Organic Carbon Pools in Estonian Forest Soils

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In the work the soil organic carbon (SOC) content of Estonian forest soils is analysed by 20 soil groups, whereas the data are taken from the database PEDON and CATENA. The SOC pools (Mg ha^{-1}) for upland mineral soils (*Leptosols, Cambisols, Luvisols, Albeluvisols, Podzols, Regosols;* totally 11 groups), lowland mineral soils (*Gleysols, Histic Podzols, Fluvisols;* 6 groups) and wetland organic soils (*Histosols;* 3 groups) are given separately for forest floor (FF), humus cover (HC) and soil cover (SC). On the basis of different soil type characteristics and their distribution superficies, the SOC and soil organic matter (SOM) pools for the whole Estonian forest land were calculated. It was discovered that in the studied part of Estonian forest soils SC 314.4±27.1 Tg of organic carbon is sequestrated, from which 57.1% is situated in HC and 42.9% in subsoil. 13,9% of the total SOC pool belongs to the forest floor, which is the superficial part of HC. Accumulated in forest soils, organic carbon is sequestrated into 602±51 Tg SOM. The generalised data by different soil types, as well as elucidated pedoecological regularities are observed also on the background of Estonian postlithogenic mineral soil matrixes. HC quality is characterised on the basis of forest soil HC classification.

Key words: forest soils, soil humus status, humus cover type, carbon sequestration, SOC and SOM pools, soil matrix table

Introduction

The soil organic carbon (SOC) is a widely distinguishable factor in soil forming, development and functioning (McFee & Kelly 1995, Lal *et al.* 1998, Pulleman *et al*. 2000, Shaffer & Ma 2001). The long history of soil organic matter (SOM) researches demonstrates a multitude of approaches (Batjes 1996, Robert 2001, Rusco *et al*. 2001), among which the quantification SOC and SOM flow and sequestration in soil cover are of utmost importance (Kern 1994, Bernoux *et al*. 2002; Nemeth *et al*. 2002, Zhou *et al*., 2003). The SOC may be sequestrated in different soil horizons in very different forms and states (DeBusk *et al*. 2001), among which the key role belongs to soil humus. The organic matter flow throughout the soil cover begins with falling litter on the surface or into the soil, continues with the processes of breakdown, decomposition and transformation of SOM and ends with SOM disappearance from the soil via its utilisation by soil organisms in nutrition chains, via complete mineralization or via illuviation into non-actively functioning horizons. Each soil type has certain differences in the above-mentioned three-link chain of SOC flow (input => acting => output). Depending on the soil properties, the carbon sequestrated in SOM may have very varying properties and quality from the ecological point of view, as well as residence time in soil or turnover intensity, which is possible to reflect by humus cover types (Kõlli 1992). In the present work the features connected with SOC are united into the term soil humus status (Kõlli & Kanal 1995). The humus status of soil is by the essence functioning of soil in relation to SOM or the peculiarity of SOC flow throughout the soil cover.

The main tasks of this work were: (1) determination of SOC pools in different types of Estonian forest soils; (2) analysis of forest floor, humus cover, soil cover and subsoil role in SOC sequestration into forest soils and (3) elucidation of generalised pedoecological regularities of forest soil humus status and quality on the basis of Estonian soil matrixes.

Materials and methods

For superficies of Estonian forest land 2015.7 thousand hectares is taken, which existed in reality during the years 1993 - 1998, forming 44.6% of the total area (Statistical… 2003). The division of forest land from different aspects is shown in Figure 1. The quantitative characteristics of forest soils originate mainly from soil profile horizons database PEDON, which contains the data of 232 experimental areas founded on forest soils. Profiles of mineral soils are quantified relatively well in the database, which was compiled mainly during 1967-85 and was updated in 1986-95 and in 1999-2002. As data about organic soils in database PEDON was rather scarce, the materials of this work were com-

