REPORT

ON IMPLEMENTATION OF THE RESEARCH PROGRAM

ELABORATION OF FOREST REFERENCE LEVEL FOR LATVIA FOR THE PERIOD BETWEEN 2021 AND 2025

ACTIVITY

AGM MODEL DESCRIPTION

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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.
Treestand	- A collection of trees within a forest stand.
Simple treestand	- A stand in which the trees are of similar height (the deviance does not exceed 20%).
Compound treestand	- 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 specias forms less than 95% of the stand.
Dominating tree species	- A tree species which has the greatest wood stock (if the dominatig 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 stange 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 canlater form a new stand and become a forestry object.
Kraft classes	- Classification of trees to describe their social state: • class 1st – (virsvaldkoki) – the tallest trees and trees with the greatest circumference with a well developedd crown and the treetops of which rise above the crown of the surrounding trees; • Class II – (valdkoki) – form the main crown cover, the trunks are a little smaller than those of class 1st trees; • class III – (līdzvaldkoki) – the tree crowns are relatively less developed, less wide, placed inbetween class 1st and II tree crowns in the bottom part of the crown cover; • class IV – (nomāktie koki) – the crowns are smaller than those of class III trees. The treetops reach the bottom part of the crown cover. The trees noticably 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 – (stipri nomāktie koki) – 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 tthe 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 stumo, bole (middle part) and stem top.

ABBREVIATIONS

$\mathbf{a_0}$	–	The biological age of a forest element, years
$\mathbf{a_{1.3}}$	–	The age of a forest element at breast height, years
$\mathbf{a_1}$	–	The age of a forest element at the height of 1.3 m in the beginnning of the actualization period, years
$\mathbf{a_2}$	–	The age of a forest element at the height of 1.3 m at the end of the actualisation period, years
$\mathbf{\Delta a}$	–	The age difference between stump height and at 1.3 m (a_0-$a_{1.3}$), years
B	–	Orlov's site index
$\mathbf{d_{ij}}$	–	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
$\mathbf{d_1}$	–	average diameter of forest elements at the height of 1.3 m in the beginning of actualization
$\mathbf{d_2}$	–	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}
$\mathbf{g_1}$	–	basal area of a forest element in the beginning of actualization period, m^2ha^{-1}
$\mathbf{g_2}$	–	basal area of a forest stand at the end of actualization period, m^2ha^{-1}
$\mathbf{g`_2}$	–	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};
$\mathbf{g_{max}}$	–	The greatest possible basal area of a forest element, m^2ha^{-1}
$\mathbf{G_{max}}$	–	The greatest possible basal area of 1st storey, m^2ha^{-1}
$\mathbf{g_{norm}}$	–	Normal basal of a forest element, m^2ha^{-1}
$\mathbf{G_{norm}}$	–	Normal basal area of trees of 1st storey, m^2ha^{-1}
h	–	Average height of forest element, m
$\mathbf{h_1}$	–	Average height of forest element in the beginning of actualization, m
$\mathbf{h_2}$	–	Average height of forest element at the end of actualization, m
$\mathbf{h_{dom}}$	–	Dominant height of forest element, m
$\mathbf{h_{dom1}}$	–	Dominant height of forest element in the beginning of actualization, m
$\mathbf{h_{dom2}}$	–	Dominant height of forest element at the end of actualization, m
$\mathbf{h_{20,50,100}}$	–	Estimated height of forest element at a particular age at breast height (20, 50 or 100 years), m
$\mathbf{k_{ij}}$	–	Composition coefficient of indiviual 1st storey forest element
m	–	Wood stock of a forest element, m^3ha^{-1}
M	–	Wood stock of a forest stand, m^3ha^{-1}
$\mathbf{m_1}$	–	Wood stock of a forest element in the beginning of actualization period, m^3ha^{-1}
$\mathbf{m_2}$	–	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}
$\mathbf{n_1}$	–	Number of trees in a forest element in the beginning of actualization period, ha^{-1}
$\mathbf{n_2}$	–	Number of trees in a forest element at the end of actualization period, ha^{-1}
$\mathbf{n_{max}}$	–	highest possible number of 1st floor trees in a forest element, ha^{-1}
$\mathbf{N_{max}}$	–	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 (virsaugstuma) in a forest stand, m
t	–	Duration od 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 stohastic 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 five years) management practice, but users will be 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.

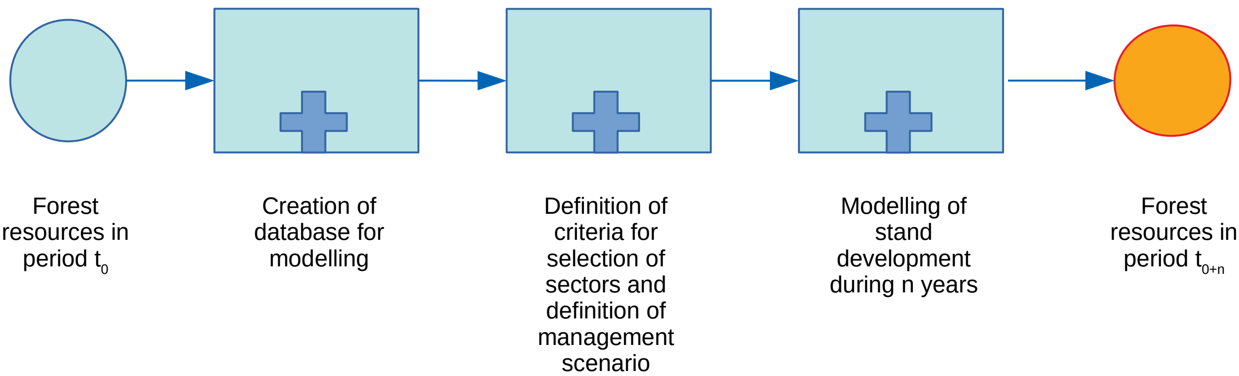

Figure 1 Scheme of the LVMI Silava changes in forest resources projections process based on NFI data.

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).

