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Original Research

Assessment of C Stock in Forest Soils in Poland Over the Last 30 Years

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Abstract

We presented the results of study on carbon C stock in forest soils of coniferous and mixed deciduous-coniferous habitats in Poland. The C stock was calculated for each soil horizon and for the layer to a depth of 1 m. We compared the results of studies conducted today with 30 years ago and assessed changes in C accumulation in soils during that period of time. The C stock in the compared habitats did not increase within 30 years, even though the age of the tree stands increased from 55 to 85 years.

Keywords: forest soil, soil organic carbon, C stock

Introduction

Carbon accumulation in soils depends on both natural and management factors. Powers et al. [1] suggest that C stock in soils is to a great extent conditioned by the forest management type, contrary to findings by Bruckmann et al. [2]. According to Li et al. [3], soil C stocks are correlated with characteristics of tree stands, and generally constitute a function of vegetation type expressed as site index and land topography, especially in soils of mountain forests. Pei et al. [4] emphasize that soil C stock is closely related to soil properties and depends on the topography-wetness-index. Stewart et al. [5] find that soil C stock is determined by the stability of soil organic matter, which depends on the amount of silt and clay particles. According to Gulde et al. [6], the inflowing organic matter is rapidly decomposed. Seely et al. [7] report that the soil carbon pool is affected by the duration of a production cycle, while Fernandez-Getino et al. [8] stress the influence of plant species and growth conditions. Nave et al. [9] state that the influx of N (deposit, fertilizers) may increase carbon accumulation in forest soils, whereas Grandy et al. [10] did not note such dependence. Schlup et al. [11] emphasize land use type as the main factor determining carbon binding in soils, and point out that C stocks increase in the following series: cultivated lands < grasslands < forests < swamps. At the same time, the authors conclude that if the land use category remains stable over the next two decades, the rate of C accumulation will decrease by ca. 4% by 2030. Heim et al. [12] stated that the yearly rate of C accumulation in soils was 0.43 Mg C/ha in Switzerland, 0.55 Mg C/ha in Central Europe, and even 1.07 Mg C/ha in Greece.

Thus, differences in C stock in soils are due to the impact of various factors on carbon accumulation, but they can as well be a result of various methods used for its evaluation. Schöning et al. [13] and Heim et al. [12] pay attention to the need to consider the horizontal and vertical variability of soils within a given area, which can significantly differentiate the results obtained. Carbon stocks in soils have been assessed in layers of various depths, e.g.: 30 cm [1, 3, 14], 40 cm [15], 100 cm [13], and even 200 cm [16] or to the bedrock, regardless of soil thickness [17, 18].

The rate of C accumulation in soils is not the same as the C stock growth rate, as they both depend on the intensity of soil organic matter transformation. Decomposition of organic matter, just as carbon accumulation, depends on many factors, including climatic conditions and their changes over time, which recently have been rated as most important.

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Lützow and Kögel-Knaber [19], on the basis of the analysis of ca. 100 works made by various authors, conclude that temperature rise significantly enhances organic matter decomposition, which can lead to a decrease in soil C stock. Bellamy et al. [20] state that in the last 25 years in England and Wales the losses of C in soils amount to 0.5-4.4% per year, and Smith et al. [21] state that, for Central Europe, they oscillate at ca. 0.05% per year. The correlation of losses in soil C stock with temperature rise is also reported by other authors [22-24]. The simulation of changes in carbon accumulation in soils in different provinces of China, in light of climate change scenarios over the period from 1980 to 2080, indicates that carbon stock in soils will decrease by 2.7 Mg/ha until 2020, and the decrease of C stock may amount to ca. 8 Mg/ha in 2080 [25]. Xu et al. [23] point to significant discrepancies between the empirical and calculated results, but at the same time they state that soil C stock is going to decrease.

Liu et al. [26] assessed the soil C stock in the area of 620 thou. ha in the temperature gradient from 3.6 to 14ºC, and the precipitation gradient from 150 to 800 mm. When precipitation was lower than 250 mm, the C stock in the 0-40 cm soil layer amounted to 4-6 kg/m^2, and when precipitation was higher than 500 mm, the C stock was ca. 6 kg/m^2. Carbon stocks were found to vary significantly depending on land use category and soil clay contents.