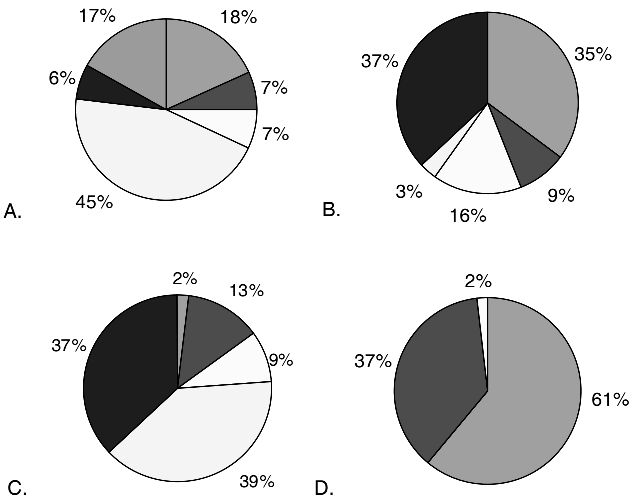


Figure 1. Land use and characterization of forest soils:
A. Land use: arable land in use - 18 %; set aside arable land - 7 %; other agricultural land - 7%; forest land - 45%; inland waters - 6%; other area - 17%;
B. Texture: sandy - 35%; sandy loam - 9%; loamy - 16%; cleyey - 3%; peaty - 37%;
C. Moisture regime: dry, aridic - 2%; fresh or normal, udic - 13%; moist, endogleyic - 9%; wet mineral, epigleic, aquic - 39%; wet peaty, histic - 37%;
D. Distribution of soils by soil matrix tables: postlithogenic mineral soils - 61%; postlithogenic organic soils - 37%; synlithogenic soils - 2%.

pleted by the humus status research transects data from the database CATENA, which was formed during itinerary field studies in 1987-1992.

In the work, the data on soil texture, SOC concentrations and pools, and soil materials, the bulk density of humus (A), raw humuous or raw-organic (AT), histic (T), eluvial (E) and illuvial horizons (B) as well as loss by ignite of forest floor (O) were used. The SOC content was determined by the Tjurin method (Arinouskina 1970) and the particle size distribution of fine earth by pipette method according to Kachinsky (1965). The role of rock fragments in soil horizons was determined in the course of field works by their volume. The pools of SOC by soil types were estimated for three soil cover layers: (1) forest floor (FF), (2) humus cover (HC) or epipedon, which consists of forest floor and/or humus, raw humuous or peat *(histic)* horizons and (3) soil cover (SC) or solum as a whole, whose depth reaches from the surface to the unchanged parent material or C horizon. Therefore the SC consists of HC and subsoil. But in the sequence SC=>HC=>FF, each following is the intersection of the previous and each previous contains subset of the following. The thickness of SC is determined by the depth of border between B and C horizons. In the presence of BC horizon the HC thickness was measured from surface to the middle of BC horizon. The main quantitative parameters of soil humus status are HC thickness and morphology, SOC and/or SOM concentrations and pools, and HC quality (type). For the work's compactness SOM concentrations and pools by soil types are not presented. But generalised data about SOM in Estonian forest soils (see Table 4) is received directly from the database, not by calculation from the SOC data. For the characterisation of HC quality, the HC classification of forest soils elaborated for Estonia was used (Kõlli 1992). The type of HC reflects the complexity of soil humus status. The SOC and SOM pools in databases PEDON and CATENA were determined on the basis of their content in fine earth and soil bulk density, taking into account the content of coarse fragments in soil profile. The bulk density samples were taken approximately from one third of profiles. Later the received information was generalised and used in the calculation of SOC and SOM pools by different soil types and soil cover layers.

For the calculation of means and for the analysis of variance, the PC program MS Excel was used. The soil group names and codes are given in the system of the World Reference Base for Soil Resources (WRB; FAO *et al*. 1998). The correlation between Estonian Soil Classification (ESC) and WRB for Estonian postlithogenic mineral soils is shown on Figure 2. Presented matrix was used also for the generalisation of the data on SOC, SOM, total N and others by different soil types, as well as for different layers and horizons of soil profiles.

Results and discussion

The thickness of forest soil SC is mostly between 40 and 90 cm, with standard deviation 8-25 cm (Table 1) or with coefficient of variability 13-38%. Only average thickness of *Leptosols, Fluvisols* and *Regosols* is smaller. In most cases the thickness of mineral soil forest floor is between 2 and 5 cm, only of some *Gleysols* and specially *Histic Gleysols* and *Histosols* it may be remarkably thicker. In dominating cases HC thickness is between 16 and 26 cm, of course thinner than that of *Podzols,* where humus horizon is absent at all.