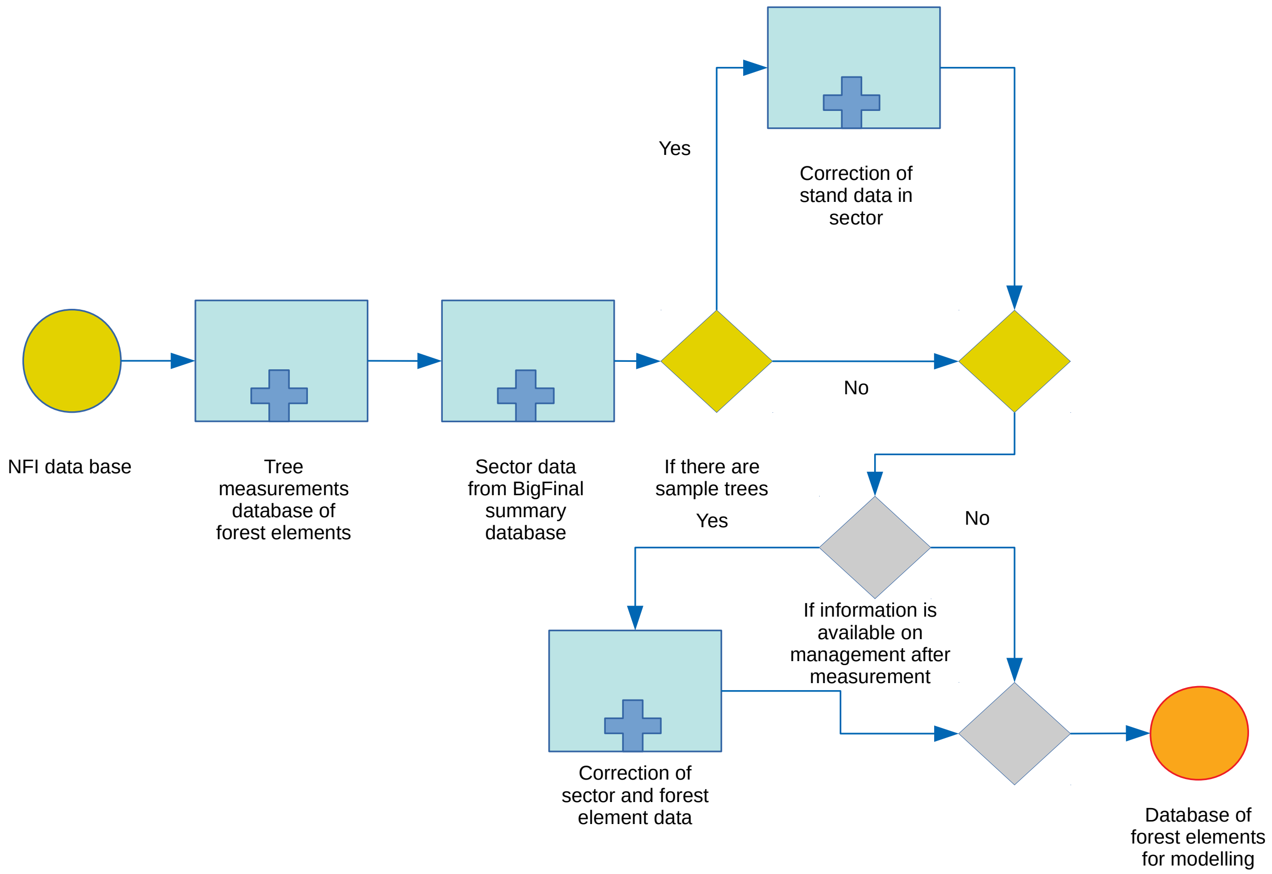

Figure 2 Scheme of developing the data table.

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[1]

Column name	Description	Unit of measurement
ID	Automatically generated number	

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

Column name	Description	Unit of measurement
IbIPLID	Identifier of sampling plot	
SEKTNR	Name of sector	
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	Augšanas gaitas modelēšanas iterācijas cikls (0-uzmērītie dati, 1-aprēķinātie dati uz tekošo gadu, 2- 1/2 no definētā cikla, 3 un vairāk pilni cikli). *Vajadzētu ģenerēties automātiski* *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	Coeficient 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}

Column name	Description	Unit of measurement
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}
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	Meža elementa paaudze (ja ekoloģiskie koki, tad 6, ja raksturkoks, tad 9, citiem 1) Generation of the forest element (if the ecological trees – 6, if (raksturkoks) – 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.

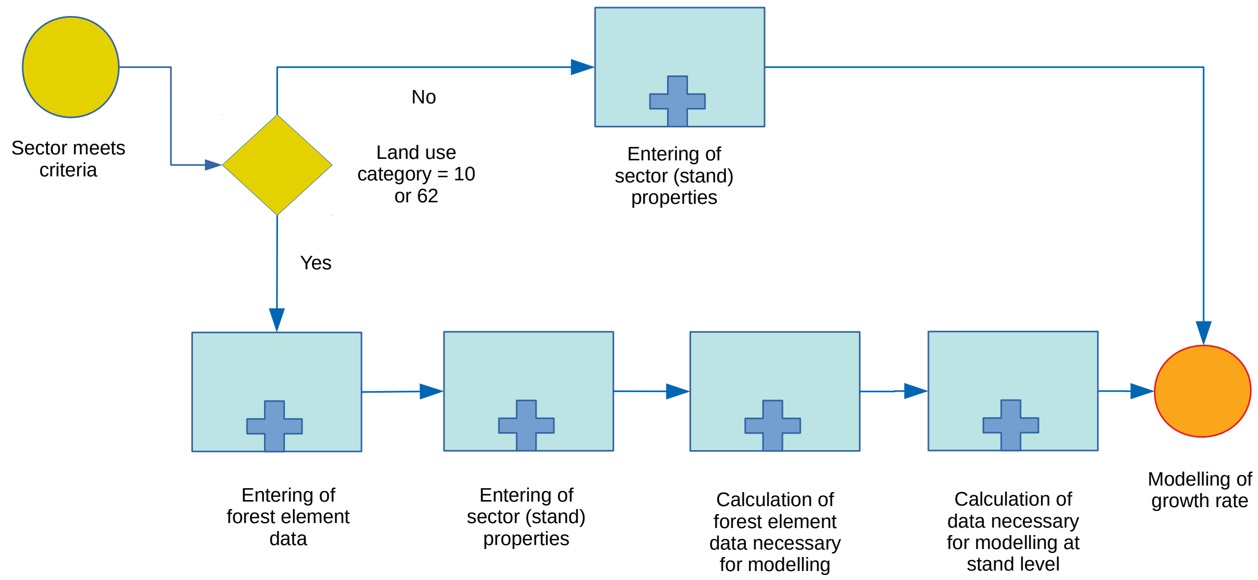

Figure 3 Data selection, input and calculations of forest element and forest stand data needed for the modelling of the growing process.

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}).

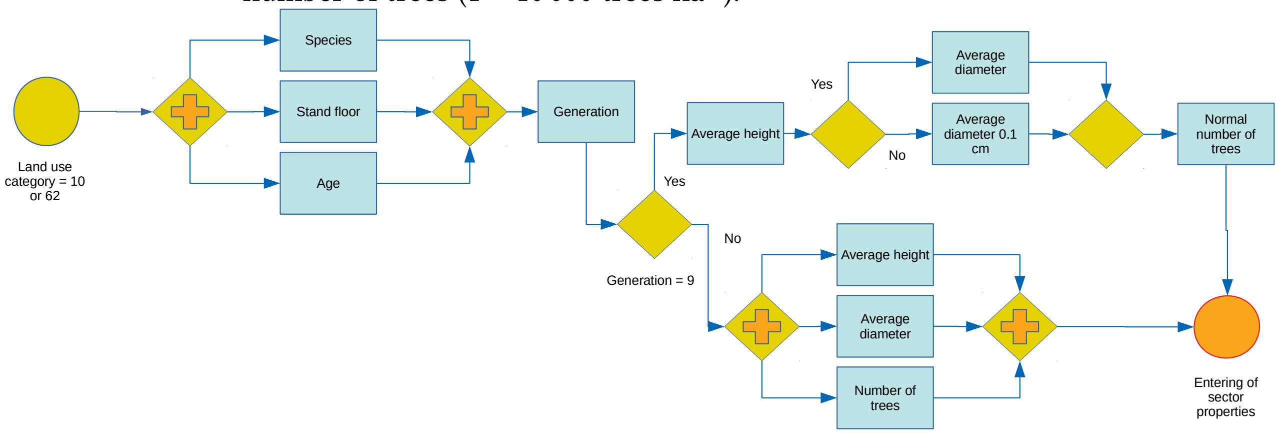

Figure 4 Scheme of data input for the taxation of individual forest element.