The aim of this work is to assess the C stock in soils of the coniferous and mixed deciduous-coniferous forest habitats, and to evaluate changes in carbon accumulation in soils over the last 30 years.

Materials and Methods

In order to evaluate changes in the soil carbon stock, we used the results of the study conducted at forest plots located in various regions in Poland, in the years 1976-78 [27]. This study was repeated after three decades, in the years 2007-10, on the five plots chosen among those analyzed earlier. These plots represent habitats of dry coniferous forest (Lubsko plot), fresh coniferous forest (Tuchola, Janów Lubelski, and Przymuszewo plots) and mixed deciduous-coniferous forest (Miłomłyn plot). The tree stands in these plots were at that time about 50-55 years old (archival data), and now their age was about 80-85 years. Additionally, we used the results of the analysis of C content in soils of the habitats of mixed deciduous-coniferous forest located in various regions of the country. We analyzed the archival results of analyses of soils sampled from 8 plots, and the results obtained from 6 plots in the years 2007-10 (18 soil profiles in each study period). The analyzed soils represent the same forest habitat, whereas they differ with respect to soil type.

According to the WRB classification [28] the following soil types were identified: haplic podzol at the Lubsko and the Janów Lubelski plots, albic arenosol at the Przymuszewo and the Tuchola plots, and haplic arenosol at the Miłomłyn plot. In the mixed deciduous-coniferous forest brunic arenosol, haplic arenosol and haplic cambisol occurred.

In the past, as well as at present, soils for analyses were sampled from the same respective genetic horizons in the soil profile. The thickness of soil horizons was measured in both terms. In each plot, depending on its size, from three to eight soil profiles were set, taking into account the variability of local topography and properties of tree stand (quality of undergrowth, density and height of trees). Soils with intact structure also were sampled to 100 cm^3 cylinders in order to measure the soil bulk density (BD) by weighing method.

Soils were air dried and sieved through a 1-mm mesh before analysis. The C content in soils was measured with a TOC-5000A autoanalyzer (Shimadzu model), by ignition in 1000ºC, three runs per sample at least. In the past the soil organic C was measured, for each sample thrice, by Tiurin method (wet combustion). Values of TOC for each soil sample constitute an average of three determinations.

The C stock in each genetic soil horizon was measured, and then in the whole soil profile to the depth of 1 m. The same calculations were performed for the results achieved in the past.

The results of soil TOC content and C stock obtained in the study conducted in the years 2007-10 were compared with the results obtained 30 years ago.

The results were statistically prepared, by calculating average layer thickness, bulk density, TOC content, and C stock in each horizon, and SD values were calculated by which these averages are characterized.

Results

In the habitats of coniferous forests, mainly podzols and arenosols derived from sands occur, and in the mixed habitats arenosols and cambisols derived from clayey sands and clay occur. Depending on the soil type, in the 1 m deep layer there occur the following horizons: O, A, AE, E, Bbr, Bfe, Bv, BC, BvC, and C. The C stock in the soil profile depends on the depth of each horizon, its bulk density and the C content in particular layers that form the 1 m deep soil layer. In the previous studies it was stated that the C stock was found to accumulate up to more than 90% in the O, A, E, and B horizons, down to a depth of 40-50 cm [29].

All the soils under study are acidic, with pH increasing with the soil depth from 3.2-4.4 for the O and A horizons, 4.6-5.3 for the B horizons, to 5.3-6.2 for the bedrock.

In Lubsko plot haplic podzol soils derived from very poor, glaciofluvial, and eolic loose sands occur, on which the habitats of dry coniferous forests (dry CF) developed. The C content in the O horizon amounted to 32.93% 30 years ago, and at present it is significantly higher (45.36%). In the deeper horizons (AE, Bfe, BC), the C content was higher in the past than it is now, and in the AE horizon almost three times higher (Table 1). However, the C stock in the O horizon is now slightly lower than in 1976-78, despite the higher TOC content. This is related to a lower soil bulk density in this horizon, which means that the local organic matter is less decomposed, i.e. more raw.

Table 1. Soil characteristics at the Lubsko plot in the past and at present (dry CF, haplic podzol).

