Humus status of postlithogenic arable mineral soils

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Abstract. In the work soil organic carbon (SOC) and soil organic matter (SOM) contents of Estonian postlithogenic mineral arable soils are analysed by 13 soil groups, whereas the data are taken from the database PEDON. The SOC and SOM concentrations (g kg^{-1}) and pools (Mg ha^{-1}) for *Leptosols, Cambisols* (3 groups), *Luvisols* (2 groups), *Albeluvisols* (3 groups) and *Gleysols* (4 groups) are presented separately for humus cover (HC) and soil cover (SC). On the basis of different soil type characteristics and their distribution, superficies the SOC and SOM pools for the whole Estonian arable land were calculated. It was revealed that in the studied part of Estonian arable soils or in arable SC (forming 85.8% of total arable land) 86.4 ± 13.1 Tg of organic carbon is sequestrated, from which 77.3% is situated in HC and 22.7% in subsoil. This quantity of SOC is sequestrated into 149 ± 25 Tg SOM. The generalisation of the data received by different soil types, as well as elucidation of pedoecological regularities is performed on the background of Estonian postlithogenic soil matrix. The characterisation of HC quality is done on the basis of arable soils HC classification.

Key words: arable soils, soil humus status, humus cover type, carbon sequestration, SOC and SOC concentration and pools, matrix of postlithogenic soils

INTRODUCTION

The soil organic matter (SOM) is considered to be the most important factor for many features connected with soil: soil forming, its development and continuous functioning (Paustian et al., 1997; Smith et al., 1997; West & Post, 2002). In the present work the role of SOM from the soil humus status aspect is discussed (Kõlli & Kanal, 1995).

The humus status of soil is by its essence functioning of a soil in relation (concordance) to the organic matter or the peculiarity of organic matter flow throughout the soil cover. Humus status embraces a certain sequence of features, beginning with falling (accession) of dead organic matter (or litter) on the surface or into a superficial layer of soil. The flow is continued with the processes of breakdown, decomposition and transformation of SOM. It ends with the processes of SOM disappearance from the soil via its utilisation by soil edaphon (organisms, as the actively acting part of a soil) in nutrition chains, via complete mineralisation or via illuviation into different kinds of B horizons or into other non-actively functioning horizons. Only few flow processes connected with SOM were mentioned above. Depending on the ecological conditions, each soil type has certain differences in the so-called three net (link) chain of flow (input => acting => output). The SOM quantities, acting intensity of soil edaphon, SOM residence time in soil and other parameters and features characteristic to certain soil types may differ (Kern et al., 1997; Percival et al., 2000, Gijsman et al., 2002). But there also exist differences in input composition (biochemical, ash content), input dynamics, characteristics of deposition, soil previous-present status, etc. Several differences among different soils exist also in the interaction of SOM with edaphon, as well as with soil's solid, liquid and gaseous phases. As a result of this, the SOM may be sequestrated in very different forms and states (Falloon et al., 1998; DeBusk et al., 2001; Shaffer & Ma, 2001), the characteristics of which can be reflected by humus cover types (Kõlli, 1994) or with parameters of humus quality. Extremities of processes in this (the latter) net of chain reach from complete mineralisation to resting into non-decomposed state (peat of raised bogs). But between these two extremities very different types of humus and very varying transformation processes may exist. It is understandable that ecological processes taking place with SOM are also connected with microsites of soil matrix, but these features are studied on micro scale level (physically very strongly bind humus to very easily or quickly disappeared or used by edaphon SOM).

Long history of SOM researches demonstrates a number of approaches in this area (Batjes, 1998; Rusco et al., 2001; Halvarson et al., 2002; Kimble et al., 2002). Among others, researches connected with quantification SOM or soil organic carbon (SOC) flow and sequestration in soil cover are very popular (Kern, 1994; Smith et al., 1997; Bernoux et al., 2002; Nemeth et al., 2002; Zhou et al., 2003). In the current work research was carried out on macro-morphological level, using quantitative approach, which means that soils' profiles were characterised by their horizons, from which the samples reflecting the soil mean properties were taken.

The main task of the work is: (1) to analyse SOC and SOM contents (concentration by mass) and pools in Estonian postlithogenic mineral arable soils; (2) to analyse the role of humus cover, soil cover and subsoil in SOC and SOM turnover on mineral arable soils and (3) to elucidate some pedoecological regularities of arable soil humus status on the basis or in the framework of Estonian postlithogenic mineral soil matrix and of SOM management.

