EU LIFE Programme project
"Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland"

REPORT

ON IMPLEMENTATION OF THE PROJECT

DEMONSTRATION OF CLIMATE CHANGE MITIGATION MEASURES IN NUTRIENTS RICH DRAINED ORGANIC SOILS IN BALTIC STATES AND FINLAND

WORK PACKAGE
MODELLING OF IMPACT OF CLIMATE CHANGES ON GHG EMISSIONS PROJECTIONS(C.2)
ACTIONS

Deliverable title	**Mathematical equations and tools for elaboration of projections of GHG emissions from organic soils**
Deliverable No	C2/2
Agreement No.	LIFE18 CCM/LV/001158
Report No.	2024_C2/2
Type of report	Final
Elaborated by	LIFE OrgBalt team

2024

Report title	**Mathematical equations and tools for elaboration of projections of GHG emissions from organic soils**
Work package	Modelling of impact of climate changes on GHG emissions projections (C.2)
Authors	A. Lazdiņš, A. Butlers. A. Bārdule, A.Turks, G.Saule
Photos and drawings	A. Butlers. A. Bārdule, A. Lazdiņš
Report No.	2024_C2/2
Type of report	Final
Place	Salaspils
Organization	Latvia State Forest Research Institute "Silava"
Contact information	Riga street 111. Salaspils. LV-2169 Phone: +37129183320 E-mail: ieva.licite@silava.lv Web address: www.silava.lv
Date	2024
Number of pages	35

"LIFE OrgBalt compiled the first regional Baltic/ Finnish GHG emission factors for managed nutrient-rich organic soils (current and former peatlands), which have been made available for the customary scientific review and further verification for national GHG inventories in the hemiboreal region in Finland and the Baltic countries. While the project analysed selected CCM measures for drained organic soils in agriculture and forestry and developed spatial models and tools, it also identified remaining knowledge gaps. To bridge the remaining limitations and fill the gaps, it is essential to continue GHG measurements and model development, as well to broaden and complete the scope of the evaluated CCM measures in the after-LIFE-project period, notably by including rewetting and restoration of peatlands that are currently considered to be among the most recommended CCM measures on drained peatlands in the EU. In addition, the developed Simulation and PPC models still include limited macroeconomic considerations and lack assessment of all environmental impacts. For all these reasons, these models should be used carefully in CCM strategy development for identification of gaps in climate neutrality transition policy and funding frameworks and need further optimization for broader applicability as decision-making tools."

SUMMARY

This document serves as an extensive guide for understanding and applying mathematical concepts in the context of the LIFE OrgBaltic project. It is structured into several chapters, each dedicated to different mathematical tools and equations used in the modelling phases.

Additional information is provided in Libreoffice Calc compatible spreadsheet model for calculation of GHG emissions under different management conditions and comparison of different management scenarios.

The first chapter "Calculation assumptions" provides basic assumptions, which are already summarized in the project report "Tables with default parameters for calculations of efficiency of the climate change mitigation measures". Here the default parameters are provided for Latvia, but in the spreadsheet model it is possible to change the default values and to elaborate calculation scenarios for 5 countries or regions by adaptation of different assumptions to the local conditions.

Chapter "Calculations of GHG emissions in non-forest lands" provides equations and additional assumptions for grasslands, croplands and wetlands. Carbon stock changes in living biomass and soil and GHG emissions from soil can be calculated here. It is also possible to compare 2 non-forest scenarios here, e.g. to estimate the effect of conversion of cropland with organic soil to grassland. It is important to note that the estimates are approximation, since different management practices, e.g., use of crops with large biomass production, can result in significantly different emissions' pattern.

Another chapter "Calculations of GHG emissions in forest lands" provides more detailed calculation for all scenarios considering growing of trees. It includes, in addition to the non-forest land calculations, carbon stock changes in dead wood, litter, harvested wood products (HWP) and substitution effect of energy wood. Economic calculations provides preliminary data on the potential costs and incomes due to implementation of the measure.

The last chapter of the report "Reduction of GHG emissions" describes, how 2 scenarios are compared to calculate GHG mitigation effect, additional cost and income. The model can be adjusted to different management conditions and regions, while the integrity of the references should be retained. Simplified model version, where country specific data can be entered instead of selection is elaborated to ensure even easier adjustment of the model to specific management scenarios.

Calculation assumptions

ABBREVIATIONS

C = carbon

CH_4 = methane

CO_2 = carbon dioxide

GHG = greenhouse gas

IPCC = Intergovernmental Panel on Climate Change

N_2O = nitrous oxide

TABLE OF CONTENTS

Tables

Calculation assumptions

1. CALCULATION ASSUMPTIONS

Calculation assumptions are based on the report “Tables with default parameters for calculations of efficiency of the climate change mitigation measures”.

The assumptions in **Error! Not a valid bookmark self-reference.** are used for the forecast of the yield of wood products, including the yield of lumber [1] and board wood [2] from saw logs, the amount of wood processing residues [3] that are transformed into wood biofuel after processing, as the relative share of round timber produced, as well as by-products of paper production that are transformed into wood of biofuels [5], as the relative proportion of pulpwood produced, and losses in the preparation of logging residues, as the relative proportion of crown biomass left in felling [6]. Preparation of stump biomass for biofuel production is not evaluated in the calculation. The coefficients are specific for the species and type of felling. The values entered in **Error! Not a valid bookmark self-reference.** are expert judgment. The proportion of bark is calculated from the volume of round timber. An expert's assumption is used in the calculation of the proportion of bark [4].

Table 1. Assumptions for characterizing the yield of wood products and logging residues

The dominant species	Type of harvest	Sawn-materials yield from saw logs	Plate-wood yield from saw logs	Output of woodworking residues	The proportion of bark	By-products of paper production	Logging residue losses
ID		[1]	[2]	[3]	[4]	[5]	[6]
Spruce	Thinning	25%	25%	50%	9%	50%	50%
Scots pine		25%	25%	50%	9%	50%	50%
Birch		25%	25%	50%	9%	50%	50%
Hybrid poplar		25%	25%	50%	9%	-	50%
Aspen		25%	25%	50%	9%	50%	50%
Black alder		25%	25%	50%	9%	-	50%
Other species		25%	25%	50%	9%	-	50%
Spruce	Main felling	25%	25%	50%	9%	50%	30%
Scots pine		25%	25%	50%	9%	50%	30%
Birch		25%	25%	50%	9%	50%	30%
Hybrid poplar		25%	25%	50%	9%	-	30%
Aspen		25%	25%	50%	9%	50%	30%
Black alder		25%	25%	50%	9%	-	30%
Other species		25%	25%	50%	9%	-	30%

A timber yield forecast calculation is required if this data is not prepared by the AGM tool. Purpose of timber yield calculations The coefficients for predicting the yield of timber types are prepared according to the equations developed by JSC "Latvijas valsts meži", which take into account the type of felling, the dominant tree species and the average volume of the cut tree trunk without bark (AS 'Latvijas valsts meži'. 2010). Calculation coefficients are given in Table 2.

Table 2. Coefficients for calculating the yield of timber types

Type of felling	Species	Assortment	a	b	c	d
ID			[7]	[8]	[9]	[10]
Main felling	Aspen	12-17.9	0.0339	-0.1105	0.0659	0.0250
		Firewood	-0.2724	1.1721	-1.4547	0.8198
		18-23.9	0.0626	-0.2308	0.2012	0.0076
		24<	0.1093	-0.5102	0.6688	-0.0511
		PM 7-49.9	0.0666	-0.3206	0.5188	0.1986
	Birch	12-17.9	0.0677	-0.2084	0.1458	-0.0080
		Firewood	-0.0477	0.1578	-0.1253	0.0598
		FIA 18<	-0.0496	0.0916	0.0034	-0.0009
		FIB 18<	0.2414	-1.1339	1.3990	-0.1136
		PM 7-49.9	-0.2119	1.0927	-1.4229	1.0627
	Black alder	12-17.9	0.7819	-1.7200	0.9175	-0.0196
		Firewood	-0.9365	2.6240	-2.1950	1.1127
		18-23.9	0.5889	-1.5957	1.1145	-0.0752
		24<	-0.4343	0.6916	0.1630	-0.0179
	Hybrid poplar	12-17.9	0.6569	-1.4486	0.7090	0.0819
		Firewood	-1.2127	3.0268	-1.9295	0.9740
		18-23.9	0.5558	-1.5782	1.2204	-0.0559
	Scots pine	10-13.9	0.0542	-0.1287	0.0462	0.0351
		14-17.9	0.2436	-0.6652	0.4115	0.0605
		Firewood	-0.5307	1.7369	-1.7533	0.5643
		18-27.9	0.6905	-2.3510	2.1808	-0.1459
		28<	-0.2041	0.5633	-0.0721	0.0015
		A 28<	-0.0709	0.1384	0.0043	-0.0022
		Poles 18<	0.0024	-0.0104	0.0113	-0.0022
		Low quality logs 18<	0.0209	-0.0571	0.0919	0.0039
		PM 7-49.9	-0.2060	0.7739	-0.9204	0.4850
	Spruce	10-13.9	0.2120	-0.0472	-0.2098	0.1186
		14-17.9	1.9789	-2.5517	0.7940	0.0626
		6-9.9	0.0627	-0.0360	-0.0214	0.0118
		Firewood	-0.1404	0.1497	-0.0500	0.0702

