Acta Agrophysica, 2001, 50, 17-28

CHARACTERISTICS OF THE MEADOW HYDROGENIC SOILS IN PRZEDMOŚCIE AGAINST THE BACKGROUND OF FORMING PLANT COMMUNITIES

A. Bogacz[1], *D. Grodzińska*[1], *K. Chachuła*[1], *D. Kasowska*[2]

[1]Institute of Soils Science and Agricultural Environment Protection
[2]Department of Botany and Plant Physiology, Agricultural University in Wrocław
Grunwaldzka 53, 50-305 Wrocław, Poland

A b s t r a c t. The aim of this work was to compile characteristics of some selected physical, physico-chemical and chemical properties of the reclaimed hydrogenic soils in the meadow part of the Przedmoście bog in the context of new forming plant communities. Melioration work conducted in this area before the Second World War ended peat accumulation processes. Consequently, drying peat began to disintegrate and mineralise. Analyses of floral lists proved that the existing vegetation replaced the original bog plant communities, which flourished in this area in the past. Descriptions of profiles point to the existence of mixed formations (gyttja, peat) often containing high quantities of $CaCO_3$. Peat formations present in the profiles are usually at the advanced degree of decomposition (H>7) and contain substantial quantities of ash. This high degree of ash content and bulk density results in strong compaction and muddy soil horizons. A low coefficient of C/N showed intense mineralization of organic matter in the upper soil horizons.

K e y w o r d s: hydrogenic soils, melioration, meadow, plant community, soil properties.

INTRODUCTION

Hydrogenic soils in valley habitats display specific properties. Their properties depend on the organic matter accumulated during bog forming processes [2,13]. In the past, such lands were subjected to melioration in order to reclaim them for agriculture. Consequently, a natural bog habitat was transformed into arable fields and grasslands. Intense melioration work, concentrated mainly on water drainage and consequently, agricultural use of these soils resulted in a number of changes in the physical, physico-chemical, chemical and biological properties, often leading to soil degradation [8]. Changes in air and water conditions in these soils were a direct cause of changes in the muck forming process [14].

The aim of this work was to compile characteristics of some selected physical, physico-chemical and chemical properties of the reclaimed hydrogenic soils in the meadow part of the Przedmoście bog in the context of new forming plant communities.

OBJECT DESCRIPTION

The meadow part of the bog was situated 25 km north-west from Wroclaw and approximately 2 km north-east from the village of Przedmoście. The research object consisted of 11 ha of land in the IV, V and VI class of soil agricultural valuation. The object is situated in the fluvial area of the prehistoric Odra riverbed in the zone influenced by two types of hydrological supply: fluvigenic and soligenic. The historic bog forming process was conditioned by excessive saturation with water, shape of topographic profile and presence of non-permeable third grade silts in the soil base covered with a thin layer of alluvial sand. This led to the formation of peat layers with considerable horizon depth from 90 to 300 cm, often formed on lake mud also known as gyttja [11]. Melioration work conducted in this area before the Second World War ended peat accumulation processes. Consequently, the drying peat began to disintegrate and mineralise.

METHODS

In the spring of 1998, four soil profiles were selected from the meadow part of the bog. Fourteen soil samples were obtained from the genetic levels of the selected profiles for subsequent determination of physical properties. Sixteen additional soil samples were taken from the surface levels at depths of: 0-5, 10-15, 20-25, and 30-35 cm for the determination of physico-chemical and chemical properties. At the same time the floral lists were compiled within the 10 x 10 m surface of selected profiles. Each of the individual surfaces was classified to the relevant prognostic soil moisture complex (PKWG).

The following physical properties were determined in the collected material:

- ash content by burning in a muffle furnace at 550 ^{o}C over 4 hours,
- bulk density with the Kopecky's cylinders of 100 cm^3 volume,
- water properties including field water capacity of the soil (pF=2.0) with a sand box and kaolin sand box made by Eijkelkamp company,
- maximum hygroscopic capacity by the Nikolayev's method.