1976-78					
Horizon n=5	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	4	0.20	32.93±3.36	26.3	72.1
AE	10	1.39	1.57±1.04	21.9	
Bfe	14	1.54	0.63±0.18	13.5	
BC	20	1.56	0.22±0.13	6.8	
C	52	1.65	0.04±0.02	3.6	
2007-10					
Horizon n=6	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	5±1	0.12±0.02	45.36±3.07	25.0±6.2	48.8
AE	13±4	1.38±0.05	0.576±0.207	9.5±2.2	
Bfe	15±6	1.47±0.07	0.581±0.193	12.0±6.3	
BC	32±8	1.68±0.03	0.023±0.001	1.2±0.3	
C	35±12	1.65±0.02	0.020±0.001	1.1±0.5	

Table 2. Soil characteristics at the Tuchola plot in the past and at present (fresh CF, albic arenosol).

1976-78					
Horizon n=4	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	2±1	0.12±0.02	36.18±0.77	10.0±5.1	43.7
AE	6±2	1.37 ±0.13	1.36±0.64	11.4±5.6	
Bv	18±8	1.53±0.12	0.41±0.16	11.2±8.1	
BvC	26±9	1.60±0.07	0.17±0.06	7.7±4.5	
C	48±5	1.63±0.12	0.05±0.02	3.4±1.8	
2007-10					
Horizon n=3	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	4±0	0.11±0.01	43.76±0.70	18.5±2.0	43.4
AE	7±2	1.38±0.10	1.025±0.093	9.4±3.0	
Bv	16±6	1.58±0.05	0.527±0.135	12.7±5.1	
BvC	32±7	1.71±0.07	0.024±0.001	1.3±0.3	
C	41±10	1.69±0.02	0.021±0.001	1.5±0.4	

The C stock in the 1 m deep soil layer in Lubsko plot has decreased in the last 30 years from 72.1 to 48.8 Mg/ha (Table 1).

Tuchola plot soils are classified as albic arenosol derived from loose sands. The habitats developed there were classified as dry CF in 1976-78, whereas after 30 years of tree stand growth they were classified as fresh coniferous forests (fresh CF). The TOC content in the organic soil horizon is now higher by ca. 20%, and in the AE horizon by ca. 25% lower than 30 years ago (Table 2). The increase in C stock in the organic horizon over the last 30 years results from a higher TOC content and a higher thickness than that layer at present. The C stock down to 1 m depth amounted to 43.7 Mg/ha in 1976-78, and 43.4 Mg/ha at present, so it has not changed over the 30-year growing period of the stands (Table 2).

Table 3. Soil characteristics at the Janów Lubelski plot in the past and at present (fresh CF, haplic podzol).

1976-78					
Horizon n=6	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
Ofh	5±1	0.14±0.03	41.67±5.13	31.7±11.1	81.5
AE	11±4	1.32±0.27	1.72±0.70	24.0±13.1	
Ees	9±4	1.58 ±0.13	0.60±0.37	7.8±3.9	
Bfe	16±9	1.50±0.13	0.59±0.55	11.1±7.5	
BC	26±3	1.64±0.06	0.09±0.08	3.5±2.9	
C	33±15	1.69±0.08	0.05±0.03	3.4±2.2	
2007-10					
Horizon n=6	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
Ofh	5±1	0.12±0.03	40.97±5.30	25.8±9.8	58.9
AE	6±2	1.37±0.12	1.066±0.173	9.3±3.8	
Ees	6±2	1.56±0.04	0.517±0.149	4.6±1.5	
Bfe	11±3	1.50±0.05	0.823±0.255	12.7±4.3	
BC	42±12	1.64±0.05	0.074±0.040	4.9±2.1	
C	30±13	1.66±0.03	0.038±0.016	1.6±0.3	

Soils of Janów Lubelski plot are classified as haplic podzol with a well-developed podsolic E horizon. The material that these soils are derived from is loose sands. Forest habitats that developed on these soils, both in the past and at present, were classified as fresh CF. The TOC content in soil horizons of this plot was higher 30 years ago than it is now (Table 3), with the exception of the Bfe horizon. The C stock in the 1 m soil layer amounted to 81.5 Mg/ha in the past, and at present it is 58.9 Mg/ha. The decrease in the C stock is especially visible in the AE and E horizons, 2.5 times and almost two times, respectively, which is due to the lower average thickness of these horizons and to the lower TOC contents (Table 3).

