2013).

1. General Issues of the Monitoring of Forest Resources
   - 1.1. The objectives of the monitoring of forest resources shall be as follows:
     - 1.1.1. to obtain operational and accurate information regarding forest resources for national and international statistical needs;
     - 1.1.2. to control the dynamics of the forest area;
     - 1.1.3. to obtain accurate information regarding wood resources, their structure and dynamics;
     - 1.1.4. to obtain information for assessment of the dynamics of the condition of forest ecosystems, damage to forest and biological diversity;
     - 1.1.5. to obtain information for forecasting of the forest resources and for the needs of the GHG inventory;
     - 1.1.6. to accumulate historical information regarding the course of development of forest stands.
   - 1.2. The object of the monitoring of forest resources is the territory where growing and/or dead wood resources are found, regardless of the form of property.
   - 1.3. The task of the monitoring of forest resources is to obtain the following information at large in the State and in division according to property groups (State properties and other properties):
     - 1.3.1. forest land areas in division according to forest land categories;
     - 1.3.2. division of areas covered with trees, outside the forest land;
     - 1.3.3. forest stand areas and standing volumes in division according to the dominant tree species, age decades, site quality classes, height and basal area groups, limitations of economic activities and indications of nature protection, types of forest regeneration and forest types;
     - 1.3.4. cutover areas in division according to forest types;
     - 1.3.5. the annual increment of forest stands, the annual dead rate and the annual felled amount in division according to the dominant tree species;
     - 1.3.6. the characterisation of damages to forest stands by the area and stock in division according to the dominant tree species and causes of damages (damages by insects, damages by disease, damages by wildlife, damages by storms, snowbreak and damages of similar types, damages by fire, other damages);
     - 1.3.7. areas of forest stands with undergrowth in division according to the species of the undergrowth and the groups of covering;
     - 1.3.8. areas of forest stands with advanced growth in division according to tree species and groups of covering;

1.3.9. areas and stocks of the forest land covered with trees and bushes, but not forming a forest stand, in division according to tree and bush species;

1.3.10. the total biomass of the wood (wood stock of growing trees and bushes and deadwood and biomass above the stump in division according to tree species, their stumps, roots, as well as biomass of the fallen deadwood) in division according to tree species;

1.3.11. information regarding wood resources growing outside the forest and their dynamics.

1.4. Information shall be collected in accordance with the definitions of the Forest Law and the Temperate and Boreal Forest Resources Assessment.

INVENTORY UNITS

1.5. Inventory unit network of the monitoring of forest resources

1.5.1. The monitoring of forest resources shall be carried out according to the principle of bi-level selection:

1.5.1.1. a network of sample plots shall be created in the first level selection. Sample plot tracts with four sample plots in each shall be selected;

1.5.1.2. sample plot tracts shall be laid out evenly throughout the State territory in 4 x 4 km distance from each other following the principle that they form an equilateral triangle (Figure 1). Each year one fifth of all sample plots shall be surveyed, ensuring impartial layout of annual surveys evenly throughout the State territory;

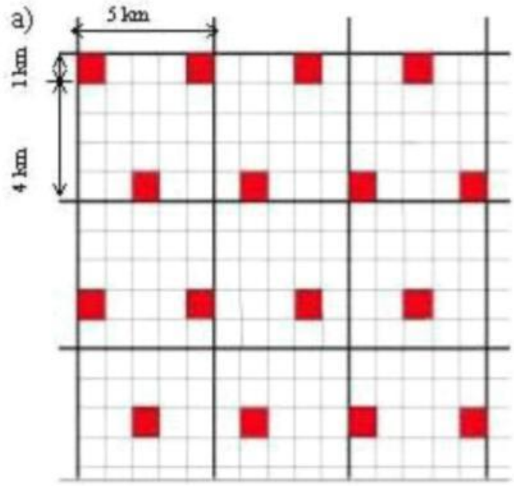

Figure 1: Scheme of the Layout of Sample Plot Tracts.

1.5.1.3. sample plot tracts shall be laid out on a network of orthophoto map sheets (Figure 2). Sample plots shall be laid out in sample plot tracts, grouping them by four in one tract. Sample plots within the scope of a tract shall be laid out in vertices of a 250 x 250 m square;

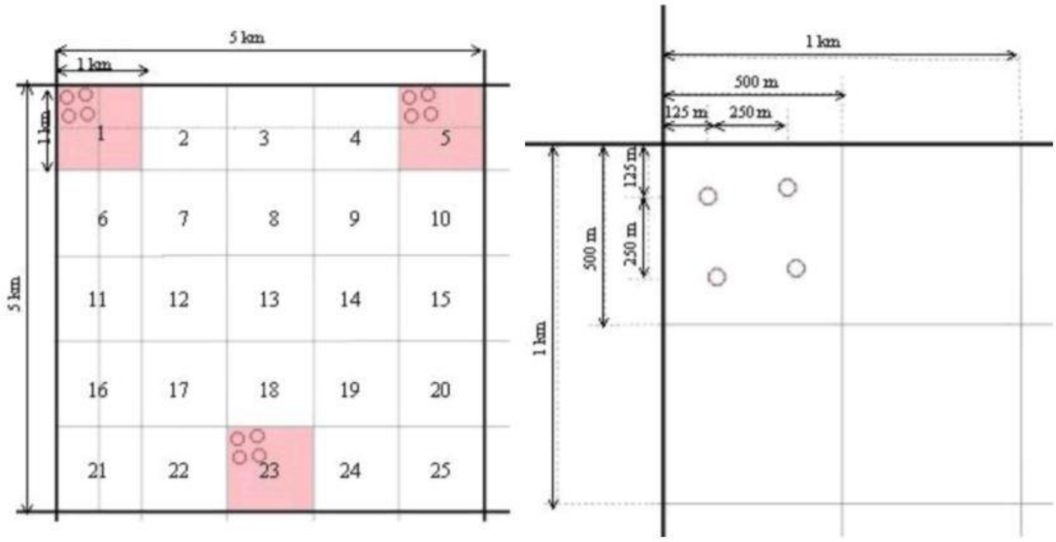

Figure 2: Tract and sample plot selection scheme on orthophoto map sheets.

1.5.1.4. in the second level of selection inventory trees shall be selected in all sample plots selected in the second round in order to assess the height, age, increment, quality and damages. Such trees shall be selected in proportion to the size (diameter) of the existing trees. The intensity of selection shall be 20-30% for all trees for which the diameter is measured;

1.5.2. a sample plot network shall be created according to a systematic layout scheme with a randomly selected reference point. Each sample plot shall be surveyed once during a complete cycle of the monitoring of forest resources, i.e., once every five years;

1.5.3. in performing re-measuring in sample plots, changes during a time period of five years shall be assessed. Annual indicators shall be obtained by dividing the total changes in the re-measurement period by the number of years of the time period.

1.6. Inventory element scheme;

1.6.1. Inventory sample plots in a sample plot network shall be laid out in tracts, which have edges of 250 m in length and they are oriented in the direction of the North, East, South and West. The centre of the sample plot shall be deviated from the vertex of the tract by 25 m counter-clockwise (Figure 3);

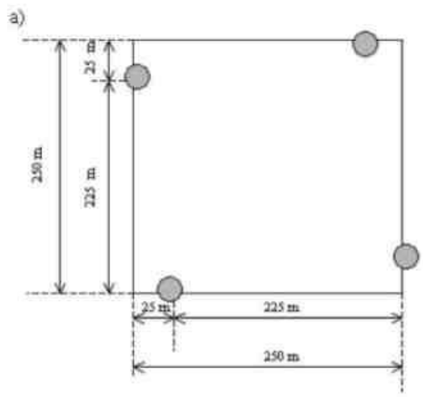

Figure 3: Layout Scheme of Sample Plots.

1.6.2. The main element of inventory is a permanent inventory sample plot of a fixed radius, the area of which is 500 m² (radius in a plane is 12,62 m) and in which trees, as well as fallen deadwood with diameter of 14,1 cm or more are surveyed (Figure 4).

