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Original Research

Carbon Accumulation and Distribution in Profiles of Forest Soils

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Abstract

We studied the soil organic carbon (SOC) and water extractable organic carbon (WEOC) distribution in 22 profiles of forest soils in Poland. The soils in all plots were derived from sand. The bulk density, pH, content of particle sizes <0.02 mm, SOC, and WEOC were determined for each horizon of the soil profiles. The stock of SOC was found to accumulate up to more than 90% in the O, A, E, and B (Bv, Bfe, and Bbr) horizons, down to a depth of 40-50 cm. The same percentage was found for WEOC, in general, in the BvC, BC, and C horizons below 50 cm. The coefficient of correlation between the SOC and WEOC stores in the horizons with a high content of both fractions was 0.725, and it decreased to 0.125 in the horizons with a small content of SOC and WEOC. The SOC accumulation is to a greater extent affected by the site type and the age of pine stand than by the soil type, but stock of WEOC is higher in the Haplic Podzol than in the other types of the examined soils.

Keywords: soil organic carbon, soil dissolved carbon, storage, distribution, soil profile

Introduction

C stocks in forest soils fluctuate from 50 to more than 200 Mg·ha^{-1}, depending on climate and soil conditions [1-5], the age and type of the tree stand [1, 6-8], and management practices [9-11]. Difficulties in comparing results obtained by various authors arise due to C stocks being assessed in layers varying in thickness. Some authors have reported data on C stores down to a depth of 50 cm [9, 11, 12] while others, like Weishampel et al. [8], have reported down to 40 cm. Still others, like Don and Kalbitz [13], have reported C stores down to 60 cm or even 1 m, as did Hughes et al. [6] and Janssens et al. [14], whereas Rumpel et al. [15] and Chiti et al. [16], for example, reported values only for select genetic horizons.

Chiti et al. [16] suggested that C accumulation in forest soils should be assessed in individual genetic horizons in view of their differing properties, while the C stock should be considered as the sum of C accumulation down to a definite depth. The above studies provide evidence that properties of respective horizons, such as density, content of particles <0.02 mm, and Fe and Al contents, affect both stability and solubility of soil organic matter [17-19]. The stability was chiefly considered within the context of stabilization mechanisms, which are largely mediated by soil structure and texture as well as by the content of soluble fractions of organic substances – dissolved organic matter (DOM).

Methods for soil DOM assessment have been widely discussed, as regards both sampling of material for analysis and procedures used for determination of C in the above fraction. Water-soluble organic carbon was determined after extraction with water or other extractants. C content was determined in the sampled material *in situ* (lysimeters) as DOC – dissolved organic carbon [20, 21]. Water was used for DOM extraction in Rees and Parker [20], Fang and Moncrieff [22], Don and Kalbitz [13], Kiikkila et al. [23], and Huang et al. [24], while a 0.5 mM NaCl solution was used by Fröberg et al. [25] and a 5 mM $CaCl_2$ solution by McDowell [26] and Zhao et al. [27].

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Table 1. Description of studied area

Site	Age of stands	Forest floor	Index site, stand quality class	Soil	Site type
Lubsko	70-80	*Cladonia* sp., mosses, cowberry	low, IV	Haplic Podzol derived from sands of fluvial accumulation	Dry pine forest, *Cladonio-Pinetum*
Janów Lubelski	70-80	Mosses, heath, cowberry, bilberry	medium, III	Haplic Podzol derived from fluvioglacial and dune sands	Fresh pine forest, *Peucedano-Pinetum*
Tuchola	70-80	Mosses, cowberry	low, IV/III	Albic Arenosol derived from outwash plain sands	Fresh pine forest, *Leucobryo-Pinetum*
Swornegacie	60-100	Mosses, bilberry, grasses	medium, III	Albic Arenosol derived from glacial sands and gravels	Fresh pine forest, *Leucobryo-Pinetum*
Miłomłyn	100	Bilberry, ferns, grasses	high, II/I	Haplic Arenosol derived from fluvioglacial sands	Mixed coniferous-decidous forest, *Vaccinio-Piceetum*

Stand quality class, from I to IV, i.e. growing stock from 100 to 450 m^3/ha for ca. 100 year old pine.