Soils of Przymuszewo plot belong to albic arenosol derived from loose sands. The forest habitats which developed there were classified as fresh CF. The time interval between the past and recent study was only 20 years, and not 30 years as in the other plots, since archival results were obtained there in 1987. The TOC content in the organic layer is now over 20% higher, whereas in the mineral horizons lower than in the past (Table 4). The C stock in the 1 m soil layer remains almost unchanged over the 20-year period, in the past it was 61.5 Mg/ha, and at present it amounts to 57.8 Mg/ha (i.e. it decreased by ca. 5%).

Soils of Miłomłyn plot are classified as haplic arenosol derived from poorly clayey sands. The plot was originally established in the 1970's in a ca. 80-year-old stand classified as mixed deciduous-coniferous forests (DCF), so at present it is over 100 years old. The TOC content in the organic layer of the analyzed soils was 21.5% in the past, and now it is significantly higher and amounts to 37.4%. In the A horizon the TOC content is the same as in the past, while in the deeper located horizons Bbr and Bv it is now lower than in 1976-78 (Table 5). The C stock in the 1 m soil layer has decreased by 30% in the period of 30 years, in the past it amounted to 111.9 Mg/ha, and at present it is 71.8 Mg/ha. The C stock is at present significantly lower in the A horizon (lower thickness of the layer than 30 years ago) and in the Bbr horizon (lower depth and lower TOC content than in the past).

Similarly, the habitats of mixed DCF were assessed, whereas taking into account the fact that the archival and present studies were conducted in different regions of Poland, the comparison of soil C stock is only approximate. Mixed deciduous-coniferous habitats represent brunic arenosol, haplic arenosol, and haplic cambisol derived from clayey sands and clays. The average TOC content in the O layers of the soils analyzed at present is 30% higher than in the soils analyzed in the years 1976-1978, while in the A and Bbr horizons the TOC content is lower at present than in the past, whereas in deeper layers the average TOC contents were in both periods approximate to each other (Table 6). The TOC stock in the 1 m soil layer of mixed DCF is slightly higher than in the past, but the difference is small. However, due to the fact that soil carbon stock of mixed DCF was determined at present at different plots than those examined in the past, the differences in soil C accumulation may be regarded as approximative only.

Table 4. Soil characteristics at the Przymuszewo plot in the past and at present (fresh CF, albic arenosol).

1976-78					
Horizon n=10	Thickness cm	BD g/cm^3	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	3±1	0.20±0.01	33.09±4.14	20.5±6.3	61.5
AE	8±2	1.34 ±0.13	1.73±0.85	17.4±6.1	
Bv	24±8	1.47±0.08	0.40±0.16	13.9±6.4	
BvC	33±10	1.59±0.04	0.15±0.04	7.7±4.5	
C	32±10	1.57±0.04	0.04±0.02	2.0±n.d.	
2007-10					
Horizon n=8	Thickness cm	BD g/cm^3	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	4±0	0.16±0.02	41.07±5.28	25.7±9.7	57.8
AE	12±5	1.48±0.05	0.994±0.239	16.0±5.5	
Bv	26±8	1.66±0.05	0.263±0.139	10.8±7.2	
BvC	30±10	1.70±0.06	0.064±0.028	3.3±1.9	
C	28±12	1.68±0.05	0.046±0.031	2.0±1.5	

Discussion

Powers et al. [1] reports that C stock is significantly affected by forest management, since carbon accumulation in forest soils depends on, i.e., the production cycle of tree stands, and according to Seely et al. [7] depends on its duration. Carbon stock in soil decreases due to maintenance measures and changes in the stand production cycle. The reconstruction of C stock after clearing lasts for ca. 50 years of the tree stand growth [30]. According to Seely et al. [7], over 50 years of stand growth, the TOC content may be restored to the initial state and then it may increase with the age of trees.