The means of SOC pools in FF, HC and SC were calculated by summing data of individual profiles where the carbon content was determined for each horizon from soil samples taken during field research (Table 2). In upland forest soils with automorphic (normal) moisture regime SOC pools are between 60 and 100 Mg ha^{-1}, being a little higher in soils, where both

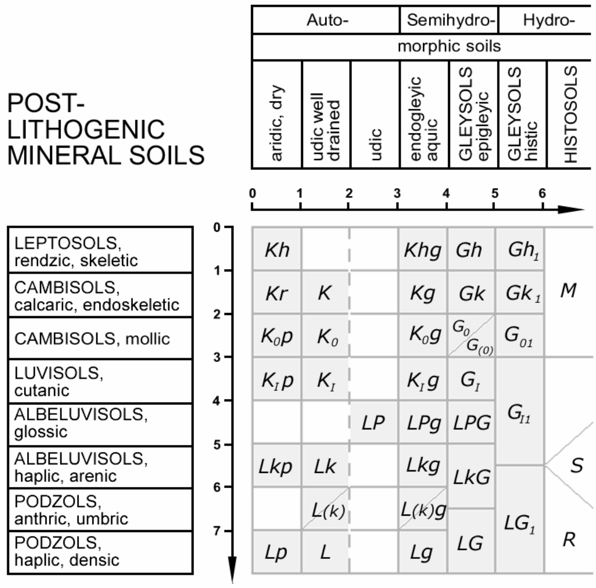


Figure 2. Correlation of Estonian postlithogenic mineral soils with WRB.
Soil codes: Kh - *Rendzic Leptosols* (Limestone rendzinas); Khg - *Endogleyic Leptosols* (Gleyed limestone rendzinas); Kr - *Calcari-Skeletic Regosols* (Pebble-rich rendzinas); K - *Calcaric Cambisols* (Pebble rendzinas); Kg - *Endogleyi-Calcaric Cambisols* (Gleyed pebble rendzinas); Ko - *Mollic Cambisols* (Leached or typical brown soils); Kog - *Gleyic Cambisols* (Gleyed typical brown soils); KI - *Cutanic Luvisols* (Eluviated (brown) soils); KIg - *Gleyic Luvisols* (Gleyed eluvial soils); LP - *Glossic Albeluvisols* (Pseudopodzolic soils); LPg - *Stagnic Albeluvisols* (Gleyed pseudopodzolic soils); Lk - *Haplic Albeluvisols* (Sod-podzolic soils); Lkg - *Gleyic Albeluvisols* (Gleyed sod-podzolic soils); L(k) - *Humic Podzols* (Humuous Podzols); L(k)g - *Gleyi-Humic Podzols* (Gleyed humuous Podzols); L - *Haplic Podzols* (Typical Podzols); Lg - *Gleyic Podzols* (Gleyed Podzols); Gh - *Epigleyic Leptosols* (Limestone gley-rendzinas); Gk - *Calcari-Skeletic Gleysols* (Pebble gley-rendzinas); Go - *Mollic Gleysols* (Leached gley-soils); G(o) - *Calcic Gleysols* (Saturated gley-soils); GI - *Dystric Gleysols* (Eluviated gley-soils); LPG - *Glossic Gleysols* (Pseudopodzolic gley-soils); LkG - *Umbric Gleysols* (Sod-podzolic gley-soils); LG - *Epigleyic Podzols* (Gley-Podzols); Gh1 - *Saprihistic Leptosols* (Limestone peaty gley-rendzinas); Gk1 - *Calcari-Histic Regosols* (Pebble peaty gley-rendzinas); Go1 - *Saprihistic Gleysols* (Saturated peaty gley-soils); GI1 - *Dystri-Histic Gleysols* (Unsaturated peaty gley-soils); LG1 - *Fibrihistic Podzols* (Peaty Podzols); M - *Sapric Histosols* (Lowland mire soils); S - *Dystric Histosols* (Transitional mire soils); R - *Fibric Histosols* (Raised bog soils).
Remarks: 1) In brackets are given Estonian soil names in direct translation; 2) the last column belongs to organic soils, which properties are close to histic soils.
Meanings of additional letters in codes: p - aridic - drought timid; g - endogleyic - gleyed; 1 - histic - peaty.