Rees and Parker [20] compared procedures for sampling the soluble fraction of soil organic substances, with regard to their effect on the content of DOC. The authors compared the results with regard to the content of DOC/WEOC in solutions under varying conditions such as, among others, soil pre-incubation (10 days, at 20ºC, in the dark); duration of reaction between the extractant (deionized water) and the soil; filtering and centrifuging of solutions; and centrifuging time and speed. The results for soil DOC content, obtained with the use of different procedures, were found to vary, but no significant differences were revealed [20].

The aim of this study is to evaluate the stores of organic and soluble C in 1m deep soil profiles under coniferous forests in Poland, with regards to soil types, as well as to determine the involvement of each horizon in that stock, i.e. the distribution of C in the soil profile.

Materials and Methods

Study Sites

The study was conducted on five plots located within coniferous forest sites at the Lubsko, Tuchola, Janów Lubelski, Swornegacie, and Miłomłyn sites (Fig. 1). The soil-vegetal cover in these plots has been described in detail in earlier works [28, 29]. Soils in all of the plots were derived from sands. Sites of coniferous forests (dry and fresh) were mainly represented by mature pine stands, while those of mixed forests were mainly represented by older pine stands (about 100 years old), with an admixture of deciduous species, including oak and beech (Table 1).

Species structure and composition in the plots was shown to be typical of the above sites, based on the plant sociological analysis of the herbaceous layer. Lichens dominated the forest floor at the dry coniferous forest sites; mosses were dominant at the fresh coniferous forest sites, with a considerable share of bilberry (*Vaccinium myrtillus*); and herbaceous plants were dominant at the mixed forest sites (Table 1).

Methods

Between two to eight soil profiles were sampled in each of the plots. Lubsko, Tuchola, Janów Lubelski, and Swornegacie plots embrace 100-200 ha pine stands growing on soils derived from loose sands. Both forest and soil types show little diversity in these plots. Soil profiles were located within smaller areas, app. 20 ha each, typical for the whole plot. The Miłomłyn plot embraced an area of app. only 20 ha. Soil profile locations were guided by local relief and structure of the forest floor. The profiles were dug down to the clearly apparent bedrock (100-120 cm).

Twenty-two soil profiles were analyzed, including: six profiles with Haplic Podzol in the Lubsko plot, three profiles with Haplic Podzol in the Janów Lubelski plot, eight profiles with Albic Arenosol in the Swornegacie plot, three profiles with Albic Arenosol in the Tuchola plot, and two profiles in the Miłomłyn plot with Haplic Arenosol [30].

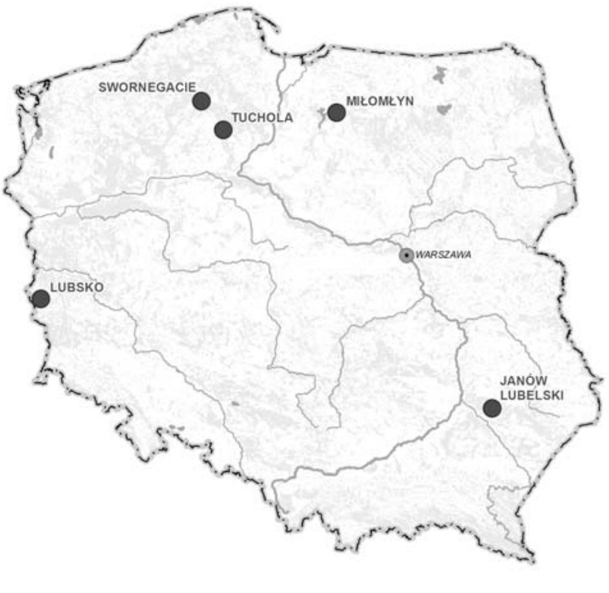


Fig. 1. Locations of study plots.

Table 2. Selected properties of the examined soil horizons and their statistics.