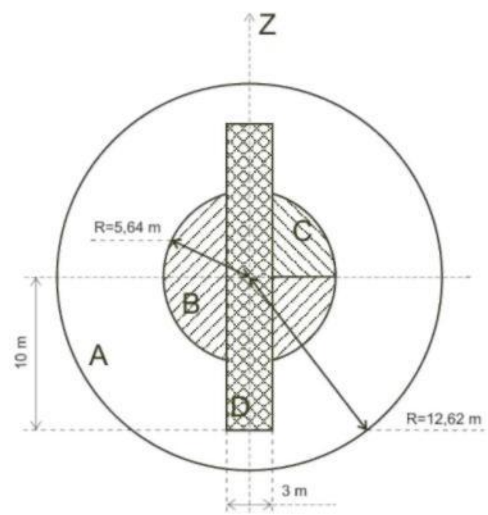

Figure 4: Sample Plot Scheme (A – 500 m² sample plot, B – 100 m² sample plot, C – 25 m² sample plot, D – sample plot of undergrowth and advanced growth inventory)

1.6.3. A second sample plot shall be earmarked at the centre of the sample 100 m² plot (R= 5,64 m) in which all trees and fallen deadwood with the diameter of the butt-end 6,1 cm or more shall be surveyed. All trees of natural origin and their outgrowth, the diameter of which in height of 1,3 m above the root collar (hereinafter – in height of 1,3 m) is 2,1 cm, shall be surveyed in the first fourth of such sample plot, calculating from the northern direction (25 m²);

1.6.4. the undergrowth and advanced growth shall be determined in a zone of the sample plot of 3 x 20 m, earmarked in a joint sample plot, in sample plots No. 1 and No. 3 in the eastern-western direction, in the sample plots No. 2 and No. 4 in the northern and southern direction;

1.6.5. fallen deadwood shall be surveyed at odd times of re-measuring of sample plots.

1.7. Earmarking of sectors into sample plots

1.7.1. Sectors shall be earmarked in a sample plot if:

1.7.1.1. they are a different form of property;

1.7.1.2. they are the territory of another state;

1.7.1.3. they have a different type of the use of land;

1.7.1.4. they are a different category of the forest land;

1.7.1.5. they have a different origin of the forest stand;

1.7.1.6. they are a different type of forest;

1.7.1.7. the age difference of forest stands exceeds 20 years;

1.7.1.8. the composition of species forming Level I of the stand differs by four or more units;

1.7.2. In identifying sectors of a sample plot, their point azimuths and distances to the centre of the sample plot in which the line dividing the sectors is crossing the border of the sample plot shall be recorded. In case of several breaking points of the line dividing sectors azimuths and distances to each breaking point shall be recorded.

1.8. Numbering of tracts and sample plots

1.8.1. The ten-digit identification number of sample plots shall consist of the tract number and the sample plot number.

1.8.2. Sample plot tracts shall be numbered according to the division sheets of the TKS-93 map sheet nomenclature system in the scale 1:1000 corresponding to geographical areas and shall be formed from numbering symbols 1-9.

1.8.3. The tenth symbol in the identification number shall be the number of the sample plot in the tract.

1.8.4. Sample plots within the scope of a tract shall be numbered from to "4" clockwise (Figure 5).

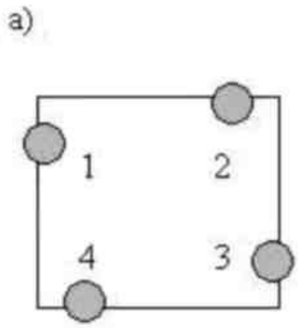

Figure 5: Numbering Scheme of Sample Plots.

1.9. Determination of co-ordinates of the tract and sample plot centre

1.9.1. The Latvian Co-ordinate System is defined with the following parameters:

Ellipsoid	WGS84
Projection	Transverse Mercator

Central meridian	24
Scale coefficient on meridian	0,9996
Deviation along x-axis	500 000 m
Deviation along y-axis	−6 000 000 m

1.9.2. The following co-ordinates of the centre of sample plot tracts have been determined according to the Latvian Co-ordinate System:

1.9.2.1. the co-ordinates of centres of sample plot tracts shall be calculated according to orthophoto map sheets and the scheme presented in Figure Sample plot tracts for the 5 x 5 km sheet of orthophoto maps in the centre of Latvia shall be laid out in three centres of 1x1 km squares. Co-ordinates of the subsequent tract centres in the distance of 4 km for the whole domestic territory of Latvia shall be calculated for the three sample plot tracts in the northern, eastern, southern and western direction in the central orthophoto map sheet of Latvia;

1.9.2.2. all co-ordinates of the next tract centre shall be calculated, using the co-ordinates of the adjacent tract centre and using the causations (62) and (63):

$$Xn = Xi \pm 004.000.00 \text{ or } Xn = Xi \quad (62)$$

$$Yn = Yi \pm 0.004.000.00 \text{ or } Yn = Yi \quad \text{, where} \quad (63)$$

Xi – co-ordinates of the width of the previous vertex;

Yi – co-ordinates of the length of the previous vertex.

1.9.3. Co-ordinates of sample plot centres shall be calculated according to co-ordinates of tract centres in conformity with the principle that the tract centre is the centre of a 250x250 m square at the corners of which sample plots are placed. In addition the offset of the centre of the sample plot from corners of the square by 25 m shall be calculated, as shown in Figure 3.

ORGANISATION OF MONITORING OF FOREST RESOURCES

1.10. Organisation of the monitoring of forest resources

1.10.1. Periodicity of the monitoring of forest resources

1.10.1.1. The monitoring of forest resources shall be carried out each year in the whole territory of Latvia.

1.10.1.2. The sample plot network shall be gradually increased for the first five years, surveying one fifth of the total number of sample plots each year.

1.10.1.3. During each next five years sample plots and inventory trees therein shall be re-measured. The time period between re-measuring of sample plots shall be five years +/-20 days.

1.10.2. Preparation works of the monitoring of forest resources

1.10.2.1. Preparation works shall be carried out in order to ensure timely and successful commencement and course of field works from January till April.

1.10.2.2. The following information shall be aggregated during the preparation works:

1.10.2.2.1. using orthophoto maps (not more than five years old), compile a list of the sample plots to be surveyed on the site during the working year;

1.10.2.2.2. prepare print-outs of the cartographic material – print-outs of orthophoto maps S 1:10 000 forest land plans (copies) S 1:10 000 and cadastral maps, print-out of a satellite map S 1:50 000 which characterises the situation in order to reach the relevant tract;

1.10.2.3. work forms shall be prepared in each next cycle of measurements, and they shall include the information on measurements from the previous cycle (the azimuth of the surveyed tree, the distance to the centre of the sample plot, the diameter in height of m and the measured height of the tree);

1.10.2.4. the measuring instruments necessary for the field work season shall be prepared.

1.10.3. Organisation of field works

1.10.3.1. Measuring of sample plots in a forest shall be carried out by five field work groups.

1.10.3.2. A field work group shall consist of a leader and an engineering technical employee. The leader of the group shall organise the group work, trips, routes, finding and measuring of a tract in sample plots, shall be responsible for any documentation, as well as take care of the transport, measuring instruments, storing and inspecting thereof.

1.10.4. Quality control of field work

1.10.4.1. Field work shall be controlled:

1.10.4.1.1. in order to prevent surveying errors and the causes for occurrence thereof;

1.10.4.1.2. in the amount of at least five per cent from the number of permanent sample plots surveyed by each working group a year;

1.10.4.1.3. by an individual working group in the composition of two people.

1.10.4.2. In field work control all such indicators of the sample field shall be surveyed in the sample field, which are repeatedly measured during re-measuring (tree azimuth, distance, diameter at height of 1,3 m, height, undergrowth and advanced growth).

METHODOLOGY OF FIELD WORKS

2. Methodology of field work of the monitoring of forest resources

   2.1. Identification of sample plots on the site

      2.1.1. The centre of sample plots on the site shall be found with the help of the global positioning system (hereinafter – GPS) according to the calculated co-ordinates, using it in navigation (point search) mode.

      2.1.2. In case if it is not possible to find the centre of the sample plot with a GPS receiver (poor detection capability in forest conditions), then the point co-ordinates shall be determined in the closest open place where taking of GSP measurements is possible. Afterwards the distance and the azimuth to be followed shall be determined in order to identify the theoretical point. Then the centre of the sample plot shall be found, using a measuring tape and compass.

