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C:N:P stoichiometry as an indicator of Histosol drainage in lowland and mountain forest ecosystems

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Abstract

Background: Peatlands form one of the largest carbon pools in the terrestrial ecosystems, representing approximately one-third of the world's soil carbon. The aim of this study was to evaluate C:N:P stoichiometry as an indicator of changes initialized by dehydration in Histosols of varied origins. Four types of Histosols from lowland and mountain areas were investigated: fibric Histosols, hemic Histosols, sapric Histosols and Histosols drainic.

Results: We established the concentration and stoichiometry of carbon, nitrogen and phosphorous in the Histosols, and found marked differences in C:N:P stoichiometry between the different types – especially the dehydrated samples. The mean C:N:P ratio of dehydrated soil was narrower than the C:N:P ratio of soil under the influence of water, which demonstrates that dehydrating Histosols leads to a narrower C:N:P stoichiometry. This is directly related to the intensification of the organic matter mineralisation process and the resulting loss of organic carbon. We recorded a 50 % lower carbon stock in the case of Histosols drainic compared to the other types of Histosols.

Conclusions: The narrower C:N:P stoichiometry in Histosols drainic is the result of an decrease in the ratio of N and P to the C content. Thus, this study demonstrates that C:N:P stoichiometry is a useful indicator of the changes that occur in Histosols as a result of dehydration.

Keywords: Dehydration, Forest soils, Lowland, Mountain, Peat soils

Introduction

It is estimated that carbon contained in soils constitutes 75 % of the world's entire organic carbon stock, and that there is twice as much carbon stock in the soil than there is in the atmosphere (Farquhar et al. 2001). Increasing carbon stocks in terrestrial ecosystems is a useful tool for the restriction of carbon dioxide emissions into the atmosphere and for combatting climate change (Dorrepaal et al. 2009; Fornara et al. 2011). Among terrestrial ecosystems, forest ecosystems contain the highest levels of organic carbon accumulation. Peatlands form one of the largest carbon pools in the terrestrial biosphere, representing approximately one-third of the world's soil carbon (Gorham 1991). Peat degradation, which is conducive to climate change, comes from the drainage of peatlands (Joosten 2009), fires (Yallop and Clutterbuck 2009) and conversion for agriculture (Carlson et al. 2013). A common cause for forest site degradation is a change in hydrological conditions, which occurs as a result of natural processes or human activities and involves vast areas of forests, primarily in lowland areas (Kabała and Marzec 2016). In dehydrated areas, an intensive aeration of the surface horizons occurs, which leads to increased mineralisation, and thus, an increase in the organic matter decomposition rate (Błońska and Lasota 2017). It has been estimated that drained peatlands in the temperate zone can lose between 1 and 2 cm of height per year, but with year-round high temperatures driving higher rates of peat decomposition, the rate can be as high as 3 to 5 cm per year. Approximately 45 % of peatland has been drained,

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and the drained peat is responsible for emission of about 25 % of the total CO_2 emissions (Slepetiene et al. 2018).

Common international names for the soils developed in organic soil material are: Histosols, peat soils, muck soils, bog soils or organic soils. According to WRB (2014), Histosols are soils that contain more than 10 cm of organic soil materials. Histosols are found at all altitudes but the vast majority occur in lowlands. In Poland, peatlands cover 12,547 km^2 – most of this area is situated in the northern part of the country; peatlands tend to occur less frequently towards the south (Ilnicki 2002). The distribution of peatlands in Poland is associated with the age of landscape, young-glacial origin in northern parts and older towards southern.

As basic components, carbon, nitrogen and phosphorus play an important role in the study of the nutrient cycle and the structure and function of the ecosystem (Sterner and Elser 2002; Huang et al. 2018). C:N:P stoichiometry offers important indicators of ecosystem function and productivity and is recognised as an effective approach to the study of feedback and relationships between the components of an ecosystem (Cleveland and Liptzin 2007; Pang et al. 2020). According to Fang et al. (2019), understanding the spatial patterns and drivers of plant and soil stoichiometry is key to improving the parameterisation of future ecological models and predicting ecosystem responses to environmental change. Until now, the C/N-ratio has most often been used to characterise soil organic matter (Tipping et al. 2016), while less attention has been paid to phosphorus, which is considered to be one of the most important regulators of the carbon and nitrogen cycle in organic soils (Zhang et al. 2017).

The aim of our research was to evaluate C:N:P stoichiometry as an indicator of changes initialized by dehydration in different Histosols types. In this study we examine soils from lowlands and mountain sites from the temperate zone of a forest in Poland to infer whether ratios of C/N, C/P and P/N are good indicators of the element content of Histosols. We hope that a better understanding of the mechanisms and factors that influence the dynamics of carbon, nitrogen and phosphorus in forest Histosols will allow for intentional creation of these phenomena in the future, which will contribute to preventing the negative effects of climate change, especially drainage.