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.

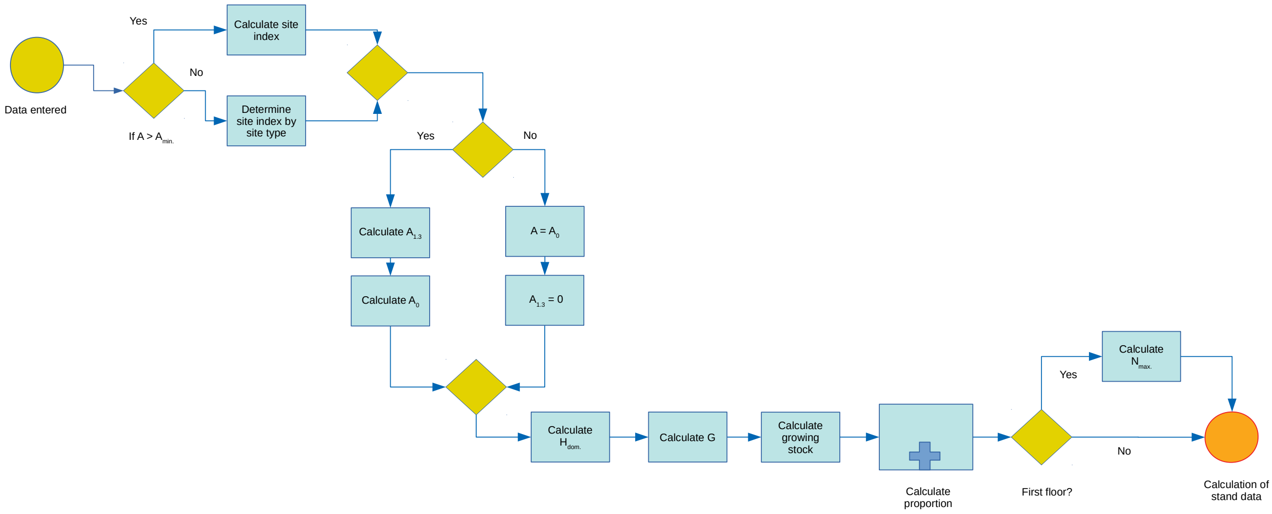

Figure 5 Scheme of the taxation data calculations necessary for the modelling of individual forest element growing

Site index of forest elements

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

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

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* (*Table* 2.3.1).

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

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)
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
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:

$$a_{1.3} = a - \Delta a_{0,}\ where$$

$a_{1.3}$ – Age of the forest element at chest height, years;
a – Age of forest element listed in the NFI database, years; (2)
Δa_0 – Difference between biological and chest height age given in the NFI database (table 2.3.3) , 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

Tree species	Tree species code	Δa_0
Alder buckthorn	33	2
Hazel	34	2
Bird cherry	35	2
Hawthorn	41	2
Crab apple	51	2
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:

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

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 (Table 2.3.4), 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							

Tree species	Tree species code	Site index						
		0	1	2	3	4	5	6
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
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 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
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:

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

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:

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

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 2.3.6.).

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

Tree species	Tree species code	ψ	α	β	ϕ
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:

$$ip = \frac{m}{M}, where \quad (7)$$

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:

$$ip = \frac{n}{N} \qquad (8)$$

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:

$$n_{max} = \alpha_1 * d^{\alpha_1} * h^{\alpha_1} * ip \text{ , where} \qquad (9)$$

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 2.3.7).

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
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

Tree species	Tree species code	α_1	α_2	α_3
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 2nd 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 1st 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 1st storey of the tree stand

The relative density of the 1st 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:

$$RB=\frac{N}{N_{max}}, where \qquad (10)$$

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 (subchapter 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. (subchapter 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 (subchapter Thinning).

DEFINING A MANAGEMENT SCENARIO

Forest regeneration

The user will be 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[2] (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

The user will be able to define artificially regenerated area content by forest type and property groups (state and other forests). The default setting models the probability of regenerated clearings sorting by property groups

[2] Meža atjaunošanas, meža ieaudzēšanas un plantāciju meža noteikumi: Ministru kabineta 2012. gada 2. maija noteikumi Nr.308.

(state and other forests) accordingly with the arithmetic average proportion of artificially regenerated forest stands in 2013-2016[3] (Table 10).

The user will also be able to define which tree species and how much will be regenerated artificially sorted by forest type and property groups (state and other forests). 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 arithmetic average proportion of artificially regenerated forest stands in 2013 – 2016. (Table 11).

Table 10 Probability of artificially regenerated forests by forest type[4]

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

[3] SFS statistikas CD 2013-2016.
[4] Arithmetic average proportion of artificially regenerated forests from in 2013-2016 in the data published by SFS.

Table 11 Probability of regenerated trees species when sowing or planting by forest type[5]

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			
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-

[5] Arithmetic average share of artificially regenerated areas in 2013-2016 in SFS data.

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
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 (artificially 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
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[6] 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[7] 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[8], 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[9] 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 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 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,
  - 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-

6 Number of trees in the First story in comparison to normal number of trees (Formula 25).

7 Meža inventarizācijas un Meža valsts reģistra informācijas aprites noteikumi: Ministru kabineta 2016. gada 21. jūnija noteikumi Nr.384.

8 Kopšanas ciršu rokasgrāmata. LVM, 2012

9 Noteikumi par koku ciršanu mežā: Ministru kabineta 2012.gada 18.decembra noteikumi Nr.935.

commercial thinning.

Table 15 Target tree species priority groups [10] 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
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

[10] 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.

Commercial thinning

The user will be 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 will be 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[11] 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[12] 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
	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 (Chapter).

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

Table 18 Priority group (suitability) of tree species according to forest type[13]

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

Final 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[14, 15] (Table 19).

13 1 –tree species suitable for forest type, 0 – tree species unsuitable for forest type.
14 Noteikumi par koku ciršanu mežā: Ministru kabineta 2012.gada 18.decembra noteikumi Nr.935.
15 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
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[16] (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[17] (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

16 SFS statistics CD 2013-2016.

17 SFS statistics CD 2015-2017

Decimal age group	Pine	Spruce	Birch	Alder	Aspen	Ash	Other species
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 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).