Specific density was assayed on the basis of ash content by the Okruszko's method. Total porosity was calculated on the basis of specific and bulk density.

From the values obtained on the pF curve, percentage calculation was performed for the macro- (>30 μm), meso- (30-0.2 μm) and micro- (<0.2 μm) soil pores against the total porosity and the value of potential usable retention (pF 2.0-4.2). On the basis of the volume of soil mesopores in each level and depth, retention capacity in the two chosen soil samples was calculated.

The following physico-chemical properties were determined:

- pH in H_2O and 1 M KCl potentiometrically,
- salinity - conductometrically,
- $CaCO_3$ by the gasometric method in the Scheibler's apparatus,
- the contents of C-total, C-organic and S-total with a CS-MAT 5500 apparatus,
- total nitrogen content by the Kjeidahl's method,
- contents of soluble K, Na, Fe and Mg forms in 0.5 M HCl extract.

Moreover, the following determinations were made in a water sample obtained from the water source area: pH, salinity and the contents of selected ions: Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}, Cl^{-}.

RESULTS

Floral characteristics of the object

Range of floral species in plant communities found in bogs depends on the hydrological conditions, and in particular, on the trophic character of water supply in any given habitat [10,12]. Unfavourable changes in the soil hydrogenic properties after water drainage, are further magnified by ploughing. This stops development of vegetation specific to bog areas and consequently destroys valuable plant communities [3]. Characteristics of the objects under this research are described in the work by Stankiewicz [11]. The actual diversification among the plant species presented in the selected parts of the bog under research are listed below:

Meadow No. I

Meadow plant community - class *Molinio-Arrhenatheretea*

Low grasses dominated ground cover: *Festuca rubra* and *Bromus mollis*. To a smaller extent: *Poa pratensis*, meadow fescue *Festuca pratensis*, *Dactylis glomerata*. Dicotyledonous class was represented by *Cirsium arvense*. Among other species there were common nettle *Urtica dioica*, *Galium mollugo*, *Potentilla reptans*, *P. anserina* and *Ranunculus acer.*

Meadow No. II

Meadow plant community - class *Molinio-Arrhenatheretea*

Meadow herbs appear in greater quantities than grasses. The following herbs were listed: *Filipendula ulmaria, Thalictrum flavum, Cirsium oleracea, Lychnis flos-cuculi Ranunculus acer, R. repens, Mentha* sp., *Angelica silvestris, Polygonum bistorta, Lathyrus pratensis, Veronika chamaedrys* and *Potentilla anserina*. The grasses were *Molinia coerulea, Deschampsia caespitosa* and *Bromus mollis*. Also listed were: *Avenastrum pubescens, Festuca rubra, Poa pratensis, Poa trivialis, Carex fusca, C. grâcilis* and *Phragmites communis.*

Meadow No. III

Meadow plant community - class *Molinio-Arrhenatheretea*

Festuca rubra dominated the ground cover. Also present: *Molinia corerulea, Deschampsia caespitosa, Dactylis glomerata, F. pratensis, Poa palustris, P. pratensis, Alopecurus pratensis, Holcus lanatus* and *Carex hirta*. Meadow herbs were well represented by *Cirsium oleraceum, Thalictrum flavum, Lathyrus pratensis, Symphytum officinale, Taraxacum officinale, Sanguisorba officinalis, Potentilla anserina, P. reptans, Ranunculus acer, R. reptens, Achillea millefolium, Galium mollugo, Cirsium arvense, Cearstium vulgatum, Moechriingia trinervia,* and *Veronica chmaedrys*.

