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Forest SOC monitoring in Lithuania – challenges and needs for the future

LITHUANIAN RESEARCH CENTRE FOR AGRICULTURE AND FORESTRY

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In 2015–2016, four projects on SOC values in national forest, non-forest land, and forest products:

1. SOC in soil and forest floor in forest land and non-forest land
2. SOC in soil and forest floor in afforested and reforested sites
3. SOC in dead wood of various decomposition levels
4. Study for development of the harvested wood products accounting system and preparation of relevant accounting methodology

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I. STUDY FOR EVALUATION OF CARBON STOCKS IN FOREST LAND AND NON-FOREST LAND IN SOIL AND FOREST FLOOR

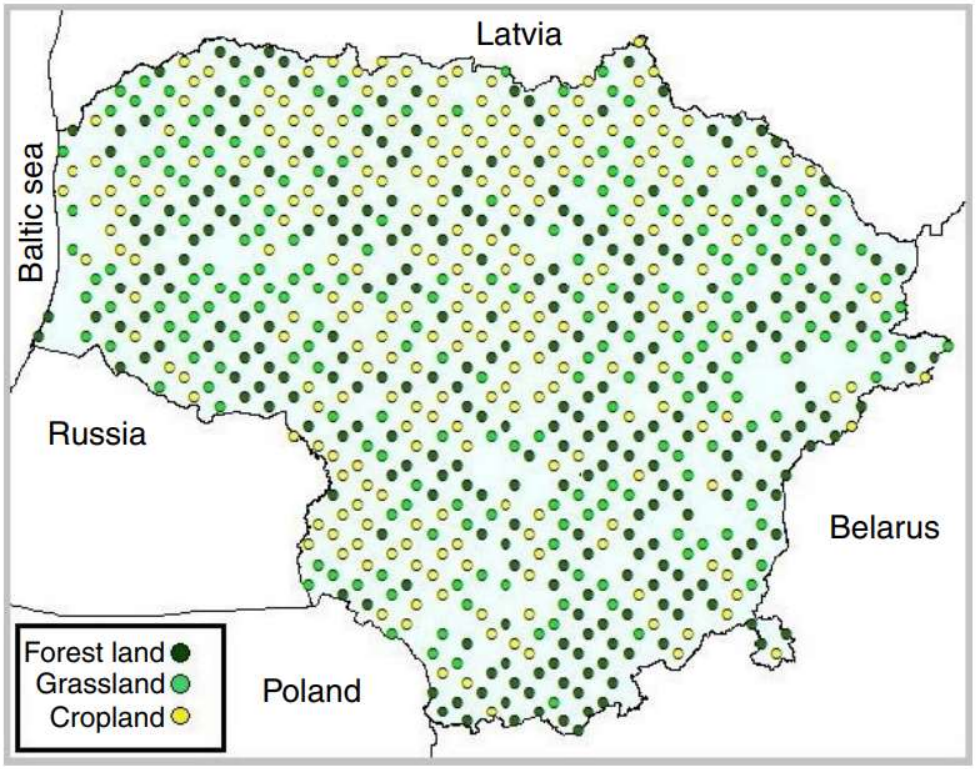
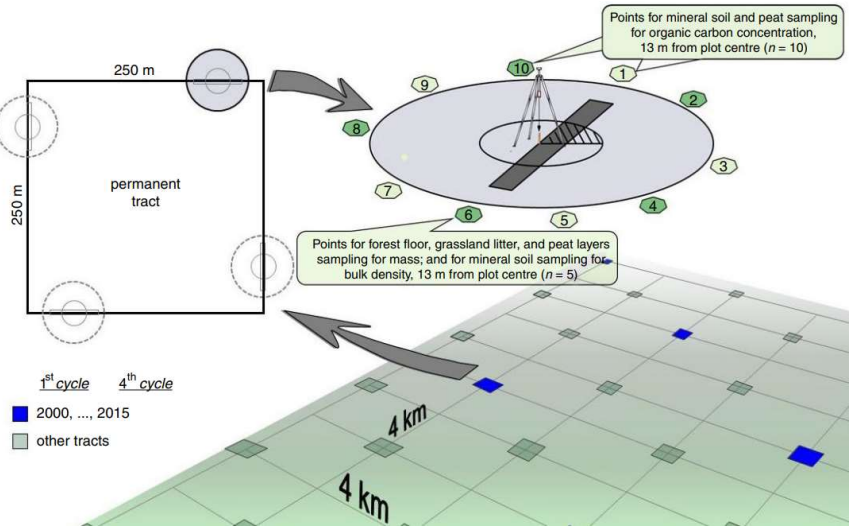


