SOIL SCIENCE ANNUAL
2022, 73(3), 157099

https://doi.org/10.37501/soilsa/157099

Classification of alluvial soils – problematic issues on the examples from South Baltic Lakelands, north Poland

Marcin Świtoniak*, Adam Michalski, Maciej Markiewicz

Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management, ul. Gagarina 11, 87-100 Toruń, Poland

* Dr hab. M. Świtoniak, swit@umk.pl, ORCID iD: https://orcid.org/0000-0002-9907-7088

Received: 2022-07-20
Accepted: 2022-12-03
Published online: 2022-12-03
Associated editor: Ł. Mendyk

Key words:

Fluvisols
Alluvial plains
Polish Soil Classification
Gleysols
Cambic
Brunic

Abstract

Alluvial soils constitute a group of soils that is very diverse in terms of their genesis and what is the effect of it – most of properties, e.g. organic carbon content, features connected with ground or stagnating water, development of B horizons or texture. It is also reflected in their systematic position. Currently, the Polish Soil Classification (PSC, 2019) distinguishes as many as 3 types of soils developed from fluvic materials: ordinary, chernozemic and brown alluvial soils. Some of soils with alluvial sediments strongly influenced by water but without diagnostic horizons can be also classified as gleysols or stagnosols. The aim of the article was to check the criteria and to verify completeness of units in the rank of types and subtypes for distinguishing alluvial soils in latest version of Polish Soil Classification (PSC, 2019). The study was carried out in area covered by Vistulian glaciation in Northern Poland. 87 profiles to the maximum depth of 210 cm were studied. 18 pedons belong to chernozemic alluvial soils, the most common type (48) was classified as brown alluvial soils, ordinary alluvial soils occurred 11 times. Moreover, 7 pedons with fluvic material were classified as gleysols. Other 3 soils represented organic and colluvial soils. Based on the conducted research some changes in Polish Soil Classification have been proposed. They are regarding the minimum thickness of fluvic materials for classifying alluvial soils, the revision of the humus subtype, the introduction of the type of gleyzemic alluvial soils in gleyzemic order or subtype of alluvial soils in type of gleysols and subtype of waterlogged soils in chernozemic alluvial soil type. The article also addresses important issues of the origin and classification of B horizons in the studied soils, and confirmed significant usefulness of soil-agricultural maps in determining the places of occurrence of alluvial soils.

1. Introduction

Alluvial soils are an crucial element in river, lake and coastal-related ecosystems. Due to their specific genesis, they can occur in all climatic zones of the world (Driessen et al., 2001). Despite some common features (e.g. stratification of the material, the influence of groundwater), the high differentiation of the pedogenic properties of these soils makes them a very diverse group (e.g. Holmes and Hearn, 1942; Sheremet, 2006; Schaetzl and Anderson, 2005). Nevertheless, these soils are still often treated by many researchers as homogenous cluster in which lithogenesis plays a major role. Such a lithogenetic approach, which is treating alluvial soils as a one unit without taking into account pedogenic transformations, can be found in many publications on various study aspects, e.g.: clay minerals (Cieśla et al., 1988), water retention (Hewelke et al., 2018), soil contamination (Cappuyns and Swennen, 2007), anthropogenic changes (Kanno et al., 1965), identification of geotechnical parameters (Yilmaz and Karacan, 1997; Młynarek et al., 2012). One of the reasons for this is because in many older versions of classification systems – including international ones – most of the pedons developed from alluvial materials were put to the one main unit. For example, according to the WRB (IUSS Working Group WRB, 2007), majority of alluvial soils were classified only as Fluvisols. This Reference Group was located on the beginning of classification key. Pedogenesis of these soils were expressed on lower rank units by qualifiers. In the third version (IUSS Working Group WRB, 2015) of this classification system more emphasis was placed on the pedogenesis of alluvial soils. Pedons developed from such deposits are represented by 24 out of 32 Reference Soil Groups. The presence of alluvial material is expressed by using the *fluvic* qualifier on lower rank units (e.g. Cipriano-Silva et al., 2020; Kawałko et al., 2021). Fluvisols Reference Group was placed on the end of the classification key and refers to young alluvial soils weakly changed by pedogenesis only. Also in Soil Taxonomy these soils are often linked by researchers automatically with suborder of Entisols – Fluvents, that consists of very young sediments (Soil Survey Staff USDA, Soil Taxonomy, 1999). Meanwhile, soils with alluvial material are also represented by many subgroups of other orders (e.g. Iqbal et. al., 2005; Hikmatullah and Al-Jabri, 2007). The classification of alluvial soils is of great importance for environmental research and may shape the awareness of the diversity of processes taking place in such soils. The international literature shows a gradual increase in the emphasis on pedogenetic processes taking place in alluvial deposits.