      2.1.3. If a line must be marked off in a relief slope, the distances measured in the slope towards horizontal plane shall be recalculated, using trigonometric causations of a right-angled triangle. The angle of the relief slope and the distance between points must be measured and the distance in a plane must be recalculated.

      2.1.4. All sample plots and their parts, which are planned for measuring in forest land, shall be divided into accessible and non-accessible after inspection on site. Such sample plots shall be considered as non-accessible, the centres of which cannot be reached due to different reasons – they are located in water reservoirs, marshes, etc.It shall be noted in the notes of the description of the sample plot.

      2.1.5. The characteristics of sample plots with non-accessible centres shall be determined, performing measurements for trees outside the sample plot, performing the necessary measurements in plots the centre of which is located as close to the theoretical centre of the sample plot as possible. In such case the location of the sample plot centre used for measurements shall be described in the note section, marking the closest trees around it.

      2.1.6. If the sample plot is accessible, however, its centre coincides with an obstacle (stone, asphalt, etc.), the centre of the sample plot shall be marked as close from the theoretical centre as possible, marking the closest trees around it, however, measurements shall be performed from the theoretical centre. Similar actions must be taken, if the centre of a sample plot touching the forest is in arable land or on an object of the forest infrastructure where destruction of the mark of the centre is possible. Such changes shall be recorded in the note box of the documents, drawing a sketch of the marked centre.

      2.1.7. In establishing a permanent sample plot on the site, one must follow the principle that it should attract as less attention during the time period until the next survey time as possible. After the survey of the sample plot, a metal bar shall be driven in the centre thereof.

2.1.8. Trees shall be marked around the centre of the sample plot, driving nails in their root collar, leaving at least 10 cm of the nail above the root collar and bending it.

2.1.9. If it is not possible to mark the centre of a sample plot with the help of trees or stumps in the sample plot (for example, young stands), then other trees outside the sample plot shall be looked for.

2.1.10. Identification of the centre of a sample plot shall be documented, indicating the tree species used for identification, its distance from the centre of the sample plot and the azimuth.

2.1.11. In repeatedly surveying sample plots, their centre shall be found with the help of a metal detector, at first finding the trees marked for ensuring identification. After the trees (or their stumps) of identification are found, using their azimuth and distance, the place where the metal bar was driven in shall be found.

2.2. Division of sample plots into sectors

2.2.1. In dividing a sample plot into sectors, the following principles must be complied with:

2.2.1.1. the whole zone of the road belongs to roads. If a road zone is also used for other purposes (electricity, communications line, fireline, ditch), then they shall be included in the main function – road;

2.2.1.2. if there are only such ditches next to a forest road, which serve only the road, then they shall be included in the area of the road;

2.2.1.3. if there is a territory not covered with forest growth next to an embankment of a forest road and the forest, exceeding 4 m in width, it shall be treated as a glade;

2.2.1.4. ditches shall be classified into two different categories: ditches belonging to the forest land and field ditches. A ditch separating forest land from other land shall be divided into two different sectors (forest ditch and field ditch) according to the bottom line of the ditch;

2.2.1.5. ditch routes are the linear object of the forest land. The status of a ditch route shall only be assigned if the width thereof is not less than 4 m and not more than 10 m;

2.2.1.6. the beginning of the ditch route shall be measured from the beginning of the ditch edge (side);

2.2.1.7. if the edge of the ditch is rounded-off, the beginning thereof shall be determined according to the displacement of the land surface plane from the plane of the ditch edge, but not farther than 4 m from the line where the land plane and ditch edge plane projections are intersecting;

2.2.1.8. if the distance from the ditch edge (side) to the forest is less than 4 m, the sector of ditch route shall not be earmarked and the territory shall be included in the ditch;

2.2.1.9. if a group of trees is less than ha or forms a zone that is narrower than 20 m, it shall be itemised as separate trees in an adjacent land category;

2.2.1.10. the owner of the forest roads shall be determined, taking into account the owner of the surrounding land;

2.2.1.11. linear objects of the forest land, which are located on the border with different properties, shall be divided into sectors with corresponding property rights according to the centre line;

2.2.1.12. measurements shall be taken by marking the number of the sector during measuring, and it shall be the basis for the performance of subsequent calculations;

2.2.1.13. the measurements to be taken for identification of sample plot sectors shall be documented.

2.3. Laying out of sample plots

2.3.1. If the border of a sector divides sample plots of m^2, m^2, 25 m^2, 60 m^2, inventory of trees of corresponding diameter, undergrowth and advanced growth shall be carried out according to sectors.

2.4. Determination of common characteristics in a sample plot

2.4.1. Determination of the forest type

2.4.1.1. In each sample plot or sector of the forest and cutover the forest type of the forest stand corresponding thereto shall be determined, using the Latvian forest typology developed by K. Bušs (Bušs K. (1981) Meža ekoloģija un tipoloģija. Rīga: Zinātne, 65 lpp.).

2.4.2. Inventory of advanced growth and undergrowth

2.4.2.1. Advanced growth and undergrowth shall be itemised in all sample plots.

2.4.2.2. The trees of the forest element which while being 1,3 m in height have not reached cm in diameter shall be included in the advanced growth. If a forest element with a diameter of less than 2,1 cm forms a dominant stand, its trees shall not be included in the inventory of the advanced growth.

2.4.2.3. The undergrowth and the advanced growth shall be itemised in a zone that is 20 m long and 3 m wide. Sectors may also include a smaller plot or no plot at all. The inventory plot of the undergrowth belonging to sectors shall be determined in office work.

2.4.2.4. The number of species and specimens for undergrowth and advanced growth trees, as well as the height and diameter of a visually selected average woody plant in the middle of it shall be determined.

2.4.2.5. The average age shall be determined for each undergrowth and advanced growth species – branch whorls shall be itemised or a tree shall be sawn outside the sample plot and its growth rings shall be counted. During inventory of the undergrowth and advanced growth all sprouts which have grown up from the earth or stump shall be counted.

2.5. Surveying of growing trees

2.5.1. Selection of inventory trees

2.5.1.1. Inventory trees shall be selected from the living trees in the sample plot, the diameter of which has been measured in height of 1,3 m. If an individual element of the stand is formed only by deadwood, the inventory trees shall also be measured for them. Generally not less than one tree out of seven trees should be selected.

2.5.1.2. If only one tree species is represented in the sample plot, then trees 3-5 from Kraft Class I, also 3-5 trees from Kraft Class II and Kraft Class III trees, as well as 1-2 trees from Kraft Classes IV and V shall be selected as inventory trees. If there is the second level in the stand, which is represented by one tree species, then at least three trees shall be selected as inventory trees. Inventory trees shall be selected in such a way that they have different diameters;

2.5.1.3. If several tree species are represented in the sample plot, then 2-3 trees from Kraft Classes I-III and 1-2 trees from Kraft Classes IV and V shall be selected as inventory trees for each of such species. If there is the second level in the stand, which is represented by more than one tree species, then at least 1-3 trees from each species shall be selected as inventory trees.

2.5.1.4. If the number of forest element trees in the sample plot is very high, then not less than one tree out of seven trees shall be selected. In selecting trees for inventory the third tree, then the 10th tree, the 17th tree, etc. shall be selected. If a sufficient number of inventory trees is not collected systematically, then the missing trees shall be selected from thicker trees.

2.5.1.5. Additional measurements shall be taken for inventory trees – the height of trees shall be determined, as well as the diameter of the tree at the root collar, the height of the first green branch, the height of the first dry branch shall be determined at each odd time of re-measuring.

2.5.1.6. In re-measuring sample plots, the same inventory trees shall be measured. Felled trees or deadwood shall be replaced with the next corresponding Kraft Class tree.

2.5.2. Determination of the distance of the tree to the centre of the sample plot

2.5.2.1. The distance from the centre of the sample plot to the centre of the tree in height of 1,3 m in horizontal direction shall be measured with the help of an ultrasonic measuring device.

2.5.2.2. The belonging of trees (growing trees, deadwood, fallen trees) to a sample plot shall be determined by their diameter in height of 1,3 m.