Meadow No. IV

Carex community - with *Carex acutiformis*

Carex acutiformis and *Carex fusca* played a dominating role in a tall carex stand. Other plant species occurred sporadically, among them were *Symphytum officinale* and *Lysimachia thyrsiflora.*

Analyses of the floral lists proved that the existing vegetation replaced the original bog plant communities, which flourished in this area in the past. Listings compiled for the profiles I-III revealed only small quantities of rare grasses and valuable herb species, whereas plants considered to be common weeds appeared in large quantities. In the group of grasses the most common were *Festuca rubra* and *Poa pratensis.* Presence of these species is characteristic of the habitats with a well-advanced degradation process. In moderately wet habitats nitrogen dependent plants commonly appear i.e. *Urtica dioica*. Presence of this species in the analysed soil confirms that an intensive peat mineralization process takes place [3]. The wettest habitat in the profile IV was represented by the *Carex* stand dominated by single *Carex* species. Other species appeared in limited numbers.

Morphology of soil profiles

Soils represented in the analysed profiles were classified according to the Taxonomy of Polish Soils [1], hydrogenic soils, in the order of post-bog soils and muck type soils. The above type was further broken down to subtypes as follows: peat-muck subtype (profile II and IV), gyttja-muck subtype (profile I) and muck-like subtype (profile III). According to FAO [16] these soils were classified as Terric Histosols. Systematic units described herein are characterised by a medium or high muck content. Descriptions of the profiles show the existence of mixed formations in their levels (gyttja, peat) often with high quantities of $CaCO_3$. Peat formations present in the profiles are usually of advanced decomposition degree (H>7) and contain substantial quantities of ash. Based on the depth of organic levels in the profiles, the studied soils can be classified as moderately deep soils and deep soils. At the time of research, in May 1998, water levels in the soils of the selected areas ranged from 20 to 60 cm below the ground and were classified according to structure into three categories (PKWG): periodically mid-dry BC, mid-dry C, and periodically dry CD.

Selected physical properties of soil

Ash content, as an important indicator of muddy process in organic formations, ranged from 39.84 % d.m. in the peat level Otni1 prof. IV to 77.31 % d.m. in the muck horizon Mtni1 prof. III. High values of this parameter may be due to either a strong inflow of mud carried by ground water, peat mineralization, or mineral molecules deposited by wind [5,9]. Peat horizons show medium to high degree of decomposition. The calculated values of specific gravity ranged from 1.89 to 2.30 Mg m^{-3} and characterised the studied formations as muddy or strongly muddy. The values of bulk density in the assayed horizons were from 0.21 to 0.95 Mg m^{-3} and pointed to high density of organic matter. Total porosity was calculated in the range of 52.5-89.1%. The highest values of this parameter were found in the peat horizons, whereas lower values appeared in muck horizons and the lowest were identified in the gyttja horizons (Table 1).

Table 1. Physical properties of analysed soils

Profile No.	Genetic horizon	Horizon depth (cm)	Sample depth (cm)	Ash content (% d.m.)	Specific density (Mg m^{-3})	Bulk density (Mg m^{-3})	Total porosity (%)	PPW pF=2.0 (% v/v)	PPW pF=4.2 (% v/v)
I	Mtni1	0-13	5-10	48.46	1.98	0.55	72.2	58.7	25.7
	Mtni2	13-43	20-25	55.57	2.06	0.67	67.6	50.9	23.4
	Mtni3	43-60	50-55	59.24	2.10	0.77	63.2	49.0	32.1
	Ogy	60-100	85-90	50.05	2.00	0.95	52.5	42.7	4.2
	D	<100	-	-	-	-	-	-	-
II	Mtni1	0-25	10-15	49.35	1.99	1.11	-	-	-
	Mtni2	25-35	30-35	53.76	2.04	0.45	78.1	66.3	30.9
	Otni	35-45	40-45	53.17	2.04	0.37	81.7	69.7	16.2
	Ogy/D	45-67	48-53	84.84	2.38	0.53	77.8	66.6	8.5
	Dgy	<67	-	-	-	-	-	-	-
III	Mtni1	0-15	10-15	77.31	2.30	1.22	-	-	-
	AM1	15-30	20-25	82.53	2.36	0.80	66.2	49.5	18.5
	AM2	30-45	35-40	82.66	2.36	1.24	-	-	-
	Mtni2	45-73	50-55	62.00	2.13	0.60	72.1	49.2	27.6
	D	73-96	85-90	89.31	2.43	0.59	75.6	66.0	5.9
	Ogy	96-108	-	-	-	-	-	-	-
	Ogy/t	108-136	-	-	-	-	-	-	-
	Otni	<136	-	-	-	-	-	-	-
IV	Mtni	0-30	30-35	47.17	1.97	0.33	83.4	59.3	18.5
	Otni1	30-70	50-55	39.84	1.89	0.21	89.1	73.4	18.0
	Otni2	70-90	85-90	57.26	2.08	0.28	86.3	70.1	17.1
	Ogy	<90	100-105	76.80	2.30	0.52	77.2	67.5	11.6