MATERIALS AND METHODS

In the present work, only the humus status of postlithogenic mineral soils of Estonian arable soils is treated. Postlithogenic mineral soils (Fridland, 1982) are not influenced by sediments accumulation transported aside or elimination of soil material from superficial layer i.e. they are formed in normal soil forming conditions. In 1993 arable soils formed 25% or ~1.1 million hectares of the total area. Arable land divisions from different aspects are shown on Fig. 1. Postlithogenic mineral soils studied in this work form 85.8% of the total arable land. The rest of the area belongs to synlithogenic soils (5.6 %) and *Histosols* (8.6%).

The quantitative characteristics of soils originate from soil profile horizons database PEDON, which contains data of 159 experimental areas founded on arable soils. Among these are 113 areas, which are situated on postlithogenic mineral soils and the profiles of which are relatively completely quantified. These areas were regularly surveyed from agricultural and environmental aspects. The database was formed mainly during 1967–85, but was updated in 1986–95, as well as in 1999–2002. In this work the data on SOC, SOM, bulk density, particle size distribution and total nitrogen content of humus or arable horizon (A), as well as raw humuous (AT), histic (T), eluvial (E) and illuvial horizons (B) were used. The SOC and humus content were determined by the Tjurin method (Arinouskina, 1970). The particle size distribution of fine earth was estimated by pipette method according to Kachinsky (1965). The role of rock fragments in different horizons was determined in the course of field works by their volume. The concentrations of SOC and SOM, bulk density and other properties were determined by soil horizons (in some cases also by 5-cm layers). The pools of SOC and SOM of different soil types were estimated in two soil cover layers: (1) in the humus cover (HC) or epipedon, which consists mostly of arable horizon, only on *Gleysols*, it may contain raw humuous and/or peaty *(histic)* materials and (2) in the soil cover (SC) or solum, whose depth reaches from the surface to the unchanged parent material, composed therefore from HC and subsoil. Generally the thickness of HC is determined by the depth of border between B and C horizons. In the presence of BC horizon, the HC thickness was measured from the surface to the middle of BC horizon. The main quantitative parameters of soil humus status are humus cover thickness and morphology, as well as SOC and/or SOM content and pools, and humus cover quality. For characterisation of humus cover quality, the humus cover classification of arable soils elaborated for Estonia was used (Kõlli, 1994). The type of humus cover reflects the complexity of soil humus status. The SOC and SOM pools were determined on the basis of soil bulk density.

For the calculation of means and for the analysis of variance, the PC program MS Exel 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 is shown on Fig. 2. This matrix embraces all Estonian postlithogenic mineral soils, whereas this matrix was also used for the generalisation of data on SOC, SOM, total N and others by different soil types, as well as for different layers of postlithogenic minerals by soil profiles.

RESULTS AND DISCUSSION

Thickness of arable soils HC depends on tillage technology, and in most cases in normal moisture conditions it is in average between 25–29 cm with standard deviation 5–8 cm (Table 1) or with coefficient of variability 19–32%. Only on *Gleysols* and *Leptosols,* the average depth of HC may be lower. Thickness of arable soils SC is mostly between 70 and 90 cm. Thinner than this are of course *Leptosols,* little developed *Cambisols (calcaric)* and *Gleysols* having reduction conditions in subsoil.

SOC and SOM pools in HC and SC were calculated by summing data of individual profiles where for each horizon of each profile carbon and humus content was determined from soil samples taken during field research. At the same time, bulk density samples were taken only approximately from one third of profiles and horizons. Later this information was generalised and used in the calculation of pools. In arable soils with normal moisture regime, SOC pools are between 46 and 63 Mg ha^{-1}, being little higher in soils, where both carbonate and clay contents are higher (Table 2). Higher than that are SOC as well as SOM pools in *Rendzic Leptosols* and in different endogleyed soils. In the highest limits, varying contents of SOC and SOM are characteristic to different kinds of Gleysols. The highest pools are characteristic to *Histic Gleysols,* whose HC composed being at different stages of decomposition (*fibric, hemic, sapric)* peat. If, according to Tjurin, in mineral layers the organic carbon content of SOM is approximately 58%, in *histic* horizons it is much lower, being an average 50%. Results of ANOVA (coefficient of variation CV) show that SOC and SOM pools in soils with *udic* moisture conditions are relatively stable, as their pools by different soils vary by 22–40% according to average characteristics. At the same time, the pools as well as concentrations of SOC and SOM may vary to a large extent in different *Gleysols* (CV – 54–76%).