2.5.2.3. A stand shall be mounted at the centre of the sample plot, to which an ultrasonic reflector shall be attached, for the determination of the distance. The source of ultrasound with the measurement indicator shall be held horizontally to the reflector by the central axis of the tree.

2.5.2.4. The distance of only standing trees to the centre of the sample plot shall be recorded in the inventory card of trees.

2.5.2.5. The distance for fallen trees shall be measured only to determine their belonging to the sample plot.

2.5.3. Determination of azimuth in order to identify the location of the tree

2.5.3.1. Azimuth of a tree shall be measured from the centre of the sample plot with an instrument intended for measuring of angles (compass), which has been secured with the help of a stand, with accuracy of 1^0.

2.5.3.2. The stand shall be aligned at the centre of the sample plot with the help of a weight. The direction for trees which have toppled shall be determined according to the line connecting the centre of the sample plot with an imaginary perpendicular line drawn towards the centre of the stump.

2.5.3.3. Azimuth shall be registered as an instrument reading, without taking into account the magnetic variation.

2.5.3.4. Azimuth shall be measured only for growing trees and snags, azimuth need not be measured for stumps and fallen trees.

2.5.3.5. Surveying of trees shall begin from magnetic North, clockwise.

2.5.4. Determination of the distance of the tree to the centre of the sample plot

2.5.4.1. The distance to the tree shall be measured in height of 1,3 m, towards the axis line of the tree (half of the diameter). If the tree is located in a relief slope, then the distance to it shall be measured towards height of 1,3 m (parallel to the land surface), determining the land surface angle and recalculating the distance on the horizontal plane.

2.5.4.2. If due to a poor visibility of the tree (accurate determination of azimuth or measuring of the distance is hindered by the projection of another closer tree bole) or it is not possible to take an accurate measurement of the diameter of the tree in height of 1,3 m, the reason for the possible error shall be noted in the “Notes” of the tree measurement sheet.

2.5.5. Determination of the characteristics of a tree bole

2.5.5.1. Measurement and assessment of trees and stumps shall be performed in each sample plot or sector, which falls into forest, forest land or also an area covered with trees outside the forest land.

2.5.5.2. The following shall be determined for each tree and entered in the tree inventory table:

2.5.5.2.1. the distance of the tree to the centre of the sample plot (+/- 1 cm);

2.5.5.2.2. the tree azimuth (+/- 1^0);

2.5.5.2.3. the species (according to the classifier);

2.5.5.2.4. the level;

2.5.5.2.5. the Kraft Class;

2.5.5.2.6. the diameter of the tree in height of m (+/- 1 mm);

2.5.5.2.7. the diameter of the tree for inventory trees at the root collar (+/- 1 mm) (at each odd time of re-measuring);

2.5.5.2.8. the height of the tree for inventory trees (+/- 0,5 m);

2.5.5.2.9. the height of the first green, first dry branch (+/- 0,5 m);

2.5.5.2.10. damages (type of the damage, intensity of the damage, height (location on the tree)).

2.5.6. Determination of the level of a tree

2.5.6.1. For each tree diameter of which is measured belonging to the first or second level shall be determined.

2.5.6.2. All trees height differences of which do not exceed 20% shall be joined in the first level. Other trees shall form the second level, if their height is not less than one fourth of the height of the first level trees.

2.5.6.3. Trees of the advanced growth, diameter of which exceeds 2,1 cm and which do not belong to the second level, shall be marked as the trees of the third level. Measurements in relation to these trees shall be used in order to determine the total amount of biomass.

2.5.7. Determination of the Kraft Class

2.5.7.1. The Kraft Class shall be determined for each tree of the first level, for which the diameter is measured. Kraft Classes shall be grouped according to the following principles:

2.5.7.1.1. Kraft Class I – pre-dominant trees – the tallest and thickest trees of the stand, which have a well-developed crown and the tops of which overlook the joint canopy of the stand, shall be included in the dominant stand;

2.5.7.1.2. Kraft Class II – dominant trees – form the main canopy of the stand, their boles have slightly smaller dimensions than Kraft Class I trees. Such trees shall form 20-40% of the total number of trees, and their stock shall form 40-70% of the total stock of the stand, they shall be included in the dominant stand;

2.5.7.1.3. Kraft Class III – co-dominant trees – crowns of trees are relatively less developed, narrower, squeezed in between crowns of Kraft Class I and II trees and are located at the lower part of the joint canopy, however, they shall be included in the dominant stand;

2.5.7.1.4. Kraft Class IV – suppressed trees – tree crowns are shorter and narrower than those of Kraft Class III trees. They reach the lower part of the main canopy with theirs tops. Trees fall significantly behind Kraft Class I-III trees by dimensions, they are much thinner and shorter, they shall be included in the dominated stand;

2.5.7.1.5. Kraft Class V – very suppressed trees – are located below the dominant canopy of the stand, their crown is either dying off or has already died off, they shall be included in the dominated stand.

2.5.8. Determination of the diameter of a tree

2.5.8.1. For all trees in the sample plot, which have reached the diameter of 2,1 cm in height of 1,3 m, the diameter shall be measured in height of 1,3 m with accuracy of 0,1 cm.

2.5.8.2. The place where the diameter was measured shall not be marked on trees.

2.5.8.3. In measuring the diameter of a tree, the following provisions of measuring shall be conformed to:

2.5.8.3.1. the place where the diameter is measured at height of 1.3 m has to be determined using a ruler that is 1,3 m long. If trees branch lower than in height of 1,3 m, diameters of two trees shall be measured. If there is a scar or a protuberance at the height of 1,3 m, then the diameter shall be measured above and below this place, recalculating the average value afterwards;

2.5.8.3.2. the diameter shall not be measured for trees, which have not reached the diameter of 2,1 cm in height of 1,3 m;

2.5.8.3.3. if tree is located on the border of the sample plot, then its diameter in height of 1,3 m from the root collar shall be measured;

2.5.8.3.4. if the vertical axis of the tree is located in the sample plot, then it shall be surveyed, if it is located outside the border of the sample plot, it shall not be surveyed;

2.5.8.3.5. the diameter of all trees shall be measured including the bark; if trees are without bark, for example, dead, then the diameter shall be measured without bark and a relevant note shall be made in the note box.

2.5.9. Determination of the height of a tree

2.5.9.1. Height shall be measured only for trees selected for inventory and for all snags.

2.5.9.2. The total height of a tree shall be measured, as well as the height of the first green branch and the height up to the first dry branch at least 2 cm in width shall be measured at every odd time of survey.

2.5.9.3. The height shall be measured with the height measuring device, with accuracy of m.

2.5.9.4. The height of a tree shall be measured from the place where the top of the tree is accurately visible.

2.5.9.5. In case if a tree is growing obliquely, the distance for taking of the measurements of height shall be determined from the place located athwart to the top from the ground. Height shall be measured from the place towards which the slope of the tree is oriented. Generally, if it is possible to select a corresponding inventory tree, the height of oblique trees shall not be measured.

2.5.9.6. In determining distance from the perpendicular projection of the top of the tree to the centre of the tree bole, it is possible to calculate the length of the tree.

2.5.9.7. The height projection of a tree H_v in vertical plane and the distance of the top from the base H_h shall be measured. The height of a tree shall be calculated using the formula (64):

$$H=\sqrt{H_v^2+H_h^2}$$, where (64)

H_v – height projection of a tree in vertical plane;

H_h – distance of the top from the base.

2.5.9.8. The height of the beginning of the crown shall be measured in the same way. The beginning of the crown shall be determined according to the first green branches growing from the bole.

2.5.10. Determination of radial increment and age

2.5.10.1. Radial increment (hereinafter – increment) shall be determined using the method of drill holes during the first cycle of survey for such forest elements, the average diameter of which exceeds 10 cm.

2.5.10.2. Increment and age for trees shall be determined outside the sample plot in the same forest stand to which the trees of the sample plot (sector) belong. If trees corresponding to the forest element are not located outside the sample plot, trees of the sample plot shall be drilled, returning the core back into the drill hole and smearing the drill hole up with grafting wax.