Horizon	Number of profiles	Parameter	Thickness	Bulk density	<0.02 mm	pH	SOC	WEOC
			cm	g·cm^{-3}	min-max	min-max	mg·kg^{-1}	
O	22	mean	4	0.13	-	3.5-4.5	406,910	3,410
		v%	35	23			12	63
AE	20	mean	10	1.41	2-7	4.3-5.2	8,290	164
		v%	42	7			42	31
A	2	mean	14	1.36	4-8	4.4-4.7	19,560	156
		v%	26	2			26	21
E	3	mean	7	1.56	2-4	4.6-4.8	5,620	137
		v%	25	3			31	12
Bbr	2	mean	10	1.52	2-7	5.0-5.1	6,610	91
		v%	7	1			47	3
Bv	13	mean	24	1.63	1-5	5.1-5.4	2,840	50
		v%	36	4			52	30
Bfe	9	mean	16	1.51	1-3	4.6-5.1	4,290	105
		v%	20	3			38	25
BvC	13	mean	34	1.69	1-4	4.9-6.1	489	28
		v%	32	4			60	35
BC	9	mean	43	1.67	0-5	4.8-5.6	471	56
		v%	25	2			48	32
C	20	mean	28	1.67	5	5.2-5.9	352	46
		v%	44	2			54	55

v% – variability coefficient

Description of soil profiles under each of the stands was made according to the Classification of forest soils of Poland [30]. Samples of the organic horizon were taken by removing all of the material present within a 10x10 cm frame, in three replicates, while the mineral soil was sampled from each horizon using a cylinder of 100 cm^3 volume. Three parallel cylinders driven into the middle of each horizon were then removed, starting with the one at the bottom of the profile. Bulk density was determined by a weight method: the soil in the cylinders was weighed, and then dried out at 105ºC to a stable mass.

Other soil properties (pH, content of particles <0.02 mm, soil organic carbon, water extractable organic carbon) were determined in the soil sampled from each of the genetic horizons of the soil profiles.

All samples were first air-dried, and then mineral samples were sieved through a 1 mm mesh. Analyses were performed on the fine soil. Soil pH was determined in 1 M KCl (1:2.5 mass to volume ratio). The content of particles < 0.02 mm was determined by sediment method according to Casagrande modified by Prószyński (areometrically). Organic C was determined in air-dried (20-25ºC) and pulverized samples, using the TOC automatic analyzer. Field and laboratory methods of soil study, with the exception of C determination using the TOC analyzer, are described in detail in the Catalogue of Methods by Ostrowska et al. [31].

WEOC was determined in the organic horizons (without pulverization) by extracting the soil with deionized water in a soil-to-solution ratio of 1:10. In the mineral horizons the ratio was 1:3. Soil samples (6 g from the O horizon and 20 g from the mineral horizons) were poured with 60 cm^3 of deionized water and shaken for 30 min., then centrifuged for 10 min. at 6,000 r.p.m. The supernatant was collected using a pump and was not filtered. The content of C in the solution was determined using the TOC automatic analyzer with an SSM-5000A attachment for soil samples.

Stocks of C in every genetic horizon were calculated according to the formula:

$$\text{stock (Mg·ha}^{-1}\text{)} = \text{horizon thickness (cm)} \cdot \text{soil density (g cm}^{-3}\text{)} \cdot \text{content of C} \cdot 10^{-4}$$

Statistical analysis was made with the use of a atatistics program, and the variability of the basic parameters and Pearson's correlation coefficients (p=0.05) were calculated.

Table 3. Selected properties of soil horizons and their statistics (mean values and variability coefficient in brackets).