Materials and methods

Study area

One hundred and twelve plots of Histosols distributed throughout Poland in lowland (86 study plots) and mountainous (26 study plots) areas were selected for the study (Fig. 1). In some cases, more than one plots of Histosols were selected for research in one region (point on the map Fig. 1). The mountain plots were situated above 500 m a.s.l. Four types of Histosols were investigated: fibric Histosols, hemic Histosols, sapric Histosols and Histosols drainic. The sapric Histosols contained less than one-sixth recognisable plant tissue after the material was gently rubbed, while the fibric Histosols contained more than two-thirds recognisable plant tissue (after rubbing); hemic Histosols were intermediate, with amounts that landed between fibric and sapric peat. For the Histosols drainic, the surface horizons were artificially drained. In the lowlands, the Histosols drainic were represented by 21 plots, the fibric Histosols by 25 plots, the hemic Histosols by 21 plots, and the sapric Histosols by 19 plots. In the mountains, the drainic Histosols were represented by 9 plots, the fibric Histosols by 3 plots, the hemic Histosols by 6 plots, and the sapric Histosols by 8 plots. Fibric Histosols were associated with landlocked depressions, hemic Histosols were associated with the valleys of free-flowing watercourses with acidic sand fractions. Sapric Histosols were associated with river valleys fed with fertile flowing waters. Fibric Histosols are associated with communities of coniferous species, while acidophilic species dominate in the undergrowth. In the case of hemic Histosols, we found the communities to be richer, and the stands are mixed with pine, spruce, birch and alder. Stands on sapric Histosols consist of various species of alder, and the undergrowth vegetation is very diverse, with the participation of species requiring fertile soil rich in nutrients (Table 1). We dug a soil pit (to 1-m depth) on each research plot, and we distinguished the soil horizons. Furthermore, we took samples from each horizon for further analysis.

Laboratory analysis of the soil samples

After delivery to the laboratory, we dried and sieved (through 2.0-mm mesh) the soil samples obtained in the field. We analysed the pH of the samples using the potentiometric method, and we measured the total carbon (C) and total nitrogen (N) contents with an elemental analyser (LECO CNS TrueMac Analyser, Leco, St. Joseph, MI, USA). As all the samples were carbonate-free, the total C was assumed to be organic carbon. Total P was determined using inductively coupled plasma optical emission spectrometry (ICP-OES, iCAP 6500 DUO, Thermo Fisher Scientific, Cambridge, UK) after prior mineralisation. A mixture of concentrated nitric and perchloric acids was used to mineralise the soil samples, and we performed the calculation of the C/N, C/P and N/P ratios on a molecular level. The C, N and P stoichiometry was calculated for the surface horizons (in the range 0 – 15 or 40 cm) of the tested soils. Moisture was expressed as percentage of weight and bulk density (Bd) was determined using 250 cm^3 Kopecky cylinders (Ostrowska et al. 1991).

