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Forest habitats and forest types on chernozems in south-eastern Poland

Abstract: The objective of the study is the presentation of the chemical properties of forest chernozems and the features of forest habitats developed on chernozems in south-eastern Poland. The assessment of the trophic status of chernozems was presented based on the Trophic Soil Index (SIG). Moreover, the paper presents the diversity of forest vegetation on chernozems. The research covered 15 plots from the habitat inventory performed for the Mircze and Strzelce Forest Districts (SE Poland). Habitat conditions were characterised on the research plots, with particular consideration of the soil and vegetation. The analysed soils were featured by the presence of thick humus horizons and the occurrence of calcium carbonate. High SIG values confirm the eutrophic status of the analysed soils. In general, fresh and wet habitats of broadleaved forests (Lśw and Lw), as well as fresh habitats of broadleaved upland forest (Lwyżśw) develop on chernozems in Poland. They are associated with multi-species broadleaved tree stands. The conducted research indicates that, in current environmental conditions, the potential plant community is oak-hornbeam forest with predominance of oak, hornbeam, and abundant admixtures of other broadleaved species. High trophic status of the analysed chernozems is confirmed by high bonitation of tree stands and richness of forest floor vegetation.

Keywords: forest soil; habitat conditions; soil properties; Trophic Soil Index

INTRODUCTION

In Poland, forests particularly occur on land with poor soils, as reflected in prevailing types of forest habitats. The structure of forest habitats is slightly dominated by coniferous forest, which cover over 50.4% of the forested area of Poland, whereas the broadleaved forest habitats occupy 49.6% of the area (Forest in Poland. Lasy w Polsce 2018). Chernozemic soils occupy only slightly above 3% of the total area of Poland (Łabaz and Kabała 2014; Kabała 2019). Chernozems cover a small fraction of forested land only in selected parts of the country, particularly in the uplands of south Poland (especially the Lublin Upland). Due to their exceptional properties, chernozems have been prized for agriculture for thousands of years, while forests have been in majority cleared. According to the Polish Classification of Forest Soils (Klasyfikacja 2000), one type of 'leached chernozems' is distinguished.

It is generally agreed that Central European chernozems originated in a continental climate with steppe, forest-steppe or forest-meadow vegetation on carbonate bedrocks (Borowiec 1964; Eckmeier et al. 2007; Kabała 2019). Human activity in the late Holocene led to the destruction of forests on the most fertile soils. Only scarce fragments of tree stands are currently encountered on chernozems in the Lublin Upland. Also the chernozems in the Głubczyce Plateau (SW Poland) are considered to developed with the contribution of thermophilic steppe-forest vegetation, particularly with oaks and minor contribution of lime, maple and, in the later period, hornbeam (Licznar 1976). Due to the fertility of chernozems, the preserved fragments of tree stands have the form of multi-species broadleaved forests on the habitat of eutrophic broadleaved upland forests (Lwyżśw). Potential vegetation is floristically rich association of *Tilio-Carpinetum typicum* in the upland form (Lasota and Błońska 2013).

The objective of the study is to present the chemical properties of forest chernozems in south-eastern Poland and properties of forest habitats developed on chernozems. The assessment of the trophic status of chernozems was derived based on the Trophic Soil Index (SIG), after Brożek et al. (2011). Moreover, the research attempts to present the diversity of forest vegetation on chernozems in south-eastern Poland.

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MATERIALS AND METHODS

The study was conducted in the Mircze and Strzelce Forest Districts administered by the Regional State Forest Directorate in Lublin. According to the physico-geographical regionalisation of Poland by Kondracki (1977), the areas are located in the mesoregions of the Hrubieszów Basin, Pobuże Basin, Sokal Perch (Mircze Forest District) and Horodło Perch (Strzelce Forest District). The study concerned 15 research plots from habitat inventory performed for the Mircze and Strzelce Forest Districts by the Office of Forest Management and Land Surveying in Lublin (Operat 2009, 2015). Site conditions were characterised on the research plots with particular consideration of soil and vegetation. A soil pit was dug on each research plot, and the soil profile was described in detail. Samples for laboratory identification were collected from each genetic horizon with the exception of horizon Ol. On each research plot, a phytosociological relevé using the Braun-Blanquet method and a taxonomic description of the tree stand were performed. Based on geological and soil characteristics, forest floor vegetation and species composition, the affiliation of each research plot to a type of forest habitat was determined. Classification of Forest Soils (Klasyfikacja 2000) and Polish soil Classification (Systematyka 2019) were used for description of soil profiles.