2.5.10.3. For forest elements, the average diameter of which is less than cm, the increment shall be determined as the division of the forest element stock by the age of the forest element. For such purpose the average tree selected by estimation by sight shall be sown outside the sample plot in height of m and the growth rings shall be counted.

2.5.10.4. The age of forest elements, the diameter of which exceeds 10 cm, shall be determined in the following way:

2.5.10.4.1. if there are more than 40% in the stand of the forest element stock, two trees shall be drilled until the pith for determination of age. If the age difference is more than 15 years, a third tree shall be drilled;

2.5.10.4.2. if the forest element stock in a stand is less than 40%, one average tree selected by estimation by sight shall be drilled for determination of age;

2.5.10.4.3. age shall be determined for all forest elements.

2.5.10.5. In order to determine increment, trees in addition to those trees for which age has been determined shall be drilled. Width of growth rings of the last 5 and 10 years shall be measured for determination of increment.

2.5.10.6. The last growth ring shall not be measured for determination of increment – measuring shall be commenced from the end of the latewood layer of the previous year.

2.5.10.7. At least five trees shall be drilled for determination of increment for each forest element. If the necessary number of increment trees is not found on the sample plot and its vicinity, a smaller number of trees shall be drilled.

2.5.10.8. Drilled trees must represent as different diameters as possible. Generally increment shall be determined for the 1-2 thinnest, 1-2 thickest and 2-3 medium trees of the stand (including trees drilled for determination of age).

2.5.10.9. A drill hole for determination of the width of growth rings shall always be made in the thickest place of the bark.

2.5.10.10. Drill holes for determination of the width of growth rings, if possible, shall not be made in eccentric trees. If a drill hole must be made in trees damaged by wildlife, the drill hole shall be made on the opposite side of the tree.

2.5.10.11. Width of the last 5 years and 10 years (for coniferous trees and oak, ash with accuracy of mm, other tree species – with accuracy of 0,5 mm), as well as bark thickness up to the growth ring of the current year shall be recorded in the forest.

2.5.10.12. In determining age for rotten trees, in addition the thickness of the part of the wood from the end of the bark to the beginning of rot shall be determined.

2.5.10.13. The current increment of a forest element in re-measuring cycles shall be determined as the difference of the living tree stock between survey times.

2.5.10.14. Age of a forest element in re-measuring cycles shall be determined:

2.5.10.14.1. adding five years to the previously determined age;

2.5.10.14.2. if the forest element was not surveyed during the last time of survey, its age shall be determined according to the methodology described in this Chapter.

2.5.11. Description of forest stands, if the diameter of a dominant stand is less than cm

2.5.11.1. In forest stands, in which the diameter of dominant tree species in height of m has not reached cm or the height has not reached m, trees shall be measured as follows:

2.5.11.1.1. the average tree of the forest element shall be selected;

2.5.11.1.2. the height of the average tree shall be determined;

2.5.11.1.3. the diameter of the average tree in height of 1,3 m shall be determined:

2.5.11.1.4. if height of 1,3 m has been reached, the diameter shall be measured; if the diameter is less than 1 cm, it shall be marked as 1 cm;

2.5.11.1.5. if height of 1,3 m has not been reached, the diameter shall be marked as 1 cm.

2.5.11.1.6. Any element of the forest stand shall be marked with one measured and described tree, azimuth and marking the distance from the centre of the sample plot with 1.

2.5.11.1.7. In forest stands, in which the height of the dominant tree species has not reached height of 1,3 m, the age of trees shall be determined at the root collar; for planted trees the age of the plant need not be taken into account, if determination thereof is possible.

2.5.12. Determination of damages to trees

2.5.12.1. A note regarding damages shall be made for each tree in the sample plot.

2.5.12.2. The following shall be indicated for a damaged tree – the type, intensity, location of the damage (location on the tree). The name of the damage shall be indicated according to the classifier.

2.5.12.3. The following types of damages shall be recorded:

2.5.12.3.1. damages by insects;

2.5.12.3.2. damages by diseases;

2.5.12.3.3. damages by wildlife;

2.5.12.3.4. damages by wind, damages by snow and damages caused by other abiotic factors;

2.5.12.3.5. damages by fire;

2.5.12.3.6. damages by water;

2.5.12.3.7. other, including anthropogenic damages.

2.5.12.4. Damages shall be characterised as follows in detail:

2.5.12.4.1. damages to the bole (tumour, other diseases, scares resulting from damages by wildlife, etc.) – shall be registered if vertical projection of the damages at the widest places forms more than% of the bole perimeter). All scars located one above the other shall be considered one scar. If scars are located horizontally, their width shall be added up;

2.5.12.4.2. gnawed off sprouts, buds, needles, leaves or sprouts, buds, needles, leaves otherwise damaged by wildlife and diseases – until 10 years of age shall be registered itemising each damage at the vertex of the bole. Damages to the remaining part of the bole shall be recorded, if they form 20% or more;

2.5.12.4.3. if a tree has died, the intensity of the damage shall be noted as and the tree shall be included in the dead group “snags”;

2.5.12.4.4. if the tree has a broken top, but the crown is alive and the tree keeps growing, the intensity of the damage shall be noted as 99.

2.5.12.5. Intensity of the damage shall be assessed as follows:

2.5.12.5.1. damages to the bole – width of the damage (%) from the tree perimeter;

2.5.12.5.2. gnawed off or otherwise damaged sprouts, buds, needles, leaves – percentage of damages from the total number.

2.5.12.6. The place of the damage shall be indicated as a part of the tree where the damage is recorded. The following places of damages shall be indicated:

2.5.12.6.1. roots and stumps up to cm above the root collar;

2.5.12.6.2. the lower part of the bole from the height of the stump up to the first green branch;

2.5.12.6.3. whole bole from the height of the stump up to the top;

2.5.12.6.4. the upper part of the bole from the first green branch up to the top;

2.5.12.6.5. the top;

2.5.12.6.6. branches in the living crown;

2.5.12.6.7. branches which have grown out of the bole and are more than 2 cm wide;

2.5.12.6.8. buds and sprouts;

2.5.12.6.9. leaves and needles.

2.5.12.7. If there is more than one type of damage to the tree, the damage which is the closest to the root collar shall be recorded.

2.5.12.8. New tree damages which have not been recorded in the previous time of measuring shall be recorded during re-measuring of sample plots.

2.6. Measuring of static death rate (fallen deadwood)

2.6.1. In measuring death rate, the species, position (stub or lying deadwood) and diameter at the thin-end and butt-end shall be determined.

2.6.2. If a bole length with a stump has remained for fallen deadwood, the diameter of the butt-end shall be measured in the distance of 1,3 m from the root collar, assuming that the diameter of the thin-end is 1 cm.

2.6.3. If the fallen deadwood is a broken top, the diameter of the butt-end shall be measured at the breaking point, assuming that the diameter of the thin-end is 1 cm.

2.6.4. If the fallen deadwood is a bole shiver, diameters shall be measured at both ends of the fallen deadwood.

2.6.5. The diameter of stubs shall be measured in height of 1,3 m and at the end of the stub. If a tree part (fallen deadwood) that has separated from the stub is visible, it shall be assumed that the diameter of the thin-end of the stub is the diameter of the butt-end of such fallen deadwood.

2.6.6. If the stub is less than 1,3 m long, the butt-end of the stub shall be measured at the root collar.

2.6.7. If direct measuring of the thin-end of the stub is not possible, it shall be determined by the height of the stub, assuming that the diameter of the thin-end of the stub is the same as the height of the stub.

2.6.8. Freshly prepared assortments, wood at delivery roads, sown tree stumps, as well as stumps of broken trees less than 0,5 m short shall not be included in death rate.

2.6.9. Such fallen deadwood shall be measured, which are more than 6,1 cm wide at the butt-end. The belonging of the fallen deadwood to the sample plot A or B shall be determined according to the location of the fallen deadwood in the sample plot.

2.6.10. If the butt-end of the fallen deadwood is located in a sample plot, the length of the whole fallen deadwood shall be measured also if part of the fallen deadwood is located outside the sample plot.

2.6.11. If the butt-end of the fallen deadwood is located outside the sample plot, the fallen deadwood shall not be measured.