In Estonia there have always existed problems of transformation of lands from one purpose to another, but recently it has become prevalent to leave more and more arable land into an unused state or to transform it into forestland. In 1993, arable soils formed 25% or 1,130800 hectares of the total area. In 2003 only 72% of arable soils were used in total. At the same time, it is well known that properties of soils do not change quickly, as the changes in soil properties take several years to become real forest or grassland soil. For this reason, in our work the bases for calculation are SOC and SOM stocks sequestrated in arable land soil cover, the superficies of arable land taken equal to its existing maximum, which is approximately ~1.1 million hectares. Such quantity of arable land superficies existed during more than 20 years. Postlithogenic mineral soils form 85.8% of this area (Fig. 1A). Therefore the soils studied form approximately 21.4% of the total Estonian territory.

In calculation of SOC and SOM pools, the data on soil distribution by R. Kokk (1995) were used. Table 3 demonstrates the role of different arable soil groups in SOC sequestration. Analogously to total pools of SOC, SOM pools were also calculated. The results of both calculations are presented in Table 4. It reveals that in postlithogenic arable mineral soils 86.4 ± 3.1 Tg SOC is sequestrated, which is accumulated in SOM or in humus situated in different soil layers. 77.3 % of it is situated in an active layer or in HC and 22.7% in subsoil. The turnover time of HC organic carbon is much shorter than in subsoil and is controllable by soil management and tillage technology. As great differences exist between arable postlithogenic automorphic (LP, CM, LV and AB), situated mostly on uplands, and hydromorphic or wetland (GL) soils, the generalised humus status data are also provided separately for these two parts in Table 4. The comparison of these two subdivisions of arable soils shows that the subsoil of hydromorphic soils is relatively and also absolutely poorer in SOC and SOM in comparison with automorphic soils. On the other hand, the average contents of SOM in HC of these soils (in Mg ha^{-1}) are very high being approximately 1.5 times richer than in automorphic soils. But the quality of this humus is low from the agricultural viewpoint.

In Estonian arable postlithogenic mineral soils 149 ± 25 Tg organic matter is accumulated, from which the prevailing part (2/3) is humus. In the soils researched, the peat share was low, as in course of land reclamation instead of *Histic Gleysols* peat horizons the humus horizons had started to form. Different types of peat may be found to a large extent in *Histosols*, which form 8.6% of arable lands. In the nearest future, when probably more precise soil varieties distribution data, as well as humus data of *Histosols* and synlithogenic soils will be available, the pools calculated in Tables 3 & 4 may be updated.

When comparing sequestrated arable land soil cover SOC and SOM in Estonia with other regions of the world (Kern, 1994; Bernoux et al., 2002; Zhou et al., 2003 and others), the character of Nordic area is revealed, where soil cover is relatively thin and poor in humus (Tables 2 & 3). Though SOM pools in Gleysols are relatively high in comparison with *Phaeozems* and *Chernozems* (Nemeth et al., 2002), they are very different from those by the quality of humus being unstable and chemically unsaturated.

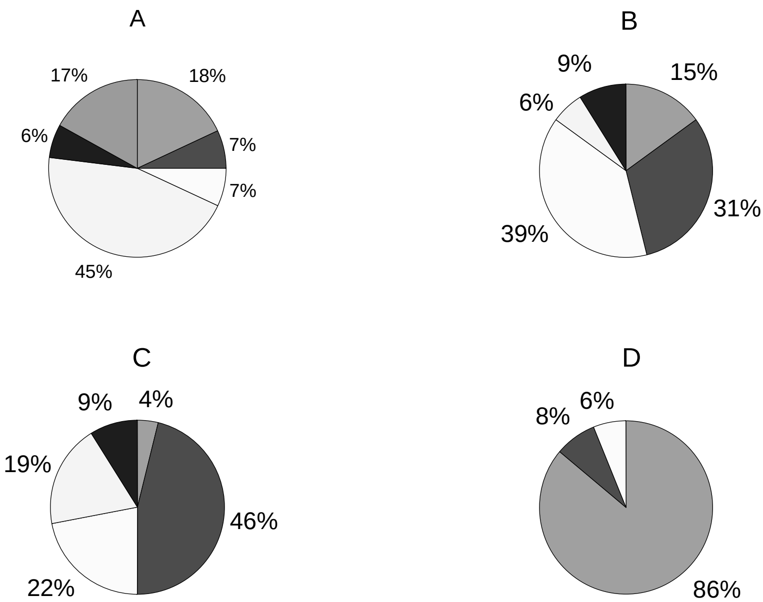

Fig. 1. Land use and characterisation of arable soils in Estonia.

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 – 15%; sandy loam – 31%; loamy – 39%; cleyey – 6%; peaty – 9%.

C. Moisture regime: dry, aridic – 4%; fresh or normal, udic – 46%; reclamated moist, endogleyic – 22%; reclamated wet mineral, epigleic, aquic – 19%; reclamated wet peaty, histic – 9%.