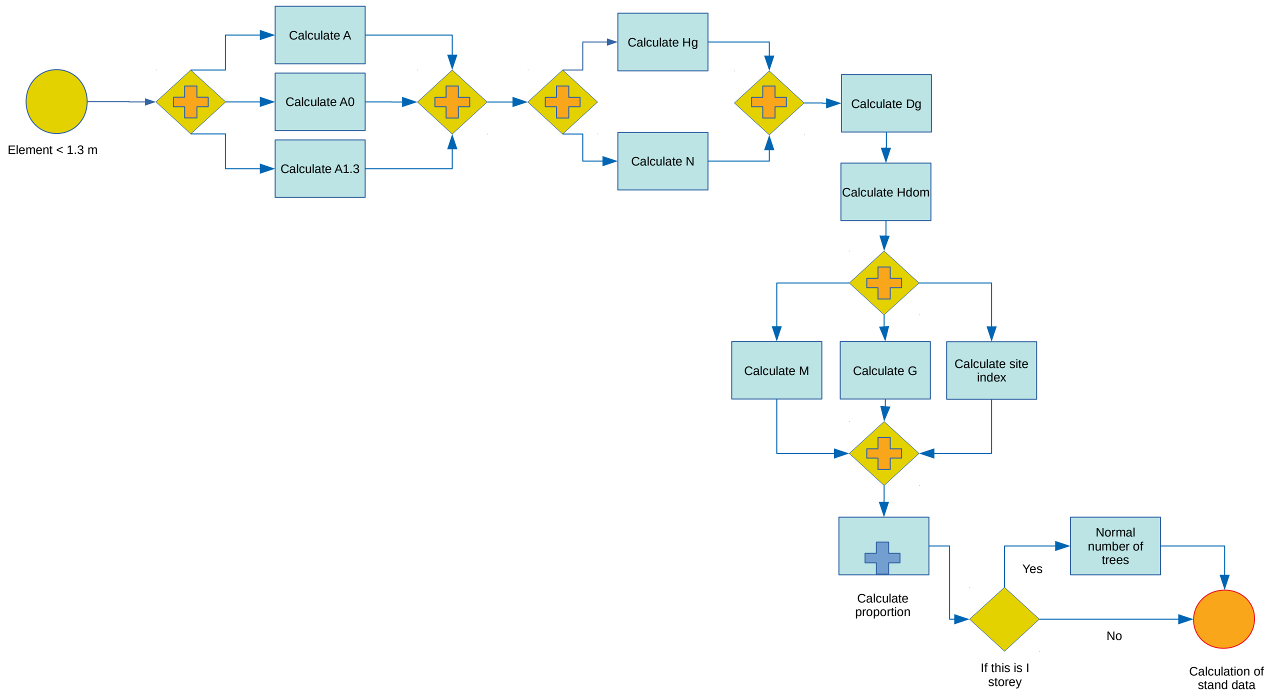

Figure 6 Scheme of the modelling of growth of individual forest elements of a forest stand before reaching a height of 1.3 m.

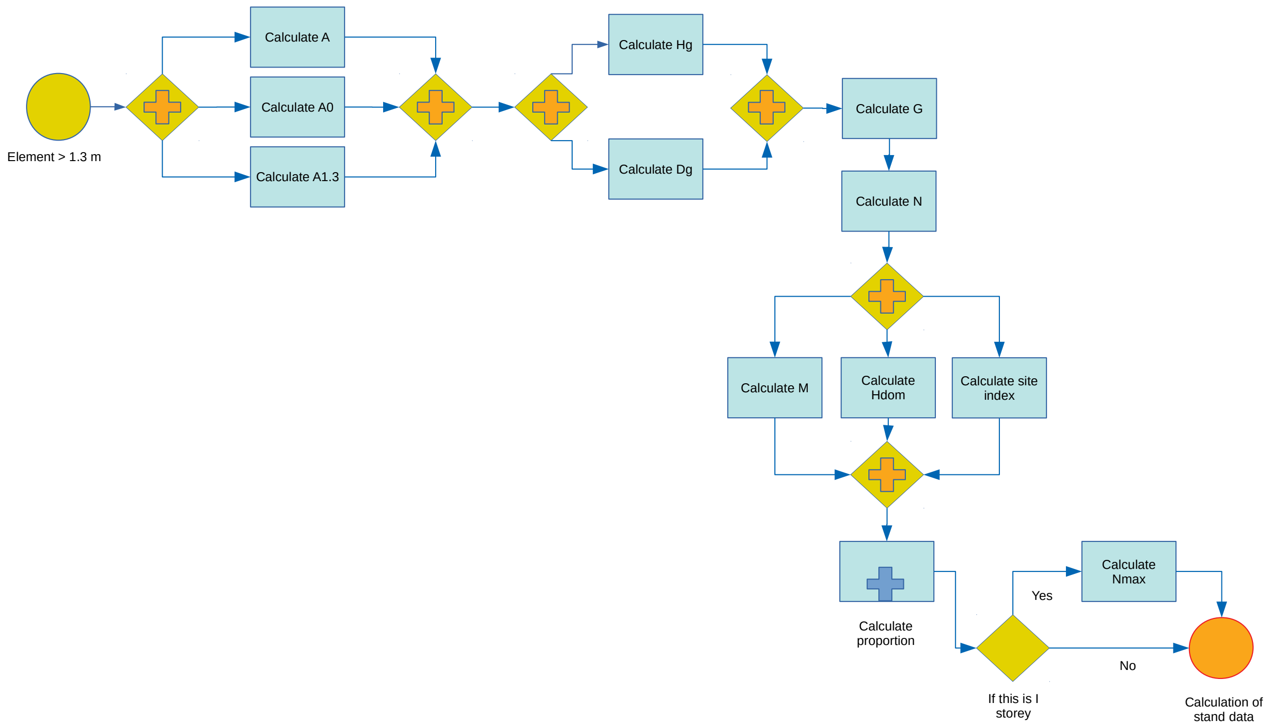

Figure 7 Scheme of the modelling of growth of individual forest elements of a forest stand after reaching a height of 1.3 m.

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 (Table 2.3.4), years;
α_{1-3} – Coefficients (Table 4.1.1).

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
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 4.1.2).

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

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	
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
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:

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

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 4.3.1).

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

Tree species	Tree species code	α_1	α_2	α_3
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
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:

$$n_2 = (1 - 0.01 * t) * n_1, \text{ where} \tag{15}$$

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:

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

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:

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

g_2 – Projected cross-section area of the forest element at the end of actualization period, $m^2 ha^{-1}$;
g_1 – Projected cross-section area of the forest element in the beginning of actualization period, $m^2 ha^{-1}$;
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), $m^2 ha^{-1}$;
SI – Projected height of the forest element (formula 13) at a specific chest height age (Table 5.3.2, ASI), m;
$\alpha_i; \beta_i$ – Coefficients (Tables 4.5.1. and 4.5.2).

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

g_2 – Projected cross-section area of the forest element at the end of actualization period, $m^2 ha^{-1}$;
g_1 – Projected cross-section area of the forest element in the beginning of actualization period, $m^2 ha^{-1}$;
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 (Tables 4.5.1. and 4.5.2).

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
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

Tree species	Tree species code	α_0	α_1	α_2	α_3	α_4	α_5
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) [18]

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
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

[18] 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 tiek rēķināts kokaudzes produktivitātes raksturojošais augstums.

Tree species	Tree species	α_0	α_1	α_2	A_{lim}	A_{SI}
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:

$$g_{max}=\frac{\alpha_1}{1+\left(\frac{d}{\alpha_2}\right)^{\alpha_3}}*ip\text{, where} \tag{19}$$

g_{max} – Maximum cross-section area of the forest element, $m^2 ha^{-1}$;
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;
α_i; β_i – coefficients (Table 4.5.3).

$$g_{max}=\beta_1*(1-\exp(-\beta_2*h))*ip\text{, where} \tag{20}$$

g_{max} – maximal basa area of forest element, $m^2 ha^{-1}$;
d – projected diameter of forest element at breast height, cm;
h – projected average height of forest element, m;
ip – share of forest element;
α_i; β_i – coefficients (Table 4.5.3).

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

Tree species	Tree species code	α_1	α_2	α_3	β_1	β_2
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
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:

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

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

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

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

Wood stock

The wood stock of the forest element is considered to be 2 m^3ha^{-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:

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

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

Tree species	Tree species code	α_1	α_2	α_3	Hmax
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

Tree species	Tree species code	Natural mortality	Amax
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
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.