2.6.12. Death rate shall be classified according to its quality groups:

2.6.12.1. fresh death (until the bark of the bole begins to peal);

2.6.12.2. death of average age (from the time when bark of the bole begins to peal until epiphytes begin to occur on less than 10 % of the cover of the visible surface of the bole);

2.6.12.3. pieces of rotten wood (cover of epiphytes is more than 10 % of the visible surface of the bole).

2.6.13. All types of death rate shall be measured at odd times of surveying sample plots. Only such death rate shall be surveyed at even survey times, which has occurred after the previous measuring.

2.7. Description of changes of growing trees in cycles of re-measuring

2.7.1. The belonging of a tree to the following groups of changes of growing trees surveyed during the previous measuring shall be recorded in cycles of re-measuring (if applicable):

2.7.1.1. the tree has been cut down and taken away (or logging is taking place at the time of surveying);

2.7.1.2. the tree has been cut down and left in the forest;

2.7.1.3. the tree has fallen in windfall and taken away;

2.7.1.4. the tree is standing and dead;

2.7.1.5. the tree has fallen in windfall;

2.7.1.6. the tree is broken and forms a stub;

2.7.1.7. the top of the tree has been broken;

2.7.1.8. the tree has been gnawed off by a beaver.

2.7.2. The wood volume of any the above mentioned tree group shall be determined as the living tree volume calculated in the previous cycle of surveying. The sum of tree volumes belonging to each group in a sample plot shall form the stock corresponding to each group. The annual death rate and the fallen amount shall be determined by diving the total amount of the group by the number of years of the cycle of surveying.

2.8. Data registration and storage

2.8.1. The data obtained as a result of surveying sample plots initially shall be registered in work tables or their equivalents on the field computer.

2.8.2. Data of the monitoring of forest resources shall be copied from field computers to the data base not less than once in two weeks.

2.8.3. Logical control of data shall be performed and the data errors detected shall be returned to the field working group for correction in order to take repeated measurements in the sample plot.

2.8.4. Data obtained in surveying of sample plots for each year of the monitoring of forest resources and a full cycle of five years shall be permanently stored in the form of data base, ensuring a possibility to analyse the information in historical development. Permanent data bases shall ensure a possibility to supplement them with new indicators to be determined at any time.

2.8.5. The information compiled during preparation work and cartographic materials shall be stored in printed form until the next survey when they are updated with as new data as possible.

CALCULATIONS OF PARAMETERS OF MONITORING ELEMENTS

3. Methodology for Calculation

3.1. Determination of division of the area according to the types of land use and the categories of forest land

3.1.1. Division of the area according to the types of land use initially shall be determined after the first level of selecting sample plots where the type of land use shall be determined at points located at every m according to orthophoto maps or satellite images in accordance with the types of land use determined in the State.

3.1.2. The total area of forest land according to the annual sample plot survey data shall be determined as follows:

$$Qm=Q*pm \quad \text{or} \quad (65)$$

$$Qm=Km*qR \quad (66)$$

$$Qm=(qm*qR)/500 \quad \text{, where} \quad (67)$$

Q – the total territory of Latvia;

Qm – the areas of forest land;

pm – proportion of forest land.

$$Pm=Km/K \quad \text{, where}$$

Km – sum of the sample plot or its parts, which are included in the forest land and have been itemised, in units;

K – the total number of sample plots in the State. (68)

$$K= Q/qR \quad \text{, where}$$

qR – the area represented by one sample plot;

qm – the area of all sample plots and sectors falling into forest land. (69)

3.1.3. The area assessment error in percentage shall be calculated:

$$PQm=((1-pm)/((kK-1)*pm))*100 \quad (70)$$

3.2. General principles for the calculation of the indicators of wood resources in sample plots

3.2.1. In each sample plot or sample plot sector the indicators of wood resources shall be calculated differently for each forest element, considering the smallest cluster of trees of the stand, for which the values of taxation indicators are determined, as the forest element. It is the part of a stand, which consists of one level, advanced growth and trees of species.

3.2.2. Values of additive taxation indicators at the stand level shall be obtained as the relevant sums. Indicators that depend on the area shall be expressed per 1 ha.

3.3. Determination of the number of trees

3.3.1. Number of the forest element trees Ni:

$$N_i = \frac{n_i}{m}$$

, i=1,2...,l , where (71)

Ni – number of the forest element trees, ha

l – number of the relevant forest elements (species of trees);

ni – number of trees in the sample plot in i-th forest element;

m – recalculation coefficient of the sample plot concentric circle (concentric circle Am = 0,0025, concentric circle Bm =0,01, concentric circle Cm = 0,05).

3.3.2. Number of trees of a stand (level of a tree stand) N, ha^{-1}:

$$N = \sum_i N_i$$

, i=1,2...,l (72)

3.4. Determination of the basal area of the stand

3.4.1. Basal area of the forest element Gi:

$$G_i = \frac{\pi}{40000m} \sum_j d_j^2$$

, j=1,2...,ni , where (73)

Gi – basal area of the forest element, $m^2 * ha^{-1}$

dj – diameter in height of 1,3 m, cm.

3.4.2. Basal area of the stand (level of the tree stand) G, m^2 * h-1

$$G = \sum G_i$$

, i=1,...,l (74)

3.5. diameter in height of m

3.5.1. Diameter of the forest element in height of 1,3m Di, cm:

$$D_i = 100\sqrt{\frac{4G_i}{\pi \cdot N_i}}$$ (75)

3.6. Average height

3.6.1. Average height of the forest element Hi, m:

3.6.1.1. if the number of inventory trees of the forest element nu is less than 5, its average height shall be calculated as the arithmetic mean:

$$H_i = \frac{\sum_j h_j}{n_i}$$, i=1,...,l, where (76)

hj – height of the tree, m

3.6.2. if the number of inventory trees of the forest element nu is more than 5, the height shall be calculated for each tree according to the measurements of inventory trees: heights shall be calculated for each of trees according to the measuring of the inventory trees performed:

Table 1: Output Information for Determination of Parameters of the Contour Line Equation

Diameters, cm	D1	D2	. . .	Dk
Height of trees, m	H1	H2	. . .	Hk

3.6.3. an equilateral hyperbola arc with the following equation shall be used for levelling of heights:

$$H = H_0 + \frac{D}{K \cdot D + C}$$, where (77)

H_0 – 1,3 m.

3.6.4. the parameters of the contour line equation shall be found using formulas (20) and (21):

$$C = \frac{N \cdot \sum \frac{1}{D_i \cdot (H_i - 1{,}3)} - \sum \frac{1}{D_i} \cdot \sum \frac{1}{H_i - 1{,}3}}{N \cdot \sum \frac{1}{D_i^2} - \sum \frac{1}{D_i} \cdot \sum \frac{1}{D_i}}$$ (78)

$$K = \frac{\sum \frac{1}{H_i - 1{,}3} - C \cdot \sum \frac{1}{D_i}}{N}$$ (79)

3.6.5. after determination of the contour line height of each D1,3 m tree is known.