Calculation assumptions

Type of felling	Species	Assortment	a	b	c	d
		18-27.9	3.2228	-5.0622	2.4443	-0.0550
		28<	-0.2904	0.1783	0.5099	-0.0321
		Low quality logs 18<	-0.0763	-0.0077	0.1452	0.0033
		PM 7-49.9	-4.9692	7.3769	-3.6122	0.8205
Thinning	Aspen	12-17.9	0.5592	-1.1869	0.6358	-0.0191
		Firewood	2.0856	-1.2707	-0.7086	0.7343
		18-23.9	0.5933	-1.1952	0.6079	-0.0311
		24<	-0.3895	0.3742	0.0399	-0.0041
		PM 7-49.9	-2.8485	3.2786	-0.5750	0.3200
	Birch	12-17.9	0.6263	-0.6459	0.1659	-0.0037
		Firewood	3.4293	-1.4652	-0.0487	0.0901
		FIB 18<	-1.9262	1.5544	-0.0727	0.0022
		PM 7-49.9	-2.1299	0.5569	-0.0445	0.9114
	Black alder	12-17.9	3.9099	-6.1471	2.4010	-0.0820
		Firewood	0.4936	2.5091	-2.0793	1.0651
		18-23.9	-3.9167	3.3285	-0.3414	0.0202
		24<	-0.4865	0.3092	0.0198	-0.0033
	Hybrid poplar	12-17.9	5.7592	-7.7544	2.7791	-0.0721
		Firewood	-6.4055	7.7060	-3.1357	1.0853
		18-23.9	0.6465	0.0483	0.3567	-0.0132
	Scots pine	10-13.9	1.1890	-2.3049	0.7424	0.0738
		14-17.9	1.8589	-4.0513	1.9056	-0.0330
		6-9.9	-0.3656	0.8966	-0.5953	0.1250
		Firewood	-1.1057	2.1413	-0.8431	0.1926
		18-27.9	0.3739	-1.6720	1.7189	-0.0841
		28<	-0.3768	0.7335	-0.2015	0.0127
		A 28<	0.0074	-0.0163	0.0082	-0.0003
		Low quality logs 18<	0.5909	-0.6489	0.2101	-0.0085
		PM 7-49.9	-2.1720	4.9220	-2.9452	0.7218
	Spruce	10-13.9	11.6270	-9.5729	1.6378	0.0416
		14-17.9	13.2470	-12.5580	3.0184	-0.0612
		6-9.9	0.7843	0.0041	-0.4134	0.0957
		Firewood	-1.0618	0.3326	0.2256	0.0597
		18-27.9	4.4392	-5.8942	2.4259	-0.0883
		28<	0.7191	0.2455	-0.0370	0.0016

Calculation assumptions

Type of felling	Species	Assortment	a	b	c	d
		Low quality logs 18<	-3.4646	2.8136	-0.3616	0.0181
		PM 7-49.9	-26.2910	24.6300	-6.4957	0.9328

Factors characterizing GHG emissions in forest lands are given in Table 3. The values of coefficients in Table 3 are determined by the dominant species, moisture regime and provision of nutrients. GHG emissions from soil (CH_4 emissions from ditches, proportion of ditch area. CH_4 emissions from the rest of the area. N_2O emissions from soil and CO_2 emissions from soil) are calculated only for organic soils. Only in organic soils, the moisture regime and provision of nutrients are taken into account. Wood density, carbon content in wood, period of decomposition of dead wood, accumulation of carbon in the ground cover when reaching the equilibrium state, and the period of reaching the equilibrium state are species-specific indicators. However, in the GHG forecasting tool, all indicators can be predicted to be linked to moisture regime and nutrient supply, assuming that the empirical data set will improve in the future and the accuracy of forecasts can be improved.

GHG emissions and carbon accumulation circulation coefficients for non-forest lands are given in Table 4. The indicator carbon accumulation in the biomass of ground cover plants in the steady state ([22] and [23]) is used both in mineral soils and in organic soils. The other indicators are used only in organic soils. In the calculation, you can choose two variants of non-forest land - grassland and arable land. An additional parameter is organic soil or mineral soil. The calculation assumes that all organic soils in grasslands and arable lands have been meliorated.

Soil emission factors correspond to the results of LIFE REstore projects (Lazdiņa et al.. 2019; Lupiķis. 2019; Lupiķis & Lazdiņš. 2015).

Calculation assumptions

Table 3. Emission factors and coefficients characterizing carbon circulation in forest lands

The dominant species	Humidity mode	Provision of nutrients	Wood density, tons m^{-3}	Carbon in wood, tons per ton^{-1}	Decomposition period of dead wood, years	CH_4 emission factor for ditches, kg CH_4 ha^{-1} per year	Proportion of ditch area	CH_4 emission factor, kg CH_4 ha^{-1} per year	N_2O emission factors, kg N_2O ha^{-1} per year	CO_2 emission factor, tons of CO_2 ha^{-1} per year	Carbon accumulation in the ground cover, tons C ha^{-1}	Period of reaching the steady state, years
ID			[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
Spruce	Drained	Good	0.4	0.5	40	217.0000	3%	-6.8992	1.7417	13.3409	12.1	150
Spruce	Drained	Poor	0.4	0.5	40	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Spruce	Wet	Good	0.4	0.5	40			1.3467	0.5971	13.8380	12.1	150
Spruce	Wet	Poor	0.4	0.5	40			32.4505	0.0680	6.7820	12.1	150
Spruce	Dry	-	0.4	0.5	40						12.1	150
Scots pine	Drained	Good	0.4	0.5	40	217.0000	3%	-6.8992	1.7417	13.3409	12.1	150
Scots pine	Drained	Poor	0.4	0.5	40.0	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Scots pine	Wet	Good	0.4	0.5	40.0			1.3467	0.5971	13.8380	12.1	150
Scots pine	Wet	Poor	0.4	0.5	40.0			32.4505	0.0680	6.7820	12.1	150
Scots pine	Dry	-	0.4	0.5	40.0						12.1	150
Birch	Drained	Good	0.5	0.5	20	217.0000	3%	-2.9200	1.5871	15.9170	12.1	150
Birch	Drained	Poor	0.5	0.5	20.0	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Birch	Wet	Good	0.5	0.5	20.0			-1.1644	3.1114	13.2244	12.1	150
Birch	Wet	Poor	0.5	0.5	20.0			32.4505	0.0680	6.7820	12.1	150
Birch	Dry	-	0.5	0.5	20.0						12.1	150
Aspen	Drained	Good	0.5	0.5	20	217.0000	3%	-2.9200	1.5871	15.9170	12.1	150
Aspen	Drained	Poor	0.5	0.5	20.0	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Aspen	Wet	Good	0.5	0.5	20.0			-1.1644	3.1114	13.2244	12.1	150

Calculation assumptions

The dominant species	Humidity mode	Provision of nutrients	Wood density, tons m^{-3}	Carbon in wood, tons per ton^{-1}	Decomposition period of dead wood, years	CH_4 emission factor for ditches, kg CH_4 ha^{-1} per year	Proportion of ditch area	CH_4 emission factor, kg CH_4 ha^{-1} per year	N_2O emission factors, kg N_2O ha^{-1} per year	CO_2 emission factor, tons of CO_2 ha^{-1} per year	Carbon accumulation in the ground cover, tons C ha^{-1}	Period of reaching the steady state, years
Aspen	Wet	Poor	0.5	0.5	20.0			32.4505	0.0680	6.7820	12.1	150
Aspen	Dry	-	0.5	0.5	20.0						12.1	150
Hybrid poplar	Drained	Good	0.5	0.5	20	217.0000	3%	-2.9200	1.5871	15.9170	12.1	150
Hybrid poplar	Drained	Poor	0.5	0.5	20.0	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Hybrid poplar	Dry	-	0.5	0.5	20.0						12.1	150
Black alder	Drained	Good	0.5	0.5	20	217.0000	3%	7.7714	0.9429	10.1017	12.1	150
Black alder	Drained	Poor	0.5	0.5	20.0	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Black alder	Wet	Good	0.5	0.5	20.0			228.3429	3.9286	13.4200	12.1	150
Black alder	Wet	Poor	0.5	0.5	20.0			32.4505	0.0680	6.7820	12.1	150
Black alder	Dry	-	0.5	0.5	20.0						12.1	150
Other species	Drained	Good	0.5	0.5	20	217.0000	3%	-2.9200	1.5871	15.9170	12.1	150
Other species	Drained	Poor	0.5	0.5	20.0	217.0000	3%	25.5898	-0.0751	4.2120	12.1	150
Other species	Wet	Good	0.5	0.5	20.0			-1.1644	3.1114	13.2244	12.1	150
Other species	Wet	Poor	0.5	0.5	20.0			32.4505	0.0680	6.7820	12.1	150
Other species	Dry	-	0.5	0.5	20.0						12.1	150