D. Distribution of soils by soil matrices: postlithogenic mineral soils – 86%; postlithogenic organic soils – 8%; synlithogenic soils – 6%.

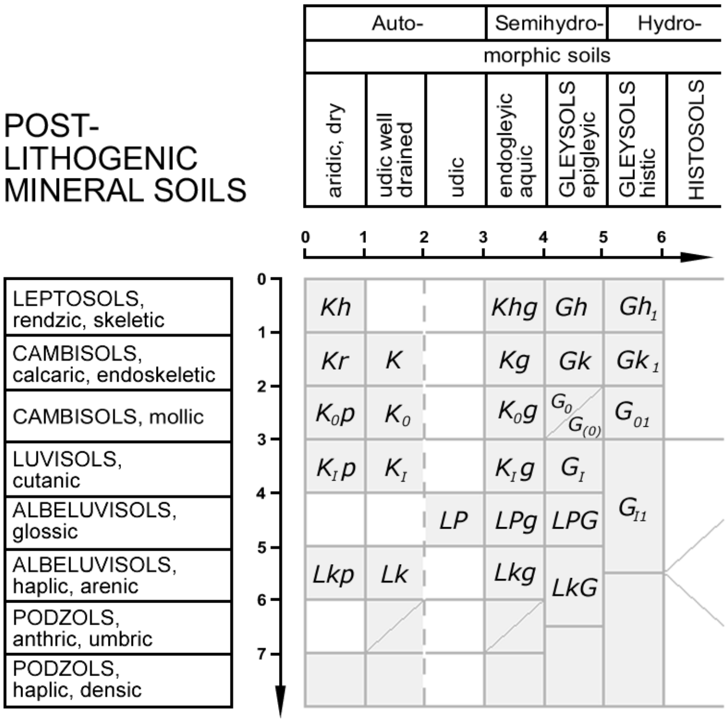

Fig. 2. Correlation of Estonian postlithogenic arable mineral soils with WRB.

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); 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); 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). Remarks: 1) Estonian soil names in direct translation are given in brackets; 2) Two last rows belonging to forest soils and the last column belonging to organic soils are not presented here.

Meanings of additional letters in codes: p – aridic - drought timid; g – endogleyic - gleyed; 1 – histic - peaty.

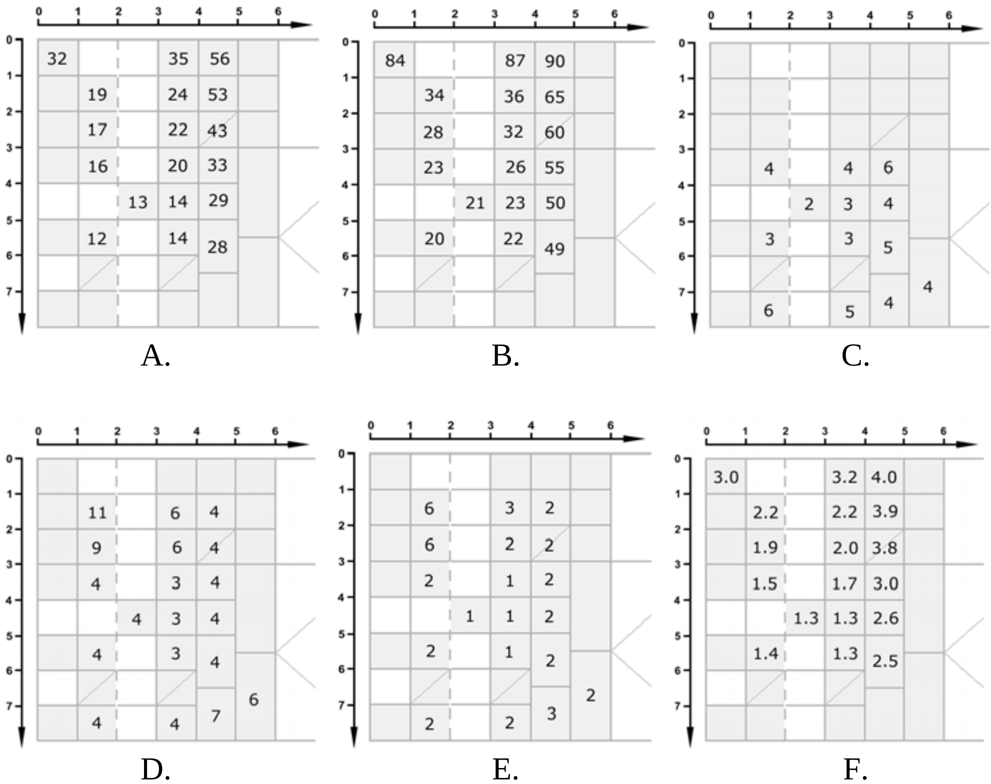

Fig. 3. SOC content (g kg^{-1}) in soil cover by soil types and diagnostic horizons. A. A horizons of arable soils; B. A horizons of forest soils; C. E and Ea horizons; D. B horizons; E. BC-horizons; F. – N content (g kg^{-1}) in A horizons of arable soils.