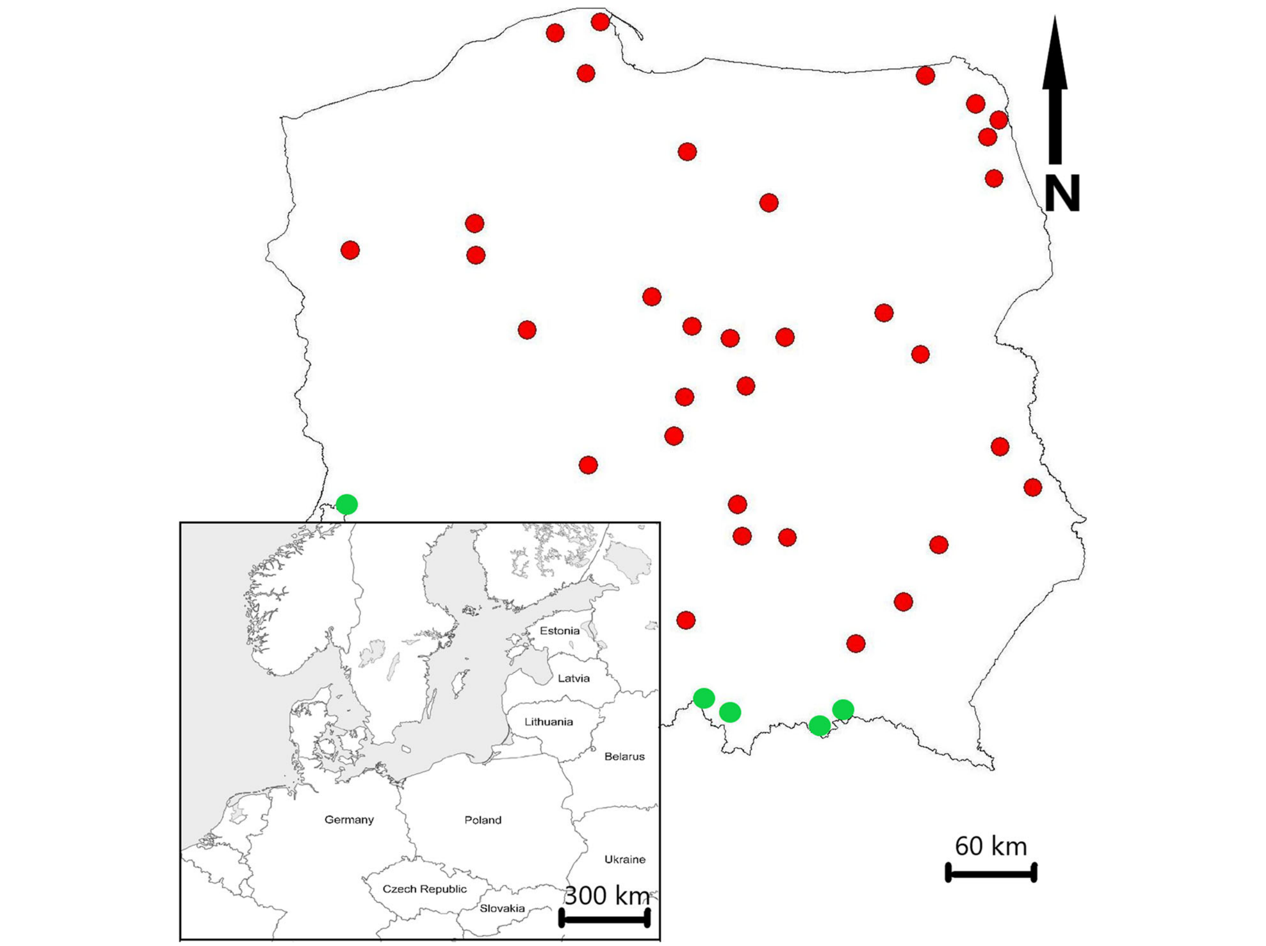

Fig. 1 Localization of study plots in Poland (red points: lowland plots; green point: mountain plots)

Table 1 Characteristics of vegetation on research plots

Localization	Type of Histosol	Plant community	Dominant undergrowth species
Lowland	H. drainic	*Molinio-Pinetum*, *Betuletum pubescentis*	*Molinia caerulea*, *Dryopteris dilatata*, *Calamagrostis arundinacea*, *Juncus effusus*, *Juncus conglomeratus*
	fibric H.	*Vaccinio uliginosi-Pinetum*	*Sphagnum* sp., *Vaccinium uliginosum*, *Ledum palustre*, *Oxycoccus palustris*
	hemic H.	*Sphagno squarrosi-Alnetum*	*Sphagnum* sp., *Thelypteris palustris*, *Carex canescens*, *Peucedanum palustre*
	sapric H.	*Ribeso nigri-Alnetum*	*Lucopus europaeus*, *Carex elongata*, *Scirpus sylvaticus*, *Iris pseudacorus*
Mountain	H. drainic	*Abieti-Piceetum*, *Calamagrostio villosae-Peceetum*	*Vaccinium myrtillus*, *Dryopteris dilatata*, *Dryopteris carthusiana*, *Luzula sylvatica*, *Calamagrostis villosa*
	fibric H.	*Calamagrostio villosae-Piceetum*	*Sphagnum* sp., *Vaccinium myrtillus*, *Oxycoccus palustris*, *Galium hercynicum*
	hemic H.	*Bazzanio-Piceetum*	*Sphagnum* sp., *Bazzania trilobata*, *Juncus effusus*, *Carex nigra*
	sapric H.	*Caltho-Alnetum*	*Caltha palustris*, *Chaerophyllum hirsutum*, *Valeriana simplicifolia*, *Filipendula ulmaria*, *Chrysosplenium altenifolium*

H drainic Histosol drainic, *fibric H.* fibric Histosol, *hemic H.* hemic Histosol, sapric *H.* sapric Histosol

The soil organic carbon stock (C_S), nitrogen stock (N_S) and phosphorus stock (P_S) were calculated as a sum of stocks in soil horizons. In each of the analysed soils, the stock was calculated for a 1-m^2 soil block area at a 100-cm depth from the surface. Stock up to 100 cm was treated as a total stock of organic carbon, and we calculated the stock for the particular depths by summing the C, N or P stock at subsequent genetic soil horizons according to the formula:

$$C_S\ (Mg\ ha^{-1}) = C \times D \times m$$
$$N_S\ (Mg\ ha^{-1}) = N \times D \times m$$
$$P_S\ (Mg\ ha^{-1}) = P \times D \times m$$

where C = carbon content at the subsequent genetic horizon (%), N = nitrogen content at the subsequent genetic horizon (%), P = phosphorus content at the subsequent genetic horizon (%), D = bulk density (g.cm^{-3}), m = thickness of the horizons (cm).

Statistical analysis

To assess differences between means for properties of Histosols, we used Tukey's HSD test. We used the principal components analysis (PCA) method to evaluate the relationships between soil properties and type of Histosol, and a general linear model (GLM) was used to investigate the effect of the type Histosol, localisation and moisture on carbon, nitrogen and phosphorus stock. All statistical analyses were performed with Statistica 10 software (2010).

Results

The tested soils differed in both chemical properties and moisture (Table 2). Lower statistically significant levels of moisture were recorded for the Histosols drainic, regardless of the location of the research plots. Furthermore, the surface horizons of the tested soils differed in pH. Sapric Histosols had the highest pH, while fibric Histosols had the lowest, regardless of the location. The lowland area did not show any significant differences in carbon content between the different types of Histosols. Samples from the mountains, however, revealed a significantly higher C content in fibric Histosols. Histosols in the mountains showed no differences in N content; this is in contrast to the results from the lowlands, which revealed that the highest nitrogen content was recorded in the sapric Histosols (Table 2). Moreover, sapric Histosols had a significantly higher P content, both for the samples from the mountains and from the lowlands.