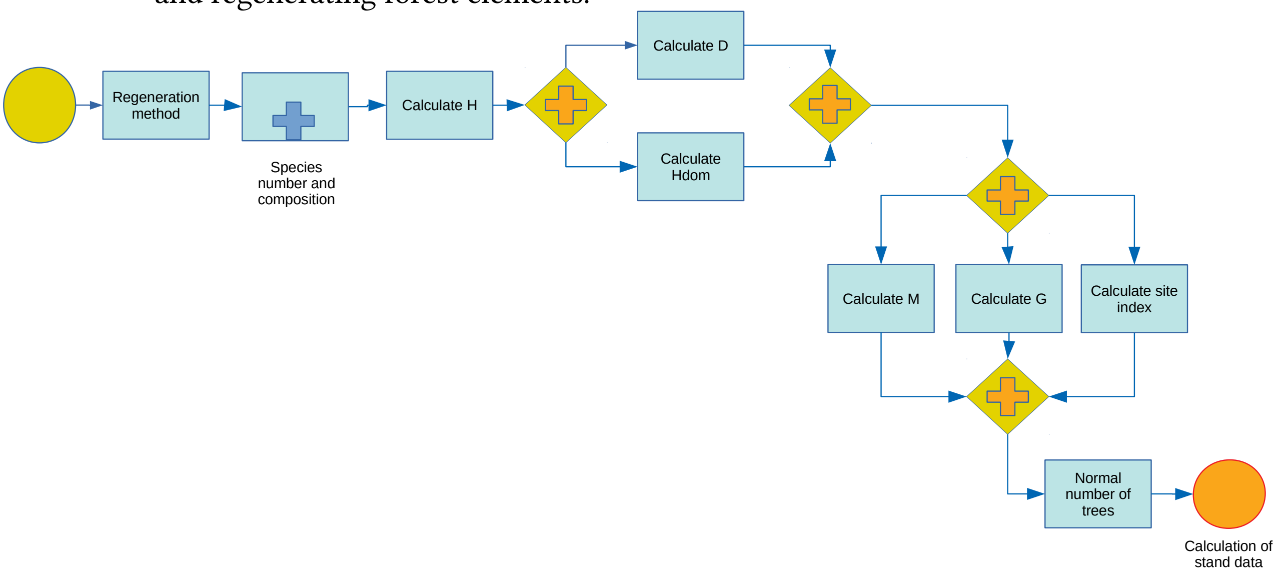

Figure 8 Scheme of regenerating model after clear felling.

Method of regeneration

The user can define the number of clearings to be regenerated naturally or artificially 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 artificially regenerated forests is modelled sorting by property group (state and other) in accordance with the arithmetic average proportion of artificially 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 artificially regenerated stands.

Soil scarification

In the default setting soil scarification is only used for artificially 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 artificially (Figure 9)

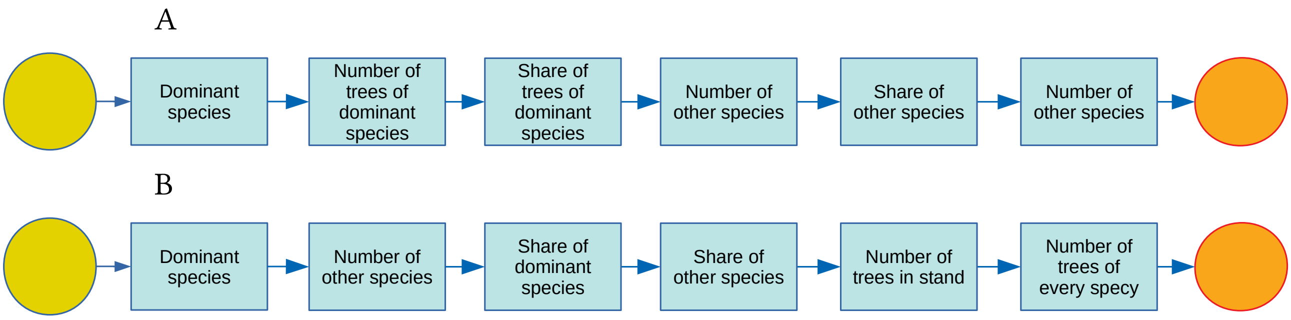

Figure 9 Scheme of species content and number in a forest stand after clear felling.

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 artificially 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 artificially 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
Slapjais gārša	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.	22	0.85	0.95	0	2

Forest type	Forest type code	Proportion of dominating tree species		Number of other species	
		Min	Max	Min	Max
mel.					
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[19] sorted by forest type

Forest type	Probability of other species													
	Pin	Spr	Bir	Ald	A sp	Gr Ald	Oak	Ash	Lin	Elm	Elm	G Will	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
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	

[19] Proportion of tree species in NFI data

Forest type	Probability of other species													
	Pin	Spr	Bir	Ald	A sp	Gr Ald	Oak	Ash	Lin	Elm	Elm	G Will	Osi	Br leaf trees
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 artificially 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[20] 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	

[20] arithmetic average proportion of naturally regenerated areas in 2013 – 2016 according to SFS data

Forest type	Tree species						
	pine	spruce	birch	alder	aspen	grey alder	other species
Myrtillosoi-polytrichosa		0.025	0.360	0.115	0.220	0.280	
Slapjais gārša		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
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

Forest type	Forest type code	Proportion of dominating tree species		Number of other tree species	
		Min	Max	Min	Max
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 artificially, 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 12. 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.

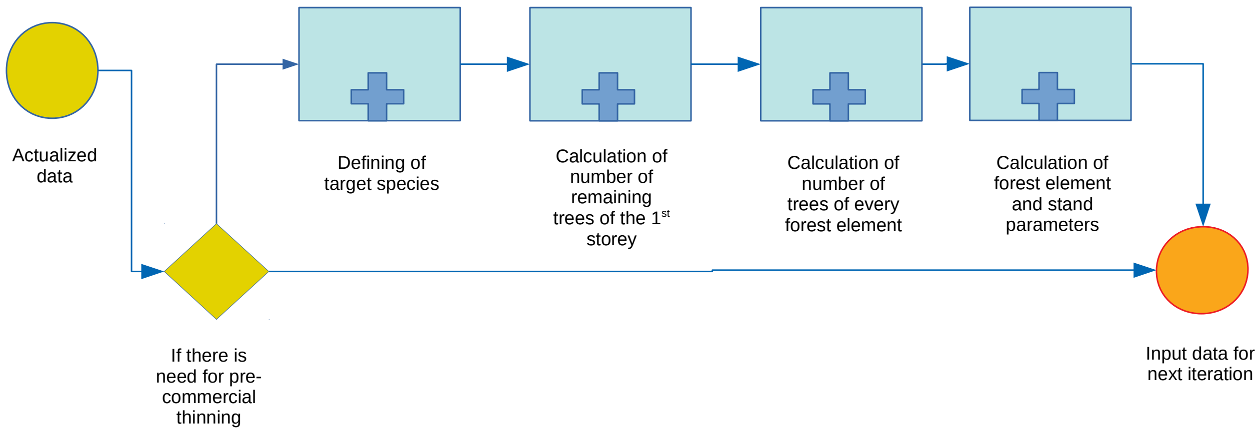

Figure 10 Scheme of pre-commercial thinning.

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:

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

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 5.2.1).

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

Tree species	Tree species code	N_{norm}				N_{min}		
		α_1	α_2	α_3	α_4	α_1	α_2	α_3
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
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:

- tree species (priority code 1-8) which are defined in an order of priority of target tree species,
- 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,
- 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 artificially regenerated plots the target species is the artificially 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.