Calculation assumptions

Table 4. Emission factors and coefficients characterizing carbon circulation for organic soils in non-forest lands

Land use	Steady-state carbon stock, tons C ha^{-1}		Carbon contribution to the soil, tons C ha^{-1} per year				Proportion of ditch area	CH_4 emission factor for ditches, kg CH_4 ha^{-1} per year	CH_4 emission factor, kg CH_4 ha^{-1} per year	N_2O emission factors, kg N_2O ha^{-1} per year	CO_2 emission factor, tons of CO_2 ha^{-1} per year
	surface	under-ground	surface	under-ground	small roots	other in-come					
ID	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]
Arable land	4.4	0.9	2.7	0.6	0.3		5%	1165.0	2.0852	9.6643	15.9465
Lawn	3.2	1.2	0.9	0.5	0.7		5%	1165.0	26.5641	0.5029	11.7282

N_2O and CH_4 emissions are converted to CO_2 equivalents using the so-called IPCC Assessment report 5 (Table 5).

Table 5. CO_2 equivalents

SAY	ID	CO_2 equivalent
CH_4	[32]	28
N_2O	[33]	265

The AGM tool can give calculation results in terms of stock, biomass or carbon stock or all of these indicators, but if the results are not available, the calculations are performed using Table 6 coefficients that calculate the trunk, above-ground, branch and underground biomass in the cross section of species. These coefficients were developed for the calculation of individual trees, and in this simplified calculation they are applied to the whole stand, so it is better to use the calculations of the AGM model, where the biomass can be calculated in the section of forest elements.

Table 6. Biomass conversion factors1

The dominant species	Biomass	a	b	c	d	e	m	k
ID		[34]	[35]	[36]	[37]	[38]	[39]	[40]
Spruce	AGB	-0.5244	8.8563	0.0000	0.3879	0.0000	19.0000	1.0127
	SB	-2.5842	7.0769	0.0232	0.9631	0.0000	15.0000	1.0022
	BGB	-2.4967	10.8184	0.0000	0.0000	0.0000	14.0000	1.0388
Scots pine	AGB	-1.4480	8.7399	0.0000	0.5624	0.0000	16.0000	1.0086
	SB	-2.8125	7.1368	0.0118	1.1270	0.0000	15.0000	1.0053
	BGB	-3.2937	9.0334	0.0000	0.5353	0.0000	14.0000	1.0350
Birch	AGB	-2.1284	9.3375	0.0221	0.2838	0.0000	11.0000	1.0041
	SB	-2.9281	8.2943	0.0184	0.7374	0.0000	11.0000	1.0020
	BGB	-3.6432	0.0000	0.0000	0.0000	2.5127	0.0000	1.0060
Hybrid poplar	AGB	-1.9434	9.7506	0.0337	0.0000	0.0000	11.0000	0.9900
	SB	-2.8955	8.3896	0.0226	0.6148	0.0000	11.0000	1.0058
	BGB	-2.3114	10.3644	0.0000	0.0000	0.0000	15.0000	0.9917
Aspen	AGB	-1.9434	9.7506	0.0337	0.0000	0.0000	11.0000	0.9900
	SB	-2.8955	8.3896	0.0226	0.6148	0.0000	11.0000	1.0058
	BGB	-2.3114	10.3644	0.0000	0.0000	0.0000	15.0000	0.9917
Black alder	AGB	-1.6846	9.3412	0.0221	0.2489	0.0000	14.0000	0.9962
	SB	-2.4428	8.4713	0.0295	0.5315	0.0000	13.0000	1.0069
	BGB	-2.6672	0.0000	0.0000	0.0000	2.1004	0.0000	1.0145
Other species	AGB	-2.1284	9.3375	0.0221	0.2838	0.0000	11.0000	1.0041
	SB	-2.9281	8.2943	0.0184	0.7374	0.0000	11.0000	1.0020

Calculation assumptions

The dominant species	Biomass	a	b	c	d	e	m	k
	BGB	-3.6432	0.0000	0.0000	0.0000	2.5127	0.0000	1.0060

The carbon input with tree litter residues in forest lands in organic soils is calculated using Table 7 given coefficients. Carbon input with ground cover plant residues in forest lands with organic soils is calculated using Table 8 given coefficients. These indicators are not calculated in mineral soils, where it is assumed that the soil carbon accumulation is in a state of equilibrium. Table 7. 8 and 9 include maximum cross-sectional area values ([46]. [52] and [58]). If the actual cross-sectional area exceeds the maximum value, the maximum values from the relevant tables are used in the calculation.

Table 7. Coefficients for carbon input calculations with tree litter and small roots

The dominant species	a	b	c	d	e	Max. G, m2 ha^{-1}
ID	[41]	[42]	[43]	[44]	[45]	[46]
Spruce	-0.000008	0.000542	-0.011340	0.190236	0.000000	30.0
Scots pine	-0.000014	0.000969	-0.021880	0.245253	0.000000	30.0
Birch	0.000003	-0.000309	0.011431	-0.042937	0.000000	26.0
Aspen	0.000003	-0.000309	0.011431	-0.042937	0.000000	26.0
Hybrid poplar	0.000003	-0.000309	0.011431	-0.042937	0.000000	26.0
Black alder	0.000003	-0.000309	0.011431	-0.042937	0.000000	26.0
Other species	0.000003	-0.000309	0.011431	-0.042937	0.000000	26.0

Table 8. Coefficients for carbon input calculations with ground cover plant residues, litter and roots

The dominant species	a	b	c	d	yes	Max. G, m2 ha^{-1}
ID	[47]	[48]	[49]	[50]	[51]	[52]
Spruce	-0.000003	0.000199	-0.003232	0.024756	1.465097	30.0
Scots pine	-0.000014	0.000776	-0.014467	0.104824	2.540835	30.0
Birch	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Aspen	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Hybrid poplar	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Black alder	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Other species	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0

Carbon storage in forest land in ground cover plant biomass is calculated for all forest land to assess changes in carbon storage in case of land use change, for example afforestation of arable land or grassland. The coefficients of the equations for calculating the carbon accumulation are given in Table 9.

Calculation assumptions

Table 9. Coefficients for calculations of carbon accumulation in ground cover plant biomass

The dominant species	a	b	c	d	e	Max. G, m2 ha^{-1}
ID	[53]	[54]	[55]	[56]	[57]	[58]
Spruce	-0.000003	0.000199	-0.003232	0.024756	1.465097	30.0
Scots pine	-0.000014	0.000776	-0.014467	0.104824	2.540835	30.0
Birch	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Aspen	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Hybrid poplar	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Black alder	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0
Other species	0.000009	-0.000494	0.008583	-0.083487	1.263489	26.0

Table 10 given coefficients for carbon accumulation calculations in forest lands, depending on the cross-sectional area of the stand. This indicator is not used for areas that are arable land or grassland before the implementation of the measure.

Table 10. Coefficients for calculation of carbon accumulation in dead wood in forest lands

The dominant species	a	b	c	d	e
ID	[59]	[60]	[61]	[62]	[63]
Spruce	0.000424	-0.030501	0.710823	-7.083432	93.865713
Scots pine	0.000037	-0.006855	0.270987	-3.903290	61.217237
Birch	0.000178	-0.013469	0.312192	-2.664939	18.727676
Aspen	0.000178	-0.013469	0.312192	-2.664939	18.727676
Hybrid poplar	0.000178	-0.013469	0.312192	-2.664939	18.727676
Black alder	0.000178	-0.013469	0.312192	-2.664939	18.727676
Other species	0.000178	-0.013469	0.312192	-2.664939	18.727676

In forest lands, the carbon accumulation in the wood products prepared from the trees cut in the previous cycle is also calculated. Carbon stock is calculated using cross-sectional area as a variable indicator. Calculation coefficients for calculations of carbon stored in lumber are given in Table 11, in slab wood - Table 12 and in paper and cardboard products - Table 13.