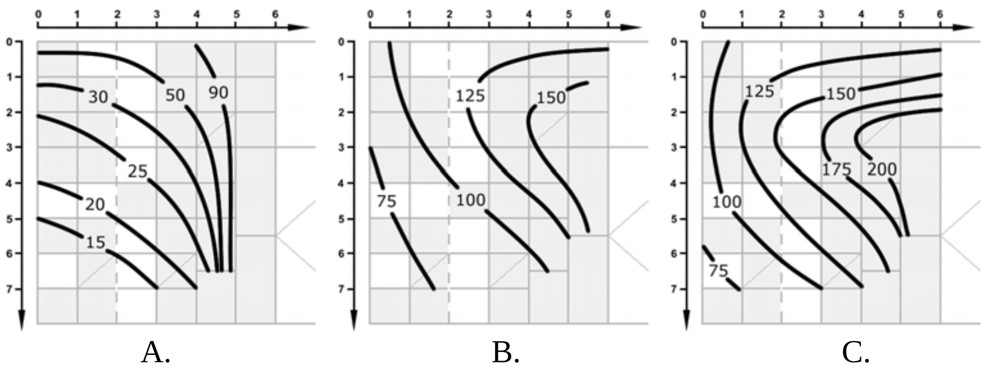

Fig. 4. Isolines of generalised SOM contents and pools in postlithogenic arable mineral soils.

A. SOM content in arable layer of soil (g kg^{-1}); B. SOM pools (Mg ha^{-1}) in humus cover; C. SOM pools (Mg ha^{-1}) in soil cover.

Table 1. Studied postlithogenic mineral soil groups on arable lands of Estonia.

Soil group names	Soil code by WRB	% from arable land*	n	Depth (M ± SD), cm	
				HC	SC
Glossic & Gleyiglossic Albeluvisols	AB gs gsg	21.3	13	26 ± 6	93 ± 8
Mollic &Endogleyic Cambisols	CM mo gln	14.5	26	29 ± 7	56 ± 18
Cutanic &Endogleyic Luvisols	LV ct gln	13.5	8	27 ± 5	74 ± 20
Mollic & Calcic&Eutric Gleysols	GL mo cc eu	10.3	6	22 ± 4	38 ± 15
Calcaric & Endoskeletic Cambisols	CM ca skn	11.1	20	27 ± 5	36 ± 11
Luvic & Epidystric Gleysols	GL lv dye	5.8	4	26 ± 5	54 ± 22
Hapli & Endogleyic Albeluvisols	AB ha gln	5.2	21	25 ± 8	73 ± 15
Saprihistic Gleysols	GL his	2.5	1	18	33
Spodic & Dystric Gleysols	GL sd dy	0.8	2	23	100
Rendzic & Skeletic&Gleyic Leptosols	LP rz sk gl	0.8	12	21 ± 4	22 ± 6

- by Kokk, 1995

Table 2. SOC and SOM pools (M ± SE) in postlithogenic arable mineral soils.

Soil code by WRB	n	SOC pools Mg ha^{-1}		SOM pools Mg ha^{-1}	
		HC	SC	HC	SC
LP rz sk gl	12	77 ± 9.0	78 ± 10.3	129 ± 14.0	131 ± 5.5
CM ca skn	20	59 ± 3.0	68 ± 4.1	103 ± 5.0	117 ± 6.7
CM mo	20	63 ± 5.2	94 ± 7.6	109 ± 8.9	162 ± 12.9
LV ct	4	56 ± 8.4	84 ± 8.6	96 ± 14.3	146 ± 14.8
AB gs gsg	13	49 ± 3.8	69 ± 3.9	83 ± 7.3	116 ± 7.3
AB ha	15	46 ± 7.1	74 ± 7.9	79 ± 12.4	127 ± 13.5
CM gln	6	86 ± 16.8	120 ± 17.6	149 ± 29.0	206 ± 30.4
LV gln	4	68 ± 13.0	100. ± 19.0	117 ± 22.9	173 ± 33.4
AB gln	6	58 ± 7.0	81 ± 9.0	100 ± 12.0	138 ± 15.7
GL mo cc eu	6	74 ± 17.3	83 ± 17.9	127 ± 30.0	142 ± 30.7
GL lv dye	4	131 ± 49.7	144 ± 44.7	224 ± 85.3	247 ± 76.4
GL sd dy	2	34	53	58	92
GL his	1	189	194	378	386

Table 3. SOC pools (M ± SE) in postlithogenic arable mineral soils.