The mean lowland Histosols' C/N-ratio ranged between 18.8 and 41.6, while mountain Histosols ranged between 23.1 and 49.2 (Table 2). Sapric Histosols had a low C/N-ratio regardless of its sample location. It also had a significantly lower C/P-ratio regardless of location. The C/P-ratio was highest in the fibric Histosols (Table 2), while we found a significantly lower N/P-ratio in sapric Histosols. These results demonstrate the significant differences in the concentrations of C, N and P, as well as in the ratios of C:N:P between different types of Histosols. In the current study, we found higher C:N:P ratio values in the fibric Histosols, regardless of localisation. In the case of lowland Histosols, the C:N:P ratio ranged between 797:42:1 and 2264:56:1, while the mountain Histosols had the lowest ratios, with the lowest at 583:27:1, and the highest at 3531:62:1. In the case of the sapric Histosols, the lowest C:N:P ratio was recorded regardless of localisation. Meanwhile, we also noted a reduction of the C:N:P ratio for the Histosols drainic (Table 2). The statistical analysis indicates a strong relationship between the C/P-ratio and the pH of the studied soils (r = −0.538) (Fig. 2). A positive correlation of C/N with C/P in Histosols was also determined (r = 0.695) (Fig. 2). The strong influence of the type of Histosols on the C/N, C/P and N/P ratios was confirmed by GLM analysis (Table 3). Additionally, we confirmed the importance of the localisation of Histosols for the N/P-ratio.

The current research confirms the importance of the type of Histosols on the accumulation of C, N and P. Regardless of the location of the research plots, a significantly lower C stock was recorded in the Histosols drainic, while the highest was found in the sapric Histosols (Fig. 3). The results for the sapric Histosols also indicated significantly higher nitrogen and phosphorus stock. The lowest accumulation of N and P were found in the fibric and Histosols drainic (Figs. 4 and 5). The GLM analysis confirmed that the Histosol type was the strongest factor in shaping the C, N and P stock. With regard to the P stock, the importance of location and moisture content was also confirmed (Table 4). A projection of the variables on the factor plane clearly demonstrated the relationship of Histosol types with their properties (Fig. 6). Moreover, the PCA analysis confirmed that the highest C/N, C/P and N/P ratios were associated with fibric Histosols, while sapric Histosols had the highest pH and C, N and P reserves. All of the types of Histosols tested differed in moisture levels (Fig. 6).

Discussion

The Histosol types we examined in the current study are characterised by different C/N, C/P and N/P ratios. The lowest ratios were found in the sapric Histosols, which also had the highest pH and a significantly higher content of N and P. The low C/P and N/P-ratio in sapric Histosols confirms the increase of nutrients in soil organic matter in relation to the C content. The properties

Table 2 Basic properties of soil in the first horizon

	Type of Histosol	M	pH H_2O	pH KCl	C	N	P	C/N	C/P	N/P	C:N:P
Lowland	H. drainic	40.86 ± 12.00^{b}	4.62 ± 1.34^{b}	3.74 ± 1.37^{b}	35.79 ± 16.60^{a}	1.54 ± 0.73^{bc}	0.05 ± 0.02^{b}	27.7 ± 12.9^{b}	1895.0 ± 1116.7^{a}	66.1 ± 24.0^{ab}	1895:66:1
	fibric H.	82.21 ± 6.46^{a}	3.65 ± 0.21^{c}	2.88 ± 0.23^{c}	39.08 ± 6.47^{a}	1.11 ± 0.25^{c}	0.05 ± 0.01^{b}	41.6 ± 10.5^{a}	2264.4 ± 579.7^{a}	56.0 ± 14.2^{b}	2264:56:1
	hemic H.	77.90 ± 6.20^{a}	4.45 ± 0.60^{b}	3.62 ± 0.66^{b}	41.51 ± 11.81^{a}	1.90 ± 0.62^{ab}	0.06 ± 0.02^{b}	26.0 ± 6.9^{bc}	2123.0 ± 1523.6^{a}	79.5 ± 46.5^{a}	2123:80:1
	sapric H.	78.09 ± 6.04^{a}	5.90 ± 0.84^{a}	5.37 ± 1.01^{a}	32.21 ± 7.33^{a}	2.02 ± 0.47^{a}	0.11 ± 0.03^{a}	18.8 ± 3.4^{c}	796.9 ± 327.6^{b}	42.4 ± 16.6^{b}	797:42:1
Mountain	H. drainic	44.02 ± 8.56^{b}	5.27 ± 1.36^{ab}	4.58 ± 1.32^{ab}	19.85 ± 8.90^{b}	1.03 ± 0.44^{a}	0.05 ± 0.02^{b}	23.5 ± 5.7^{a}	986.8 ± 339.3^{b}	43.8 ± 17.5^{a}	987:44:1
	fibric H.	81.80 ± 7.45^{a}	3.78 ± 0.22^{b}	2.79 ± 0.29^{b}	45.10 ± 5.79^{a}	1.24 ± 0.51^{a}	0.05 ± 0.04^{b}	49.2 ± 26.4^{a}	3531.0 ± 3213.9^{a}	62.4 ± 26.2^{a}	3531:62:1
	hemic H.	82.72 ± 4.74^{a}	4.74 ± 0.36^{ab}	4.03 ± 0.57^{b}	33.34 ± 11.63^{ab}	1.42 ± 0.46^{a}	0.06 ± 0.01^{b}	28.5 ± 11.7^{a}	1376.9 ± 546.6^{ab}	49.7 ± 16.3^{a}	1377:50:1
	sapric H.	80.54 ± 7.11^{a}	6.09 ± 0.64^{a}	5.53 ± 0.65^{a}	30.47 ± 9.18^{ab}	1.63 ± 0.46^{a}	0.13 ± 0.02^{a}	23.1 ± 10.0^{a}	582.7 ± 134.8^{b}	27.1 ± 7.8^{a}	583:27:1