Site	Horizon	Thickness	Bulk density	SOC	WEOC
		cm	g·cm^{-3}	mg·kg^{-1}	mg·kg^{-1}
Lubsko	O	4 (19)	0.12 (16)	407,480 (10)	4,950 (67)
	AE	13 (21)	1.37 (4)	4,110 (14)	192 (29)
	Bfe	17 (17)	1.51 (4)	3,380 (27)	101 (31)
	BC	39 (27)	1.68 (2)	408 (63)	62 (31)
	C	26 (45)	1.65 (2)	287 (11)	71 (39)
Janów Lubelski	O	4 (13)	0.10 (6)	405,800 (19)	3,540 (59)
	AE	6 (10)	1.37 (14)	12,480 (9)	217 (22)
	E	7 (25)	1.56 (3)	5,620 (31)	137 (12)
	Bfe	15 (29)	1.50 (3)	6,110 (16)	114 (6)
	BC	52 (4)	1.66 (3)	597 (9)	45 (23)
	C	16 (20)	1.66 (1)	523 (10)	59 (15)
Tuchola	O	4 (0)	0.10 (6)	415,100 (10)	1,910 (33)
	AE	7 (31)	1.35 (4)	8,060 (25)	138 (12)
	Bv	16 (37)	1.55 (4)	4,290 (24)	65 (34)
	BvC	32 (22)	1.70 (6)	247 (9)	40 (22)
	C	42 (25)	1.69 (1)	227 (5)	38 (20)
Swornegacie	O	4 (48)	0.16 (15)	410,750 (13)	2,880 (36)
	AE	12 (42)	1.48 (3)	9,940 (24)	133 (22)
	Bv	26 (33)	1.66 (3)	2,630 (53)	45 (20)
	BvC	30 (32)	1.70 (3)	640 (44)	26 (28)
	C	28 (42)	1.68 (3)	383 (71)	26 (38)
Miłomłyn*)	O	2	0.10-0.12	345,400-412,900	2,570-3,330
	A	11-16	1.34-1.37	16,030-23,100	133-179
	Bbr	9-10	1.51-1.53	4,390-8,830	89-93
	Bv	23-32	1.59-1.61	1,290-1,730	37-54
	BvC	50	1.63-1.65	250	15-25

*) – for Miłomłyn minimum and maximum values

Results

Depending on the soil type, the following horizons were found to occur in the profiles analyzed: O, A, AE, E, Bbr, Bv, Bfe, BvC, BC, and C. All of the soil samples were strongly acidic or acidic, and were derived from sands containing particles <0.02 mm up to 10% (Table 2).

The mean SOC content in the O horizon varied from 37.9 to 41.5%, with the lowest value recorded from the Haplic Arenosol (Miłomłyn plot). The differentiation of mean SOC content in the A (AE, A) horizon was distinctly higher (4,110-19,570 mg·kg^{-1}) than that in the O horizon, with the lowest value detected in the Haplic Podzol (Lubsko plot) and the highest in the Haplic Arenosol (Miłomłyn plot). The differentiation of mean SOC content was also high in the B (Bfe, Bbr, Bv) horizon (1,660-6,610 mg·kg^{-1}), with the lowest value recorded in the Albic Arenosol (Swornegacie plot) and the highest value recorded in the Haplic Arenosol in the Miłomłyn plot. These differences may be explained by the differences inherent to soil subtypes and site types (Table 1). The BvC, BC, and C horizons contained significantly less SOC than the overlying horizons (Tables 2, 3).

WEOC presented a higher variability than SOC (Tables 2, 3). The values of variability coefficients for the mean contents of SOC and WEOC in the selected soil horizons, in all of the plots, were generally higher than the values calculated for the individual plots. This is understandable, as these values are controlled by both the variability in soil and site type and stand age not only within a given plot, but also

Table 4. Soil mass, SOC, and WEOC stocks down to a depth of 1 m.

Site	soil mass to 1 m depth	SOC	WEOC	WEOC/C
	Mg·ha^{-1}			%
Lubsko	15,280	40.5	1.56	3.84
Janów	15,470	54.4	1.28	2.36
Swornegacie	15,860	50.6	0.87	1.43
Tuchola	15,750	37.3	0.84	2.25
Miłomłyn	15,480	59.5	0.82	1.37

among the respective plots. The coefficient of correlation between the contents of organic and dissolved C was 0.809 ($p=0.05$). The above coefficient calculated for the group of organic and humic horizons (O+AE+A) was 0.725, and for the E+Bfe+Bbr+Bv group of horizons it was 0.579. The latter horizons contributed significantly to the amount of C stock in the soils. No relationship was detected between the SOC and WEOC in the group of BvC+BC+C horizons.