Soil code by WRB	% of area	Area in 10^3 ha	Total pools in Gg		SE of pools Gg	
			HC	SC	HC	SC
LP rz sk gl	0.8	9.0	693	702	81	93
CM ca skn	11.1	125.5	7405	8534	377	515
CM mo	9.7	109.7	6911	10312	570	834
LV ct	6.3	71.2	3987	5981	598	612
AB gs gsg	21.3	240.9	11804	16622	915	940
AB ha	3.3	37.3	1716	2760	265	295
CM gln	4.8	54.3	4670	6516	912	956
LV gln	7.2	81.4	5535	8140	1058	1547
AB gln	1.9	21.5	1247	1742	151	194
GL mo cc eu	10.3	116.5	8621	9670	2015	2085
GL lv dye	5.8	65.6	8594	9446	3260	2932
GL sd dy	0.8	9.0	306	477	152*	438*
GL his	2.5	28.3	5349	5490	2674*	2745*

* SE is taken equal to 50% of mean.

Table 4. Generalized data on SOC and SOM content in Estonian postlithogenic arable mineral soils.

No.	Characteristic	Unit	Upland or automorphic soils (9)	Wetland or hydromorphic soils (4)	All postlithogenic soils
1.	Percent from total arable area	%	66.4	19.4	85.8
2.	Superficies	10^3 ha	750.8	219.4	970.2
3.	SOC pools in soil cover	Tg	61.3 ± 5.1	25.1 ± 8.0	86.4 ± 13.1
	- from that in humus cover		44.0 ± 4.9	22.8 ± 8.1	66.8 ± 13.0
	- from that in subsoil		17.3	2.3	19.6
4.	Average SOC pools in soil cover	Mg ha^{-1}	81.7 ± 6.8	114.3 ± 36.5	89.0 ± 13.5
	- from that in humus cover		58.6 ± 6.6	104.2 ± 36.9	68.9 ± 13.4
	- from that in subsoil		23.1	10.1	20.1
5.	SOM pools in soil cover	Tg	104.9 ± 10.3	44.5 ± 14.4	149.4 ± 24.8
	- from that in humus cover		75.6 ± 8.7	40.7 ± 14.7	116.3 ± 23.4
	- from that in subsoil		29.3	3.8	33.1
6.	Average SOM pools in soil cover	Mg ha^{-1}	139.8 ± 13.8	202.8 ± 65.7	154.0 ± 25.5
	- from that in humus cover		100.7 ± 11.5	185.5 ± 67.0	119.9 ± 24.1
	- from that in subsoil		39.1	17.3	34.1

Table 5. Humus cover (HC) types of arable postlithogenic mineral soils.

HC types	% fromarable soils	SOC in HCg kg^{-1}	SOC in HCkg m^{-2}	SOC in SCkg m^{-2}
eluvic moder humous	27–30	12–15	5–8	7–11
neutral mild humous	15–17	15–20	6–8	7–12
eutrophic organo-mineral	11–13	30–120	8–10	8–13
acid low humous	7–10	6–9	3–5	4–7
pebble mild humous	5–7	26–32	6–8	6–8
mesotrophic organo-mineral	5–7	20–60	6–7	9–12
dry calci-humous	2–3	23–30	5–6	5–6
fulvic low humous	~ 2	9–14	4–6	6–8
dry neutral-humous	< 2	12–15	4–5	5–6
oligotrophic organo-mineral	< 1	15–40	5–6	6–8

Characteristics of humus quality are presented in Table 5, where rough estimation of different arable soils HC types share is shown. One quarter to one third of arable soils have eluvic moder humuous HC, which in most cases is moderately acid and needs periodical liming. Relatively low humus and carbonate content in this type of HC causes the forming of moderate to weak soil structure and these arable soils need amelioration of their humus status. The best agronomic properties are characteristic of neutral mild humuous HC type, which forms 1/6 of arable land. Approximately the same share of HC is organo-mineral, from which the best ones (*eutrophic organo-mineral*) are well humified, with neutral reaction, rich in nutrition elements and formed on *Gleysols* rich in carbonates. The only constraint of pebble mild humous HC is a high content of coarse soil particles, which may hinder tillage of the soil. This information demonstrates also very clearly that the largest pools of SOC, and consequently also of SOM matter, are characteristic of *Albeluvisols* and *Luvisols* soil covers due to remarkable SOC retaining capacity of their subsoil layer. This phenomenom is caused by processes of SOC eluviation from A horizon and its illuviation into B horizon.