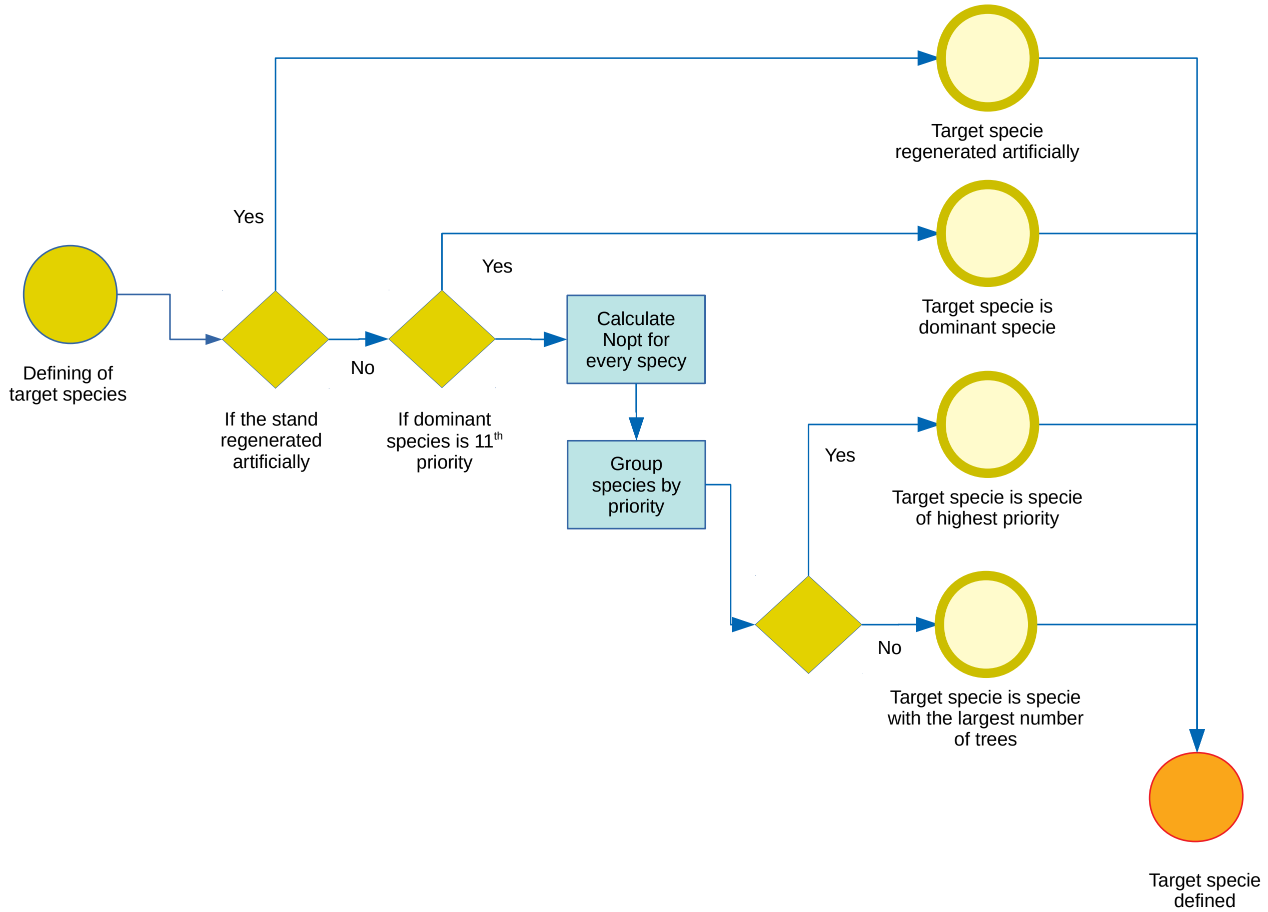

Figure 11 Scheme of determining the target species of the 1st storey of the forest stand.

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 5.2.3).

Table 37 Coefficients for the determining of the optimal number of trees in the 1st storey of the tree stand

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 (Table 5.2.1).

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.

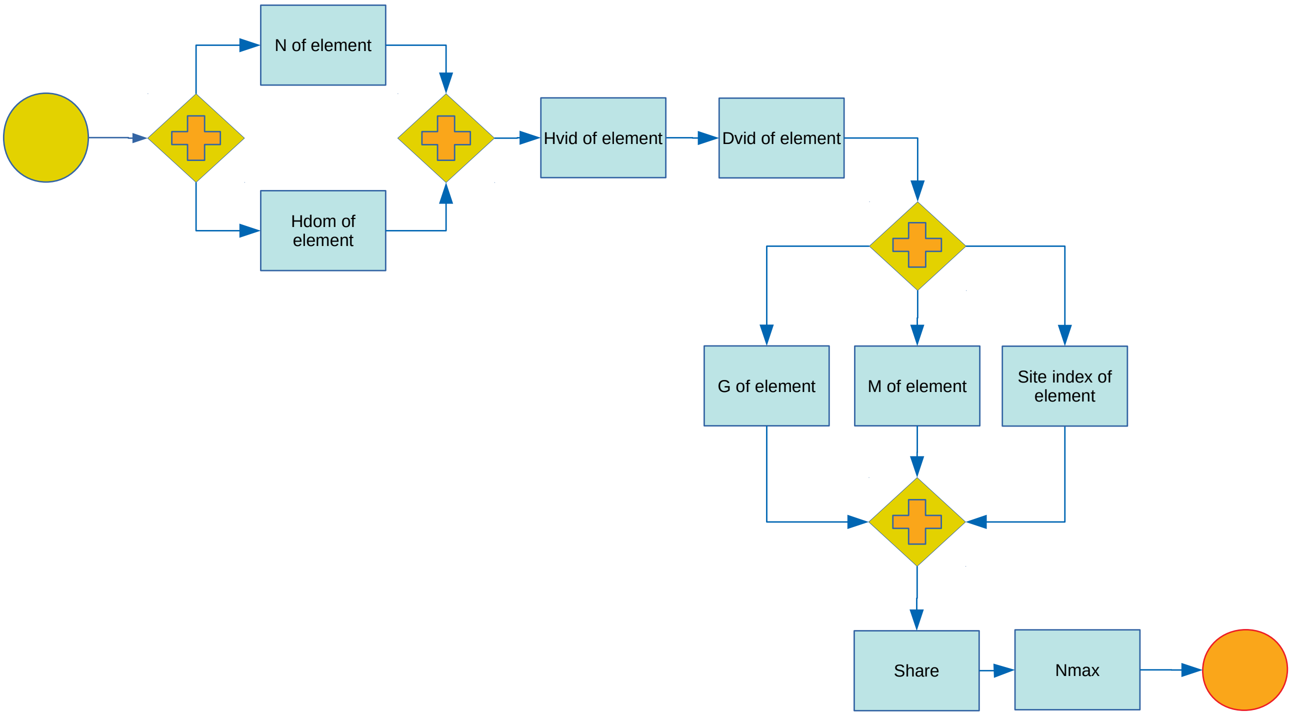

Figure 12 Scheme of calculations of taxation data of individual forest elements of the 1st storey after pre-commercial thinning.

Average height

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

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

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 (Table 2.3.5).

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:

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

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 5.2.4).