The contents of both C fractions in individual horizons were demonstrated to vary between plots (Table 2, 3), as were the values of C stock down to a depth of 1 m (Table 4). The Albic Arenosol under an approximately 80-year-old pine stand was found to contain the lowest C store (Tuchola plot). The local stock of SOC was 37.3 Mg·ha^{-1}, to which the dissolved fraction of C contributed 2.25%. The involvement of the O and AE horizons in the store of SOC was equal to 65%, while that of the Bv horizon was about 30%. The BvC and C horizons had a store of dissolved C equal to 60% (Fig. 2).

The average stock of SOC in the Albic Arenosol under the 60-100-year-old tree stand in the Swornegacie plot was found to be 60.6 Mg·ha^{-1}, and dissolved C accounted for 1.44% of this value. The two horizons, O and AE, contained most of the SOC stock in the 1 m soil layer (73%), while their contribution to the stock of dissolved C was only 48% (Fig. 2).

The stock of SOC in the Haplic Arenosol under the 100-year-old pine stand, with a considerable admixture of deciduous species (Miłomłyn plot), was about 59.5 Mg·ha^{-1}, wherein the share of dissolved C amounted to 1.38%. The horizons accounted for the amount of accumulated SOC as follows: A – 54%, Bbr – 17%, O – 14%, Bv – 12%, and C – 3%. However, the pattern of dissolved C storage for the same horizons was somewhat different: A – 30%, Bv – 24%, BvC – 20%, Bbr – 17%, and O – 7% (Fig. 2).

In the Lubsko and Janów Lubelski plots, the C stores in the Haplic Podzol varied, and the accumulation of C was lower in Lubsko than in Janów Lubelski. In Lubsko, the mean SOC stock down to a depth of 1 m was 40.5 Mg·ha^{-1}, with dissolved C accounting for 3.85% of the latter amount. A 90% accumulation of SOC was stored in the O, AE and Bfe horizons (Fig. 2), whereas dissolved C accumulated in the largest amounts in the BC horizon (26%), with the contribution of the remaining horizons to the store of dissolved C being quite similar (from 16 to 21%).

The average stock of SOC in the Haplic Podzol soil down to a depth of 1 m in the Janów Lubelski plot was 54.4 Mg·ha^{-1}, with a dissolved C contribution of 2.35%. In the 1 m layer, the pattern of SOC storage was as follows: the highest contribution was found for the O horizon (34%), followed by the Bfe horizon (25%), and the AE horizon (18%). The pattern for the dissolved C store was similar to that encountered in soils of the Lubsko plot in that the largest stores were found in the BC (31%) and Bfe (20%) horizons, while the contribution of the remaining horizons to that stock were much alike and amounted to 12-13% for each of the horizons (Fig. 2).

The mass of all soils examined to a 1 m depth was almost the same (about 15,000 Mg·ha^{-1}), which testifies to the great homogeneity of their mineral composition. The highest share in most of the soils, down to a depth of 1 m, was represented by the BvC, BC, and C horizons (29-52%). However, a high contribution of the Bv horizon (27%) was also found in the Albic Arenosol in the Swornegacie plot, and of the Bfe horizon (15-17%) in the Haplic Podzol in the Lubsko and Janów Lubelski plots. This was due to the thickness of the above horizons. In the same soil mass, the lowest contribution (0.1-0.4%) was found for the O horizons, followed by the A/AE horizons (5-11%).

Discussion

The results of our study indicate that the C stock in the 1 m layer of soil derived from sand under coniferous forests is within the range of 40-60 Mg·ha^{-1}. Higher C values are noted in soils under about 100-year-old stands than in those under 60-80 years old. Other authors also report an increase in the soil C accumulation with stand age [6, 11]. Stevens and Wesemael [7] argue that the increase in C accumulation with stand age may not be detected until the stand is 40-50 years old, as such a period of growth is needed to replenish losses of C stores brought about by a change in the forest production cycle. Nilsen and Strand [10] report that damage to the soil organic layer, which occurs during thinning (especially in younger stands) leads to losses of C.