Samples were subjected to the determination of physico-chemical properties (Ostrowska et al. 2001). The results of the laboratory analysis of soils were taken from Operat (2009, 2015). Bulk density was determined using Kopecky cylinders, soil texture by sieve-hydrometer method, soil reaction by potentiometric method in water and 1M KCl and hydrolytic acidity by the Kappen method. The content of total nitrogen was determined by the Kjeldahl method and total organic carbon by the modified Tiurin method followed by calculation of C/N ratio. Base cations were determined in 1M ammonium acetate at pH 7. Base saturation was calculated using base cation content and hydrolytic acidity. Moreover, the Trophic Soil Index was calculated (Brożek et al. 2011).

The calculation of soil organic carbon stock (SOC_S) for surface horizon (uppermost mineral horizon A) was performed in accordance with the following formula:

$$SOC_S = C \cdot D \cdot m \ (\mathrm{Mg\ ha^{-1}}),$$

where: C is organic carbon content in the genetic horizon (%), D is bulk density (g cm^{-3}), and m is a thickness of the horizon (cm).

RESULTS

The soil analyses shows a classic arrangement of chernozem horizons, i.e. A-AB-B-Cca or A-AB-B-Ck according to Polish soil Classification (Systematyka 2019) and international systems. Surface mineral humus horizons (A) have a thickness from 17 to 75 cm and the underlying transitional horizons (AB, ABbrg) from 19 to 85 cm (Table 1). Total depth of mineral humus horizons A and AB is 41-110 cm. Soils have pH in H_2O in a range from 5.1 to 7.9, and pH in KCl from 3.8 to 7.3. Nevertheless, majority of the soils under investigation show weakly acidic reaction in the surface horizons (pH in H_2O 5.6–6.9). Due to the development of the soils under study from loess are dominated by the silt fraction (above 60%, with the exception of three profiles), followed by smaller share of clay fraction (1–37%) and sand fraction (usually <20%, in three profiles the content of very fine sand reaches 43–44%) (Table 1). Organic carbon content in the surface mineral horizons ranges from 0.78 to 3.28% and the content of nitrogen from 0.08 to 0.30%. The values of C/N ratio oscillate around 10. Particular profiles differ in the content of calcium carbonate and depth of its occurrence (Table 1). In six profiles, calcium carbonate (ranging from 1.5 to 12.6%) was found in deep horizons (from 93 to 100 cm), while in the other soils its presence was determined at a lower depth (from 30 to 79 cm). Base cations content in soils varies from 2.0 to 33.5 cmol(+)·kg^{-1}. Taking into account the base cations content and hydrolytic acidity, the base saturation of soils was approximated at the level 25.6 to 98.3% (Table 2). Minimum carbon stock in the surface mineral humus horizons was 52.8 Mg·ha^{-1} and the maximum value was 261.5 Mg·ha^{-1} (Table 3).

The values of Trophic Soil Index calculated for chernozems from the Mircze and Strzelce Forest Districts were high, from 35 to 40, suggesting eutrophic status of habitats (Table 3). The determination of SIG involved the calculation of the impacts of <0.02 mm fraction pools (Czsp), base cations pools (Sz), ratio of hydrolytic acidity to fraction <0.02 mm in the soil column of 1 m^2 cross-section and 1.5 m depth (Yp) as well as the ratio of nitrogen content to C/N in the first mineral humus horizon (Np). The pools of <0.02 mm fraction (Czsp) were in the range of 433–1010 kg·1.5 m^{-3} and base cations pools (Sz) in a range of 143–408 mol·1.5 m^{-3}. In the described chernozems, the ratio of acidity to <0.02 mm fraction pools (Yp) was variable and ranged from 0.022 to 0.218 mol·1.5 m^{-3}. The ratio of nitrogen content to C/N in first mineral humus horizon (Np) varied from 0.008 to 0.032 (Table 3).