3.7. Stock of the tree stand

3.7.1. Stock of the forest element Mi, m³ * ha⁻¹

$$M_i = \frac{1}{m} \sum_j v_j$$, j=1,2...,l, where (80)

vj – volume of the tree bole, m^3

$$v_j = \psi \cdot h_j^{\alpha} \cdot d_j^{\beta \cdot \lg h_j + \varphi}$$, where (81)

hj – height, m;

dj – diameter in height of 1,3 m, cm;

Ψ, α, β, φ – volume coefficients of the bole which depend on the species of the tree (Table 2)

Table 2: Values of Volume Coefficients of the Bole

Tree species	Ψ	α	β	φ
Pine	$1,6541*10^{-4}$	0,56582	0,25924	1,59689
Spruce	$2,3106*10^{-4}$	0,78193	0,34175	1,18811
Birch	$0,9090*10^{-4}$	0,71677	0,16692	1,75701
Aspen	$0,5020*10^{-4}$	0,92625	0,02221	1,95538
Black alder	$0,7950*10^{-4}$	0,77095	0,13505	1,80715
Grey alder	$0,7450*10^{-4}$	0,81295	0,06935	1,85346
Oak	$1,3818*10^{-4}$	0,56512	0,14732	1,81336
Ash	$0,8530*10^{-4}$	0,73077	0,06820	1,91124

3.7.2. Stock of the stand M, $m^3 * ha^{-1}$

$$M = \sum_i M_i$$, i=1,2...,l (82)

3.7.3. Stock of snags Ms, $m^3 * ha^{-1}$ shall be calculated using the formulas (83), (84) and (85).

3.7.4. Stock of fallen deadwood Mk, $m^3 * ha^{-1}$ shall be calculated:

3.7.4.1. if the length of the trunk has remained for a fallen deadwood and it altogether is located within the borders of the concentric circle, its volume shall be calculated using the formulas (84) and (86):

$$M_{k1} = \frac{1}{m} \sum_j v_j$$, j=1,2...,n where (83)

n– the number of trees corresponding to Paragraph 154.1

3.7.4.2. if the fallen deadwood is a shiver of a tree or a part in the concentric circle of a torn-up tree, its volume shall be calculated according to the simple centre plot formula of F. Huber:

$$v_j = \frac{\pi \cdot d_{1/2}^2}{4} L$$, where (84)

vj – volume of the fallen deadwood, m^3

L – length of the part in the concentric circle of the fallen deadwood, m;

$d_{1/2}^2$ – diameter at the middle of the fallen deadwood, m.

$$M_{k2} = \frac{1}{m}\sum_j v_j$$, j=...,nk2, where (85)

nk2 – number of the trees corresponding to Paragraph 154.2

3.7.4.3. Total stock of the fallen deadwood Mk, $m^3 * ha^{-1}$

$$M_k = M_{k1} + M_{k2}$$ (86)

3.7.5. Stock of stubs Mst, $m^3 * ha^{-1}$

$$v_{st} = \frac{\pi \cdot d_{1/2}^2}{4} h_{st}$$, where (87)

$$M_{st} = \frac{1}{m}\sum_j v_{stj}$$

v_{st}, m^3 – volume of an individual stub; , $j=1,2...,n_{st}$, (88)

$d_{1/2}$ – diameter at the middle of the stub (to be measured directly), m;

h_{st} – height of the stub, m.

3.8. Biomass of the tree crowns

3.8.1. Biomass of the tree crowns shall be calculated according to the volume of the tree bole (Table 3):

Table 3: Biomass of the Tree Crowns According to the Volume of the Tree Bole

Height of trees, m	Biomass of the tree crown (t) per 1 m^3 of the bole volume		
	for pine	for spruce	for deciduous trees
6	0.15	0.47	0.18
8	0.12	0.38	0.15
10	0.10	0.31	0.13
12	0.08	0.26	0.11
14	0.07	0.22	0.09
16	0.06	0.18	0.08
18	0.05	0.15	0.07
20	0.04	0.13	0.06
22	0.04	0.11	0.05
24	0.03	0.10	0.04
26	0.03	0.09	0.04
28	0.02	0.08	0.03

Height of trees, m	Biomass of the tree crown (t) per 1 m^3 of the bole volume		
	for pine	for spruce	for deciduous trees
30	0.02	0.07	0.03

3.9. Actual current increment of the stock

3.9.1. Actual current increment of the stock ZMi shall be calculated, using the formula (:

$$Z_M = 12732{,}4\psi G H^{\alpha} D^{\beta \lg H + \varphi - 2}\left[\frac{Z_H(\alpha + \beta \lg D)}{H} + \frac{Z_D(\varphi + \beta \lg H)}{10D}\right]$$, where (89)

ZMi – actual current periodical increment of the stock on average, m^3 * h-1 * g-1

G – basal area of the forest element in height of 1,3 m, $m^2 * ha^{-1}$

H – the average height of the forest element, m;

D – the average diameter of the forest element in height of 1,3 m, cm;

ZD – the increment in diameter of the relevant lustrum of the forest element, mm:

$$ZD = 2iu$$, where (90)

i – the average width of the relevant growth ring of the forest element, mm;

u – coefficient of the thickness of the bark (Table 4);

ZH – the increment in height of the relevant of the forest element, mm:

$$Z_H = \frac{2iH(aD + b)}{cD + 100}$$, where (91)

a,b,c – coefficients of the course of growth in height.

Table 4: Values of Empirical Coefficients

Tree species	Increment in height			Bark volume			u
	a	b	c	p	q	w	
P	−0.0642	6.356	27.105	20.6	143.9	19.53	1.103
S	−0.0256	1.693	5.794	5.25	117.6	5	1.046
B	−0.0728	−1.51	−35.71	0.2	110.2	0.02	1.095
A	−0.0357	2.352	12.829	0.78	109.9	0.67	1.061
BA	0.005	7.24	90.909	−0.55	119	−0.36	1.081
GA	0.0958	3.478	45.988	−49.1	93.3	−45.83	1.05
O	−0.0728	−1.51	−35.71	0.2	110.2	0.02	1.095
As	−0.0728	−1.51	−35.71	0.2	110.2	0.02	1.095

In stands which have not reached cm in diameter, the annual increment shall be calculated as general quantity on the whole level of the stand according to the formula:

$$ZMn=((MA*n)/A)$$, where (92)

MA – current stock of the stand, (m^3 * ha^{-1});

A – age in years;

n – time period (years).

3.9.2. Actual current increment of the stand ZM, m^3 * ha^{-1} * g-1

$$Z_M = \sum_i Z_{Mi}$$,i=1,2...,l (93)

3.10. Mass of the stock and current increment of the stock

3.10.1. Values of the above mentioned categories of the stock and current increment of the stock shall be expressed in mass units (t) multiplied by recalculation coefficient km (t * m^3).

3.10.2. The following values of the coefficient km have been determined in the Latvian State Standard LVS 82 1997: for pine and aspen – 0,81, for spruce – 0,73, for birch – 0,94.

3.11. Assessment of the wood

3.11.1. Values of the above mentioned categories of the stock and current increment of the stock shall be calculated including bark. Values of the relevant part of the wood shall be obtained dividing them by the bark volume coefficient s:

$$s = \frac{pd_j + q}{wd_j + 100}$$, where (94)

p,q,w – bark volume coefficient (Table 4).

3.12. Assessment of bark

3.12.1. Values of the bark of the above mentioned categories of the stock and current increment of the stock shall be calculated as differences, deducting values of the relevant part of the wood from the stock or its increment.

3.13. . Evaluation of stand parameters and their variation per unit of area

3.13.1. Taking into account that the size of the basic sample plot in the monitoring of forest resources is 500 m^2, but it is divided into smaller sample plots and sectors with different dimensions, the calculation method of average weighted values shall be used in evaluating the average indicators and their variation. Indicators of the stand per 1 ha shall be calculated as follows:

$$\ddot{Y}= \sum(Y_i*p_i)/ \sum p_i$$, where dispersion (95)

$$\sigma(\tilde{Y})^2=\sum((Y_i-\ddot{Y})^2*p_i)/ \sum p_i$$, where (96)

Y_i – value of the parameter of the stand per 1 ha in i-th sample plot unit

$$Yi = yi/xi$$, where (97)

yi – value of the parameter in i-th sample plot unit;

xi – area of the sample plot unit, m^2;

Ÿ – average indicator of the stand per 1 ha;

pi – part of the sample plot.

$$pi = xi/q$$, where (98)

area of the sample plot (0,05 ha).

3.13.2. The average indicator per 1 ha dispersion shall be determined as follows:

$$\sigma(\ddot{Y})^2=\sigma(\tilde{Y})^2/n \quad (99)$$

3.13.3. Standard deviation of average indicators in absolute values:

$$\sigma(\ddot{Y})=(\sigma(\ddot{Y})^2)^{1/2} \quad (100)$$

and percentage:

$$P_{\ddot{Y}}= ((\sigma(\ddot{Y}))/\ddot{Y})*100$$, where (101)

$\sigma(\tilde{Y})2$ – dispersion of the parameter of the stand per 1 ha;

n – number of units of sample plots (sample plots, sectors).