Mean ± SD. *H. drainic* Histosol drainic, *fibric H.* fibric Histosol, *hemic H.* hemic Histosol, *sapric H.* sapric Histosol, *M* moisture in % weight; small letters in the upper index of the mean values mean significant differences between type of Histosol

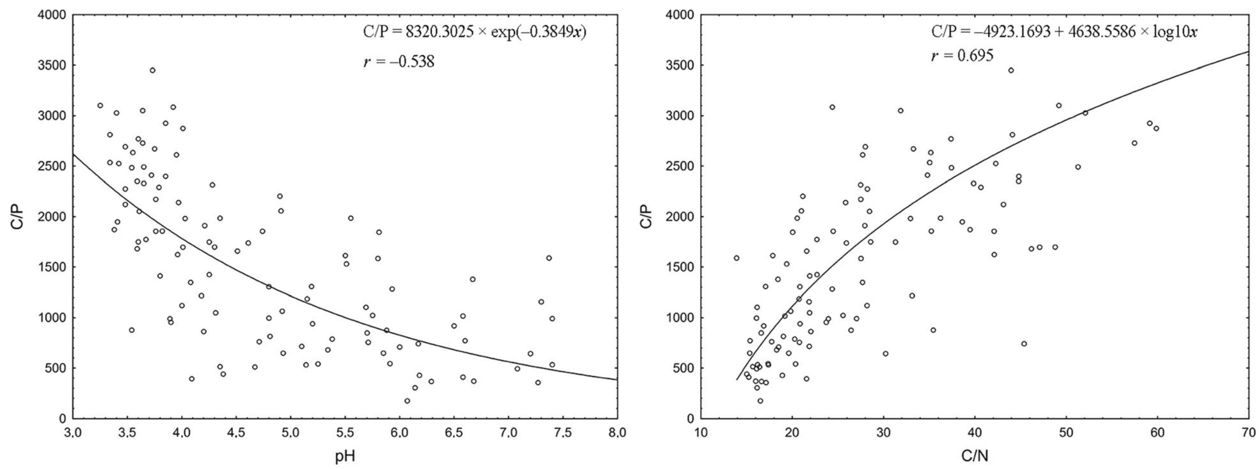

Fig. 2 Relationships between C/P ration with pH and C/N ratio

of the tested Histosols are the effect of the influence of water chemistry which in the case of sapric Histosols is a source of nutrients. The most important driver of Histosols properties is water level and chemistry (Glina et al. 2019). The results of Jonczak et al. (2015) studies show that specific environmental conditions of headwater areas have a strong impact on Histosols, their properties and vertical distribution of the forms of carbon and nitrogen. In addition, we found that the conditions under which soils are developed – wet and dry conditions or alternating dry and wet conditions – are important for shaping the C/N, C/P and N/P ratios. The low C/N-ratio reflects a more intensive decomposition of soil organic matter as well as the quality of this organic matter and the rates of microbial transformation processes (Santos et al. 2020). The rate of decomposition, which depends on microorganism activity, is related to moisture levels (Davidson and Janssens 2006; Qi et al. 2013). In fact, soil moisture is the principal environmental factor that regulates SOM decomposition (Wang et al. 2016). Dehydrated soils lose C at a faster rate, and therefore lower C/N or C/P ratios can be expected (Leifeld et al. 2020). Drainage of organic soils have been found to increase organic carbon mineralisation and CO_2 emissions (Lal et al. 2004; Wang et al. 2017), and in the case of the Histosols drainic, we recorded significantly lower organic carbon content. Phosphorus also plays a role in shaping the rate of decomposition of organic matter, and organic matter, being poorer in nitrogen and phosphorus, is much more resistant to bacterial degradation (Wetzel 2001). The phosphorus accumulation and the C/P-ratio values we are reporting here are characteristic of dehydrated Histosols (Worrall et al. 2016; Becher et al. 2020). Meanwhile, the relative importance of the P content depends on the amounts of carbon, lignin, cellulose, polyphenol and nitrogen; their ratios to P are also considered predictors of decomposition (Baggie et al. 2004). The Histosols we tested for this research differed in C:N:P stoichiometry, with the lowest (583:27:1) found in the sapric Histosols. In this type of Histosols, the C:N:P stoichiometry is similar to mineral soils. As Cleveland and Liptzin (2007) noted, the C:N:P stoichiometry in soil amounts to 186:13:1. Moreover, Kirkby et al. (2011) suggested that mineral soil is characterised by an even narrower C:N:P:S stoichiometry (52:5:1:1). The low values of the C:N:P stoichiometry for the sapric Histosols are due to nutrient availability – nitrogen and phosphorus, especially. Fibric Histosols and hemic Histosols had lower levels of components, which results in higher C:N:P stoichiometry values. In the case of dehydrated Histosols drainic, we noted a decrease in C:N:P stoichiometry, which is directly related to the increased mineralisation of organic matter. In our research, soils with high C:N:P stoichiometry are characterised by significantly lower phosphorus content, which may limit the growth of microorganisms, and consequently, the microbial decomposition of organic matter. Research has shown that rates of mineralisation and immobilisation are related to residue-P content and the C/P-ratio (Seggar et al. 1998). In addition, the critical content of a residue above which