TABLE 1. Chemical properties of the analysed soils

Profile	Horizon	Depth	pH H_2O	pH KCl	C	N	C/N	$CaCO_3$	sand	silt	clay
		cm			%			%			
Mircze 1	A	1–65	5.6	5.0	2.80	0.26	10.7		20	65	15
	AB	65–110	5.8	5.3					15	70	15
	BCk	110–150	7.5	6.9				3.78	17	68	15
Mircze 2	A	1–30	6.9	6.4	2.54	0.24	10.7		43	37	20
	AB	30–80	7.2	6.8				2.25	32	44	24
	BCk	80–120	7.8	7.3				10.22	31	44	25
Mircze 3	A	0–75	5.4	4.8	2.36	0.22	10.7		11	67	22
	AB	75–110	6.1	5.6					8	69	23
	BCk	110–150	6.9	6.3				1.52	6	70	24
Mircze 4	A	0–25	5.8	5.4	2.87	0.30	9.7		44	24	32
	ABbrg	25–110	6.9	6.5					40	25	35
	Ckg	110–150	7.8	7.2				12.61	40	25	35
Mircze 5	A	1–30	5.6	5.0	3.12	0.29	10.8		24	44	32
	ABbrg	30–110	6.5	5.9					34	31	35
	Ckg	110–150	7.3	7.0				11.27	35	30	35
Mircze 6	A	1–76	6.1	5.5	2.98	0.28	10.8		18	69	13
	ABbrg	76–95	6.6	6.0					14	71	15
	Ckg	95–150	7.6	7.1				3.90	5	76	19
Mircze 7	A	1–36	5.6	5.1	3.28	0.30	10.9		17	69	14
	ABbrg	36–93	6.5	5.8					13	72	15
	Ckg	93–150	7.5	6.9				3.72	2	79	19
Mircze 8	A	1–17	6.5	5.9	2.79	0.30	9.4		12	73	15
	ABbr	17–44	6.6	6.0					8	74	18
	BCk	44–85	7.4	6.8				0.74	6	75	19
	Ck	85–150	7.6	7.2				5.34	5	76	19
Mircze 9	A	1–40	6.6	6.1	3.22	0.30	10.7		20	67	13
	AB	40–82	7.6	7.2				2.12	17	68	15
	BCk	82–150	7.8	7.3				5.43	15	70	15
Mircze 10	A	1–33	6.4	5.8	2.73	0.28	9.6		0	80	20
	ABbr	33–53	6.7	6.2					0	79	21
	Bbr	53–100	7.4	6.8				4.72	0	77	23
	Ck	100–150	7.6	7.2				6.26	0	77	23
Mircze 11	A	1–39	6.2	5.7	2.98	0.27	11.0		41	25	34
	AB	39–110	7.3	6.8				6.74	43	22	35
	BCk	110–150	7.6	7.1				13.52	43	20	37
Strzelce 1	A	1–39	5.7	4.5	1.88	0.16	11.8		18	73	9
	AB	39–74	7.7	7.1	0.53	0.05	106	0.50	14	69	17
	BCk	74–102	8.4	7.5				9.24	12	71	17
	Ck	102–150	8.5	7.7				9.07	11	73	16
Strzelce 2	A	1–17	6.5	5.7	2.42	0.22	11.0		12	75	13
	AB	17–79	6.8	5.5					16	65	19
	Ck	79–150	7.9	7.3				4.20	8	74	18
Strzelce 3	A	1–42	5.1	3.8	0.78	0.08	9.8		15	76	9
	Bbr	42–67	5.9	4.0					11	64	25
	BCk	67–88	5.9	4.0				0.05	11	63	26
	Ck	88–150	6.0	4.0				0.10	13	65	22
Strzelce 4	A	1–41	5.4	4.0	1.36	0.12	11.3		18	72	10
	BbrC	41–72	6.1	4.1				0.04	14	65	21
	Ck	72–150	6.2	4.0				0.11	10	56	34

Explanation: C – organic carbon content, N – total nitrogen content. Designation of soil horizons according to Classification of Forest Soils (Klasyfikacja 2000) and Polish Soil Classification (Systematyka 2019).