Table 11. Coefficients for calculating carbon accumulation in lumber (5.C & 5.NC) in forest lands

The dominant species	a	b
ID	[64]	[65]
Spruce	-0.437336	20.840077
Scots pine	-0.476845	22.100373
Birch	-0.304579	12.090044
Aspen	-0.096996	4.826518
Hybrid poplar	-0.145217	29.000000
Black alder	-0.304579	12.090044

The dominant species	a	b
Other species	-0.304579	12.090044

Table 12. Coefficients for calculating carbon accumulation in slab wood (6 1. 6 2. 6 3. 6.4.1. 6.4.2. 6.4.x. 6.4.3) in forest lands

The dominant species	a	b
ID	[66]	[67]
Spruce	-0.420516	20.038535
Scots pine	-0.458505	21.250359
Birch	-0.292864	11.625042
Aspen	-0.093266	4.640883
Hybrid poplar	-0.139632	28.011337
Black alder	-0.292864	11.625042
Other species	-0.292864	11.625042

Table 13. Coefficients for carbon accumulation calculations in paper and cardboard products (10) in forest lands

The dominant species	a	b
ID	[68]	[69]
Spruce	-0.008311	0.403860
Scots pine	-0.344292	1.253129
Birch	-1.495479	4.966780
Aspen	-0.805852	2.326979
Hybrid poplar	0.000000	0.000000
Black alder	0.000000	0.000000
Other species	0.000000	0.000000

Input data per year in Table 14 is generated by the AGM tool, using in calculations a set of data corresponding to the calculation structure of the State Forest Register and assumptions for everyday forestry, preparing a scenario that characterizes the continuation of everyday forestry (alternative scenario according to

2. CALCULATION ASSUMPTIONS

Calculation assumptions are based on the report "Tables with default parameters for calculations of efficiency of the climate change mitigation measures".

The assumptions in **Error! Not a valid bookmark self-reference.** are used for the forecast of the yield of wood products, including the yield of lumber [1] and board wood [2] from saw logs, the amount of wood processing residues [3] that are transformed into wood biofuel after processing, as the relative share of round timber produced, as well as by-products of paper production that are transformed into wood of biofuels [5], as the relative proportion of pulpwood produced, and losses in the preparation of logging residues, as the relative proportion of crown biomass left in felling [6]. Preparation of stump biomass for biofuel production is not evaluated in the calculation. The coefficients are specific for the species and type of felling. The values entered in **Error! Not a valid bookmark self-reference.** are expert judgment. The proportion of bark is calculated from the volume of round timber. An expert's assumption is used in the calculation of the proportion of bark [4].

Table 1. In the scenario of the implementation of measures (according to

3. CALCULATION ASSUMPTIONS

Calculation assumptions are based on the report "Tables with default parameters for calculations of efficiency of the climate change mitigation measures".

The assumptions in **Error! Not a valid bookmark self-reference.** are used for the forecast of the yield of wood products, including the yield of lumber [1] and board wood [2] from saw logs, the amount of wood processing residues [3] that are transformed into wood biofuel after processing, as the relative share of round timber produced, as well as by-products of paper production that are transformed into wood of biofuels [5], as the relative proportion of pulpwood produced, and losses in the preparation of logging residues, as the relative proportion of crown biomass left in felling [6]. Preparation of stump biomass for biofuel production is not evaluated in the calculation. The coefficients are specific for the species and type of felling. The values entered in **Error! Not a valid bookmark self-reference.** are expert judgment. The proportion of bark is calculated from the volume of round timber. An expert's assumption is used in the calculation of the proportion of bark [4].

Table 1), assumptions are used that characterize the growth course by implementing climate change mitigation measures in the maximum or user-defined volume, in the scenario of the implementation of the measures it can be indicated whether additional measures are being implemented (forest melioration, use of fertilizers and wood ash), assuming the implementation of these actions in the calculation of the growth course.

Table 14. Calculated parameters of the growth model for characterizing growth

Nr.	Parameter	Unit of measure	ID	Transcript
1.	Bon	-	[70]	Site index
2.	A	Gadi	[71]	Plant age
3.	H	m	[72]	Average tree height
4.	D	cm	[73]	Average tree diameter
5.	G	m^2 ha^{-1}	[74]	Total cross-sectional area of the stand
6.	N	trees ha^{-1}	[75]	The number of trees in the kingdom
7.	M	m^3 ha^{-1}	[76]	The total stock of the stand
8.	Incr.	m^3 ha^{-1} per year	[77]	Actual (stand) current potential average periodic growth
9.	Night	m	[78]	The average height of the felled tree
10.	Dnoc	cm	[79]	The diameter of the average sawn tree
11.	Gnoc	m^2 ha^{-1}	[80]	Total cross-sectional area of felled trees
12.	Nnoc	trees ha^{-1}	[81]	The total number of trees cut down
13.	Mnoc	m^3 ha^{-1}	[82]	Total stock of felled trees
14.	Mvid.	m^3	[83]	Average stock of sawn wood
15.	Hatm	m	[84]	Average dead tree height
16.	Datm	cm	[85]	Diameter of average dead wood
17.	Gatm	m^2 ha^{-1} per year	[86]	Total cross-sectional area of dead trees

Calculation assumptions

Nr.	Parameter	Unit of measure	ID	Transcript
18.	Natm	trees ha^{-1} per year	[87]	The total number of dead trees in the canopy
19.	Matm	m^3 ha^{-1} per year	[88]	Total stock of dead trees

Parameter values Table 15 is taken from Table 4, based on the user's choice in parameter [89] (Table 15). The parameter [89] in the user menu is used to determine whether the data on carbon input to the soil with plant residues and GHG emissions from the soil are used in the carbon cycle calculation (parameter [107]. Table 16). This parameter is not used in mineral soils.

Table 15. Input data for characterization of GHG emissions in non-forest lands

Parameter		Unit of measure	ID	Value
Land use		-	[89]	Grassland or arable land
Soil type		-	[90]	Organic or mineral soil
Steady-state carbon accu-mulation	surface	tons of C ha^{-1}	[91]	-
	underground	tons of C ha^{-1}	[92]	-
Carbon input to the soil	surface	tons C ha^{-1} per year	[93]	Use only on organic soils
	underground	tons C ha^{-1} per year	[94]	Use only on organic soils
	small roots	tons C ha^{-1} per year	[95]	Use only on organic soils
	other income	tons C ha^{-1} per year	[96]	Use only on organic soils
Proportion of ditch area		%	[97]	Use only on organic soils
CH_4 emission factor for ditches		kg CH_4 ha^{-1} per year	[98]	Use only on organic soils
CH_4 emission factor for the rest of the area		kg CH_4 ha^{-1} per year	[99]	Use only on organic soils
N_2O emission factor		kg N_2O ha^{-1} per year	[100]	Use only on organic soils
CO_2 emission factor		tons CO_2 ha^{-1} per year	[101]	Use only on organic soils

4. CALCULATIONS OF GHG EMISSIONS IN NON-FOREST LANDS

In non-forest lands (arable lands and grasslands), the calculation of GHG emissions consists of GHG emissions from soil in organic soils (Table 16).

Table 16. Calculations of GHG emissions in non-forest lands in organic soils

GHG	Units of measurement	ID
CO_2 emissions from living biomass (carbon input to the soil)	tons CO_2 ha^{-1} per year	[102]=[93]+[94]+[95]+[96]
CH_4 emissions from ditches	tons of CO_2 eq. ha^{-1} per year	[103]=([98]*[97])/1000*[32]
CH_4 emissions from soil	tons of CO_2 eq. ha^{-1} per year	[104]=([99]*(100%-[97]))/1000*[32]
N_2O emissions from soil	tons of CO_2 eq. ha^{-1} per year	[105]=[100]/1000
CO_2 emissions from soil (hetero-trophic respiration)	tons CO_2 ha^{-1} per year	[106]=[101]
Total GHG emissions	tons of CO_2 eq. ha^{-1} per year	[107]=[102]+[103]+[104]+[105]+[106]

In mineral soils, only the index of carbon accumulation in understory plants ([21]+[22]) from Table 4, which is compared to carbon storage in ground cover plants through climate change mitigation measures.