Table 1. Studied forest soil groups and thickness of soil cover layers

Group No	Soil or soil association	Soil code by WRB	% from forest land[1)]	n	Thickness (M+SD)[2], cm		
					FF	HC	SC
I	*Rendzic&Skeletic&Gleyic Leptosols*	LP rz sk gl	0.8	7	2.0±0.8	17±4.6	24±3.6
II	*Calcaric&Endoskeletic Cambisols*	CM ca skn	1.9	5	2.2±0.6	23±10.2	56±18.9
III	*Mollic&Endogleyic Cambisols*	CM mo gln	3.3	12	2.1+1.3	20+9.2	47+8.1
IV	*Sceletigleyic Cambisols*	CM gls	1.3	3	2.5+1.2	19+8.1	43+9.8
V	*Cutanic&Endogleyic Luvisols*	LV ct gln	2.4	11	2.7±1.1	24±5.7	70±18.8
VI	*Glossic&Gleyiglossic Albeluvisols*	AB gs gsg	3.6	18	3.1±0.8	19±5.0	92±18.7
VII	*Haplic Albeluvisols*	AB ha	2.7	5	2.8±1.1	25±5.5	86±13.9
VIII	*Endogleyic Albeluvisols*	AB gln	1.6	21	3.7±2.0	17±6.2	72±19.4
IX	*Haplic Podzols*	PZ ha	3.8	18	4.4±2.8	4.5±2.4	67±25.0
X	*Endogleyic Podzols*	PZ gln	2.2	9	5.3+1.3	6.1+2.9	62+16.7
XI	*Mollic&Calcic&Eutric Gleysols*	GL mo cc eu	12.1	8	3.0+2.2	26+5.1	39+12.6
XII	*Luvic&Epidystric Gleysols*	GL lv dye	8.0	16	4.0+3.0	25+4.0	55+21.0
XIII	*Spodic&Umbric&Dystric Gleysols*	GL sd um dy	9.2	8	8.4±4.4	16.0±5.2	70±14.6
XIV	*Saprihistic Gleysols*	GL his	5.3	5	5.0±2.6	23±5.3	51±11.9
XV	*Fibrihistic Podzols*	PZ hif	3.1	13	15.4±7.7	14.8±4.1	76±18.0
XVI	*Eutric&Salic Fluvisols*	FL eu sz	1.1	16	3.0±2.4	18.4±7.8	26±5.7
XVII	*Eutric&Sapric Histosols*	HS eu sa	16.3	16	5.0±0	30.0±0	50±0
XVIII	*Dystric Histosols*	HS dy	6.9	10	7.0±0	30.0±0	50±0
XIX	*Fibric Histosols*	HS fi	13.7	8	10.0±0	30.0±0	50±0
XX	*Protic&Spolic Regosols*	RG pr sp	0.7	0	0	<10	<25

Table 2. SOC sequestration capacity (Mg ha^{-1}, M±SE[1]) of different forest soils

Group No	Soil code by WRB	n	SOC pools[2], Mg ha^{-1} FF	HC	SC
I	LP rz sk gl	8	7.7±2.4	82±14	102±15
II	CM ca skn	6	7.2±1.5	87±25	109±22
III	CM mo gln	13	4.1±0.5	49±6	76±5
IV	CM gls	3	5.9±1.7	73±23	96±25
V	LV ct gln	12	5.1±0.9	75±6	95±6
VI	AB gs gsg	19	7.2+0.9	42+4	64+4
VII	AB ha	5	10.4±2.0	56±13	88±10
VIII	AB gln	23	11.2+1.2	41+4	65+4
IX	PZ ha	21	15.3±1.2	16±1	45±5
X	PZ gln	10	21.1+1.7	22+3	44+4
XI	GL mo cc eu	15	10.5±2.0	113±15	120±16
XII	GL lv dye	16	13.1±2.5	118±14	126±13
XIII	GL sd um dy	7	30.4±5.8	39±9	113±16
XIV	GL his	5	35.8±9.1	165±42	209±33
XV	PZ hif	13	45.3+5.3	46±5	114±13
XVI	FL eu sz	16	10.5±2.0[3]	73±8	84±9
XVII	HS eu sa	16	33.3	172±7	333±15
XVIII	HS dy	10	28.6	84+5	210+14
XIX	HS fi	8	23.3	44±4	139±9
XX	RG sp pr	0	0	16+8	43+22

1) M - mean, SE - standard error;
2) FF - forest floor, HC - humus cover, SC - soil cover;
3) Not determined, taken equal to GL mo cc eu.

carbonate and clay contents are higher. Remarkably lower from that SOC pools are accumulated into automorphic *Podzols* (40-50 Mg ha^{-1}), where the humus horizon is not formed. SOC pools (110-210 Mg ha^{-1}) higher than in automorphic soils are characteristic of different kinds of *Gleysols*. The highest pools are characteristic of *Sapric Histosols,* as well as other *Histosols,* which SC is composed of peat being at different stages of decomposition (*fibric, hemic, sapric)*. The carbon sequestration capacity of *Histosols* per peat volume as well per weight increases with the increase in their degree of decomposition and/or bulk density.