TABLE 2. Cation exchange capacity and base saturation in soils under study

Profile	Horizon	Depth	Y	Ca	Mg	K	Na	BC	BS
			cmol(+)·kg^{-1}						%
Mircze 1	A	1–65	5.68	14.01	1.99	0.40	0.05	16.4	74.3
	AB	65–110	4.57	19.24	2.21	0.31	0.07	21.8	82.7
	BCk	110–150	4.15	13.18	1.82	0.25	0.06	15.3	78.7
Mircze 2	A	1–30	5.32	13.81	0.55	0.20	0.07	14.6	73.3
	AB	30–80	2.83	15.24	1.46	0.22	0.07	17.0	85.7
	BCk	80–120	1.21	25.77	1.40	0.23	0.07	27.5	95.8
Mircze 3	A	0–75	2.72	17.76	0.69	0.14	0.05	18.6	87.3
	AB	75–110	2.24	19.01	0.47	0.15	0.05	19.7	89.8
	BCk	110–150	1.92	14.47	0.39	0.14	0.09	15.1	88.7
Mircze 4	A	0–25	2.28	14.43	1.99	0.37	0.04	16.8	88.1
	ABbrg	25–110	0.93	16.23	2.12	0.34	0.07	18.8	95.3
	Ckg	110–150	0.73	23.14	1.78	0.25	0.06	25.2	97.2
Mircze 5	A	1–30	3.61	9.54	0.94	0.13	0.06	10.7	74.7
	ABbrg	30–110	2.25	11.63	1.17	0.12	0.08	13.0	85.3
	Ckg	110–150	0.82	32.29	1.01	0.15	0.08	33.5	97.6
Mircze 6	A	1–76	3.12	10.56	0.97	0.12	0.05	11.7	78.9
	ABbrg	76–95	2.83	11.36	1.12	0.11	0.09	12.7	81.8
	Ckg	95–150	0.78	32.41	1.14	0.11	0.09	33.7	97.7
Mircze 7	A	1–36	1.27	14.48	1.16	0.16	0.06	15.9	92.6
	ABbrg	36–93	2.67	4.68	0.86	0.15	0.04	5.7	68.2
	Ckg	93–150	1.18	14.60	0.89	0.19	0.10	15.8	93.0
Mircze 8	A	1–17	1.32	10.62	1.96	0.19	0.06	12.8	90.7
	ABbr	17–44	1.14	12.18	2.15	0.20	0.08	14.6	92.8
	BCk	44–85	0.89	12.28	2.05	0.20	0.05	14.6	94.2
	Ck	85–150	0.72	15.55	1.46	0.16	0.06	17.2	96.0
Mircze 9	A	1–40	2.82	7.60	1.42	0.20	0.05	9.3	76.7
	AB	40–82	2.37	9.05	1.45	0.21	0.07	10.8	82.0
	BCk	82–150	2.11	8.60	1.36	0.16	0.05	10.2	82.8
Mircze 10	A	1–33	4.18	6.83	0.54	0.08	0.05	7.5	64.2
	ABbr	33–53	3.72	7.59	0.63	0.11	0.06	8.4	69.3
	Bbr	53–100	1.29	11.36	0.97	0.11	0.09	12.5	90.7
	Ck	100–150	1.02	12.23	1.02	0.12	0.09	13.5	93.0
Mircze 11	A	1–39	2.56	7.84	1.11	0.38	0.05	9.4	78.6
	AB	39–110	1.92	10.49	0.67	0.17	0.27	11.6	85.8
	BCk	110–150	1.34	11.24	0.81	0.23	0.05	12.3	90.2
Strzelce 1	A	1–39	5.20	7.35	1.14	0.28	0.02	8.8	62.9
	AB	39–74	1.08	17.35	1.25	0.20	0.02	18.8	94.6
	BCk	74–102	0.55	28.41	1.09	0.16	0.02	29.7	98.2
	Ck	102–150	0.42	22.67	1.08	0.17	0.03	24.0	98.3
Strzelce 2	A	1–17	3.53	12.83	1.72	0.34	0.02	14.9	80.9
	AB	17–79	2.62	12.85	1.57	0.24	0.03	14.7	84.9
	Ck	79–150	0.86	28.14	1.35	0.22	0.03	29.8	97.2
Strzelce 3	A	1–42	5.67	1.38	0.36	0.19	0.01	2.0	25.6
	Bbr	42–67	3.84	9.23	1.46	0.29	0.07	11.1	74.2
	BCk	67–88	4.06	9.11	1.49	0.29	0.06	11.0	73.0
	Ck	88–150	3.52	7.78	1.25	0.23	0.06	9.3	72.6
Strzelce 4	A	1–41	5.38	3.00	0.75	0.32	0.02	4.1	43.2
	BbrC	41–72	2.96	7.96	1.70	0.25	0.03	9.9	77.1
	Ck	72–150	3.33	13.11	2.74	0.36	0.06	16.3	83.0

Explanation: Y – hydrolytic acidity, BC – base cations content, BS – base saturation.