5. CALCULATIONS OF GHG EMISSIONS IN FOREST LANDS

The user menus required for GHG emissions are listed in Table 17. The dominant tree species are spruce, pine, birch, aspen, poplar hybrid, black alder and other species. The soil type in this case is mineral soil or organic soil (poor or rich). The moisture regime affects the calculations of GHG emissions in organic soils - in peatlands the soil is drained, in bogs - rewetted. The supply of nutrients also applies only to organic soils – in broad-leaved forests the supply of nutrients is good, in the other types of bogs and peat forests – satisfactory. The afforestation or forest management menu belongs to the description of the climate change mitigation measure - in all scenarios related to the change of land use to forest land. "afforestation" should be selected in this parameter, and "forest management" in scenarios not related to the change of land use. The use of logging residues means that all logging residues, including those from stock maintenance fellings, are used for the preparation of wood biofuel, if [6] coefficient

6. CALCULATION ASSUMPTIONS

Calculation assumptions are based on the report "Tables with default parameters for calculations of efficiency of the climate change mitigation measures".

The assumptions in **Error! Not a valid bookmark self-reference.** are used for the forecast of the yield of wood products, including the yield of lumber [1] and board wood [2] from saw logs, the amount of wood processing residues [3] that are transformed into wood biofuel after processing, as the relative share of round timber produced, as well as by-products of paper production that are transformed into wood of biofuels [5], as the relative proportion of pulpwood produced, and losses in the preparation of logging residues, as the relative proportion of crown biomass left in felling [6]. Preparation of stump biomass for biofuel production is not evaluated in the calculation. The coefficients are specific for the species and type of felling. The values entered in **Error! Not a valid bookmark self-reference.** are expert judgment. The proportion of bark is calculated from the volume of round timber. An expert's assumption is used in the calculation of the proportion of bark [4].

Table 1, which characterizes the loss of logging residues, is not 100%.

Table 17. User menus in forest lands

Pointer	ID	Notes
The dominant tree species	[108]	The dominant tree species grows
Soil type	[109]	Mineral soil or organic soil, in afforestation scenario cannot differ between scenarios ([110]=[90])
Humidity mode	[111]	Drained or rewetted (according to the planned condition)
Provision of nutrients	[112]	Good or satisfactory, a parameter used in organic soils.
Afforestation or forest management	[113]	Carbon storage characterization menu, applicable only in scenarios not related to planting trees on cropland or grassland
Use of logging residues	[114]	Mark ("yes" or "no") for the use of logging residues (left behind or used to make biofuel)

After calculating the equations in Table 18, with the exception of carbon accumulation in ground cover plants ([117]), is used only in organic soils ([109]="organic soil". Table 17). Values of coefficients [41], [42], [43], [44], [45] and [46] Table 18 choose Table 7, depending on the value of the dominant species Table 17 ([108]). Values of coefficients [47], [48], [49], [50], [51] and [51] Table 18 choose Table 8, depending on the value of the dominant species Table 17 ([108]). Values of coefficients [53], [54], [55], [56], [57] and [58] Table 18 choose Table 9, depending on the value of the dominant species Table 17 ([108]).

Table 18. Calculation of carbon uptake by forest litter and ground cover plants

Pointer	Parameter	Calculation
Carbon uptake by tree residues and litter	tons C ha^{-1} per year	[115]=[41]*(IF([74]>[46];[46];[74]))^4+[42]*(IF([74]>[46];[46];[74]))^3+[43]*(IF([74]>[46];[46];[74]))^2+[44]*IF([74]>[46];[46];[74])+[45]
Carbon uptake by ground cover crop residues	tons C ha^{-1} per year	[116]=[47]*(IF([74]>[52];[52];[74]))^4+[48]*(IF([74]>[52];[52];[74]))^3+[49]*(IF([74]>[52];[52];[74]))^2+[50]*IF([74]>[52];[52];[74])+[51]

Calculation assumptions

Pointer	Parameter	Calculation
Carbon storage in ground cover plants	tons of C ha^{-1}	[117]=[53]*(IF([74]>[58];[58];[74]))^4+[54]*(IF([74]>[58];[58];[74]))^3+[55]*(IF([74]>[58];[58];[74]))^2+[56]*IF([74]>[58];[58];[74])+[57]
Total carbon input by plant residues	tons C ha^{-1} per year	[118]=[115]+[116]

The calculation of GHG emissions in forest lands consists of changes in carbon accumulation in living and dead biomass of woody plants, wood products, ground cover (in case of afforestation) and the substitution effect of wood biofuel. In organic soils. GHG emissions caused by the carbon cycle in the soil, as well as CH_4 and N_2O emissions from the soil are additionally calculated. The parameters of carbon cycle and GHG emission calculations are summarized in Table 19. These parameters are selected from

7. CALCULATION ASSUMPTIONS

Calculation assumptions are based on the report "Tables with default parameters for calculations of efficiency of the climate change mitigation measures".

The assumptions in **Error! Not a valid bookmark self-reference.** are used for the forecast of the yield of wood products, including the yield of lumber [1] and board wood [2] from saw logs, the amount of wood processing residues [3] that are transformed into wood biofuel after processing, as the relative share of round timber produced, as well as by-products of paper production that are transformed into wood of biofuels [5], as the relative proportion of pulp-wood produced, and losses in the preparation of logging residues, as the relative proportion of crown biomass left in felling [6]. Preparation of stump biomass for biofuel production is not evaluated in the calculation. The coefficients are specific for the species and type of felling. The values entered in **Error! Not a valid bookmark self-reference.** are expert judgment. The proportion of bark is calculated from the volume of round timber. An expert's assumption is used in the calculation of the proportion of bark [4].

Table 1 and 3, based on the menus Table 17.

Table 19. Parameters of GHG emission calculations in forest lands

Parameter	Unit of measure	Calculation
Wood density	tons m⁻□	[119]=[11]
Logging residue losses in maintenance felling	-	[120]=[6]
Logging residue losses in the main felling	-	[121]=[6]
Carbon content of biomass	tons C in ton^{-1}	[122]=[12]
CH_4 emission factor for ditches	kg CH_4 ha^{-1} per year	[123]=[14]
Proportion of ditch area	%	[124]=[15]
CH_4 emission factor	kg CH_4 ha^{-1} per year	[125]=[16]
N_2O emission factor	kg N_2O ha^{-1} per year	[126]=[17]
CO_2 emission factor	tons CO_2 ha^{-1} per year	[127]=[18]
Carbon accumulation in ground cover at steady state	tons of C ha^{-1}	[128]=[19]
The period of carbon accumulation in the ground cover	gadi	[129]=[20]
Decay period of dead wood	gadi	[130]=[13]
Lumber yield from round timber (5.C & 5.NC)	%	[131]=[1]
Board wood yield from round timber (6.1. 6.2. 6.3. 6.4.1. 6.4.2. 6.4.x. 6.4.3)	%	[132]=[2]
Output of paper and cardboard products from pulp-wood (10)	%	[133]=100%-[5]
Proportion of bark from round timber	%	[134]=[4]

Tree biomass calculation (Table 20) is performed if such information is not available from the AGM tool. The equations use specific coefficients of the dominant species and biomass category ([34], [35], [36], [37], [38], [39] and [40]), given in Table 6. Biomass can be calculated according to biomass categories Table 6 – SB (trunk biomass). AGB (above ground biomass). BB (branch biomass). BGB (underground biomass).

Calculation assumptions

Table 20. Calculation of tree biomass

Parameter	Unit of measure	Calculation
Growing trees, stem biomass (SB)	tons ha^{-1} per year	[135]=([40]*EXP([34]+[35]*([73]/([73]+[39]))+[36]*[72]+[37]*LN([72])+[38]*LN([73])))*[75]/1000
Growing trees, above ground biomass (AGB)	tons ha^{-1} per year	[136]=([40]*EXP([34]+[35]*([73]/([73]+[39]))+[36]*[72]+[37]*LN([72])+[38]*LN([73])))*[75]/1000
Growing trees, branch biomass (BB)	tons ha^{-1} per year	[137]=[136]-[135]
Growing trees, below ground biomass (BGB)	tons ha^{-1} per year	[138]=([40]*EXP([34]+[35]*([73]/([73]+[39]))+[36]*[72]+[37]*LN([72])+[38]*LN([73])))*[75]/1000
Stock growth, stem biomass (SB)	tons ha^{-1} per year	[139]=[135]/[76]*[77]
Stock growth, aboveground biomass (AGB)	tons ha^{-1} per year	[140]=[136]/[76]*[77]
Stock growth, branch biomass (BB)	tons ha^{-1} per year	[141]=[137]/[76]*[77]
Stock growth, belowground biomass (BGB)	tons ha^{-1} per year	[142]=[138]/[76]*[77]
Fell trees, trunk biomass (SB)	tons ha^{-1} per year	[143]=([40]*EXP([34]+[35]*([79]/([79]+[39]))+[36]*[78]+[37]*LN([78])+[38]*LN([79])))*[81]/1000
Fell trees, above ground biomass (AGB)	tons ha^{-1} per year	[144]=([40]*EXP([34]+[35]*([79]/([79]+[39]))+[36]*[78]+[37]*LN([78])+[38]*LN([79])))*[81]/1000
Fell trees, branch biomass (BB)	tons ha^{-1} per year	[145]=[144]-[143]
Fell trees, belowground biomass (BGB)	tons ha^{-1} per year	[146]=([40]*EXP([34]+[35]*([79]/([79]+[39]))+[36]*[78]+[37]*LN([78])+[38]*LN([79])))*[81]/1000
Dead wood, stem biomass (SB)	tons ha^{-1} per year	[147]=([40]*EXP([34]+[35]*([85]/([85]+[39]))+[36]*[84]+[37]*LN([84])+[38]*LN([85])))*[87]/1000
Dead wood, above ground biomass (AGB)	tons ha^{-1} per year	[148]=([40]*EXP([34]+[35]*([85]/([85]+[39]))+[36]*[84]+[37]*LN([84])+[38]*LN([85])))*[87]/1000
Dead wood, branch biomass (BB)	tons ha^{-1} per year	[149]=[147]-[146]
Dead wood, belowground biomass (BGB)	tons ha^{-1} per year	[150]=([40]*EXP([34]+[35]*([85]/([85]+[39]))+[36]*[84]+[37]*LN([84])+[38]*LN([85])))*[87]/1000