Table 3 Summary of general linear model (GLM) analysis of the effect of Histosol type, localization and moisture for the C/N, C/P and N/P ratio

	C/N		C/P		N/P	
	F	*p* value	*F*	*p* value	*F*	*p* value
Type of Histosol	23.862	**0.0000**	11.682	**0.0000**	8.067	**0.0001**
Localization	0.493	0.4840	1.979	0.1624	7.769	**0.0063**
Moisture	0.026	0.8727	0.612	0.4358	2.660	0.1059

Significance effect ($P < 0.05$) are shown in bold

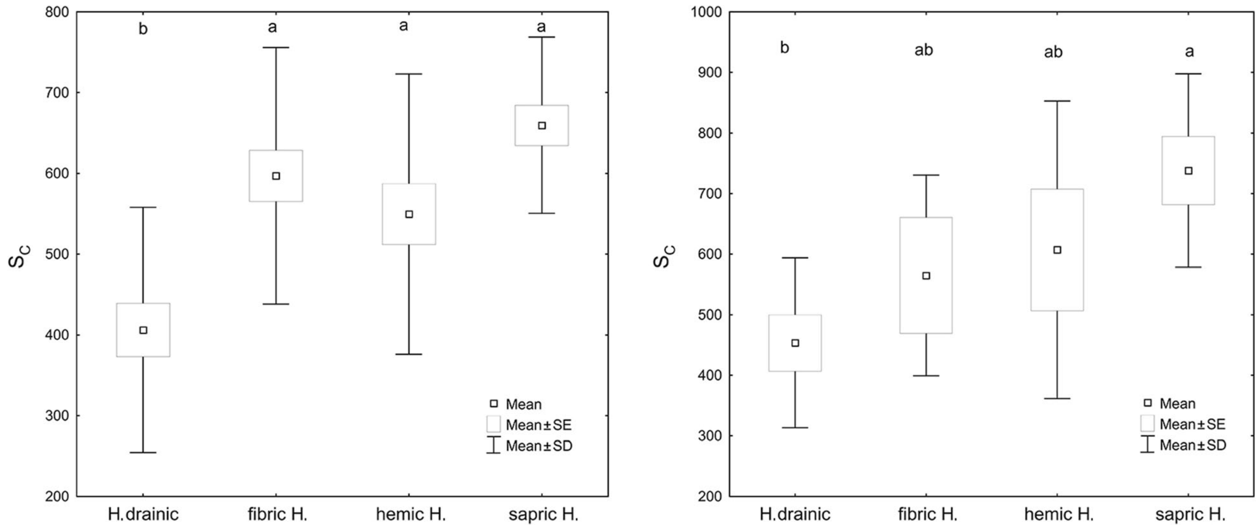

Fig. 3 Carbon stock in different type of Histosol (on the left lowlands, on the right mountains; letters (**a**, **b**) mean significant differences between type of Histosols)

P is not immobilised has been reported to be 0.2–0.3 % (Baggia et al. 2004). Fibric and hemic Histosols had the widest C:N:P stoichiometry, which can be explained by their high moisture and acidity, both of which limit decomposition rates.

The relationships described above apply to Histosols from lowland and mountain areas. We found that the C:N:P stoichiometry was lowest in the sapric Histosols and highest in the fibric Histosols for samples from both the mountains and the lowlands. In the mountains as well as in the lowlands, the drainage effect of Histosols can be seen through the reduced C/N, C/P and N/P ratios, which are the result of soil organic matter mineralisation. In mountainous areas characterised by lower temperatures and higher rainfall, Histosols are also exposed to periodical drying, which leads to an increase in their hydrophobicity, and consequently, to a change in chemical properties. Furthermore, Histosols' hydrophobicity is enhanced by poorly decomposed peat-forming plant fibres (Łachacz et al. 2009; Kalisz et al. 2015). Changes in peatland conditions as a result of groundwater oscillations initialize the transformation of peat in moorsh, which leads to changes in its structure through the modification of hydrophilic properties into hydrophobic ones (Szajdak et al. 2020). Changes in peat structure during wetting and drying influences the