Research on alluvial soils was carried out in Poland by many authors in various regions of the country (e.g. Laskowski, 1986; Cieśla et al., 1988; Banaszuk, 1987; Chojnicki, 2001, 2002; Paluszek, 2004; Kabała et al., 2011; Michalski, 2013; Mendyk et al., 2015; Kobierski and Banach-Szott, 2022) from the spring areas (Jonczak, 2015) up to the estuary areas under the influence of the Baltic Sea (Hulisz et al., 2015). They generally concern studies on soils developed from fluvial sediments (e.g. Dąbkowska-Naskręt, 1994; Niedźwiecki et al., 2010a; Łabaz and Kabała, 2016) but also in some cases lacustrine *fluvic* material was under investigations (Łachacz and Nitkiewicz, 2021). The complexity and heterogeneity of soil-forming processes in alluvial deposits was described already in the 1950s by Strzemski (1955). Great importance to the pedogenic differentiation of alluvial soils was reflected from the very first editions of the Polish Soil Classification. Despite the fact that these soils constitute only about 4% of the country's area (Bednarek and Prusinkiewicz, 1997; Sykuła et al., 2019), out of the 11 distinguished types in second edition of PSC (1959), as many as 4 concerned soils of "contemporary river terraces". These disproportions result from the fact that the first editions of PSC put a lot of emphasis on soils of high agricultural value, and alluvial soils are one of the most fertile soils in Poland. In next two editions of PSC (1974, 1989) alluvial soils were divided into only two types (river and marsh alluvial soils) with four subtypes. In the 2011 version, the division into 3 types with a total of 5 subtypes has already been introduced. In the latest version of the Polish Soil Classification (PSC, 2019), soils developed from fluvial or lacustrine deposits are still (like in previous edition from 2011) present on main taxonomic level by three types: (I) chernozemic, (II) brown and (III) ordinary alluvial soils. Their considerable differentiation was highlighted by introducing as much as 14 subtypes in total. Moreover, in the latest version of the PSC (2019), a taxonomical key has been introduced for the first time, which will significantly change the rules for soil classification (Kabała et al., 2019).

Therefore, the aim of the article was to evaluate the sixth edition of the PSC (2019), especially in terms of:

– checking the criteria for distinguishing individual features related to litho- and pedogenesis in soils developed from alluvial materials;
– verification of completeness of alluvial units in the rank of types and subtypes;
– proposing the correction of the current and introduction of new systematic units for the described soils.

It based on a set of broad spectrum of soil profiles located in flooded areas of selected rivers of South Baltic Lakelands in Northern Poland.

2. Study area and methods

The study was carried out in area covered by Vistulian glaciation in Northern Poland. The investigated area is located within the range of Pomeranian phase (16–17 kyr BP) of the Weichselian glaciation (Niewiarowski, 1959, 1986; Niewiarowski and Wysota, 1986; Marks, 2012).

The area is located in the zone of moist and cool temperate climate (IPCC, 2006). According to Köppen–Geiger Climate Classification, the region is located in the fully humid zone with temperate and warm summer (Kottek et al., 2006). Average annual air temperature (based on data obtained in the central part of studied area at the Koniczynka meteorological station, Chełmno Lake District from period 1994 – 2019) is 8.7°C (Kejna et al., 2020). The warmest month is July with average air temperature of 19.1°C, and the coldest month is January with average air temperature of –1.6°C. The average annual precipitation is about 550 mm with the majority of precipitation occurring in summer.

87 profiles mostly to the depth of 150 cm (maximum depth of 210 cm) were studied. All profiles were located in floodplains within four mesoregions (Fig. 1; Kondracki, 2009; Solon et al., 2018): Toruń Basin, Fordon Valley (76 and 2 profiles respectively – Vistula River floodplain in both mesoregions), Nieszawa Gap of the Vistula River (4 profiles – Złowiączka River floodplain) and Drwęca Valley (5 profiles – Drwęca River valley). Investigated floodplains were filled with Holocene alluvial deposits. In the case of the soils located within Toruń Basin, these were mainly sandy and silty flood sediments typical for Vistula Valley (Kordowski et al., 2014). Contemporary river overflows are rare – once in a few / several years, which results from the hydrotechnical regulation at the end of XIX-th century. It led also to a significant lowering of the groundwater table at the bottom of the valley. The Zgłowiączka and Drwęca valleys are definitely smaller geomorphological forms, with significant share of organic soils in their bottoms and relatively high ground water table (Andrzejewski, 1984) and long periods of spring floods (Kalinowski et al., 2011). On the soil-agricultural maps all profiles were designated by symbol "F" – as alluvial soils (Świtoniak et al., 2019) . Most of studied soils (49) were used as arable lands. In 27 cases soils were covered with meadows/pastures and 9 pedons were located within small contours of riparian forests/bushes.