3.14. Evaluation of indicators of the monitoring of forest resources in the object of inventory

3.14.1. The tree stand, increment and their number in the whole object of monitoring shall be calculated multiplying the values of such indicators per 1 ha by the number of corresponding stand groups (strata):

$$Y_i= \ddot{Y}_i*Q_i$$, where (102)

Ÿi – value of the inventory indicator of a stand group;

Qi – area of the i-th stand group, ha.

3.14.2. An error of a tree stock and their number in the whole area shall be determined according to the formula:

$$P_{Ti}= (P(_{\ddot{Y}i})^2+(P_{(Qi)}{}^2)^{1/2}$$, where (103)

P(Ÿi) – error of the monitored indicators of the i-th stand group (%);

P(Qi) – error of the area of the i-th stand group (%).

3.14.3. The increment balance for a group of stands in an object of inventory shall be evaluated combining the whole stock of sample plots of such group and including the trees cut down between the monitoring of forest resources.

3.15. Determination of age of a forest element

3.15.1. Age of a forest element shall be determined according to the formula:

$$Af = (Am + Ai) \quad \text{, where} \qquad (104)$$

Af – actual age of the forest element (years);

Am – the age of trees determined in the forest at height of 1,3 m (years);

Ai – correction of the actual age (Table 5).

Table 5: Correction of Actual Age of the Forest Element

No.	Tree species	Correction (years)
1.	Coniferous trees	7
2.	Oak, flattering elm, elm	5
3.	Birch, black alder, ash, linden, maple	3
4.	Aspen, poplar, grey alder	2

CLASSIFIERS TO BE USED IN THE MONITORING OF FOREST RESOURCES

1. Types of sample plots

No	Type of the sample plot	Code
1.	Permanent sample plots	1

2. Accessibility of the centre of sample plots

No	Centre of the sample plot	Code
1.	Accessible	1
2.	Not accessible	2

3. Forms of property

No	Name of the form of property	Code
1.	Public forests:	
2.	State	1
3.	Other public authorities (local governments)	2
4.	Private forests:	
5.	Private individuals	3
6.	Undertakings	4
7.	Other private institutions	5

4. Categories of forest land and other land

No	Name	Code
1.	Forest	10
2.	Stunted stand	11
3.	Burn	12
4.	Windfalls	13
5.	Felled area	14
6.	Marshes	
7.	Moss marsh	21
8.	Herbaceous marsh	22
9.	Transitional swamp	23
10.	Glade	30
11.	Glade	31
12.	Glade for feeding forest animals	32
13.	Heath	33
14.	Sands	34
15.	Overflowing clearing	40
16.	Land under forest infrastructure objects	
17.	Forest road	51
18.	Clearance	52

No	Name	Code
19.	Block ride	521
20.	Mineralised strip	522
21.	Forest ditch	53
22.	Forest channel	531
23.	Ditch route	532
24.	Other objects of the forest infrastructure	
25.	Seed plantations	541
26.	Recovered land	542
27.	Forest water reservoir	543
28.	Recreational area	544
29.	Other land of special significance	545
30.	Land outside the forest land	
31.	Arable land	60
32.	Grassland	61
33.	Forest in agricultural land (number of trees > units/ha	62
34.	River	63
35.	Overgrown agricultural land (bushes or trees < units/ha	64
36.	Lake, pond	65
37.	Agricultural ditch	66
38.	Motor road with a belt	67
39.	Railway with a belt	68
40.	Overgrown quarry	69
41.	Fresh quarry	70
42.	Alluvial land of a river	71
43.	Yard (household plot)	72
44.	Towns, villages	73
45.	Industrial routes (electricity, gas, oil, etc.)	74

5. Origin of the stand

No	Type of origin	Code
1.	Naturally from seed	11
2.	Naturally from sprouts	12
3.	Anthropogenic (by sowing or planting)	20

6. Types of forest

No	Name	Code
1.	1. Dry forests	
2.	Cladinoso Callunosa	1
3.	Vacciniosa	2
4.	Myrtillosa	3
5.	Hylocomiosa	4

No	Name	Code
6.	Oxalidosa	5
7.	Aegopodiosa	6
8.	2. Wet forests	
9.	Callunoso-sphagnosa	7
10.	Vaccinioso-sphagnosa	8
11.	Myrtilloso-sphagnosa	9
12.	Myrtilloso politichosa	10
13.	Dryopteriosa	11
14.	3. Marsh forests	
15.	Sphagnosa	12
16.	Caricoso-phragmitosa	14
17.	Dryopterioso-caricosa	15
18.	Filipendulosa	16
19.	4. Dry mineral forests	
20.	Callunosa mel.	17
21.	Vacciniosa mel.	18
22.	Myrtillosa mel.	19
23.	Mer curaliosa turf. mel.	21
24.	5. Turf forests	
25.	Callunosa turf. mel.	22
26.	Vacciniosa turf. mel.	23
27.	Myrtillosa turf. mel.	24
28.	Oxalidosa turf. mel.	25

7. Division of trees in Kraft Classes

No	Name	Code
1.	Kraft Class I	1
2.	Kraft Class II	2
3.	Kraft Class III	3
4.	Kraft Class IV	4
5.	Kraft Class V	5

8. Belonging of Tress to a Stand Level

No	Name	Code
1.	1st level tree	1
2.	2nd level tree	2
3.	3rd level tree	3

9. Tree species

No	Name	Code
1.	Pine	1
2.	Spruce	3

No	Name	Code
3.	Birch	4
4.	Black alder	6
5.	Aspen	8
6.	Grey alder	9
7.	Oak (common)	10
8.	Ash	11
9.	Linden	12
10.	Larch	13
11.	Other pines (Jack pine, Weymouth pine)	14
12.	Other spruces (white spruce, Douglas fir)	15
13.	Elm, flattering elm	16
14.	Beech	17
15.	Hornbeam	18
16.	Poplar	19
17.	Willow	20
18.	Goat willow	21
19.	Cedar	22
20.	White fir	23
21.	Maple	24
22.	Crabapple	51
23.	Cherry	56

10. Bush species

No	Name	Code
1.	Osier	30
2.	Junipers	31
3.	Rowan-trees	32
4.	Buckthorns	33
5.	Hazel-trees	34
6.	Bird-cherries	35
7.	Honeysuckles	36
8.	Viburnums	37
9.	Spindle-trees	38
10.	Ribes sp.	39
11.	Currants	40
12.	Hawthorns	41
13.	Jasmines	42
14.	Elders	43
15.	Spiraea	44
16.	Lilacs	45

No	Name	Code
17.	Cotoneasters	46
18.	Barberries	47
19.	Dogwood	48
20.	Rosa sp.	49
21.	Siberian peashrub	50
22.	Coniferous trees	52
23.	Deciduous tree	53
24.	Unidentifiable species	54
25.	Mezereon	55
26.	Common buckthorn	30

11. Damages

No	Name	Code
1.	Windthrows, windfalls, snow-breaks, snow crushes	10
2.	Water	20
3.	Wildlife	30
4.	Fire	40
5.	Diseases	50
6.	Insects	60
7.	Others	70

12. Damaged place

No	Name	Code
1.	Roots and stumps up to 30 cm above the root collar	1
2.	Lower part of the bole from stump up to the first green branch	2
3.	Whole bole from the height of the stump up to the top	3
4.	Upper part of the bole from the first green branch up to the top	4
5.	Top	5
6.	Branches in the living crown	6
7.	Branches which have grown out of the bole and are more than 2 cm wide	7
8.	Buds and sprouts	8
9.	Leaves and needles	9

13. Placement of fallen deadwood

No	Name	Code
1.	Lying fallen deadwood	none
2.	Stub	2

14. Death rate quality groups

No	Name	Code
1.	Fresh	1
2.	Old (epiphytes cover >% of the surface)	2

No	Name	Code
3.	Rotten wood	3
4.	Living stub	4

15. Group of changes in trees in re-measuring of the sample plot

No	Name	Code
1.	Tree has been cut down and taken away (or logging is taking place at the time of surveying)	1
2.	Tree has been cut down and left in the forest	2
3.	Tree has fallen in windfall and taken away	3
4.	Tree is standing and dead (snag)	4
5.	Tree has fallen in windfall	5
6.	Tree is broken and forms a stub	6
7.	The top of the tree has been broken	7
8.	The tree has been gnawed off by a beaver	8