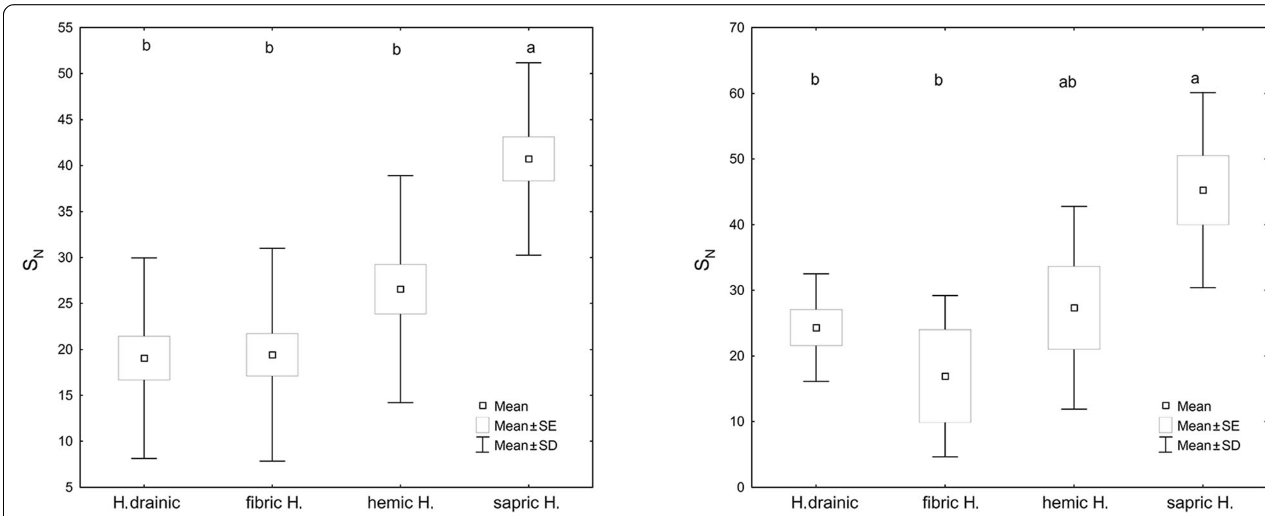

Fig. 4 Nitrogen stock in different type of Histosol (on the left lowlands, on the right mountains; letters (**a**, **b**) mean significant differences between type of Histosols)

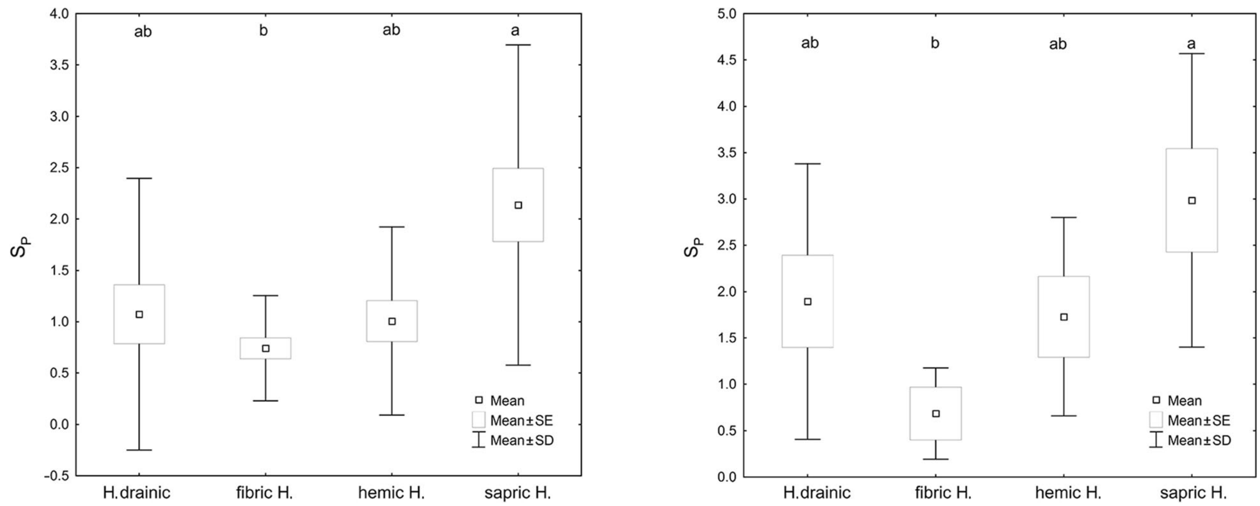

Fig. 5 Phosphorus stock in different type of Histosol (on the left lowlands, on the right mountains; letters (**a**, **b**) mean significant differences between type of Histosols)

heterogeneous distributions of microbial habitats and activity in peat soil, and plays a crucial role in the emission and sequestration of CO_2 and CH_4 fluxes in peatlands (Rezanezhad et al. 2016).

Any changes in temperature, moisture or nutrient availability due to climate change or land management could have significant effects on carbon fluxes and sequestration rates of carbon in the forest ecosystem (Keith et al. 1997). The current research proves the effect of dehydration on the carbon stock, and to a lesser extent, on the nitrogen stock. Regardless of the sample location, we recorded significantly lower carbon stock in the drainic Histosols.

Research has shown that dehydration, in addition to the influence of mineralisation, affects the diversity of plants; in fact, dehydration causes the disappearance of peat-forming plants. In our research, Histosols drainic were associated with vegetation typical of fresh and wet habitats (i.e. *Calamagrostis arundinacea*, *Molinia caerulea*, *Dryopteris dilatata*), and did not contain peat-forming plants. According to Weissert and Disney (2013), sphagnum is important for the formation of deep peat and could potentially be used to assess the quality of peatlands. Water level shifts drive vegetation change, particularly because woody plants are generally more productive under drawdown conditions, while sphagnum mosses are favoured in wetter, or even flooded, conditions (Zhong et al. 2020). In the case of the Histosols we studied, vegetation turned out to be a good indicator of differences in chemical properties. In the lowlands, sapric Histosols were associated with *Ribeso nigri-Alnetum* plant communities and in the mountains with *Caltho-Alnetum* plant communities. Fibric Histosols in the lowlands were covered with *Vaccinio uliginosi-Pinetum* plant communities and in the mountains with *Calamagrostio villosae-Piceetum*. In the case of the Histosols drainic, we recorded a 50 % lower carbon stock compared to other types of Histosols. In Histosols drainic, the C reserve was about 400 Mg·ha^{-1}, regardless of the sample location. The remaining types of Histosols tested had C reserves ranging between 562 and 683 Mg·ha^{-1} in the lowlands, and between 564 and 738 Mg·ha^{-1} in the mountains. It can be assumed that the loss of C in the Histosols drainic is the effect of long-term drainage. The peatland soils, mainly over the last two centuries have been drained by agricultural and forestry management (Glina et al. 2016b).