All profiles were described in stage of field works. From 20 profiles disturbed soil samples were taken from every genetic soil horizons. Standard soil analyses were performed using the methods as follows: total organic carbon (TOC) content — by Tiurin's method; total nitrogen content by Kjeldahl method; $CaCO_3$ content – volumetric Scheibler method; particle-size distribution — by sieve and sedimentary areometric method; pH of soil-to-solution ratio of 1:2.5 using 1 M KCl and distilled H_2O as the suspension medium. Color has been described according to Munsell Soil Color Charts (2000).

Presenting location of studied soil profiles (Figure 1) was created in ArcMap 10.8 on the basis of BDOT10k database (source: https://mapy.geoportal.gov.pl). The systematic position and symbols/names of diagnostic horizons were given after the sixth edition of the Polish Soil Classification (PSC, 2019) and WRB (IUSS Working Group WRB, 2015). English-language names of soil units (PSC, 2019) were given as proposed by Kabała et al. (2019).

3. Results

Among all 87 profiles 19 had mollik horizons (Figure 2. PSC, 2019). One of them was classified as chernozemic colluvial soil, 18 pedons belong to chernozemic alluvial soils (mostly Fluvic

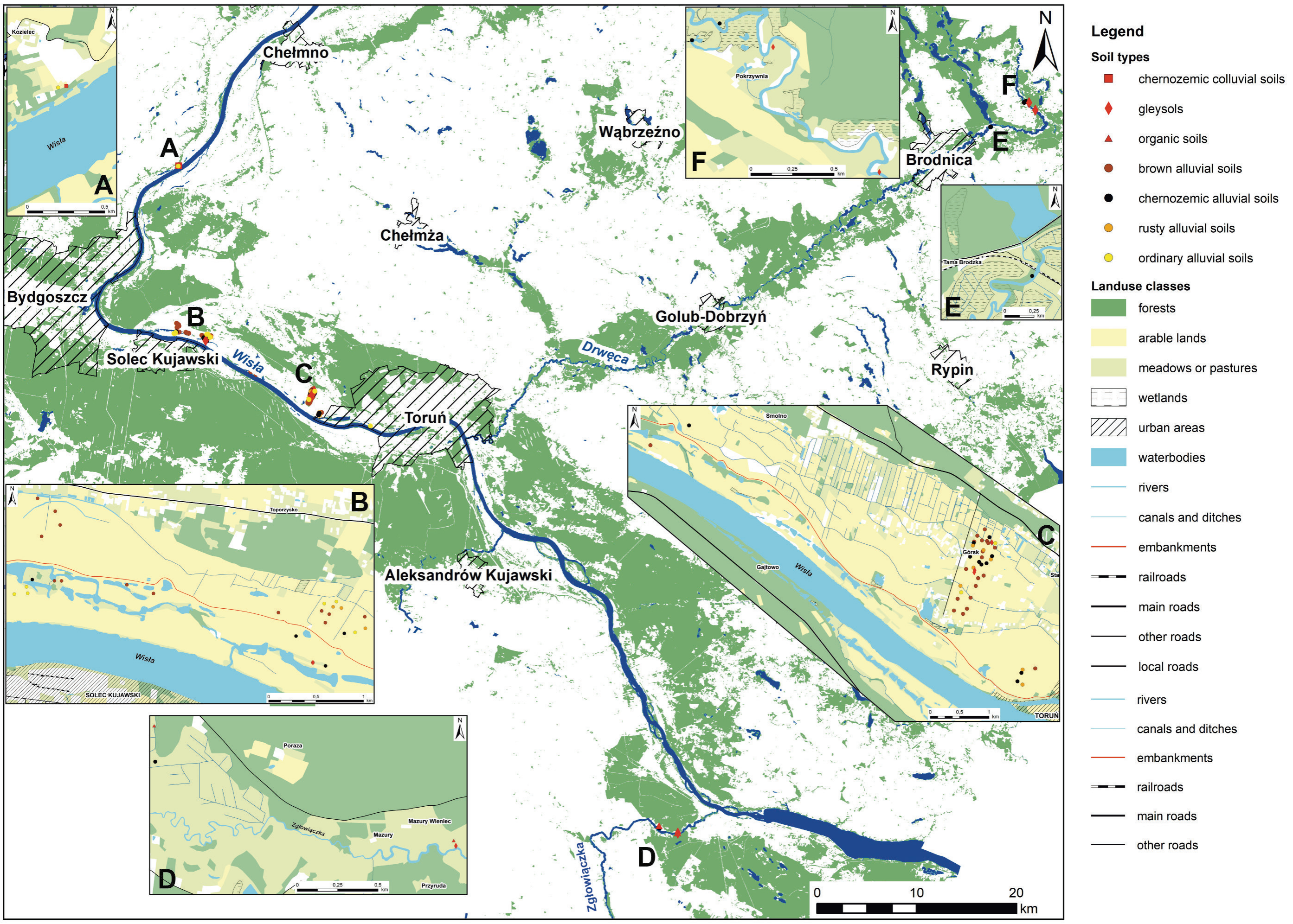

Fig. 1. Location of soil profiles

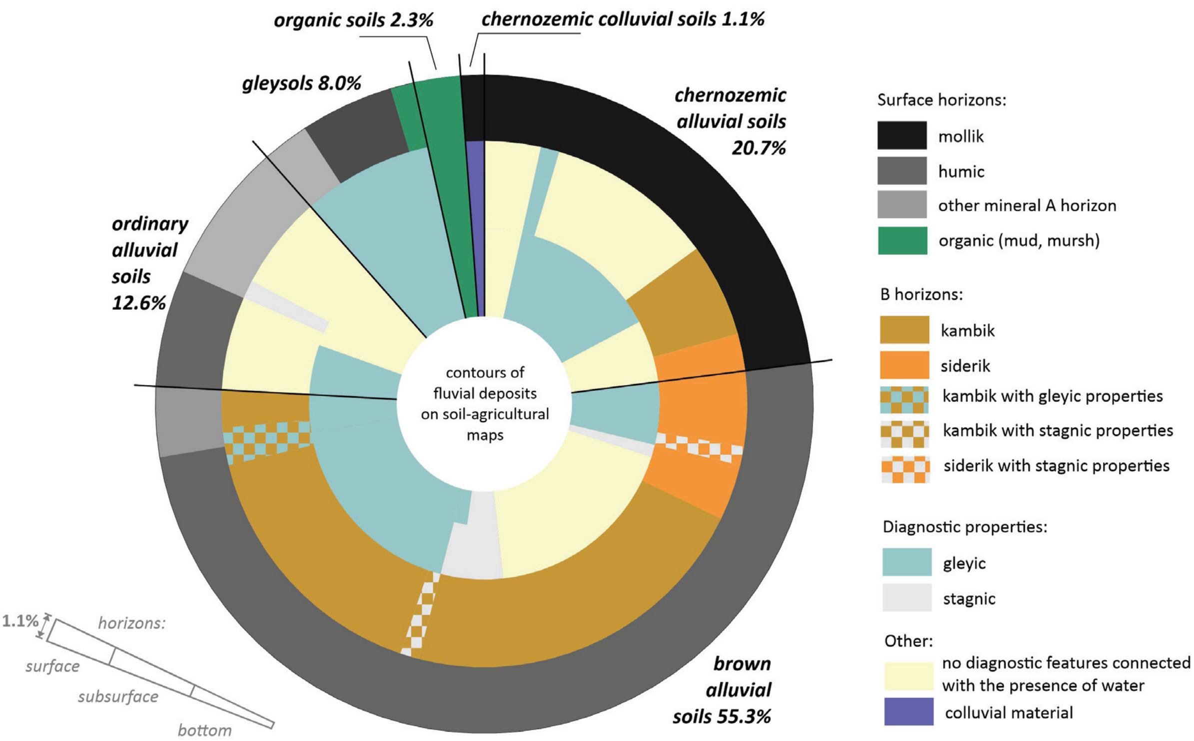

Fig. 2. Main features and systematic position of investigation soils

Phaeozems in WRB). Within this type only three represented typical subtype. In 12 pedons gleyic subtype was noticed. In seven profiles kambik (5) and siderik (2) diagnostic horizons (Brunic qualifier in WRB) were also present (subtypes of brown and rusty chernozemic alluvial soils respectively).

The most common type was that classified as brown alluvial soils (Fluvic Cambisols or Fluvic Brunic Arenosols in WRB) – 48 cases. Most of them had loamy or silty texture in B horizons (kambik) but in 8 soils also sandy Bv (siderik) horizons were noticed (subtype – rusty alluvial soils). 45 of brown alluvial soils were classified also as humic and about 50% was also put to gleyic subtype.

Ordinary alluvial soils (Fluvisols in WRB) occurred 11 times. Shallow *gleyic* properties with lack of other diagnostic horizons or properties allowed to classify 7 pedons with fluvic material only as gleysols (Gleysols in WRB). Two profiles represented organic soils (Histosols in WRB).