FIGURE 1 Selected sample plots for soil sampling in the permanent plots grid (9 × 9 km) of Lithuanian National Forest Inventory (NFI) (2015; total $n = 754$; forest land $n = 288$; grassland $n = 218$; cropland $n = 248$)



- **forests, croplands and grasslands**
- **forest floor and surface 0–30 cm layer**
- **0–10 cm and 10–30 cm**
- **forest floor: mass, SOC concentrations & stocks**
- **mineral soil: bulk density, SOC concentrations & stocks**

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TABLE Mean mass of forest floor (OL+OF+OH) and plant litter in perennial grassland and mean organic carbon (OC) stocks in major soil groups [WRB, 2014 (2015)]

	Forest land			Perennial grassland		
Major soil groups	**Number of plots**	**Mean mass (t ha^{-1})**	**Mean OC stocks[b] (t ha^{-1})**	**Number of plots**	**Mean mass (t ha^{-1})**	**Mean OC stocks (t ha^{-1})**
Cambisols	8	4.1 ± 0.6 a (3.0, 5.2)	1.6 ± 0.2 a (1.2, 2.1)	34	0.7 ± 0.1 b (0.5, 0.9)	0.3 ± 0.0 b (0.2, 0.3)
Luvisols +Retisols	82	13.6 ± 3.5 b (6.7, 20.5)	5.6 ± 1.5 b (2.6, 8.5)	113	1.6 ± 0.2 c (1.2, 1.9)	0.6 ± 0.1 bc (0.4, 0.7)
Planosols	26	10.5 ± 3.4 ab (3.7, 17.3)	4.0 ± 1.3 ab (1.5, 6.5)	7	1.6 ± 0.8 bc (0.1, 3.2)	0.6 ± 0.3 bc (0.0, 1.2)
Arenosols	92	15.5 ± 1.5 b (12.6, 18.4)	6.3 ± 0.6 b (5.0, 7.6)	52	1.2 ± 0.2 bc (0.9, 1.5)	0.5 ± 0.1 bc (0.3, 0.6)
Podzols	21	59.8 ± 16.6 c (27.3, 92.3)	25.7 ± 7.2 c (11.7, 39.7)	1	0.2 a	0.1 a
Gleysols[a]	20	15.0 ± 7.1 (1.1, 28.8)	6.6 ± 3.3 (0.1, 13.1)	2	3.2 ± 0.7 (0.0, 7.5)	1.3 ± 0.3 (0.0, 3.1)
Histosols	36	11.7 ± 2.4 b (6.9, 16.4)	4.9 ± 1.1 b (2.8, 6.9)	8	1.9 ± 0.6 c (0.7, 3.2)	0.8 ± 0.3 bc (0.3, 1.3)
Fluvisols	3	2.3 ± 1.0 a (0.3, 4.2)	0.9 ± 0.4 a (0.2, 1.6)	1	1.4 bc	0.5 bc

TABLE Mean stocks (t ha^{-1}) of soil organic carbon (SOC) in 0–30 cm topsoil of major soil groups in forests [WRB, 2014(2015)]

Major soil groups	LULUCF default values[a] (IPCC, 2006)	SOC stocks in Europe (De Vos et al., 2015)	SOC stocks in Lithuania	
			Mean	*n*
Cambisol	95	71.4	118	8
Luvisols +Retisols	95	68.9/66.4	96	82
Planosols	–	51.5	77	26
Arenosols	71	40.9	56	92
Podzols	115	52.8	92	21
Gleysols	87	104.0	102	20
Histosols	–	186.0	150	36
Fluvisols	–	81.9	80	3

[a]Cold temperate, moist climate region (IPCC, 2006).