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

Tree species	Tree species code	α1	α2
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.

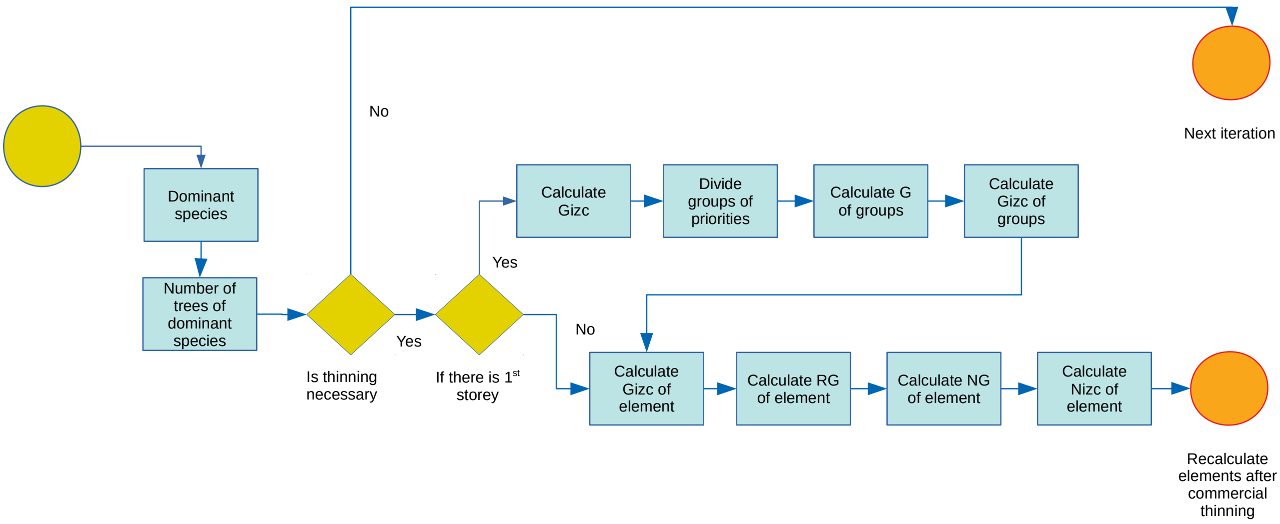

Figure 13 Scheme of modelling commercial thinning.

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.

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

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:

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

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 5.2.4).

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

Tree species	Tree species code	G_{norm}			G_{min}		
		α_1	α_2	α_3	α_1	α_2	α_3
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:

$$G_{pecKKC} = k * G_{min}, where \tag{35}$$

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, $m^2 ha^{-1}$;
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:

$$G_{min} = \frac{\alpha_1}{1+\alpha_2 * \exp(-\alpha_3 * H)}, where \quad (36)$$

G_{min} – Minimum cross-section area of the dominating tree species of the I storey listed in regulations, $m^2 ha^{-1}$;
H – Average height of the dominating tree species of the I storey, m;
α_i – Coefficients (Table 5.2.4)

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:

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

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:

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

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:

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

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).

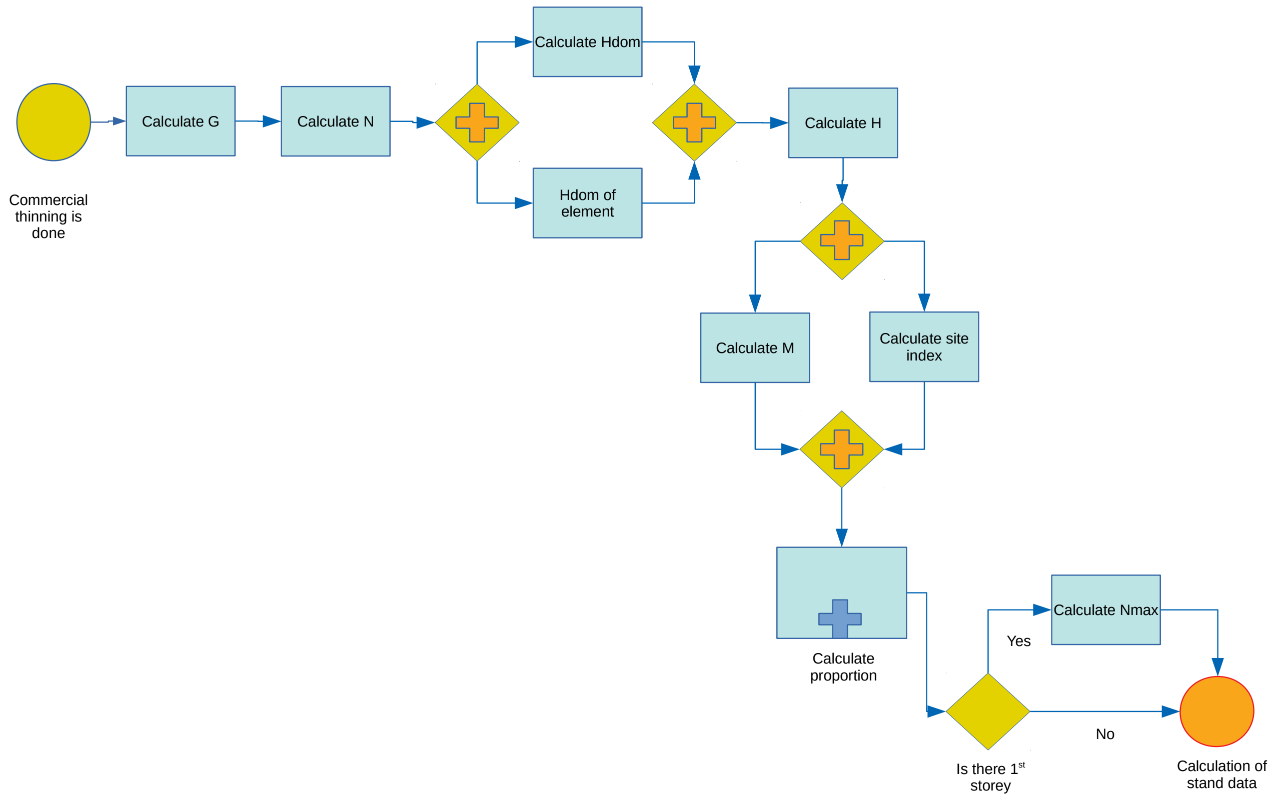

Figure 14 Calculation of taxation data of forest elements after commercial thinning

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:

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

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 (Table 2.3.5).

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 , the calculation of the proportion of the forest element is described in chapter , the calculation of the maximum number of trees is described in chapter .

The calculation of taxation indicators of stand is described in chapter .

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 vai 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	goba	Maple	Aspen
Aegipodiosa	6	Oak	Linden	Ash	goba	Maple	Alder
Callunoso-sphagnosa	7	Pine					
Slapjais Vacciniosa	8	Pine					
Myrtilloso-sphagnosa	9	Pine	Oak	Birch			
Myrtillosoi-polytrichosa	10	Oak	Linden	Ash	goba	Alder	Aspen
Slapjais gārša	11	Oak	Linden	Ash	goba	Alder	Alder
Sphagnosa	12	Pine	Birch				
Caricoso-phragmitosa	14	Pine	Birch				

Forest type	Forest type code	Priority group					
		1	2	3	4	5	6
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:

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

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:

$$G_{krit} = \alpha_1 * H^{\alpha_2}, where \qquad (45)$$

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 5.3.2).