4. Discussion

4.1. Fluvic material

The most important feature taken into account in distinguishing alluvial soils is the presence of *fluvic* material. According to PSC (2019) such stratified fluvial, lacustrine or marine deposits have to appear in soils classified as alluvial types (chernozemic, brown or ordinary) somewhere in the depth between 0 and 150 cm from the soil surface. In the case of the studied soils, only in two profiles (despite their location within the contours marked as F on the soil-agricultural maps), such sediments were not recorded at the soil surface and in upper part of pedons. In one place, only thick organic material was noticed, in the other – the soil was developed of slope materials (colluvium) of thickness more than 50 cm, covering the alluvial deposits.

In the remaining 85 soils, alluvial material was present in at least part of the profile. One of these profiles was classified within the order of organic type (Histosol in WRB) because the *fluvic* mineral material with thickness of 30 cm was covering thick murszik horizon. Other 84 profiles belongs to mineral alluvial units – chernozemic, brown or ordinary alluvial soils (Fluvic Phaeozems, Fluvic Cambisols or Arenosols and Fluvisols respectively in WRB) or gleysols.

The minimal thickness of alluvial deposits is not defined in PSC (2019) as it is in WRB (2015) where minimum 25 cm is required. It seems appropriate to introduce such a requirement in PSC – it would facilitate the correlation with the Fluvic and Fluvisol qualifications in WRB (2015). Nevertheless, in studied soils the minimal thickness of alluvial deposits were 30 cm (Fig. 3). The average thickness of the *fluvic* material is difficult to determine. In as many as 40 soils, the lower limit of these sediments exceeded 140 cm and was not reached mainly due to groundwater. In the soils where the lower boundary of *fluvic* material was found, the thickness was slightly over 70 cm. In most cases they covered the fluvioglacial sandy sediments. Mostly there were no problems with recognition of *fluvic* material. Clear stratification combined with high vertical variability of organic matter content (Figure 4, Table 1) allowed for easy identification of *fluvic* material at the stage of field work