Results of ANOVA (coefficient of variation, CV) show that SOC pools in soils with *udic* moisture conditions are in most cases relatively stable, as their pools vary by different sites on average 21-28% and only in a few cases it is between 40-50%. At the same time the pools as well as the concentrations of SOC vary to a larger extent in different *Gleysols* (CV - 36-50%). Low variation of SOC pools (V - 18-20%) of *Histosols* is caused by conditionally taken unique soil depth (50 cm).

Recently the superficies of forest land in Estonia have increased, being 2206 thousand hectares (Statistical… 2003) in 2002. But the properties of soils do not change quickly, as the changes in soil properties take several years to become real forest soil. For this reason the superficies (2015.7 10^3 ha) existing for a relatively long stabilised period were taken as the basis for our calculation. From this area (see Figure 1, D) mineral soils form 63% and organic soils 37%.

In the calculation of SOC and SOM pools the soils distribution data of R. Kokk *et al*. (1991) was used. Table 3 demonstrates the role of different forest soil groups in total SOC sequestration. Similarly to total pools of SOC, SOM pools were calculated (not presented in this work) by soil groups also. The summary results of both calculations are given in Table 4. It shows that in Estonian forest soils 314.4±27.1 Tg SOC is sequestrated, which is accumulated in the forest floor, stabilised soil humus, raw humuous(-organic) material and peat being at different stages of decomposition or in the composition of SOM situated in

Table 3. Total SOC pools (in Gg) by the different forest soil groups

Group No	Soil code by WRB	Area in 10^3 ha	Sum of SOC pools[1], in Gg FF	HC	SC	Sum of SE[2], in Gg FF	HC	SC
I	LP rz sk gl	16.1	124	1320	1642	39	225	242
II	CM ca skn	38.3	276	3332	4175	57	958	843
III	CM mo gln	66.5	931	3258	5054	33	399	332
IV	CM gls	26.2	155	1912	2515	44	603	655
V	LV ct gln	48.4	247	3630	4590	44	290	290
VI	AB gs gsg	72.6	523	3049	4646	65	290	290
VII	AB ha	54.4	566	3046	4787	109	707	544
VIII	AB gln	32.2	361	1320	2093	39	129	129
IX	PZ ha	76.6	1172	1226	3447	92	77	383
X	PZ gln	44.3	935	975	1949	75	133	177
XI	GL mo cc eu	243.9	2561	27561	29268	488	3658	3902
XII	GL lv dye	161.3	2113	19033	20324	403	2258	2097
XIII	GL sd um dy	185.4	5636	7231	20950	1075	1669	2966
XIV	GL his	106.8	3823	17622	22321	972	4486	3524
XV	PZ hif	62.5	2831	2875	7125	331	312	812
XVI	FL eu sz	22.2	233	1621	1865	44	178	200
XVII	HS eu sa	328.6	10942	56519	109424	0	2300	4929
XVIII	HS dy	139.1	3978	11684	29211	0	696	1947
XIX	HS fi	276.2	6435	12153	38392	0	1105	2486
XX	RG sp pr	14.1	0	230	619	0	116	317

1) Soil group area x mean pool; FF - forest floor, HC - humus cover, SC - soil cover; 2) Soil group area x SE of group

Table 4. Generalized data on SOC and SOM content in Estonian forest soils

Characteristic	Unit	Upland mineral soils I-X, XX	Low- or wetland mineral soils XI-XVI	Wetland organic soils XVII-XIX	All forest soils I-XX
Percent from forest area	%	24.3	38.8	36.9	100.0
Superficies	10^3 ha	489.7	782.1	743.9	2015.7
SOC pool:					
- in soil cover	Tg	35.5±4.2[1)]	101.9±13.5	177.0±9.4	314.4±27.1
- in forest floor		5.3+0.6	17.2+3.3	21.3+0.0	43.8+3.9
- in humus cover		23.3±3.9	75.9±12.6	80.4±4.1	179.6±20.6
- in subsoil		12.2	26.0	96.6	134.8
Average[2)] SOC pool:					
- in soil cover	Mg ha^{-1}	72.5	130.3	237.9	156.0
- in forest floor		10.8	22.0	28.6	21.7
- in humus cover		47.6	97.0	108.1	89.1
- in subsoil		24.9	33.3	129.8	66.9
SOM pool:					
- in soil cover	Tg	61.4±7.1	180.6±24.0	360.5±20.1	602.5±51.2
- in forest floor		8.7+1.1	34.0+6.6	43.8+0.0	86.5+7.7
- in humus cover		40.0±5.2	141.7±23.8	161.2±8.7	342.9±37.7
- in subsoil		21.4	38.9	199.3	259.6
Average[2)] SOM					
pool:	Mg ha^{-1}	125.4	230.9	484.6	298.9
- in soil cover		17.8	43.5	58.9	42.9
- in forest floor		81.7	181.2	216.7	170.1
- in humus cover		43.7	49.7	267.9	128.8
- in subsoil					