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).

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

Tree species	Tree species code	Decomposition time	Diameter	Height
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
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

Decomposition time, years	Projection period	Deadwood, %			
		new	**medium**	**old**	**decomposed**
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.

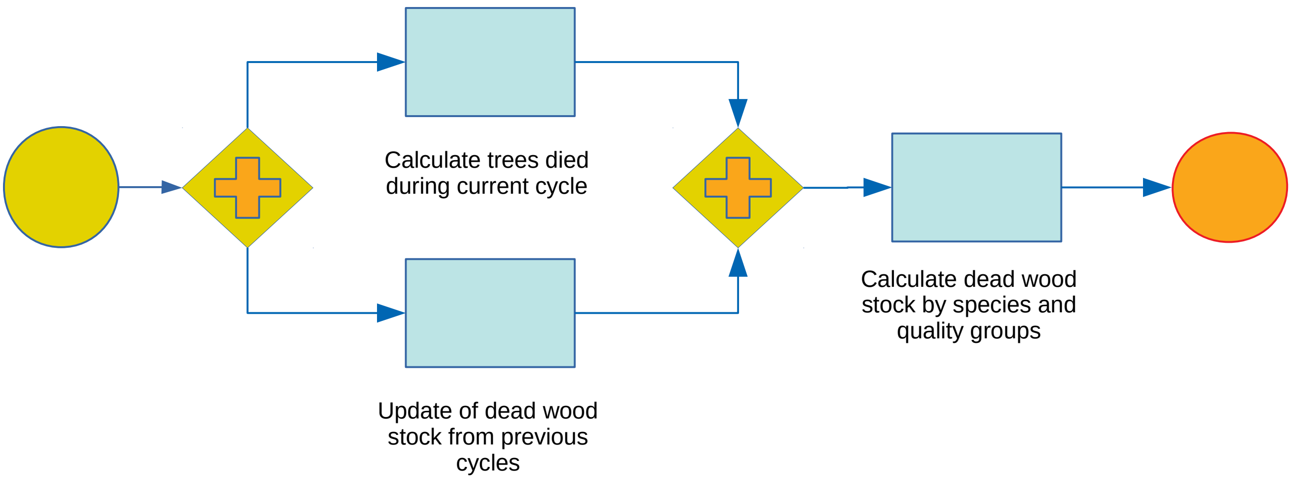

Figure 15 General scheme of deadwood calculations.

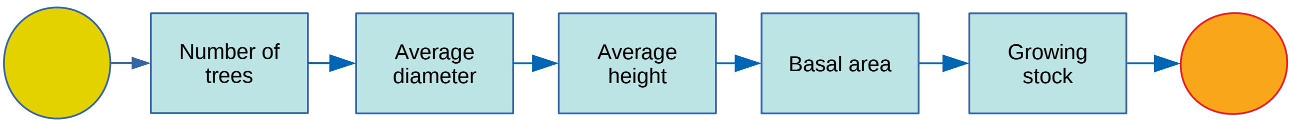

Figure 16 Scheme of deadwood taxation indicator calculation.

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

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

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 (Table 5.2.3).

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 (Table 6.2.1.).

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 6.2.1.).

Table 44 Coefficients for calculation of of average diameter of dead trees in formulas No. 59 and 60

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

Tree species	Species ID	First floor		Second floor	
		α_1	α_2	α_1	α_2
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:

$$d_{atm2} = d_{atm1} * \alpha \text{, where} \tag{49}$$

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:

$$n_{atm} = n_1 - n_{2,} \text{ where} \tag{50}$$

n_{atm} – meža elementa atmirušo koku skaits, ha^{-1};
n_1 – meža elementa koku skaits prognožu perioda sākumā, ha^{-1};
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:

$$P_m = \frac{K_m}{K}, where \tag{51}$$

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:

$$P_{Qm} = \left(\frac{1 - P_m}{(K-1) * Pm} \right)^{0.5} * 100, where \tag{52}$$

P_{Qm} – Standard error of the category, %;
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:

$$\ddot{Y} = \frac{\sum (Y_i * p_i)}{\sum (p_i)}, where \tag{53}$$

$\ddot{Y}$ – Average stand indicator for 1 ha;
Y_i – Stand parameter value for 1 ha in i sampling plot unit (formula 50);
p_i – Share of sampling plot (formula 51);
$\sigma^2_{\ddot{Y}}$ – Dispersion of stand indicator.

$$\sigma^2_{\ddot{Y}} = \frac{\sum ((Y_i - \ddot{Y})^2 * p_i)}{\sum (p_i)}, where \tag{54}$$

$\ddot{Y}$ – Average stand indicator for 1 ha;
Y_i – Stand parameter value for 1 ha in i sampling plot unit (formula 50);
p_i – Share of sampling plot (formula 51);
$\sigma^2_{\ddot{Y}}$ – Dispersion of stand indicator.

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

$$Y_i = \frac{y_i}{x_i}, where \tag{55}$$

Y_i – Stand parameter value for 1 ha in i sampling plot unit;
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:

$$p_i = \frac{x_i}{q}, where \tag{56}$$

p_i – Share of sampling plot;
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:

$$\sigma^2_{\ddot{Y}} = \frac{\sigma^2_{\hat{Y}}}{n}, where \tag{57}$$

$\sigma^2_{\ddot{Y}}$ – Dispersion of stand parameter per 1 ha;
$\sigma^2_{\hat{Y}}$ – 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).

$$\sigma_{\ddot{Y}} = (\sigma^2_{\ddot{Y}})^{0.5}, where \tag{58}$$

$\sigma^2_{\ddot{Y}}$ – Dispersion of stand parameter per 1 ha;
$\sigma^2_{\hat{Y}}$ – 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).

$$P_{\ddot{Y}} = \frac{\sigma_{\ddot{Y}}}{\ddot{Y}} * 100, where \tag{59}$$

$\sigma^2_{\ddot{Y}}$ – Dispersion of stand parameter per 1 ha;
$\sigma^2_{\hat{Y}}$ – 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 (stratas):

$$Y_i = \ddot{Y}_i * Q_i, where \tag{60}$$

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:

$$P_{Ti} = \left(P_{\ddot{Y}i}^2 + P_{Qi}^2\right)^{0.5}, where \quad (61)$$

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	

Table 49 Forest stand area and wood stock by tree stand basal area groups and dominating tree species

AGM cycle	Property type	Species	Parameter	Basal area of the tree stand, m2ha-1										Total
				0<…≤5	5<…≤10	10<…≤15	15<…≤20	20<…≤25	25<…≤30	30<…≤35	35<…≤40	40<…≤45	…>45	

Table 50 Area and wood stock of wood stands by tree stand height and dominating tree species

AGM cycle	Property type	Species	Parameter	Height of tree stand, m								Total
				0<…≤5	5<…≤10	10<…≤15	15<…≤20	20<…≤25	25<…≤30	30<…≤35	35<…≤40	

Table 51 Average height (m) of the 1st storey of wood stand by dominating tree species and age decade groups

AGM cycle	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>	

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Annex 1: Forest stand types in Latvian and Latin

Table 52: 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	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	Drained 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	Drained organic soils	22
Mētru kūdrenis	Vacciniosa turf. mel.	Km		23
Šaurlapju kūdrenis	Myrtillosa turf. mel.	Ks		24
Platlapju kūdrenis	Oxalidosa turf. mel.	Kp		25