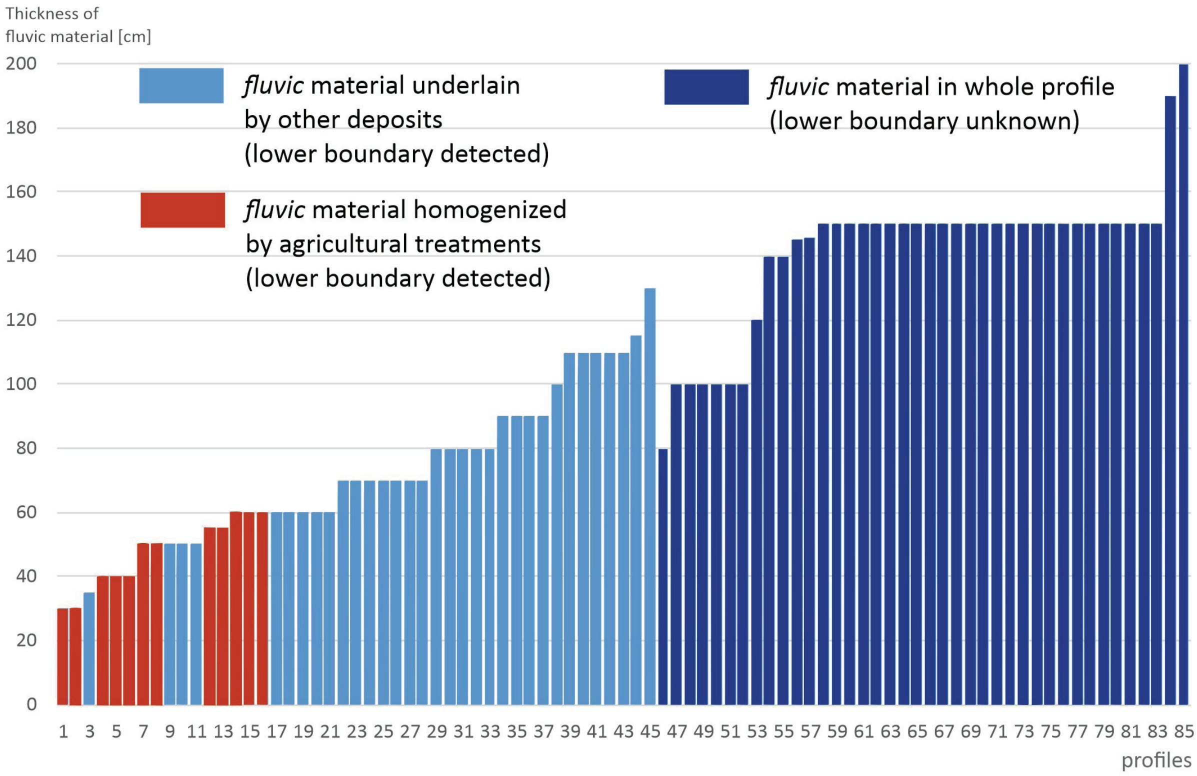

Fig. 3. Thickness of *fluvic* material

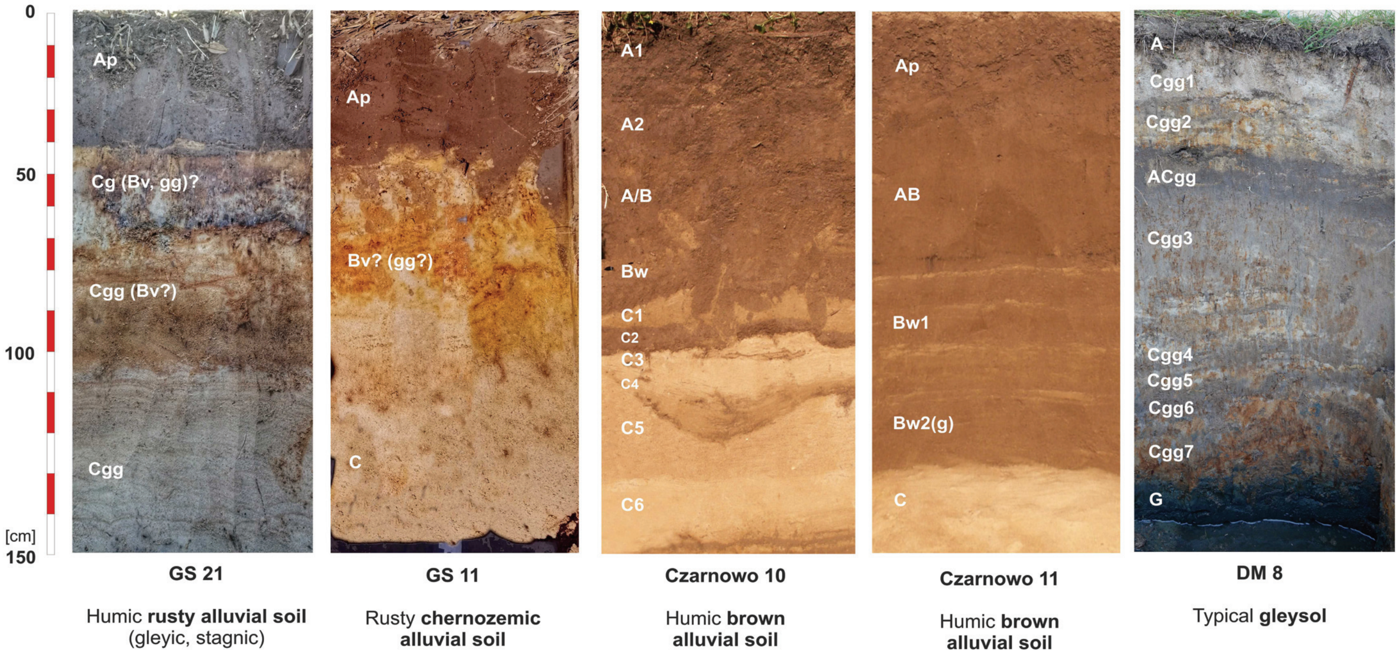

Fig. 4. Examples of investigated alluvial soils

– especially in soil with deep fluvial sediments not significantly transformed by human activity (e.g. profiles Czarnowo 10 and 11, DM 8 – Figure 4, Table 1). In 11 cases, determining whether the material has a fluvial or lacustrine origin was quite problematic due to the homogenization of this material by agrotechnical treatments. It mainly concerns thin (up to 60 cm) alluvial material, where it was mixed to its lower boundary by plowing or deep subsoiling (Figures 3 and 4 – e.g. profiles GS 11, GS 21 with alluvium thickness of about 40 cm). The problem of agrotechnical homogenization of alluvial material was also described in the Barycz Valley (Łabaz and Kabała, 2016). Identification of *fluvic* material in such cases was carried out on the basis of relatively high humus content and its texture – significant amount of silt or clay fractions (Table 1). The abundance of these fine fractions in mineral material could only be result from fluvial or lacustrine processes. Within investigated Holocene floodplains, apart alluvial deposits, mostly Late Pleistocene fluvioglacial sands can appear. They are also strongly layered but are characterized by the lack of fine fractions (silt and clay) and humus (Weckwerth et al., 2011). Some authors (e.g. Banaszuk, 1987) include such sandy, layered sands from the Late Pleistocene as alluvial materials, however, according to the PSC (2019), *fluvic* material is a Holocene sediment. In cases of strong anthropogenic homogenization of alluvial material, its recognition may be made only on the basis of expert knowledge, however, taking into account that this problem affects over 10% of the studied soils – it is very important from a cartographic point of view. According to the official rules in PSC and WRB – such soils should be classified as non-alluvial units. In studied cases if these alluvial material would be not treaded as *fluvic*, the soils would be put into brown soils (WRB – Cambisols) – 4 profiles; black earths (Gleyic Phaeozems) – 6 profiles; arenosol – 1 profile.