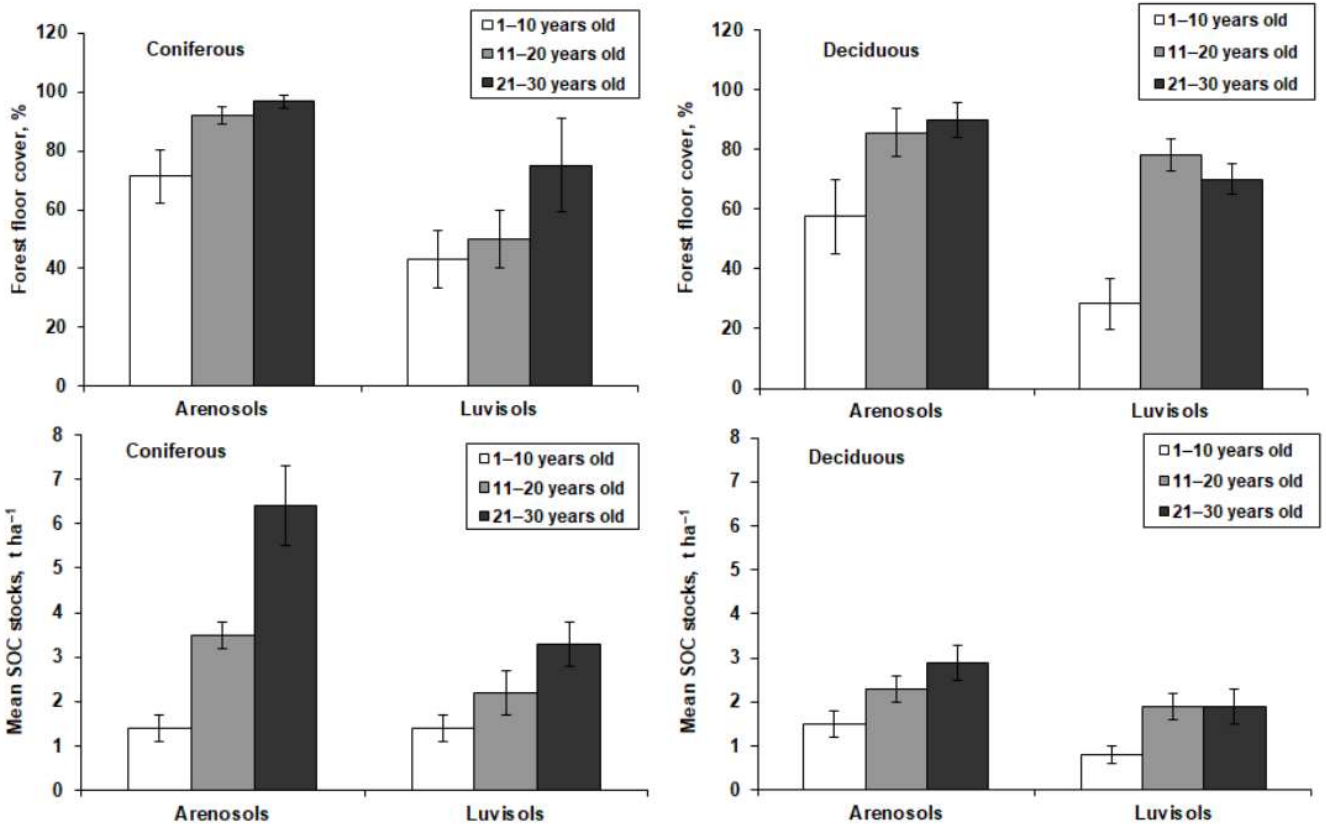
TABLE National Lithuanian values of soil organic carbon (SOC) stocks in 0–30 cm topsoil of major soil groups [WRB, 2014 (2015)] in forests, grassland, and cropland

	Forests		Perennial grassland		Cropland	
Major soil groups	***n***	**SOC, t ha^{-1}**	***n***	**SOC, t ha^{-1}**	***n***	**SOC, t ha^{-1}**
Cambisols	8	118.0 **c B** (104.4, 131.7)	34	83.2 **b A** (74.7, 91.7)	81	84.5 **b A** (79.3, 89.7)
Luvisols +Retisols	82	96.2 **bc C** (88.1, 104.4)	113	77.4 **b B** (72.1, 82.7)	129	67.0 **a A** (62.8, 71.2)
Planosols	26	76.6 **b A** (63.6, 89.6)	7	94.7 **bc A** (64.0, 125.4)	9	61.4 **a A** (48.5, 74.2)
Arenosols	92	55.7 **a A** (51.0, 60.4)	52	55.3 **a A** (50.1, 60.6)	26	62.0 **aA** (53.7, 70.3)
Podzols	21	92.0 **bc** (72.9, 111.1)	1	83.4 **b**	–	–
Gleysols	20	102.2 **bc A** (87.7, 116.8)	2	105.5 **c A** (102.9, 108.0)	1	108.7 **c A**
Histosols	36	150.5 **d A** (133.8, 167.2)	8	181.5 **d A** (130.9, 232.1)	2	243.2 **d A** (0.0, 500.1)
Fluvisols	3	79.7 **b**	1	64.6 **b**	–	–

95 percent confidence limits are given in the brackets below the mean. Different small letters a, b, c, and d indicate significant differences among major soil groups within the same land use; different capital letters A, B, C, and D indicate significant differences among land use categories within the same soil group.