Forest management in Poland, based on maintaining the multifunctionality of forests in the period between 1976 and 2010, has not changed significantly. Sylvicultural measures applied in the III and higher age classes of tree stands, although depleting the biomass pool, do not significantly affect the soil. Heim et al. [12] emphasize that C accumulation in soils depends on the soil quality, including especially the materials from which they are derived. For high variability of soil, the assessed C stock is encumbered with a significant error that can be reduced to ca. 3%, and even less, by increasing the number of soil samples from a given area, since the SD value has an effect on the possibility of comparison of the C stocks in soil in time and space. Similarly, Schöning et al. [13] state that even at low variability of soils and a significant homogeneity of habitats, differences at the level of ca. 10% in the C stock in a given area may be determined only through the analysis of soils sampled within the 5 m distance. The increase in the number of soil samples for decreasing the error in defining the change in soil carbon stock over time is only possible for small study plots (several dozen, to 100 m^2). In our studies, and also in studies conducted by other authors, the C stock in soils is compared in areas covering many hectares. In such a case, the comparison of SD used for characterization of the compared stocks is important.

Forest soils in coniferous habitats of the compared plots are derived from homogenous loose sands, and in the habitats of mixed deciduous-coniferous forest they are derived from poorly clayey sands. Soils were sampled from genetic horizons of the soil profile using the same methods in 1976-78 and 2006-10. The SD value for the C stock depends on the horizon and plot. It should be stressed that in the past as well as at present the SD values for the C stock in respective horizons remain within the same limits. Generally, the SD values by which the compared stocks are characterized are approximate to those received by other authors [12, 13].

Despite using the same methods for localizing soil profiles and soil sampling, the method of TOC measurement might have an influence on differences obtained in our assessment of the C stock in the compared areas. The soil carbon was previously determined by the Tiurin method, and at present by using an automatic TOC analyzer. Jankauskas et al. [31] compared the Tiurin and dry combustion methods in respect to agreement between the results of soil TOC contents obtained using both methods. As it follows from the studies conducted by these authors, the results of C content obtained by using Tiurin method are ca. 3-9% higher than the results obtained by using dry combustion method, while the authors analyzed arable soils. Even if we decrease the values of soil TOC obtained for the years 1976-78 by as much as 10%, the decrease in C accumulation over three decades is still visible.

Table 5. Soil characteristics at the Miłomłyn plot in the past and at present (mixed DCF, haplic arenosol).

1976-78					
Horizon n=6	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
Ofh	3±2	0.14±0.03	21.50±7.70	10.0±5.9	111.9
A	17±4	1.25±0.10	2.34±1.37	53.5 ±23.5	
BvBbr	13±2	1.33 ±0.10	0.91±0.40	29.2±8.8	
Bv	20±4	1.41±0.06	0.47±0.03	11.3±1.9	
BvC	37±7	1.54±0.05	0.13±0.05	5.8±1.6	
C	10±3	1.64±0.02	0.05±0.02	2.1±n.d.	
2007-10					
Horizon n=3	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
Ofh	2±1	0.11±0.01	37.41±3.49	9.2±2.1	71.8
A	12±3	1.35±0.02	2.357±0.780	38.0±9.5	
BvBbr	10±2	1.52±0.01	0.748±0.097	11.7±1.9	
Bv	28±5	1.60±0.01	0.247±0.028	11.1±2.7	
BvC	48±4	1.65±0.02	0.024±0.001	1.8±0.1	

According to Seely et al. [7], the C stock in forest soils increases together with tree stand growth. In our study the age of tree stands increased over a time of ca. 30 years (from ca. 55 to 80-85 years), so we could expect an increase in C stock at a level of ca. 0.55 Mg/ha/year for Central Europe as reported by Heim et al. [12]. In our study, within the period of 30 years the C stock in soils of coniferous habitats has decreased, though it should have increased by ca. 30%. Even if we take into account the difference in methods of carbon determination and SD value assessment, by which the received results are characterized, we may conclude that within the period of the last 30 years the C stock in soils of coniferous habitats not only did not increase, but has shown a downward trend.