1) ± Sum of soil groups SE; 2) Weighed (by superficies) average

different soil layers. 57.1% of SOC is situated in the active layer or in HC and 42.9% in subsoil. Forest floor (forming an average of 13.9% of the total forest soils SOC) as a fast rotating part of HC forms the dominating part from that in *Podzols*, but is negligible in carbonatic soils (see Table 2). The turnover time of HC organic carbon is much shorter than in subsoil and is controllable with soil management. As great differences exist between automorphic (LP, CM, LV, AB and PZ, situated mostly on uplands), hydromorphic mineral (GL) and organic (HS) soils, the generalised humus status data are given for these three divisions separately as well in Table 4. The role of these three big soil groups in the sequestration of total SOC pools in SC of Estonian forest soils is 11.3, 32.4 and 56.3% respectively, which is very different from the role of these soil groups from the total forest area.

The comparison of these three subdivisions of forest soils shows that subsoils of lowland mineral soils are relatively (but not absolutely) poorer in SOC and SOM in comparison with automorphic or upland soils. On the other hand, the average content of SOC in wet land soils' HC (in Mg ha^{-1}) is high being approximately 1.8 times richer than in automorphic soils. Thanks to subsoil rich in organic carbon, the most powerful organic carbon accumulators are *Histosols'* SC, where the average per one hectare's 50 cm layer is sequestrated 238 (139-333) Mg organic carbon. But the quality of this SOM is low from the ecological and especially from the edaphic viewpoint.

In Estonian forest soils 602±51 Tg organic matter is accumulated, from which the prevailing part (52.6%) is peat. As 14.4% belongs to forest floor, approximately 33% belongs to humus with different quality and availability, from which 23% (139.0 Tg) is active and 10% passive (60.3 Tg). In the Estonian forest soils the peat share is high thanks to high share of *Histosols* (different types of *Histosols* form 37% of forest lands).

When comparing sequestrated SOC and SOM in forest land SC in Estonia with other regions of the world (Kern 1994, Bernoux *et al*. 2002, Zhou *et al*. 2003 and oth.), the characteristics of soil cover relatively rich in water content (wet) is revealed, which is characteristic of Northern areas. Although SOM pools in *Gleysols* are relatively high, their humus quality is low, being unstable, chemically unsaturated and weakly condensed.

The characteristics of humus quality are presented in Table 5, where the rough estimation of the share of HC types of different forest soils is shown. 47% by pool and 37% by superficies of forest soils' area have peat type HC, which can be divided almost equally between *eutrophic* and *oligotrophic peats*. The second share of HC (28% by pools and 31% by superficies) belongs to *wet mull* and *moder*, which are potentially fertile, but suffer under water logging during some period. They are relatively well humified, with neutral reaction, rich in nutrition elements and formed on *Gleysols* rich in carbonates. The part of problematic *wet mor* HC is not high (6% by superficies). The

Table 5. Humus cover (HC) types of forest soils and SOC distribution in soil profile (or SC)

HC types	% from forest soils superficies	Exogenic SOC of HC kg m^{-2}	Endogenic SOC of HC kg m^{-2}	Exogenic SOC % from HC	Subsoil SOC % from SC
eutrophic peat	16	16-18	0	100	48
mesotrophic peat	7	8-9	0	100	60
oligotrophic peat	14	4-5	0	100	68
peaty mull	<3	10-16	2-4	81	21
peaty moder	<3	7-13	1-3	80	31
peaty mor	~3	4-5	0-0.5	>95	60
wet mull	15	1-2	9-12	9	6
wet moder	10	1-2	9-12	11	6
wet mor	6	2-4	0-2	78	65
moist mull	~3	0.5-1	7-9	9	22
moist moder	5	1-1.5	4-5	27	37
moist mor	~2	~2	<0.1	>95	50
dry & fresh mull	<5	0.5-1	4-10	8-12	21-24
dry & fresh moder	~4	0.5-1	3-7	18-22	35
dry & fresh mor	4	1-2	<0.1	>95	45-65

decrease in HC fertility of *mor* types is caused by the processes of SOC eluviation from topsoil into subsoil and its sequestration in a non (or hardly) utilisable form. Although HC types of automorphic soils form approximately 23% by superficies, their HC SOM pools are only ~12%.