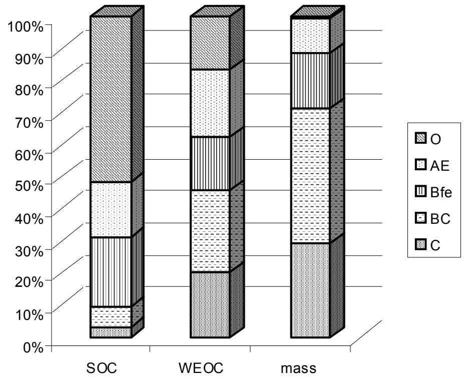
The C stock accumulated in the examined soils, in particular those under pine monocultures, approximates that reported by Kędziora et al. [32] for similar site types in Poland. However, it is lower than that found in other countries, as is shown in Chestnykh et al. [1], Lal [33], and Lexer et al. [34].

The soil C stores were evaluated by various authors based on analyses of samples taken from various depths without considering the thickness of genetic horizons.

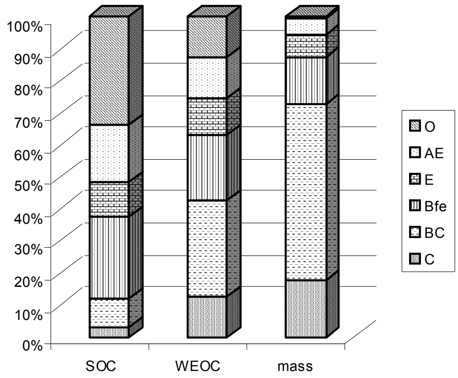
The stock of C in the soils depends on the thickness of the individual horizons and the concentration of C in each of them. The C stock was found to decrease with depth despite the thickness of deeper-lying horizons, including the BC, BvC, and C horizons, which were two to three times higher than that of the A horizon, and many times higher than that of the O horizon. This decrease is due to a decrease in C concentration by even 100 times or more from the O to C horizon. As was shown by Don et al. [35], there is a relationship between the C concentration in the profile and soil density. The coefficient of correlation between these properties, calculated based on our results, is 0.976 (p=0.05).

The C distribution in the profile was determined in layers of various thicknesses with the soil layer at 30 cm accounting for the largest share in that stock [3, 6, 9, 35]. The data on C distribution in our soils indicate that the accumulation of C in individual horizons is related to soil type and the degree of advancement of the pedogenetic process.