TABLE 3. SOC stock in the uppermost mineral horizons, SIG values and indices used for SIG calculation

Profile	SOC_s	Czsp	Sz	Yv/Czsv	N^2/C	SIG
Mircze 1	211.8	432.9	344.1	0.218	0.024	35
Mircze 2	88.3	672.3	432.6	0.074	0.022	38
Mircze 3	214.3	726.8	347.2	0.063	0.021	38
Mircze 4	84.5	869.7	408.3	0.025	0.031	39
Mircze 5	105.1	886.1	363.9	0.047	0.027	39
Mircze 6	261.5	637.7	391.5	0.064	0.026	40
Mircze 7	132.2	800.7	232.8	0.044	0.028	38
Mircze 8	52.8	840.1	315.2	0.022	0.032	38
Mircze 9	145.0	593.9	199.5	0.078	0.028	38
Mircze 10	103.6	737.4	225.4	0.056	0.029	38
Mircze 11	132.5	825.5	223.1	0.045	0.025	38
Strzelce 1	106.1	717.3	359.0	0.044	0.014	37
Strzelce 2	59.4	819.2	384.1	0.043	0.020	38
Strzelce 3	37.2	810.2	143.2	0.094	0.008	35
Strzelce 4	73.3	1009.8	218.0	0.072	0.011	37

Explanation: SOCs – soil organic carbon stock in the surface horizon, Czsp – pools of <0.02 mm fraction, Sz – pools of base cations, Yv/Czsv – ratio of hydrolytic acidity to <0.02 mm fraction pools in soil column of 1 m^2 cross-section and 1.5 m depth, N2/C – ratio of nitrogen content to C/N ratio in the first mineral humus horizon, SIG – Soil Trophic Index.

The described plots were classified to three types of forest habitats, i.e. the fresh broadleaved forest (Lśw) habitat, wet broadleaved (Lw) and fresh broadleaved upland forest (Lwyżśw) (Table 4). The aforementioned forest habitats varied in moisture status (moderately fresh variant, strongly fresh variant and moderately wet variant). The tree stands showed high species diversity associated with the moisture variant. In the habitats Lśw and Lwyżśw, hornbeam-oak tree stands were present with a variable proportion of the aforementioned species and with single admixtures of other species such as birch, maple, pine, larch and sweet cherry. At moist sites, chernozems were covered with alder, oak-ash, or ash-alder-birch tree stands with hornbeam. The tree stands were characterised by their good quality, as expressed in their bonitation, in a range of I–II classes (Table 4). Tree stands growing on chernozems had various structure of tree stand and forest floor. The second layer of tree stands was created by the hornbeam. The strongly developed understory in fresh habitats includes hazel, in wet habitats – hazel, Cornelian cherry, bird cherry and elderberry. On the plots considered in this study, diverse forest floor occurred. 75 species of vascular plants were found on the study plots. The average number of vascular plants was 22±3.3 (Table 5). The dominant species in the studied plots were *Anemone nemorosa, Galium odoratum, Asarum europaeum, Aegopodium podagraria, Dryopteris filix-mas, and Vinca minor*. In wet habitats, indicators of higher moisture occurred, namely: *Ficaria verna, Urtica dioica* and *Circaea lutetiana*.

DISCUSSION

A debatable issue is the classification of the analysed sites according to the typological classification. In the typological classification, chernozems are unquestionably recognised as eutrophic soils of habitats of broadleaved forests. The association of this type of soils with geographic-climatic regionalisation of habitat types is not conclusively determined. During the large-area inventory of forest habitats, the majority of the analysed chernozems was associated with lowland habitats (sites Lśw, Lw) and only in two cases with upland habitats (Lwyż św). The problem resulted from the lack of criteria of recognition of these habitats in the upland areas. The natural-forest regionalisation of Poland included the chernozems under study to the region IV Mazowsze – Podlasie (Zielony and Kliczkowska 2012), where no upland habitats were distinguished (Siedliskowe 2003). In terms of altitude, the boundary separating the upland and lowland areas is usually considered at the height between 200 and 300 m a.s.l. (Siedliskowe 2003). The analysed plots meet the above criterion (plots in the Mircze Forest District are located at a height of 230–270 m a.s.l., and plots in the Strzelce Forest District at a height of 215–245 m a.s.l.). Loess sediments, on which chernozems have developed, are rocks typical of uplands of southern Poland. Kondracki (1977), classifying geographic landscapes of southern Poland, next to upland carbonate and siliceous areas, distinguished a loess upland landscape. Due to the physico-geographical regionalisation, altitude and geology, the area of the Lublin and Wołyń Upland where forests on chernozems were described, should be unequivocally associated with areas with upland features. Another criterion considered in the differentiation of sites of upland and lowland habitats are the features of the vegetation cover (features of the tree stands and forest floor vegetation). In tree stands occurring in the upland areas, typically the admixtures of fir and beech differentiate the upland forms of dry-ground forests. Whereas, in the case of the plots located in the western part of the Lublin and Wołyń Uplands, due to drier climate and strong continentalism, neither fir or beech occur. Moreover, no species reported as differentiating upland and lowland sites were recorded in the forest floor vegetation (Siedliskowe 2003). The Trophic Soil Index (30–40) confirms the eutrphic character of the analysed soils. Equally high SIG values were found in soils of *Fagus sylvatica-Mercu-*