Table 21 calculates carbon accumulation in biomass, if it has not already been calculated in the AGM model. Carbon content in biomass is the coefficient [12] from Table 3. The value of the coefficient is determined depending on the selection of the dominant species [108], moisture regime [111] and supply with nutrients [112] according to Table 17.

Table 21. Calculation of carbon accumulation in tree biomass

Parameter	Unit of measure	Calculation
Growing trees, trunk biomass	tons of C ha^{-1}	[151]=[135]*[12]
Growing trees, above ground biomass	tons of C ha^{-1}	[152]=[136]*[12]
Growing trees, branch biomass	tons of C ha^{-1}	[153]=[137]*[12]

Calculation assumptions

Parameter	Unit of measure	Calculation
Growing trees, underground biomass	tons of C ha^{-1}	[154]=[138]*[12]
Stock growth, stem biomass	tons of C ha^{-1}	[155]=[139]*[12]
Stock growth, above ground biomass	tons of C ha^{-1}	[156]=[140]*[12]
Stock growth, branch biomass	tons of C ha^{-1}	[157]=[141]*[12]
Stock growth, underground biomass	tons of C ha^{-1}	[158]=[142]*[12]
Cut down trees, trunk biomass	tons of C ha^{-1}	[159]=[143]*[12]
Cut down trees, above ground biomass	tons of C ha^{-1}	[160]=[144]*[12]
Cut down trees, branch biomass	tons of C ha^{-1}	[161]=[145]*[12]
Cut down trees, underground biomass	tons of C ha^{-1}	[162]=[146]*[12]
Dead wood, stem biomass	tons of C ha^{-1}	[163]=[147]*[12]
Dead wood, aboveground biomass	tons of C ha^{-1}	[164]=[148]*[12]
Dead wood, branch biomass	tons of C ha^{-1}	[165]=[149]*[12]
Dead wood, underground biomass	tons of C ha^{-1}	[166]=[150]*[12]

Changes in carbon accumulation, as well as the total carbon accumulation in the living biomass of woody plants, are calculated in Table 22.

Table 22. Changes in carbon accumulation in the biomass of living trees

Parameter	Unit of measure	Calculation
Changes in carbon accumulation in living biomass are reviewed per year	tons C ha^{-1} per year	[167]=([156]+[158])-([160]+[162]+[164]+[166])
Carbon accumulation in living biomass is reviewed per year	tons of C ha^{-1}	$[168]=[167]_1+...[167]_n$, where $[167]_1$ – changes in carbon accumulation in living biomass 1, per year; $[167]_n$ – changes in carbon accumulation in living biomass are reported per year.

In afforested areas and non-forested lands, the carbon accumulation in dead wood before the implementation of the measure $[169]_o$ is equal to zero, so the initial carbon accumulation in this carbon storage ($[169]_o$) should be calculated only in the areas where the forest grew before the implementation of the measure. Calculation of carbon accumulation in dead wood can be done according to Table 23 for the given equations. The carbon accumulation in dead wood, which was formed as a result of logging, is already included in the calculation of $[169]_o$ in zero per year.

Calculation assumptions

Table 23. Changes in carbon accumulation in dead wood

Parameter	Unit of measure	Calculation at zero per year (if different from the others)	Calculation in the first per year (if different from the others)	Calculation in future years
Carbon uptake by dead wood	tons C ha^{-1} per year	$[169]_o$=[59]*[74]^4+[60]*[74]^3+[61]*[74]^2+[62]*[74]+[63]	[169]=[164]+[166]	
Carbon uptake by logging residues	tons C ha^{-1} per year	-	[170]=[161]+[162]	
Carbon loss in dead wood	tons C ha^{-1} per year	-	$[171]_1$=-($[169]_o$+[169]+[170])/[130]), where $[169]_o$ – carbon accumulation in dead wood at zero per year.	[171]x=-(($[169]_o$+$[169]_1$...$[169]_n$)+($[170]_1$+$[170]_n$)+($[171]_1$+$[171]_{n-1}$))/[130], where $[169]_o$ – carbon accumulation in dead wood at zero per year; $[169]_1$ – carbon intake in dead wood with dead wood in the first per year; $[169]_n$ – carbon intake in dead wood with dead wood reviewed per year; $[170]_1$ – carbon input with logging residues in the first per year; $[170]_n$ – carbon yield with logging residues per year; $[171]_1$ – carbon loss from dead wood in the first per year; $[171]_{n-1}$ – carbon loss from dead wood the year before the review per year.
Changes in carbon stock in dead wood	tons C ha^{-1} per year	-	[172]=[169]+[170]+[171]	
Carbon accumulation in dead wood	tons of C ha^{-1}	-	[173]=$[172]_o$+$[172]_1$...$[172]_n$, where $[172]_o$ – changes in carbon accumulation in dead wood at zero per year; $[172]_1$ – changes in carbon accumulation in dead wood in the first per year; $[172]_n$ – changes in carbon accumulation in dead wood are reported per year.	

Equations for calculating GHG emissions for organic soils are given in Table 24, but Table 25 conversion of GHG emissions to CO_2 equivalents and calculation of total CO_2 emissions from soil.

Table 24. GHG emissions from soil

GHG	Unit of measure	Calculation
CH_4 emissions from ditches	kg CH_4 ha^{-1} per year	[174]=[123]*[124]
CH_4 emissions from the rest of the area	kg CH_4 ha^{-1} per year	[175]=[125]*(100%-[124])
N_2O emissions	kg N_2O ha^{-1} per year	[176]=[126]
CO_2 emissions	tons CO_2 ha^{-1} per year	[177]=[127]

Table 25. Conversion of GHG emissions from soil into CO_2 equivalents

GHG	Unit of measure	Calculation
CH_4 emissions from ditches	tons of CO_2 eq. ha^{-1} per year	[178]=[174]*[32]
CH_4 emissions from the rest of the area	tons of CO_2 eq. ha^{-1} per year	[179]=[175]*[32]
N_2O emissions	tons of CO_2 eq. ha^{-1} per year	[180]=[176]*[33]
CO_2 emissions	tons CO_2 ha^{-1} per year	[181]=[177]
Total GHG emissions from soil	tons of CO_2 eq. ha^{-1} per year	[182]=[178]+[179]+[180]+[181]

The amount of carbon introduced into the produced wood products is calculated using the equations in Table 26. In calculating the yield of round timber, the proportion of bark is taken into account.

Table 26. Calculation of carbon input from the produced wood products

Wood products	Unit of measure	Calculation
Round timber. 1.2.C & 1.2.NC	tons C ha^{-1} per year	[183]=[276]*[159]/[82]*(100%-[134])
Lumber. 5.C & 5.NC	tons C ha^{-1} per year	[184]=[183]*[131]
Panel wood. 6 1. 6 2. 6 3. 6.4.1. 6.4.2. 6.4.x. 6.4.3	tons C ha^{-1} per year	[185]=[183]*[132]
Paper and cardboard. 10	tons C ha^{-1} per year	[186]=[277]*[159]/[82]*[133]
In total	tons C ha^{-1} per year	[187]=[184]+[185]+[186]

Coefficients for wood product decomposition calculations are given in Table 27 and 28. Coefficients Table 28 is calculated for each type of wood product separately. The calculation equations for GHG emissions from wood products correspond to the methodology adapted in the national GHG inventory (Rüter. 2011).