The values of soil field water capacity (PPW) were high in the peat horizons. Field soil water capacity in the horizons subjected to the muck forming process was lower than the values of this parameter in the peat horizons. Comparison between the profile I and profile IV, based on the differential analyses of porosity, revealed a significant decrease in the number of mesopores present in the muck horizons, in relation to peat horizons. This is mainly due to the muck forming process, which alters the physical and chemical soil properties, such as muck density and increase in the volume of soil micro- and macropores. Peat levels in the profile IV contained significant quantities of mesopores, while the number of macro and micro pores remained similar to the muck horizons. Different distribution of particular groups of pores was found in the gyttja levels, with lower total porosity in comparison to peat and muck horizons, where mesopores were clearly a dominating group of pores (Figs 1 and 2).

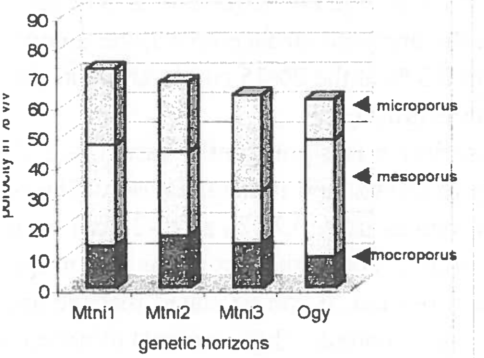

Fig. 1. Porosity in horizons (profile I).

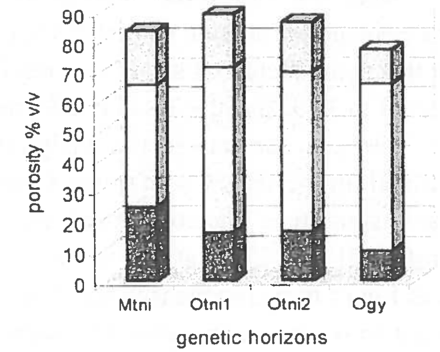

Fig. 2. Porosity in horizons (profile IV).

Physico-chemical and chemical properties of the soils

Soil reaction influences growth of bog vegetation and a number of processes occurring in organic soils. Determinations of soil pH showed neutral or alkaline reaction in the surface layers ranging from 6.62 in H_2O and 6.65 in 1 M KCl at 30-35 cm depth in profile IV to 7.83 in H_2O and 7.74 in 1 M KCl at 30-35 cm in profile III. The highest pH values were found in profile III, which can be explained by a high $CaCO_3$ content. Moreover, the lowest pH values appeared in profile IV coinciding with low content of $CaCO_3$.

Organic formations may show increased salinity due to their high sorption ability. Water flowing into peat areas may be the source of chemical compounds influencing this parameter. Salinity of the analysed soils was found in the range from 325 mS cm^{-1} at 30-35 cm depth in profile III to 840 mS cm^{-1} at 0-5 cm in profile IV. According to the relevant norms (FAO/UNESCO), some of the soil levels show a slight degree of salinity. The highest salinity values in all of the profiles were found at the 0-5 cm depth. The most probable cause is precipitation of salt in the highly mineralised ground waters supplying the peat area.

Where calcium carbonate occurs in large quantities in organic soils in the water supply areas, it significantly modifies physical, chemical and biological properties of these soils. High $CaCO_3$ content of in the analysed profiles, reaching at times over 80% in the gyttja type mineral levels, are related to the formation of mixed sediments of the gyttja-peat type as well as saturation of the organic substance with strongly mineralised supply waters.