TABLE 4. Types of soils and vegetation characteristics

Profile	Type of soil	Forest stand	Dominant species in groundcover	Type of forest site
Mircze 1	Chernozems	10Db I, Gb	*Oxalis acetosella, Anemone nemorosa, Ficaria verna, Aegopodium podagraria*	Lśw2
Mircze 2	Chernozems	5Gb I,5, 4Db II, 1Brz	*Anemone nemorosa, Galium odoratum, Maianthemum bifolium, Vinca minor*	Lśw1
Mircze 3	Chernozems	5Brz I, 3Ol II, 2Js I, Gb	*Asarum europaeum, Rubus caesius, Ficaria verna, Anemone nemorosa*	Lw1
Mircze 4	Gleyic Chernozems	Wz, Js, Gb	*Asarum europaeum, Ficaria verna, Aegopodium podagraria, Galeobdolon luteum*	Lw1
Mircze 5	Gleyic Chernozems	8Js I, 2Db I, Gb	*Anemone nemorosa, Aegopodium podagraria, Galeobdolon luteum, Ficaria verna*	Lw1
Mircze 6	Gleyic Chernozems	10Ol II, pjd. Brz	*Asarum europaeum, Anemone nemorosa, Urtica dioica, Geum urbanum, Ficaria verna*	Lw1
Mircze 7	Gleyic Chernozems	5Db I,5, 2Kl I, 1Brz	*Dryopteris filix-mas, Carex digitata, Melica nutans, Pulmonaria obscura, Geum rivale*	Lśw2
Mircze 8	Chernozems	8Gb I,5, 2Brz I,5	*Dryopteris filix-mas, Anemone nemorosa, Circaea lutetiana, Galium odoratum*	Lśw2
Mircze 9	Chernozems	10Db I, pjd. Md	*Geum urbanum, Dryopteris carthusiana, Anemone nemorosa, Maianthemum bifolium*	Lwyżśw1
Mircze 10	Chernozems	8Gb I,5, 1Brz, 1So, Gb	*Galium odoratum, Anemone nemorosa, Viola mirabilis, Pilmonaria obscura,*	Lwyżśw1
Mircze 11	Chernozems	8Db I,5, 2Gb I,5 Gb	*Asarum europaeum, Oxalis acetosella, Dryopteris filix-mas, Pulmonaria obscura, Vinca minor*	Lśw2
Strzelce 1	Chernozems	4So I, 3Db II, 2Gb, 1 Czr	*Anemone nemorosa, Asarum europaeum, Galium odoratum, Oxalis acetosella,*	Lśw2
Strzelce 2	Chernozems	7Db I,5, 3Gb, pjd. Czr	*Anemone nemorosa, Asarum europaeum, Aegopodium podagraria, Galium odoratum*	Lśw1
Strzelce 3	Chernozems	4Gb I,5, 2Db II,5, 2Brz, 2Os	*Anemone nemorosa, Asarum europaeum, Galium odoratum, Dryopteris filix-mas*	Lśw1
Strzelce 4	Chernozems	4GbI,5, 4Db I, 2So	*Anemone nemorosa, Galium odoratum, Oxalis acetosella, Viola reichenbachiana*	Lśw1

Explanation: Db – oak, Gb – hornbeam, Brz – birch, Ol – alder, Js – ash, Wz – elm, Kl – maple, Md – larch, So – pine, Czr – wild cherry; Roman numbers designate bonitation; Lśw1 – habitat of moderately fresh broadleaf forest, Lśw2 – habitat of strongly fresh broadleaf forest, Lw1 – habitat of moderately moist broadleaf forest, Lwyżśw1 – habitat of moderately fresh broadleaf upland forest.

rialis perennis and *Acer platanoides-Tilia cordata* plant communities (Lasota et al. 2010, 2011). Community composition was related to soil condition. High trophic status of the analysed chernozems is confirmed by number of vascular plant and their species composition. The diversity and composition of vascular plant community is effect of soil characteristics (Iturrate-Garcia et al. 2016).