Table 27. Calculation of common coefficients of carbon input with wood products

Coefficient	ID	Value
e	[188]	2.7

Calculation assumptions

Coefficient	ID	Value
ln(2)	[189]	LN(2)

Table 28. Coefficients specific to the type of wood products, calculation of carbon input with wood products

Coefficient	ID	Sawn materials (5.C & 5.NC)	Panel wood (6 1. 6 2. 6 3. 6.4.1. 6.4.2. 6.4.x. 6.4.3)	Paper and cardboard (10)
HL – half-life	[190]	35.0	25.0	2.0
	[191]=[189]/[190]			
e-k	[192]=[188]^-[191]			
	[193]=(1-[191])/[192]			

Carbon accumulation in wood products at zero per year is calculated if the alternative scenario is forest land, i.e. the initial carbon stock in wood products is not calculated for measures related to afforestation. Changes in carbon accumulation in wood products are calculated separately for three categories of wood products according to Table 29 for the given equations.

Table 29. Calculation of carbon cycle in wood products

Type of timber	Process	Unit of measure	Zero carbon accumulation per year (if different from the others)	Calculation of changes in carbon stock
Sawn materials; 5.C & 5.NC	c(i)	tons C ha^{-1} per year	$[194]_o=[64]*[74]+[65]$	$[194]_n=([192]*[194]_{n-1})+([193]*[195]_{n-1})$
	inflow(i)	tons C ha^{-1} per year	-	$[195]_n=[184]_n$
	ΔC(i)	tons C ha^{-1} per year	-	$[196]_n=[194]_n+1-[194]_n$
Panel wood; 6 1. 6 2. 6 3. 6.4.1. 6.4.2. 6.4.x. 6.4.3	c(i)	tons C ha^{-1} per year	$[197]_o=[66]*[74]+[67]$	$[197]=([192]*[197]_{n-1})+([193]*[198]_{n-1})$
	inflow(i)	tons C ha^{-1} per year	-	$[198]_n=[185]_n$
	ΔC(i)	tons C ha^{-1} per year	-	$[199]_n=[197]_n+1-[197]_n$
Paper and cardboard; 10	c(i)	tons C ha^{-1} per year	$[200]_o=[68]*[74]+[69]$	$[200]=([192]*[200]_{n-1})+([193]*[201]_{n-1})$
	inflow(i)	tons C ha^{-1} per year	-	$[201]_n=[186]_n$
	ΔC(i)	tons C ha^{-1} per year	-	$[202]=[200]_n+1-[200]_n$
In total	ΔC(i)	tons C ha^{-1} per year	-	[203]=[196]+[199]+[202]

Carbon in wood biofuel is calculated according to Table 30 for the given equations, separately for recycled wood, bark, woodworking residues, logging residues and Firewood. Carbon input with logging residues is calculated separately for wood obtained in maintenance felling $[207]_{kc}$

and main felling [207]$_{gc}$, if the input parameters indicate that logging residues are used for the preparation of wood biofuel.

Table 30. Amount of carbon in wood biofuel

Pointer	Unit of measure	Calculation
Recycled wood	tons C ha^{-1} per year	[204]=(1-[192])*[194]+(1-[193])*[195]+(1-[192])*[197]+(1-[193])*[198]+(1-[192])*[200]+(1-[193])*[201]
Peels	tons C ha^{-1} per year	[205]=[159]-[183]-[186]-[208]
Woodworking residues	tons C ha^{-1} per year	[206]=[159]-([184]+[185]+[186])-[208]
Logging residues	tons C ha^{-1} per year	[207]$_{kc}$=[161]*(1-[120]) [207]$_{gc}$=[161]*(1-[121])
Firewood	tons C ha^{-1} per year	[208]=[278]*[122]
In total	tons C ha^{-1} per year	[209]=[204]+[206]+[207]+[208]

In the calculation of the substitution effect of wood biofuel, it is assumed that wood processing residues, firewood, recycled wood and logging residues (if it is indicated that logging residues are used for the preparation of biofuel). The coefficients used by default to calculate the reduction of GHG emissions compare wood in district heating and natural gas (Table 31). The calculated equations correspond to the default emission factor values given in the Intergovernmental Panel on Climate Change (IPCC) guidelines (Eggleston et al.. 2006).

Table 31. Coefficients for the calculation of the biofuel substitution effect

Parameter	Unit of measure	ID	Numerical value
Emission factors for natural gas			
The lowest calorific value	MWh m^{-}[illegible]	[210]	0.0094
Boiler efficiency factor	-	[211]	85%
CO_2 emission factor	tons of CO_2 MWh^{-1}	[212]	0.1984
N_2O emission factor	tons of N_2O MWh^{-1}	[213]	0.00000036
CH_4 emission factor	tons of CH_4 MWh^{-1}	[214]	0.00000360
Characterization of biofuel			
The lowest calorific value	MWh ton^{-1}	[215]	4.9000
Boiler efficiency factor	-	[216]	80%
N_2O emission factor	tons of N_2O MWh^{-1}	[217]	0.000014
CH_4 emission factor	tons of CH_4 MWh^{-1}	[218]	0.000108

The first step of the calculation is the calculation of the amount of wood biofuel in dry tons and the amount of energy produced, as well as the amount of N_2O and CH_4 emissions in the biomass burning process (Table 32). CO_2 emissions in the form of carbon losses from living biomass are already included in the equations of carbon cycling in living biomass.

Calculation assumptions

Table 32. Calculation of the amount of replaced energy

Parameter	Unit of measure	Calculation
Biofuel:	tons per year	[219]=[220]+[221]+[222]+[223]+[224]
recycled wood	tons per year	[220]=[204]/[122]
peels	tons per year	[221]=[205]/[122]
woodworking residues	tons per year	[222]=[206]/[122]
logging residues	tons per year	[223]=[207]/[122]
Firewood	tons per year	[224]=[208]/[122]
The net amount of energy replaced	MWh per year	[225]=[219]*[215]*[216]
N_2O emissions in the combustion process	tons of N_2O per year	[226]=[225]*[217]
CH_4 emissions in the combustion process	tons CH_4 per year	[227]=[225]*[218]

The fossil fuel replaced is calculated by estimating how much fossil fuel is needed to produce the amount of energy that can be produced from woody biomass. After that, the GHG emissions that would be generated by the burning of fossil fuels are calculated (Table 33). In the next step. GHG emissions are converted into CO_2 equivalents (Table 34).

Table 33. Calculation of the substitution effect in biofuel

Parameter	Unit of measure	ID
Replaced natural gas	m3 per year	[228]=[225]/[210]/[211]
CO_2 emissions from substituted fossil fuels	tons CO_2 per year	[229]=[228]*[210]*[212]
N_2O emissions from substituted fossil fuels	tons of N_2O per year	[230]=[228]*[210]*[213]
CH_4 emissions from substituted fossil fuels	tons CH_4 per year	[231]=[228]*[210]*[214]

Table 34. Conversion of the substitution effect to CO_2 equivalents

Parameter	Unit of measure	ID
Reduction of CO_2 emissions	tons of CO_2 eq. per year	[232]=[228]
Reduction of N_2O emissions	tons of CO_2 eq. per year	[233]=([230]-[226])*[33]
Reduction of CH_4 emissions	tons of CO_2 eq. per year	[234]=([231]-[227])*[32]
Net emission reduction	tons of CO_2 eq. per year	[235]=[232]+[233]+[234]

The summary of GHG emissions includes CO_2 emissions from living woody biomass. CO_2 emissions from ground cover in forested areas (in areas where the forest grew before the implementation of the measure, this storage is not taken into account). CO_2 emissions from dead wood. CO_2 emissions from wood products. CO_2. CH_4 and N_2O emissions from organic soil, biofuel substitution effect and total annual GHG emissions (Table 35).

Calculation assumptions

Table 35. Summary of GHG emissions calculation

Parameter	Units of measurement	Calculation in the first per year (if different from the others)	Calculation in future years
CO_2 emissions from tree biomass	tons CO_2 ha^{-1} per year	[236]=[167]*44/12	
CO_2 emissions from ground cover in forested areas	tons CO_2 ha^{-1} per year	$[237]_1$=-[129]/[130]*44/12, where $[237]_1$ – CO_2 emissions from the ground cover in the first per year	$[237]_n$=IF(ABS($[237]_1$+...+$[237]_n$-1)>=[129]*44/12;0;-[129]/[130]*44/12) , where $[237]_n$ – CO_2 emissions from ground cover report per year; $[237]_1$ – CO_2 emissions from the ground cover in the first per year; $[237]_n$-1 – CO_2 emissions from the ground cover in the year before the review.
CO_2 emissions from dead wood	tons CO_2 ha^{-1} per year	[238]=[172]*44/12	
CO_2 emissions from wood products	tons CO_2 ha^{-1} per year	[239]=[203]*44/12	
CO_2 emissions from organic soil	tons CO_2 ha^{-1} per year	[240]=[181]-[118]*44/12	
CH_4 emissions from organic soil	tons of CO_2 eq. ha^{-1} per year	[241]=[178]+[179]	
N_2O emissions from organic soil	tons of CO_2 eq. ha^{-1} per year	[242]=[180]	
Biofuel substitution effect	tons of CO_2 eq. ha^{-1} per year	[243]=[235]	
Total GHG emissions	tons of CO_2 eq. ha^{-1} per year	[244]=[236]+[237]+[238]+[239]+[240]+[241]+[242]+[243]	
Cumulative total GHG emissions	tons of CO_2 eq. ha^{-1}	[245]=$[244]_1$+...+$[244]_n$ where $[244]_1$ – total GHG emissions in the first per year; $[244]_n$ – total GHG emissions reported per year.	