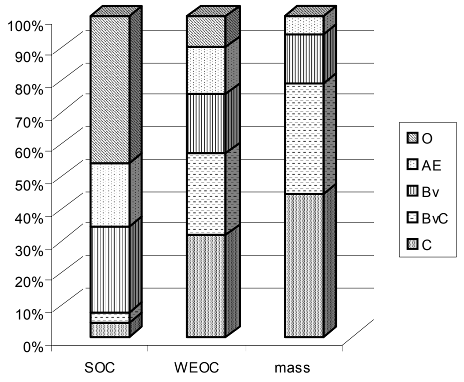
a) Lubsko



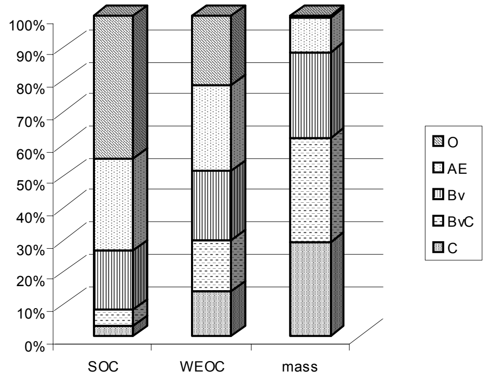
b) Janów Lubelski



c) Tuchola



d) Swornegacie



e) Miłomłyn

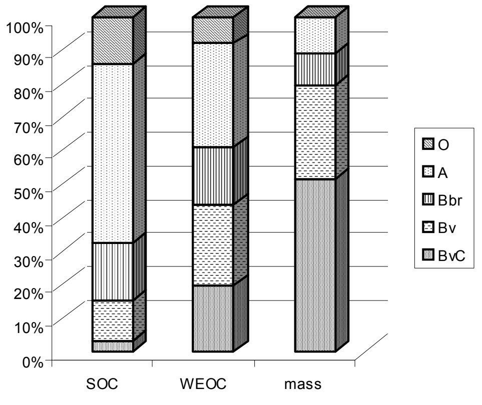


Fig. 2. Profile distribution of SOC and WEOC and soil mass to a depth of 1 m at the a) Tuchola plot, b) Swornegacie plot, c) Miłomłyn plot, d) Lubsko plot, e) Janów Lubelski plot.

Rumpel et al. [4] related the distribution of C in the soil profile to the composition of the organic substance and its age, as well as to the pedogenetic processes. The older SOM was recorded in the deeper soil horizons, where more stable organic compounds were found than in the upper soil layers. In line with Chiti et al. [16], the SOM accumulated in the A horizons originated from a recent accumulation, while that stored below the 45 cm level was about 100 to 1,500 years old.

The SOM age and stability in soils has been studied by several authors. Lützow et al. [36], have summarized more than 200 papers discussing the stability of SOM in consideration of its age, biochemical composition, solubility and soil properties (mainly their structure, texture and mineral composition). The stronger the soil texture is (silts, clays), the more stable the SOM is.

The forest soils in our study were derived from sands poor in particles <0.02 mm, which suggests a less stable SOM and a more intensive translocation of SOM, and particularly of the soluble fraction of DOM, than in soils developed from clays.

The analysis of about 200 papers made by Chantigny [37] and discussing DOM fractions in soils notes that it is the application of various procedures for obtaining DOM that causes considerable divergences as to the content of soil DOC/WEOC. The data provided by various authors suggest that the DOC content is lower than that of the WEOC. In our study, the WEOC content was determined in $mg \cdot kg^{-1}$, so it was difficult to compare these values with the WEOC concentration expressed in $mg \cdot L^{-1}$.

In clay-rich soils, Sanderman and Amundson [38] found that DOC movement from surface horizons into the mineral soil constitutes 22% of the annual C inputs below 40 cm in coniferous forests. The authors suggest that downward moving C in sandy soils is transported to greater depths. Don and Schulze [39] relate the vertical flow of DOC in the soil with the amount of precipitation and its filtration through the soil, while the coefficients of correlation between these characteristics are, respectively, 0.91 in sandy soils and 0.42 in clay-rich soils. In our study, the soils were poor in fine particle sizes, which allowed the easy flow of DOM from the organic horizon to the bedrock. A significant WEOC stock contribution in the BvC and BC horizons confirms DOM flux in soil profiles.

The release of DOC from the forest floor under a beech stand developed on a Dystric Cambisol derived from quaternary calcareous silty loess, is larger than that developed on a Podzol derived from tertiary quartzitic sandy sediments [40]. The results obtained in our study point out that the store of WEOC is higher in Podzol (1.28-1.56 $Mg \cdot ha^{-1}$) than in Arenosol (0.82-0.87 $Mg \cdot ha^{-1}$). The distribution of WEOC in the profile of Haplic Podzol varies between plots in Lubsko and Janów Lubelski, which may be linked to local variations in precipitation. This has also been corroborated by the results obtained by Don and Schulze [39]. We found a similar variability in the WEOC profile distribution between the Albic Arenosol soils (the Swornegacie and Tuchola plots). In the soils in the Tuchola plot, 26% and 32% of the WEOC stock were found to be stored in the BvC and C horizons, respectively, while in the soils in Swornegacie plot, the WEOC store was mainly controlled by the AE horizon (26%). The lowest contribution to the WEOC store was that of the C horizon (14%), which is linked with the low contribution of the C horizon volume in the soil layer down to a depth of 1 m. Fröberg et al. [41], in a 17-month experimental period, stated that total DOC fluxes down from the L, O, and A horizons amounted 45 $g \cdot m^{-2}$. Our data may be compared with the latter value. Huang et al. [24] found 60-80 mg WEOC kg^{-1} in the 0-10 cm soil layer. Values of WEOC in the AE horizons of the soils examined in our study varied between 130 and 220 $mg \cdot kg^{-1}$.