Calculation by dividing SOC pools to fine earth mass SOC concentrations (g kg^{-1}), presented on Fig. 3, enables to compare SOC retaining capacity of different soils into HC, as well as into subsoil, i.e into the eluvial and illuvial horizon of a soil cover, or of the whole soil profile. Remarkable concentration of SOC and SOM may be found in eluvial (E, Ea) horizons. Much more than E and Ea horizons have accumulated into different kinds of B horizons. Accumulated organic carbon and organic matter in BC horizons area also worth attention. For comparing SOC sequestration character in arable and forest soils, the SOC concentration of forest soil A horizons was also extracted from the database PEDON. These data demonstrate noticeably higher SOC retaining capacity of forest soils. But it must not be forgotten that in forest soils the thickness of HC is lower and, as a result of this, the SOC pools in HC and SC may be approximately on the similar level. On the same figure the contents of total nitrogen are presented. Nitrogen contents correlate very tightly with C contents. But there is little increase in C:N ratio changing from *udic* soil regime to epigleyic soils or *Gleysols* (increasing from 10.0–10.3 to 11.0–11.3). This is probably connected with the lower (earliest) stage of humification in organo-mineral humus covers. At the same time the C:N ratio decreases (data not presented here) in the direction of deeper parts of a soil profile. It seems that subsoil horizons contain always a little more extra organic matter nitrogen than superficial layers.

Generalised data about SOM concentration (g kg^{-1}) and pools (mg ha^{-1}) in HC and SC are presented on Fig. 4. It reveals that arable soil SOM (mostly humus) retaining capacity depends first of all on three factors, which are soil moisture regime, carbonate content in soil mineral part and physical clay content in fine earth. As was demonstrated above, land use and/or tillage technology have a very substantial influence to soil humus status, but this influences only superficial layers of soils. Subsoil SOM sequestration depends first of all on the thickness of SC or pedon depth. In certain cases subsoil is accumulated into *Luvisols* and *Albeluvisols* by more than 50 Mg ha^{-1} SOM. It must be mentioned that the SOM does not participate actively in soil functioning and may be dealt with as a buried resource. But from the other hand, in certain situations additional sequestration of carbon or CO_2 into the soil is needed. One way to do this is to increase soil productivity, then accumulate the formed potential into green phytomass, which afterward is used to increase SOM pools in deeper (underneath the most actively functioning soil layers) horizons. Another way is deep ploughing which disposes SOM rich layer mechanically into less functioning layers, due to which the matter is protected from decomposition or sequestrated in soil for a long period.

CONCLUSIONS

For each postlithogenic arable mineral soil certain humus and soil organic carbon retaining capacity is characteristic, depending on its tillage activity, moisture regime, and carbonate and clay content. Differences between soils are clearly visible on the postlithogenic soil matrix, where they are presented by isolines.

SOC and SOM contents and pools in HC and SC are soil-type specific, but they vary to a great extent, depending on variation of individual soil properties. Characteristics of soil type humus status indices may be used as benchmarks in arrangement of sustainable land use from the pedocentric viewpoint.

In postlithogenic arable mineral soils 86.4 ± 13.1 Tg soil organic carbon is sequestrated, which is accumulated in 149 ± 25 soil organic matter or in humus situated in different soil layers. 77.3% of this (SOC and SOM) is situated in the more active layer or in HC and 22% in subsoil, which has a very long turnover period.

The quality of arable soil humus cover is characterised by humus cover types. With good agronomical properties, neutral and pebble mild humus covers form 20–24% of total arable soils. The main constraints of dominating HC type (eluvic moder humous 27–30%) are high acidity and a low humus content. Different organo-mineral humus covers (16–20%) have high potential productivity, but they must be managed in a way promotes formation of a stable well-humified humus horizon from them.

Controlled by sustainable management, 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 their actual humus status.

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REFERENCES

Arinoushkina, E. V. 1970. *Instructions for Chemical Analysis of Soils*. Moscow University, Moscow (in Russian).

Batjes, N.H. 1998. Mitigation of atmospheric CO_2 concentrations by increased carbon sequestration in the soil. *Biol Fertil Soils,* **27,** 230–235.

Bernoux, M., Carvalho, M.C.S., Volkoff, B. & Cerri, C.C. 2002. Brazil's soil carbon stocks. *Soil Sci. Soc. Am. J.,* **66,** 1888–1896.

DeBusk, W.F., White, J.R. & Reddy, K.R. 2001. Carbon and nitrogen dynamics in wetland soils. M.J. Shaffer, L.Ma & S. Hansen (Eds.). *Modeling carbon and nitrogen dynamics for soil management*. Lewis Publishers, Boca Raton, Florida, 27–53.