Calculation assumptions

The breakdown into timber types is calculated if this information is not provided by the AGM tool. The coefficients corresponding to the type of timber, the type of felling and the tree species can be found in Table 2. Assumptions that determine the choice of coefficients are located in Table 17. To prevent a negative result, as well as a result exceeding 100%, according to Table 36 relative timber distribution calculated for the given equations is corrected using Table 37 given equations. Table 38 calculated the yield of round timber, pulp-wood and firewood in the volume of logging. All calculations are made on the volume of logging without bark, excluding firewood.

Table 36. Calculation of the relative distribution of timber types

Type of timber	Calculation
Poles 18<	[246]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
A 28<	[247]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
28<	[248]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
18-27.9	[249]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
FIA 18<	[250]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
FIB 18<	[251]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
24<	[252]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
18-23.9	[253]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
Low quality logs 18<	[254]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
14-17.9	[255]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
10-13.9	[256]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
12-17.9	[257]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
6-9.9	[258]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
PM 7-49.9	[259]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]
Firewood	[260]=[7]*[83]^3+[8]*[83]^2+[9]*[83]+[10]

Table 37. Correction of the relative distribution of different types of timber

Type of timber	Calculation
Poles 18<	[261]=IF([246]<0;0;[246])
A 28<	[262]=IF([247]<0;0;[247])
28<	[263]=IF([248]<0;0;[248])
18-27.9	[264]=IF([249]<0;0;[249])
FIA 18<	[265]=IF([250]<0;0;[250])
FIB 18<	[266]=IF([251]<0;0;[251])
24<	[267]=IF([252]<0;0;[252])
18-23.9	[268]=IF([253]<0;0;[253])
Low quality logs 18<	[269]=IF([254]<0;0;[254])
14-17.9	[270]=IF([255]<0;0;[255])
10-13.9	[271]=IF([256]<0;0;[256])
12-17.9	[272]=IF([257]<0;0;[257])

Calculation assumptions

Type of timber	Calculation
6-9.9	[273]=IF([258]<0;0;[258])
PM 7-49.9	[274]=IF([259]<0;0;[259])
Firewood	[275]=100%-([261]+[262]+[263]+[264]+[265]+[266]+[267]+[268]+[269]+[270]+[271]+[272]+[273]+[274])

Table 38. Summary of timber yield calculations

Parameter	Unit of measure	ID
Saw logs (1.2.C & 1.2.NC)	m^3 ha^{-1}	[276]=([261]+[262]+[263]+[264]+[265]+[266]+[267]+[268]+[269]+[270]+[271]+[272])*[82]*(100%-[134])
Pulpwood (10)	m^3 ha^{-1}	[277]=[274]*[82]*(100%-[134])
Firewood	m^3 ha^{-1}	[278]=[275]*[82]

8. REDUCTION OF GHG EMISSIONS

The reduction of GHG emissions is determined by differences in carbon accumulation in ground cover plant vegetation, as well as changes in carbon accumulation in other carbon stores and GHG emissions from the soil. Ground cover plants are evaluated separately, because they are not included in the living biomass cycle equation and the impact on this storage is evaluated as the difference between two equilibrium states.

An example of a two-scenario calculation for an afforestation or other project related to the planting of trees in non-forest lands is given in Table 39. In the calculation, the reduction of GHG emissions with or without the emission reduction effect of wood biofuel is separated. In scenarios where no change of land use is foreseen (measures in forest management). GHG emissions in the alternative scenario must be presented in the same way as in the scenario of the implementation of the measure - with and without the substitution effect.

Reduction of GHG emissions

Table 39. Example of GHG emission reduction calculation

Parameter	Unit of measure	Calculation in the first per year (if different from the others)	Calculation in other years
Alternative scenario			
Net GHG emissions	tons of CO_2 eq. ha^{-1} per year	[279]=[107]	
Carbon accumulation in ground cover plant biomass	tons of C ha^{-1}	[280]=[21]+[22]	
Event implementation scenario			
Net GHG emissions	tons of CO_2 eq. ha^{-1} per year	[281]=[244]	
Net GHG emissions excluding the substitution effect of forest biofuels	tons of CO_2 eq. ha^{-1} per year	[282]=[281]-[243]	
Carbon accumulation in ground cover plant biomass	tons of C ha^{-1}	[283]=[117]	
Impact of the implementation of the measure			
Changes in carbon accumulation in ground cover plant biomass	tons of CO_2 eq. ha^{-1} per year	[284]$_1$=([283]$_1$-[280]$_1$)*44/12 where [284]$_1$ – changes in carbon accumulation in the first per year; [283]$_1$ – carbon accumulation in the biomass of ground cover plants in the first per year, when implementing the measure; [280]$_1$ – carbon accumulation in ground cover plant biomass in the first per year alternative scenario.	[284]$_n$=([283]$_n$-[280]$_n$)*44/12-([284]$_1$+...+[284]$_{n-1}$) where [284]$_n$ – changes in carbon stock are reported per year; [283]$_n$ – carbon accumulation in ground cover plant biomass is reviewed per year, when implementing the measure; [280]$_n$ – carbon accumulation in understory plant biomass in the report per year in the alternative scenario; [284]$_1$ – changes in carbon accumulation in the first per year; [284]$_{n-1}$ - changes in carbon accumulation the year before the report per year.
Reduction of GHG emissions, excluding the substitution effect of wood biofuels	tons of CO_2 eq. ha^{-1} per year	[285]=[279]-[282]+[284]	
Reduction of GHG emissions through the substitution effect of wood biofuel	tons of CO_2 eq. ha^{-1} per year	[286]=[279]-[281]+[284]	
Cumulative reduction of GHG emissions, excluding the substitution effect of wood bio-	tons of CO_2 eq. ha^{-1}	[287]=[285]$_1$+...+[285]$_n$ where [285]$_1$ – reduction of GHG emissions in the first per year;	

fuel		$[285]_n$ – reduction of GHG emissions per year.
Reduction of GHG emissions cumulatively with the substitution effect of wood biofuel	tons of CO_2 eq. ha^{-1}	$[288]=[286]_1+\ldots[286]_n$ where $[286]_1$ – reduction of GHG emissions in the first per year; $[286]_n$ – reduction of GHG emissions per year.

9. LITERATURE

1. AS 'Latvijas valsts meži'. (2010). *Sortimentu iznākums galvenajā un krājas kopšanas cirtē (Output of different assortments in thinning and regenerative felling)*.
2. Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Kiyoto, T. (Eds.). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Agriculture, Forestry and Other Land Use. In *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Vol. 4, p. 678). Institute for Global Environmental Strategies (IGES).
3. Lazdiņa, D., Lazdiņš, A., Bebre, I., Lupiķis, A., Makovskis, K., Spalva, G., Sarkanābols, T., Okmanis, M., Krīgere, I., Dreimanis, I., & Kalniņa, L. (2019). Afforestation. In A. Priede & A. Gancone (Eds.), *Sustainable and responsible after-use of peat extraction areas* (pp. 178–183). Baltijas Krasti.
4. Lupiķis, A. (2019). Results of GHG emission measurements in differently managed peatlands in Latvia – the basis for new national GHG emission factors. *Sustainable and Responsible Management and Re-Use of Degraded Peatlands in Latvia*, 24–26.
5. Lupiķis, A., & Lazdiņš, A. (2015). *Soil carbon balance on drained and afforested transitional bog in forest research station Vesetnieki in Latvia*. *17*, 955. http://adsabs.harvard.edu/abs/2015EGUGA..17..955L
6. Rüter, S. (2011). *Projection of Net-Emissions from Harvested Wood Products in European Countries* (Work Report No. 2011/x of the Institute of Wood Technology and Wood Biology; p. 62). Johann Heinrich von Thünen-Institute (vTI).