The strongest layering, with its high visibility from shallow depths, was found in soils with shallow *gleyic* properties and lack of other diagnostic horizons or properties. These pedons, which accounted for as much as 8% of all cases studied, were referred to gleysols (Fig. 2). Such approach, with a strong emphasis on the role of groundwater, seems to be appropriate from the utility point of view. However, in this type of soils in PSC (2019) there is no possibility to distinguish the subtype of alluvial soils. In the WRB system (IUSS Working Group WRB, 2015), the importance of the alluvial genesis of gleysols was noticed – this feature is expressed by principal qualifier. In PSC (2019) the alluvial lithogenesis of pedons may appear in name of soil only at the genus level which is very low in taxonomy structure.

4.2. Surface humus horizons

Well-formed humus horizons are quite a common feature of alluvial soils (Pranagal and Ligęza, 2011; Głąb and Gondek, 2013; Łabaz and Kabała, 2016; Rennert et al., 2021). The high thickness of humus horizons and a significant content of organic carbon are very often the result of the redeposition processes of pedogenic material (Strzemski, 1955; Faust et al., 2000; Mayer et al., 2019; Jonczak et al., 2022). In 18 profiles of alluvial soils, the well-formed humus horizons meet the diagnostic criteria of mollik. These pedons were classified as **chernozemic alluvial soils (**mostly Gleyic Phaeozems and Gleyic Chernozems in WRB**)**. The remaining surface humus horizons (66 cases) mainly did not meet the color criterion (they were too light). Only in a 13 soils the thickness criterion for mollik (30 cm) was not achieved. The relatively large thickness of the humus horizons (almost 40 cm!) of the studied soils results from several factors – their allochthonous nature, formation in