Falloon, P.D., Smith, P., Smith, J.U., Szabo, J., Coleman, K. & Marshall, S. 1998. Regional estimates of carbon sequestration potential: linking the Rothamsted Carbon Model to GIS databases. *Biol Fertil Soils,* **27,** 236–241.

FAO, ISRIC & ISSS. 1998. *World Reference Base for Soil Resources*. World Soil Resources Reports 84. Rome.

Fridland, V. M. 1982. *Main principles and elements of soil classification bases and work programme for their creation.* Moscow (in Russian).

Gijsman, A.J., Hoogenboom, G., Parton W.J. & Kerridge, P.C. 2002. Modifying DSSAT crop models for low-input agricultural systems using a soil organic matter-residue module from CENTURY. *Agron. J*., **94,** 462–474.

Halvorson, A.D., Wienhold, B.J. & Black, A. 2002. Tillage, nitrogen, and cropping system effects on soil carbon sequestration**.** *Soil Sci. Soc. Am. J.* **66,** 906–912.

Kachinsky, N. A. 1965. *Soil Physics*, vol I. Moscow State University, Moscow (in Russian).

Kern, J.S. 1994. Spatial patterns of soil organic carbon in the contiguous United States. *Soil Sci. Soc. Am. J.,* **58,** 439–455.

Kern, J.S., Turner, D.P. & Dodson, R.F. 1997. Spatial patterns od soil organic carbon pool size in the Northwestern United States. R. Lal, J.M. Kimble, R.F. Follett, B.A. Stewart (Eds.) *Soil processes and the carbon cycle.* CRC Press, Boca Raton, Boston, NY, Washington, London. 29–43.

Kimble, J.M., Lal, R. & Follett, R.F. (Eds.). 2002. *Agricultural practices and policies for carbon sqeuestration in soil.* CRC Press, Boca Raton, London, New York, Washington.

Kokk, R. 1995. Distribution and Properties of Soils. In *Estonia. Nature*, (Raukas, A., ed.) pp. 430–439. Valgus, Tallinn.

Kõlli, R. 1994. Classification of Arable Soil Humus Cover. *Transactions EAU*., **178,** 82–86.

Kõlli, R. & Kanal, A. 1995. Humus status of arable *Podzoluvisols* and the role of annual litterfall in its formation. *Z. Pflanzenernähr. Bodenk.*, **158**, 235–241.

Nemeth, T., Micheli, E. & Paszton, L. 2002. Carbon balances in Hungarian soils. J.M. Kimble, R. Lal, R.F. Follett (Eds.) *Agricultural practices and policies for carbon sequestration in soil,* pp. 449–457.CRC Press, Boca Raton, London, New York, Washington.

Paustian, K., Collins, H.P. & Paul, E.A. 1997. Management controls on soil carbon. E.A. Paul, K. Paustian, Elliott, E.T., Cole, C.V. *Soil organic matter in temperate Agroecosystems*. Long-term experiments in North America. CRC Press, Boca Raton, New York, London, Tokio. 15–49.

Percival H.J., Parfitt, R.L. & Scott, N.A. 2000. Factors controlling soil carbon levels in New Zealand grasslands: Is clay content important. *Soil Sci. Soc. Am. J.* **64,** 1623–1630.

Pulleman, M.M., Bouma, J., van Essen, E.A. & Meijles, E.W. 2000. Soil organic matter content as a function of different land use history. *Soil Sci. Soc. Am. J.* **64,** 689–693.

Rusco, E., Jones, R. & Bidoglio, G. 2001. *Organic matter in the soils of Europe: Present status and future trends.* ESB, IES, JRC, Ispra.

Shaffer, M.J. & L. Ma. 2001. Carbon and nitrogen dynamics in upland soils. M.J. Shaffer, L.Ma, S. Hansen (Eds.). *Modeling carbon and nitrogen dynamics for soil management.* Lewis Publishers, Boca Raton, Florida, 11–29.

Smith, P., Powlson, D.S., Glendining, M.J. & Smith J.U. 1997. Opportunities and limitations for C sequestration in European agricultural soils through changes in management. R. Lal, J.M. Kimble, R.F. Follett, B.A. Stewart (Eds.) *Management of carbon sequestration in soil.* CRC Press, Boca Raton, New York. 143–152.

West, T.O. & Post, W.M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. *Soil Sci. Soc. Am. J.,* **66,** 1930–1946.

Zhou, C., Zhou, Q. & Wang, S., 2003. Estimating and analyzing the spatial distribution of soil organic carbon in China. *Ambio*, **32**,1**,** 6–12.