Muck forming process and decomposition of organic matter causes changes in the contents of organic carbon (TOC). In the analysed surface levels, the quantity of this component was small, ranging from 8.3 % at the 20-25 cm depth in the profile III to 34.9 % at the 30-35 cm depth in the profile IV.

Nitrogen contents in the analysed profiles was significantly varied and depended on the intensity of muck forming processes and mineralization of the organic substance. The contents of nitrogen ranges from 0.74 % at 20-25 cm in the profile III to 3.22 % at 0.5 cm in the profile I. The highest contents of nitrogen was found in well advanced muck levels at 0-5 cm. It can be stated that the analysed soils were characterised by high nitrogen contents. High contents of nitrogen in the organic soil had a detrimental effect on the development of vegetation by allowing vigorous growth of weeds and tall grasses. This phenomenon can be observed in the selected bog areas in Przedmoście.

The muck forming process occurring in the surface horizons shows a C/N ratio ranging from around 8 at 0-5 cm depth in the profile I to approximately 18 at 10-15 cm in the profile II. Sulphur contents in hydrogenic soils depend on the amount of organic matter in the soils and on the peat types. Organic soils contain more than twice as much sulphur than the mineral formations [7]. The surface levels contain from 0.007 % S to 0.153 % S. Majority of the analysed levels showed low sulphur content. Only two layers in the profile IV contained the second degree of sulphur abundance (Table 2).

In the surface levels of the analysed soils determinations of soluble Na, K, Mg and Fe were made, extracted from soil with 0.5 M HCl, in order to evaluate the richness of these soils. Content of macro elements show Table 3.

The analyses showed that the sodium contents in surface levels ranged from 72.0 to 288.0 mg 100 g^{-1} of soil. The 0-5 cm levels showed lower contents of this element than deeper levels, which could mean a downward migration of sodium through the soil profile. The upper levels contained on average 5 times more sodium than potassium. Such high sodium contents are connected with a high concentration of this component in the mineralised water supply.

In the hydrogenic soils with high mud content, sorption and accumulation of potassium in the surface levels of the soil is common. Potassium contents in the researched surface layers ranged from 14.4 to 57.6 mg 100 g^{-1} of soil. All of the soil profiles showed from low to medium potassium content [6]. This leads to the conclusion that these are the soils mainly with poor potassium content. Concentration

Table 2. Physico-chemical soil properties in the upper layers

Profile No.	Sample No.	Sample depth (cm)	pH H_2O	pH 1M KCl	Salinity mS cm^{-1}	$CaCO_3$ (%)	TC (%)	TOC (%)	N (%)	C/N	S (%)
I	1	0-5	7.54	7.18	575	9.1	20.2	19.1	2.32	8.2	0.022
	2	10-15	7.74	7.45	395	3.3	15.6	15.2	1.24	12.3	0.018
	3	20-25	7.68	7.44	455	19.1	16.2	13.9	1.27	10.9	0.025
	4	30-35	7.71	7.46	460	11.6	16.7	15.3	1.32	11.6	0.044
II	5	0-5	7.40	7.22	750	10.0	25.9	24.7	1.76	14.0	0.036
	6	10-15	7.51	7.26	565	14.1	23.6	21.9	1.23	17.8	0.016
	7	20-25	7.50	7.30	550	20.8	22.6	20.1	1.69	11.9	0.020
	8	30-35	7.33	7.01	385	4.4	23.0	22.5	1.31	17.1	0.090
III	9	0-5	7.67	7.43	430	50.7	16.0	9.9	0.84	11.8	0.015
	10	10-15	7.68	7.56	395	44.0	14.7	9.4	0.82	11.5	0.015
	11	20-25	7.71	7.60	325	49.1	14.2	8.3	0.74	11.2	0.009
	12	30-35	7.83	7.74	270	38.2	13.0	8.4	0.84	10.0	0.007
IV	13	0-5	7.28	7.15	840	6.0	24.5	23.8	1.46	16.3	0.086
	14	10-15	7.22	7.09	725	5.6	24.6	23.9	2.12	11.3	0.097
	15	20-25	7.20	6.91	565	4.4	30.5	29.9	2.38	12.6	0.132
	16	30-35	6.82	6.65	770	3.1	35.3	34.9	2.69	12.9	0.153