In the described chernozems, irrespectively of tree stand species composition, no erosion processes were observed. Forest management of chernozems efficiently counteracts surface water erosion, whereas in the case of arable chernozems, water erosion causes worsening of their structure (Licznar 1976). During agricultural treatments, horizons Ap of chernozems are subjected to considerable lumping and partial pulverisation (Paluszek 1995). According to Kowaliński et al. (1987), chernozemic soils in Poland are subjected to evolution due to the effect of local soil-forming factors, leading to changes in their macro and micromorphological structure and properties of the soil mass in particular genetic horizons. Over the years, chernozems developed under the impact of multi-species broadleaved tree stands with variable structure suffer from the cultivation of tree stands with a contribution of pine. On three plots subject to the study, the contribution of pine was determined at a level of 20–40%, that may negatively influence on the soil properties of the eutrophic habitats (Błońska et al. 2016, 2017, 2018). Other study plots with chernozems are associated with multi-species broadleaved tree stands. The conducted research indicates that in current environmental conditions the potential plant community is oak-hornbeam forest with predomi nance of oak, hornbeam, and abundant admixtures of other broadleaved species. Hornbeam and oak increased

TABLE 5. List of vegetation species in groundcover of research

	Mircze 1	Mircze 2	Mircze 3	Mircze 4	Mircze 5	Mircze 6	Mircze 7	Mircze 8	Mircze 9	Mircze 10	Mircze 11	Strzelce 1	Strzelce 2	Strzelce 3	Strzelce 4
Actaea spicata		+	+	+						+	+	+	+		
Adoxa moschatellina				1											
Aegopodium podagraria	2			3	4					2			2		
Ajuga reptans	1				+		1		+		+	1			1
Alliaria petiolata			+												
Anemone nemorosa	3	4	3	2	4	3		2	2	3		5	4	4	4
Anemone ranunculoides			+	1	1										
Asarum europaeum		1	3	4	3	3				2	3	3	3	4	+
Athyrium filix-femina		2					2	1		1			+		
Atrichum undulatum		2													
Brachypodium sylvaticum		+	+				+	+				+		+	
Carex digitata							3		1	1	+	1		1	+
Carex sylvatica		1	1	1		+	2	1		1	+	+	1	+	2
Circaea lutetiana		+	+	1	1	1		1						+	r
Convallaria majalis							1								
Corydalis solida				1	+					+					
Dactylis glomerata														+	
Dactylis polygama		+													
Deschampsia caespitosa							+								
Dicranum undulatum														1	
Dryopteris carthusiana	2	1					1	+	2		+	1			+
Dryopteris filix-mas	1	1	2	1	1	1	3	3		2	2	1	1	1	1
Festuca gigantea			+	1	+	+					1	+	+	r	
Ficaria verna	2		3	3	3	2				2					
Fragaria vesca	1						2	1	+						
Gagea lutea	+			+	+	+									
Galeobdolon luteum				2	3	2			+			+		+	
Galium odoratum		4	+	1	2	2		1	+	3	2	2	1	2	3
Galium schultesii									1				+		
Geranium robertianum	1		+				+								+
Geum rivale							2								
Geum urbanum	1		2		1	2	1	1	2	1	+	1	+	+	r

Table 5 continued

	Mircze 1	Mircze 2	Mircze 3	Mircze 4	Mircze 5	Mircze 6	Mircze 7	Mircze 8	Mircze 9	Mircze 10	Mircze 11	Strzelce 1	Strzelce 2	Strzelce 3	Strzelce 4
Glechoma hederacea			2	1	1									r	
Hepatica nobilis				2	1					+	1	+	+		
Hieracium lachenalii									+						
Hypnum cupressiforme												1			
Impatiens noli-tangere			2	1		1					1				
Lathyrus vernus		+		+							1		r	+	
Lilium martagon							+			+					
Luzula luzuloides		1													
Luzula pilosa									+					+	+
Lysimachia vulgaris			1												
Maianthemum bifolium	1	3	+				+		2						
Melica nutans				+			2	+	1						
Melittis melissophyllum							+								
Mercurialis perennis					+	+						r			
Milium effusum	1	+	+	1	+						+	+	+		+
Mnium affine												2			
Mnium undulatum												1		1	2
Moehringia trinervia								+							+
Mycelis muralis	1	1		+				+				+	+		+
Oxalis acetosella	3					2	2	1		2	2	2		+	3
Paris quadrifolia				+		+					+		+		
Plagiomnium undulatum		1			+										
Poa annua															+
Poa palustris														1	
Polygonatum multiflorum				+	1	+			+				+	+	
Polygonatum odoratum													r		
Primula elatior							+								
Pteridium aquilinum	2		+												
Pulmonaria obscura		2	+	2		+	2		+	3	2	1	+	+	+
Ranunculus acris							+							r	
Ranunculus lanuginosus					+	+				1					
Ranunculus repens			+												