The weighed averages of SOC contents (g kg^{-1}) in different soils (Figure 3) are received by dividing SOC pools to fine earth mass (Kõlli, Ellermäe 2003). Presenting this data on soil matrix table enables us to compare SOC retaining capacity of different soils' HC, as well as of eluvial (E, Ea) and illuvial (B, BC) horizons. For comparing SOC sequestration in arable and forest soils, the SOC concentration of arable soils A horizons are also presented there. Although the SOC concentrations of forest soils is noticeably higher, it must not be forgotten that in forest soils the thickness of HC is commonly lower and as a result the SOC pools in HC and SC may be approximately similar. The nitrogen content in soil correlates very tightly with SOC contents. Only *gleyic* and *Gleysols'* SOC and SOM pools are prevalently higher in forest soils.

The generalised data on SOM pools (Mg ha^{-1}) in FF, HC and SC is presented in Figure 4. It reveals that forest soil SOM retaining capacity is higher than in arable soil, but we must be very careful with the in-

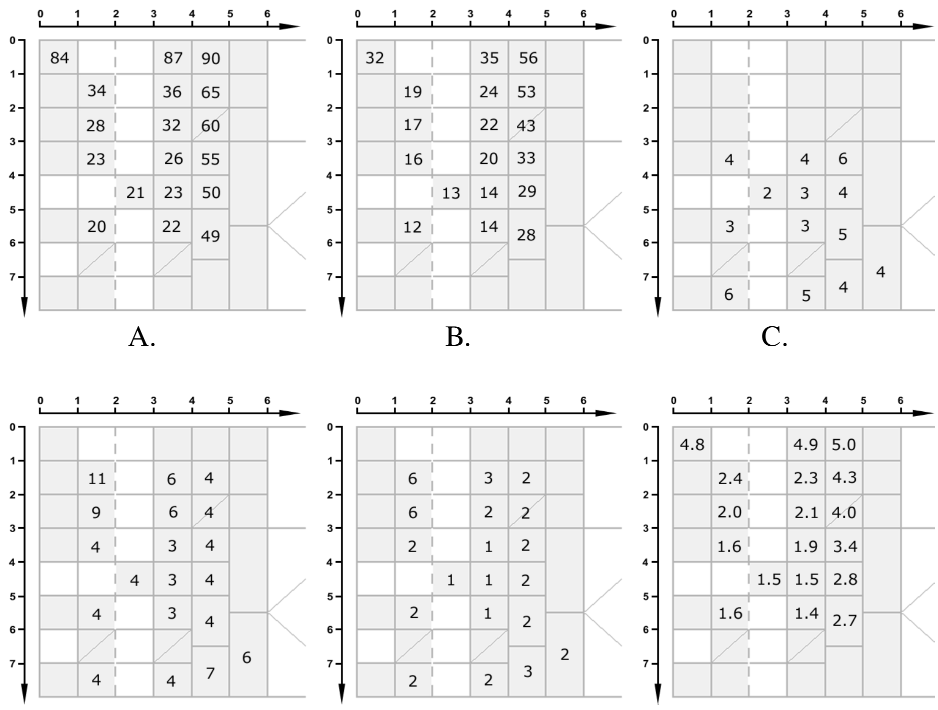
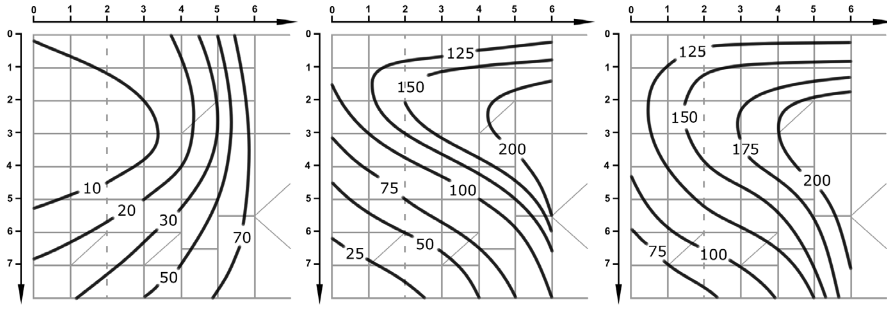