Table 4 Summary of general linear model (GLM) analysis of the effect of Histosol type, localization and moisture on carbon (S_C), nitrogen (S_N) and phosphorus (S_P) stock

	S_C		S_N		S_P	
	F	*p* value	*F*	*p* value	*F*	*p* value
Type of Histosol	3.860	**0.0115**	18.628	**0.0000**	10.083	**0.0000**
Localization	1.438	0.2331	1.015	0.3160	5.053	**0.0267**
Moisture	0.756	0.3866	0.224	0.6372	5.368	**0.0224**

Significance effect ($P < 0.05$) are shown in bold

Conclusions

The dehydration effect is shown in the C:N:P stoichiometry, as our results show that Histosol dehydration leads to a narrowing of the C:N:P stoichiometry. This is directly related to the intensification of the organic matter mineralisation process and, as a result, the loss of organic carbon. The narrower C:N:P stoichiometry in Histosols drainic is the result of lowering in the ratio of N and P to the C content. As a result of dehydration, the

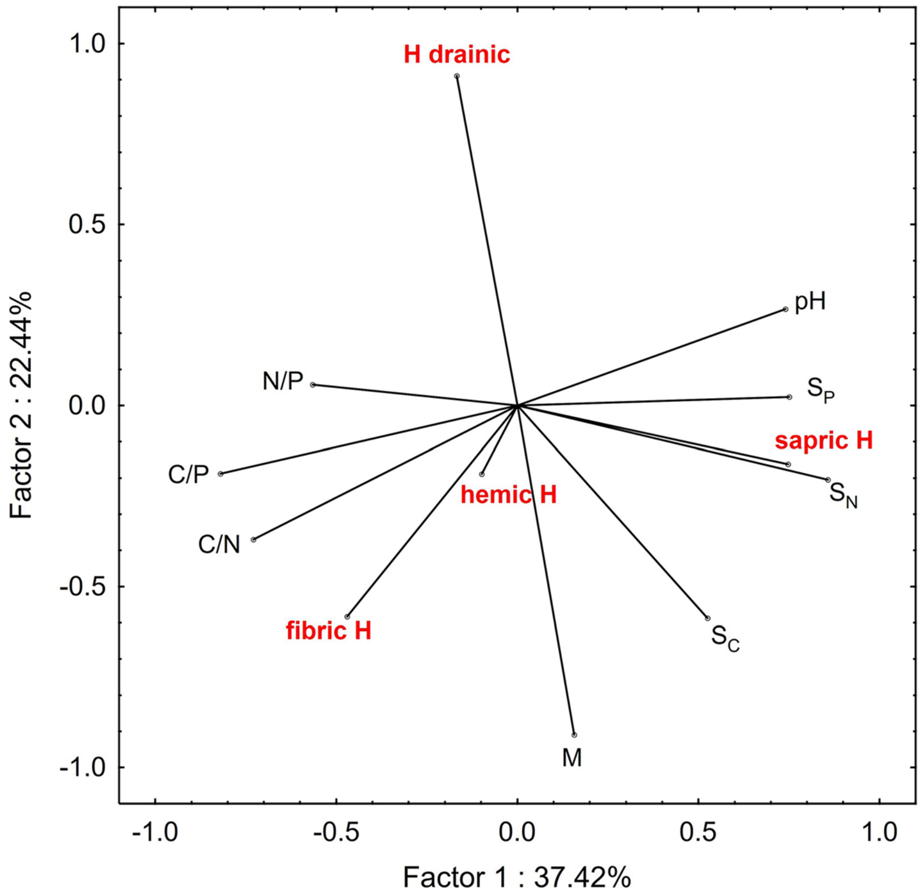

Fig. 6 The projection of variables on a plane of the first and second PCA factor

total C store in Histosols drainic is reduced by 50 %. Our results show that large C losses occur as a result of Histosol dehydration and indicate the need for their protection. These results also demonstrate the importance of maintaining an appropriate water level in peatlands, because rising water tables maintain anaerobic conditions and enhance the role of peatlands as a C sink. In order to maintain adequate carbon storage in Histosols, we must strive to maintain a balance between primary productivity and decomposition. Good practice and careful land use management is essential if we are to minimise the negative effects of climate change in Histosols.

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Authors' contributions
JL, EB designed the experiment and implemented the study. All authors analysed the results and contributed to the manuscript writing and editing. All authors read and approved the final manuscript.

Availability of data and materials
Data available on request from the authors.

Declarations

Ethics approval and consent to participate
The subject has no ethic risk.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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