2. STUDY FOR EVALUATION OF CARBON STOCKS IN SOIL AND FOREST LITTER IN FORESTS THAT WERE AFFORESTED AND REFORESTED ON NON-FOREST LAND

- Arenosols and Luvisols (also, Histosols)
- afforested agricultural land, grassland, and cropland - paired-site design
- forest floor and surface 0–30 cm layer; 0–10 cm and 10–30 cm layers
- 1–10, 11–20 and 21–30 years old coniferous and deciduous forest stands
- total, 254 plots



Mean forest floor cover (%) and mean soil organic carbon (SOC) stocks (t ha^{-1}) in the forest floor of afforested Arenosols and Luvisols in the coniferous and deciduous stands of different age.

Mean stocks (t ha^{-1}) of soil organic carbon (SOC) in 0–30 cm topsoil layers of Arenosols and Luvisols in afforested land, cropland and grassland. Different letters a and b indicate significant differences between the land-use categories within each stand age decade for Arenosols and Luvisols at the $p < 0.05$.

Land-Use Category	Arenosols			Luvisols		
	n	Mean SOC Stocks (t ha^{-1})	National SOC Values (t ha^{-1}) [b]	*n*	Mean SOC Stocks (t ha^{-1})	National SOC Values (t ha^{-1}) [b,c]
Afforested land, 1–10 years old [a]	23	50.9 ± 4.6 [a]	-	22	59.1 ± 4.0 [ab]	-
Cropland	10	69.8 ± 11.9 [a]	-	13	51.2 ± 5.5 [a]	-
Grassland	9	55.5 ± 6.4 [a]	-	9	69.6 ± 7.8 [b]	-
Afforested land, 11–20 years old	22	57.5 ± 4.9 [a]	-	21	60.3 ± 4.8 [ab]	-
Cropland	12	60.5 ± 6.5 [a]	-	12	58.1 ± 7.7 [a]	-
Grassland	11	68.1 ± 8.9 [a]	-	10	71.8 ± 8.8 [b]	-
Afforested land, 21–30 years old	22	46.3 ± 5.1 [a]	-	18	61.4 ± 4.3 [ab]	-
Cropland	11	49.4 ± 5.7 [a]	-	14	53.3 ± 6.4 [a]	-
Grassland	9	51.5 ± 11.5 [a]	-	8	73.5 ± 12.1 [b]	-
Afforested land, 1–30 years old	67	51.8 ± 2.8 [a]	55.7 [d]	61	60.2 ± 2.5 [ab]	96.2 [d]
Cropland	33	58.8 ± 4.6 [a]	62.0	39	54.1 ± 3.7 [a]	67.0
Grassland	29	59.1 ± 4.8 [a]	55.3	26	70.2 ± 5.1 [b]	77.4

[b] Armolaitis K. et. al. 2022. Evaluation of organic carbon stocks in mineral and organic soils in Lithuania. *Soil Use and Management* 38 (1): 355–368.

Challenges and needs for the future

- Lacking data on soil pH and total N and other elements
- Lacking data on soil biological properties (soil microbial biomass C and N)
- Limited 30 years period after afforestation
- Limited 30 cm depth
- Lacking modelling and mapping

Armolaitis K., Varnagirytė-Kabašinskienė I., Žemaitis P., Stakėnas V., Beniušis R., Kulbokas G., Urbaitis G. 2022. Evaluation of organic carbon stocks in mineral and organic soils in Lithuania. *Soil Use and Management* 38 (1): 355–368.

Varnagirytė-Kabašinskienė I., Žemaitis P., Armolaitis K., Stakėnas V., Urbaitis G. 2021. Soil organic carbon stocks in afforested agricultural land in Lithuanian hemiboreal forest zone. *Forests* 12 (11): 1562.