Table 3. Content of macro-elements in the soil extracted 0.5 M HCl (upper layers)

Profile No.	Sample No.	Sample depth (cm)	Na	K	Mg	Fe
			(mg 100 g^{-1} of soil)			
I	1	0-5	140.8	50.4	118.8	2 340
	2	10-15	144.0	22.4	94.8	2 030
	3	20-25	163.3	25.9	103.6	2 670
	4	30-35	160.0	28.8	101.6	2 600
II	5	0-5	150.4	57.6	108.4	2 080
	6	10-15	160.0	36.0	114.4	2 340
	7	20-25	200.0	37.4	96.0	2 120
	8	30-35	72.0	14.4	77.2	4 590
III	9	0-5	240.0	50.4	130.0	2 080
	10	10-15	278.0	40.3	122.8	2 080
	11	20-25	288.0	31.7	112.0	1 920
	12	30-35	278.4	31.7	80.0	1 990
IV	13	0-5	104.0	25.9	116.8	1 170
	14	10-15	108.8	21.6	84.4	1 320
	15	20-25	91.2	21.6	94.0	2 120
	16	30-35	88.0	21.6	97.2	2 010

of potassium in the 0-5 cm level indicates that the biological type and the exchange type of sorption plays a significant role in the prevention of potassium leaching.

Organic soils containing high quantities of $CaCO_3$ are often characterised by high magnesium content. In the analysed layers, the contents of magnesium ranged from 77.2 to 130.0 mg 100 g^{-1} of soil. Based on the established border numbers, the researched layers were characterised by medium, high or very high magnesium contents. Generally it can be stated that the analysed soils were rich in this component. Distribution of magnesium was similar to potassium in the 0-5 cm surface levels in all the profiles, as that they contained more of these components than the deeper soil levels.

Surface levels of organic soils often contain high quantities of iron [1]. Its source can be in the floodwaters overflowing from the surrounding areas or precipitation of trivalent iron from the ascending groundwater. Surface layers of the studied soils contained soluble iron quantities ranging from 1170 to 4590 mg 100 g-1 of soil. The upper levels of these layers did not contain significant concentrations of iron. This is probably related to the presence of mixed formations, such as gyttja-peat. Distribution of soluble iron in the studied soil profiles showed an opposite tendency to that of potassium and magnesium, i.e. iron contents increased with the depth.

Analysis of water from the water stream area in the Przedmoście bog

Physico-chemical properties and the chemical composition of the water stream in the bog area play a basic role in its trophic characteristics. Determinations of the selected physico-chemical and chemical parameters of water supplying the bog area show alkaline reaction, high salinity and high contents of calcium and magnesium ions (Table 4).

Table 4. Chemical properties of water in the Przedmoście peatland area

pH	Salinity µS cm^{-1}	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	SO_4^{2-}	PO_4^{3-}	Cl^{-}
		mg L^{-1}						
7.59	500	82.0	78.0	47.0	2.0	43.6	43.5	17.6

CONCLUSIONS

1. Research on the morphology of the soil profiles showed the presence of the organic mixed formations in the layers, often with high $CaCO_3$ content, which are usually characterised by a high degree of decomposition and muddy.

2. Floristic lists for individual areas showed that the forming meadow communities substitute the groups of former peatygenic flora. The lists show decreasing numbers of refined grasses and precious herb species, and increasing distribution of the plants which are commonly consider as weeds.

3. Characteristics of the physical-water soil horizons show a considerable differentiation in the distribution of macro- >30 μm (9.8-24.1 %) mezo- 30-0.2 μm (16.9-61.4 %), and micropores <0.2 μm (4.2-31.2 %) among individual formations in the profiles.