Table 5 continued

	Mircze 1	Mircze 2	Mircze 3	Mircze 4	Mircze 5	Mircze 6	Mircze 7	Mircze 8	Mircze 9	Mircze 10	Mircze 11	Strzelce 1	Strzelce 2	Strzelce 3	Strzelce 4
Rubus caesius			5	1	+			1						r	
Rubus idaeus						2		1							+
Rubus plicatus															+
Rubus saxatilis									+						
Sanicula europaea	1	+	+			+						+			
Scrophularia nodosa								+							
Stachys sylvatica			+		1	1					1		r		
Stellaria holostea				1								+	+		
Stellaria nemorum						1									
Urtica dioica			2	2	+	3	1	+				+			+
Veronica chamaedrys							+								
Veronica officinalis															r
Vinca minor	1	2									2				
Viola mirabilis		+		1						3	1				
Viola reichenbachiana	1	2		+			2		1		+	1	1	1	2
Viola riviniana								1						+	
Number of vascular plants	18	21	26	30	23	23	24	19	17	18	21	23	22	23	23

the soil pH and stimulated enzyme activity in the soil (Gruba 2004; Błońska et al. 2016).

In soils of different ecosystems, the greatest accumulation of organic carbon occurs in the surface horizons. This is related to the supply of organic remains originating from above-ground parts of plants and animals, root systems and organisms living in the soil (Zwydak et al. 2017). According to the authors, the content of organic carbon accumulated in the layer down to the depth of 50 cm constitutes 64–94% of total organic carbon stock accumulated in the soils. In the described chernozems afforested with broadleaved vegetation, high carbon content was recorded in the surface mineral humus horizons. The maximum SOC stock was 262 Mg ha^{-1}. Several papers confirm, that under variable conditions, the highest organic carbon stocks occur in the topsoil layer, down to the depth of 30 cm (Marinho et al. 2017; Börjesson et al. 2018). De Vos et al. (2015) estimated its total stocks at 3.50–3.94 Gt C in forest floors and 21.4–22.7 Gt C in mineral and peat soils down to 1 m in European forests.

CONCLUSIONS

The research confirmed the good condition of chernozems covered with forest vegetation in SE Poland. The Trophic Soil Index (SIG) confirms the eutrophic character of the analysed soils. Chernozems develop habitats of fresh and wet broadleaved forests (Lśw and Lw), as well as fresh broadleaved upland forests (Lwyżśw). They are covered with multi- species broadleaved tree stands. A potential plant association is oak-hornbeam forest with predominance of oak, hornbeam and abundant admixtures of other broadleaved species. In the case of higher moisture, chernozems are covered with tree stands with ash, elm and alder, with forest floor species typical of wet forms of oak-hornbeam forest. High trophic status of the analysed chernozems is confirmed by high bonitation class of tree stands and botanical richness of the forest floor vegetation.

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Siedliska leśne i lasy występujące na czarnoziemach w południowo-wschodniej Polsce

Streszczenie: Celem pracy jest ukazanie właściwości chemicznych czarnoziemów porośniętych lasami oraz cechy siedlisk leśnych wykształconych na czarnoziemach. Do oceny trofizmu czarnoziemów wykorzystano Siedliskowy Indeks Glebowy (SIG). Dodatkowo w pracy starano się przedstawić zróżnicowanie roślinności występującej na czarnoziemach terenów leśnych. W badaniach uwzględniono 15 powierzchni wzorcowych pochodzących z inwentaryzacji siedlisk wykonanych dla Nadleśnictwa Mircze i Strzelce. Na powierzchniach badawczych scharakteryzowano warunki siedliskowe ze szczególnym uwzględnieniem gleby oraz roślinności. Badane gleby charakteryzowały się obecnością głębokich poziomów próchnicznych, oraz zawartością węglanu wapnia. Siedliskowy Indeks Glebowy (SIG) potwierdza eutroficzny charakter badanych gleb. Czarnoziemy tworzą siedliska lasów świeżych i wilgotnych (Lśw i Lw) oraz lasów wyżynnych świeżych (Lwyżśw). Związane są z wielogatunkowymi drzewostanami liściastymi. Wyniki przeprowadzonych badań sugerują, że w obecnych warunkach środowiskowych potencjalnym zespołem roślinnym badanych czarnoziemów są grądy z dominacją dębu, grabu oraz licznymi domieszkami gatunków liściastych. Wysoki trofizm badanych czarnoziemów potwierdza bonitacja drzewostanów oraz bogactwo roślinności runa.

Słowa kluczowe: gleby leśne; warunki siedliskowe; właściwości gleb; Siedliskowy Indeks Glebowy.