Figure 3. SOC content (g kg^{-1}) in soil cover by soil types and diagnostic horizons.
A. A (or AT) horizons of forest soils; B. A horizons of arable soils; C. E and Ea horizons; D. B horizons; E. BC-horizons; F. – N content (g kg^{-1}) in A (or AT) horizons of forest soils



A. B. C.

Figure 4. Isolines of generalized SOM pools in postlithogenic forest soils.
A. SOM pools in forest floor (Mg ha^{-1});
B. SOM pools (Mg ha^{-1}) in humus cover;
C. SOM pools (Mg ha^{-1}) in soil cover.

terpretation of this phenomenon and we must not decide only after SOC and SOM concentration, but first of all on the basis of SOC or SOM pools. As was elucidated in many works, the SOC and SOM retaining capacity depends on soil moisture regime, physical clay and carbonate content in fine earth, and soil management activity. The land use and/or tillage technology have substantial influence mainly on humus status of superficial soil layers (or HC). SOM sequestration of subsoil depends first of all on the thickness of SC or pedon depth. In mineral subsoil more than 50 Mg ha^{-1} SOM may be found. This SOM may be treated as buried resource in prevailing cases. But in certain situations it is a possibility for the sequestration of additional CO_2 into the soil.

Conclusions

For each forest soil type the certain organic carbon (or organic matter) retaining capacity is characteristic, depending on soil moisture regime as well as on its carbonate and clay content. Differences between the soil types in humus status and tendencies of its changes in soils are clearly visible on the background of soil matrixes.

Organic carbon and organic matter contents and pools in forest floor, humus cover and soil cover are soil type specific, but they may vary to a great extent, depending on variation of individual site specific soil properties. Humus status indices of different soil types may be used as benchmarks in the arrangement of sustainable land use from the pedocentric (soil based) viewpoint.

In Estonian forest soils 314.7±27.1 Tg soil organic carbon is sequestrated, which is accumulated into 602±51 soil organic matter (forest floor, humus, raw humous material, peat) situated in different soil layers. 57% of this is situated in the more active layer or in humus cover and 43% in subsoil, having a very long turnover period.

Humus covers (*moist&fresh&wet&dry mull&moder*) with good edaphic properties form 38-40% of total forest soils. The main constraints of dominating HC type (*peaty&peats*) is excess of water, which causes absence of dissolved oxygen in soil and unfavourable soil environment for biological activity. Some wet humus covers (*eutrophic peat*, *peaty mull&moder,* form ~20%) have high potential productivity, but they must be managed in a way, which promotes the formation of sustainable regimes reduced utilisation of previously sequestrated SOC.

Controlled sustainable management of soils with additional CO_2 sequestration into the soil cover is based on adequate information about carbon retaining capacity of different soil types, as well as on monitoring of their actual humus status and using suitable soil management technology.

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ЗАПАСЫ ОРГАНИЧЕСКОГО УГЛЕРОДА В ЛЕСНЫХ ПОЧВАХ ЭСТОНИИ

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Резюме

В работе на основе базы данных ПЭДОН и КАТЭНА приводятся данные о содержании органического углерода в 20-ти группах лесных почв Эстонии. Данные о запасах органического углерода почв (Мг/га) аккумулированных в лесной подстилке, гумосовом покрове и почвенном покрове приведены для автоморфных (11 групп), гидроморфных минеральных (6 групп) и гидроморфных органических (3 группы) почв. Выяснилось, что общие запасы органического углерода, аккумулированные в почвенном покрове лесных земель Эстонии (2015,7 тыс. га.) составляет 314,4 $\pm$ 27,1 Тг, из которого 57,1% находятся в гумусовом покрове, а 42,9% в подпочве. В лесной подстилке, как верхней части гумусового покрова, аккумулировано всего 13,9% органического углерода. Названное количество органического углерода зафиксировано в составе почвенного органического вещества (всего 602 $\pm$ 51 Тг), свойства которого существенно различаются (гумус, торф, подстилка и др.) в зависимости от типа почв. Обобщенные характеристики гумусового состояния почв, а также выявленные экологические закономерности представлены в матричной таблице постлитогенных почв. Экологическая оценка гумусового покрова лесных почв, а также роль типов разных гумусовых покровов в общем запасе органических веществ почвы выражена при помощи классификации гумусовых покровов лесных почв Эстонии.

Ключевые слова: лесные почвы, гумусное состояние почв, тип гумусного покрова, матричная таблица постлитогенных минеральных почв, запасы органического углерода почв, сегестрация углерода