Many authors [19, 22, 24, 32-34] are of the opinion that in recent years the decomposition of organic matter in soils might have been intensified as a result of global warming, which may induce a decrease of C stock. Bellamy et al. [20] attribute the loss of carbon from the 0-20 cm soil layer by from 0.59 to even 4.4% per year to global warming. These results are denied by Smith et al. [21] since, according to these authors, yearly losses of carbon from forest soils in Europe caused by global warming oscillate at only ca. 0.05%. When we take into account this value in respect to our studies, we may estimate that in the period of 30 years the C stock would be 1.5% lower, so insignificant in relation to the expected increase.

Some authors [9, 10, 24] attribute the increase in the intensity of soil organic matter decomposition to nitrogen deposit, but it is not so obvious, since the influx of N into the forest environment may both intensify the biomass production and its decomposition. Li et al. [3] in turn suggest that the C accumulation in forest soils depends on the type of vegetation cover, which is obvious. Pei et al. [4] stated that to the purpose of assessment of the organic matter accumulation in soils the topography-wetness-index is a good tool. When we compare our results of the C stock in soils of coniferous and mixed deciduous-coniferous habitats from the past and the present ones, we may suggest that the differences in C stock are connected mainly with soil wetness.

Unger et al. [35] stated that an increase in soil moisture (precipitation) after a long-lasting drought enhances biological processes in the soil, and intensifies the influx of CO_2 into the atmosphere. The losses of carbon may reach the level of a few Mg/ha/year. Our results indicate that TOC contents in the organic horizon are now higher than 30 years ago, which may be attributed to the less intense soil organic matter decomposition (SOM) in this layer. At the same time, an increase in the TOC content in the mineral horizons indicates a lower migration of SOM deep into the soil profile. Tefs and Gleixner [36] noted the losses of C from the 0-20 cm layer amounting to ca. 5 Mg/ha in the deciduous tree stands in the period of 5 years, and at the same time an increase of the C accumulation amounting to ca. 11 Mg/ha in the deeper layer.

The biomass production depends on water availability. Delpierre et al. [37] and Liu et al. [26] stated that both soil wetness and air humidity accelerate C accumulation in soils. Long-term dry periods and a significant decrease (below 4 m) of groundwater level, especially in the coniferous habitats at the Tuchola, Przymuszewo, and Janów Lubelski plots, could significantly affect the current C accumulation

Table 6. Soil characteristics at the DCF sites in the past and at present.

1976-78					
Horizon n=18	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	4±2	0.21±0.08	30.84±7.64	26.9±14.9	117.0
AE	14±7	1.23±0.18	2.82±1.26	42.5±25.8	
Bbr	14±4	1.35±0.11	1.34±0.68	24.8±13.3	
Bv	22±9	1.52±0.13	0.39±0.11	13.4±6.6	
BvC	29±10	1.63±0.08	0.15±0.09	7.2±6.2	
C	29±12	1.66±0.10	0.06±0.02	2.2±1.4	
2007-10					
Horizon n=18	Thickness cm	BD g/cm³	TOC wt.%	C stock t/ha	C stock 0-100 cm
O	5±3	0.13±0.03	41.16±8.83	30.1±21.7	121.7
A/AE	10±3	1.32±0.10	2.15±1.04	26.6±15.4	
E	15±5	1.55±0.07	0.55±0.20	13.8±8.4	
Bbr/Bfe	20±6	1.51±0.07	0.87±0.30	26.0±11.1	
Bv	25±8	1.57±0.07	0.38±0.13	15.0±7.5	
BC/BvC	28±12	1.63±0.06	0.12±0.09	4.9±3.8	
C	31±13	1.63±0.06	0.10±0.07	5.3±4.4	

in soils. We suggest that under climate conditions prevailing in Poland, the amount of precipitation, and especially its dynamics during the vegetation period, could have a significant influence on C accumulation in forest soils. We are going to deal with the issues connected with the relationship between water and TOC in forest soils in our next work.

Conclusions

1. No increase in soil carbon accumulation, over a 30-year-long period, was found on the basis of a comparison of carbon stocks in coniferous habitats between the periods of 1976-78 and 2007-10, and even downward trends were observed.
2. In the analyzed period, the age of tree stands on investigated plots increased from ca. 55 to 85 years, which should result in an increase in C stock amounting at least to a dozen or so, or even more. We suggest that the cause of this state was the occurrence of longer periods of drought within the last 30 years, especially during vegetation periods.

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