The SOC store is higher by about 40% in the soils in the Swornegacie plot than those in the Tuchola plot. The percentage contributions of WEOC in the Swornegacie plot and in the Tuchola plot are 1.43 and 2.25, respectively. These data suggest that the SOM turnover rate, as well as the rate of dissolved organic matter translocation, is higher in Tuchola than in Swornegacie, as the stand age on both plots is similar. In the Haplic Arenosol (Miłomłyn plot), 30% of the WEOC store was contained in the A horizon, which is responsible for 54% of the SOC store. The percentage of WEOC in the SOC stock was found to be the lowest (1.37%) in these soils. Therefore, it can be suggested that it is the soil type and, thus, the pedogenetic process, which mediates the amount of WEOC and its distribution in soil profiles.

The results we obtained, as well as those of other authors [12, 35, 42], highlight the fact that the concentration of SOC and WEOC decreases with depth, whereas the distribution of the above fractions has a reverse arrangement in the profile. SOC was found to accumulate by up to more than 90% down to a depth of 40-50 cm, while WEOC was accumulated below 50 cm, which testifies to the fact that dissolved C is translocated downward from the soil surface. As observed from the papers discussed by Chantigny [37], DOC/WEOC is quantitatively bound with SOC. The coefficient of correlation ($p=0.05$) between SOC and WEOC in the O+A horizons (high content of both fractions), calculated based on our data, amounts to 0.725; in the E+Bfe+Bv+Bbr horizons it amounts to 0.579; in the BvC+BC+C horizons it amounts to 0.129; and for all the horizons combined it is 0.809. Decreasing values of the correlation coefficient in the above groups of horizons lying deeper and deeper indicate that the concentration of SOC and WEOC decreases with depth in the profile, though with various rates, which also corroborates the downward translocation of dissolved C in the profile. Don and Schulze [39] are of the opinion that SOC storage cannot be associated with an eventual flow of DOC to the groundwater. Our data shows that the potential possibility of dissolved C outflow may range from 300 to 500 kg $C \cdot ha^{-1}$ only from the BC and C horizons, which may remain within reach of the groundwater. Therefore, for lower SOC stock, more DOC may be leached away. The same results were obtained by Don and Schulze [39].

Kaiser and Guggenberger [43] suggest that soil macropores constitute the pathway for DOM outflow from the forest floor to the subsoil, and probably further to the groundwater, especially during violent precipitation episodes.

Conclusions

- The SOC accumulation is to a greater extent affected by the site type and the age of pine stand than by the soil type. However, stock of WEOC is higher in the Haplic Podzol than in the other types of the examined soils.
- Contribution of WEOC in the SOC decreases with increasing stock of SOC, which is probably related to the rate of SOM mineralization.
- Distribution of SOC and WEOC in the soil profile depends on both site and soil type. The SOC stock in soils is about 90% down to a depth of 0-40 cm, which is in the O, A (AE, A), and B (Bfe, Bbr, Bv) horizons, whereas in the BvC, BC, and C horizons the WEOC stock is from 20% to 58%.
- The coefficient of correlation (p=0.05) between SOC and WEOC in the O+A+AE horizons is 0.725. This coefficient decreases to 0.579 in the E+Bfe+Bbr+Bv horizons, and to 0.129 in the BvC+BC+C horizons. These relationships testify to an insignificant differentiation of both C forms in the BvC, BC, and C horizons.
- The profile distribution of SOC and WEOC in the soils examined indicates that the assessment of SOC accumulation may be restricted to the horizons, which are situated within the rooting zones of plants. Study on dissolved C, however (including its translocation in the profile) should be made in the entire profile, including the bedrock.

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