4. The soils were characterised by neutral and alkaline pH of 6.82-7.83 in H_2O and 6.55-7.74 in 1 M KCl and by the salinity of 430 to 840 mS cm^{-1} of the soil.

5. On the basis of observation and laboratory analyses, the surfaces I to IV were classified as three prognostic moistly-soil complexes (PKWG), i.e.: BC - seasonally draughty, CD - draughty, and C - dry.

6. High ash content and bulk density show strong level of compaction and muddiness of the analysed soil horizons.

7. A low coefficient C/N showed an intensive level of organic matter mineralization in the upper soil horizons

8. A low and medium K content and high content of Na and Mg in the upper soil organic layers was characteristic. The content of S in this layers was low.

REFERENCES

1. **Giedrojć B.:** Właściwości fizyczne i chemiczne niektórych gleb organicznych w Dolinie rzeki Średzianki na Dolnym Śląsku. Roczn. Glebozn., 36, 3, 51-65, 1985.
2. **Gotkiewicz J.:** Problematyka gleb hydrogenicznych w warunkach Polski. Szkoła letnia z zakresu gleb hydrogenicznych. Olsztyn-Osowiec-Biebrza, 65-72, 1996.
3. **Kiryluk A.:** Wpływ wieloletniego użytkowania łąkowego torfowiska niskiego na produkcję biomasy i kształtowanie się zbiorowisk roślinnych w dolinie rzeki Supraśl. Zesz. Probl. Post. Nauk Roln., 38, 149-154, 1996.
4. **Kovda V.A., Antipov-Karataivev I., Kellog C.E., Raychandhuli S.P. Szablocs J.:** Origin of Saline Soil. International Source Book, FAO/UNESCO, Paris, 1967.
5. **Kowaliński S.:** Gleby murszowe i ich przeobrażenie pod wpływem uprawy płużnej. Prace Wrocławskiego Towarzystwa Naukowego, Seria B, 124, 1964.
6. Liczby graniczne do wyceny zawartości w glebie makro i mikroelementów IUNG. Zalecenia nawozowe cz.I, Puławy, 1985.
7. **Motowicka-Terelak T., Terelak H., Witek T.:** Liczby graniczne do wyceny zawartości siarki w glebach i w roślinach. IUNG, Puławy, 15-19, 1993.
8. **Okruszko H.:** Zagadnienia degradacji torfowisk na tle właściwości fizycznych oraz żyzności torfu. Zesz. Probl. Post. Nauk Roln., 10, 37-72, 1957.
9. **Piaścik H., Bieniek B., Wojciak H.:** Skutki odwodnienia gleb torfowych w wyniku prac hydrotechnicznych na Pojezierzu Olsztyńskim. Zesz. Nauk ART Olsztyn, 20, 25-33, 1990.

10.**Prończuk J.**: Typolgiczne zasady zróżnicowania trwałych użytków zielonych na przykładzie wydzielonych typów florystycznch w dolinach rzek na niżu. IMUZ, Bibl. Wiad., 5, 16-24, 1962.
11.**Stankiewicz A**: Właściwości chemiczne gleb torfowych łąkowej części torfowiska źrodliskowego koło Przedmościa. Praca magisterska, AR Wrocław, 1983.
12.**Tołpa S.**: Rozwój zbiorowisk roślinnych na torfowisku niskim w zależności od kierunku przebiegu procesów biologicznych w podłożu torfowym. Zesz. Probl. Post. Nauk Roln., 2, 43-69, 1956.
13.**Tomaszewski J.**: Gleby błotne Polesia. Materiały do poznania gleb polskich. 4, Puławy, 1935.
14.**Tomaszewski J.**: Gleby łąkowe. PWRiL, Warszawa, 1969.
15.Systematyka Gleb Polski. Roczn. Glebozn., 40, 7-150, 1989.
16.FAO Soil Taxonomy. FAO-Rome, 1987.