Table 1
Basic properties of selected soils

Horizon	Sampling depth [cm]	Corg	Nt	C/N	$CaCO_3$ [%]	pH		Colour*		Textural class	
		[%]				H_2O	1M KCl	dry	moist	PTG 2008	USDA
GS 21 – Humic rusty alluvial soil											
Ap	0–40	0.65	–	–	–	7.0	6.5	10YR 6/2	10YR 4/2	pg	SL
Cgg (Bv, g?)	40–70	–	–	–	–	–	–	2.5Y 7/2 / 10YR 5/8	2.5Y 6/2 / 7.5YR 5/8	pl	S
Cgg (Bv?)	70–100	–	–	–	–	–	–	10YR 5/8	7.5YR 5/8	pl	S
G	100–(150)	–	–	–	–	–	–	2.5Y 7/2	2.5Y 6/2	pl	S
GS 11 – Rusty chernozemic alluvial soil											
Ap	0–40	1.20	–	–	–	8.0	7.5	10YR 5/3	10YR 3/3	pyz	SiL
Bv? (gg?)	40–90					–	–	10YR 5/8	7.5YR 5/8	pl	S
C	90–(150)					–	–	10YR 7/4	10YR 7/6	pl	S
Czarnowo 10 – Humic brown alluvial soil											
A1	0–20	3.55	0.304	12	4.4	7.5	7.1	10YR 5/2	10YR 3/2	pyi	SiL
A2	20–40	1.37	0.123	11	3.6	8.0	7.4	10YR 6/3	10YR 3/3	pyi	SiL
A/B	40–60	1.16	0.106	11	3.2	8.1	7.4	10YR 6/3	10YR 3/3	pyi	SiL
Bw	60–82	0.76	0.069	11	2.4	8.1	7.4	10 YR 6/2	10YR 4/3	pyi	SiL
C1	82–87	0.11	0.010	11	0.4	8.4	8.0	2,5Y 6/4	2,5Y 4/4	psśr	MS
C2	87–95	0.73	0.067	11	2.5	8.2	7.5	2,5Y 5/3	2,5Y 3/3	pyi	SiL
C3	95–105	–	–		0.2	8.2	7.8	2,5Y 7/4	2,5Y 5/4	plśr	MS
C4	105–122	0.17	0.014	12	0.5	8.2	7.8	2,5Y 6/3	2,5Y 4/3	psdr	FS
C5	103–130	–	–		0.2	7.7	7.4	10YR 7/4	10YR 6/3	plśr	MS
C6	130–(150)	–	–		0.3	7.9	7.3	10YR 7/4	10YR 5/4	pldr	FS
Czarnowo 11 – Humic brown alluvial soil											
Ap	0–40	1.81	0.159	11	2.7	7.9	7.2	2,5Y 5/2	2,5Y 3/2	pyi	SiL
AB	40–80	0.89	0.088	10	2.5	8.2	7.4	2,5Y 5/3	2,5Y 3/3	pyi	SiL
Bw1	80–112	0.64	0.065	10	2.6	8.2	7.4	2,5Y 6/3	2,5Y 4/3	pyi	SiL
Bw2(g)	112–132	0.60	0.065	9	2.8	8.2	7.5	2,5Y 6/3	2,5Y 4/3	pyi	SiL
C	132–(150)	–	–		0.2	7.3	7.2	10YR 7/3	10YR 6/4	plśr	MS
DM 8 – Typical gleysol											
A	0–10	1.12	0.113	10	0.1	6.8	6.0	10YR 3/1	10YR 2/1	ps	S
Cgg1	10–20	0.23	0.024	10	0.1	7.2	6.5	2.5YR 7/1	2.5YR 6/1	ps	S
Cgg2	20–30	–	–	–	0.2	7.3	6.6	2.5YR 6/1	2.5YR 6/2	ps	S
Acgg	30–45	–	–	–	1.0	7.2	6.4	2.5YR 5/1	2.5YR 4/1	pg	LS
Cgg3	45–90	–	–	–	0.1	7.5	6.8	2.5YR 6/1	2.5YR 5/1	pg	LS
Cgg4	90–100	–	–	–	0.1	7.5	6.7	2.5YR 5/1	2.5YR 4/1	pg	LS
Cgg5	100–110	–	–	–	0.3	7.7	7.2	2.5YR 6/1	2.5YR 5/1	pg	LS
Cgg6	110–120	–	–	–	0.1	7.2	6.8	2.5YR 5/1	2.5YR 4/1	pl	S
Cgg7	120–135	–	–	–	0.2	7.4	7.0	2.5YR 6/1	2.5YR 5/1	pl	S
G	135–(150)	–	–	–	2.2	8.0	7.4	GLEY2 6/10G	GLEY6/2 5/10G	pl	S

* the colour of the soil matrix

moist conditions with shallow groundwater and (where their natural thickness could have been small) from agrotechnical treatments. The formation of highly structural and deep humus horizons as a result of the agricultural use of alluvial soils has also been described in other regions of Poland – e.g. within Dobra River Valley in the Silesian Lowland (Kabała et al., 2011). The anthropogenic deepening is particularly important in the case of intensively used agricultural **brown alluvial soils**, where only in 5 cases the thickness of the A surface horizons was slightly below 30 cm. Artificial deepening of humus horizons resulted in the fact that the vast majority of **brown alluvial soils** and nearly half of **ordinary alluvial soils** met the criterion of the **humic** subtype. In author's opinion the criteria for this are not restrictive enough. In many investigated cases weakly developed Ap horizons were only deepened by plowing and only due to this had to be classified as a **humic** subtype (e.g. profile GS 21 – Table 1, Fig. 4). The authors propose to raise the criteria to analogous with Humic qualifier criterion in WRB (2015) – up to the average OC content ≥ 1% in the thickness from 0 to 50 cm (like it is e.g. in profiles Czarnowo 10 and Czarnowo 11 – Table 1, Fig. 4). Summarizing, after this changes, the criteria for distinguishing the **humic** subtype would be as follows: "having surface humus horizon with ≥ 1% soil organic carbon in the fine earth fraction as a weighted average to a depth of 50 cm from the mineral soil surface or a humus horizon with a thickness of ≥ 20 cm meeting the mollik / umbrik criteria, except for the thickness criterion".

Gleyic properties

Gleyic properties were found in as many as 71 soil profiles (82%) up to a depth of 200 cm. It is obvious that alluvial soils are developed in an environment where groundwater is quite shallow. However, the mean depth of the upper boundary of *gleyic* properties in studied soils appears to be relatively deep in all 3 alluvial types. They were 96, 106 and 134 cm in Chernozemic, Brown and Ordinary alluvial soils, respectively (Fig. 5). In 16 profiles (18%) some few oxymorphic colours and concentrations were visible but diagnostic *gleyic* properties were not noticed to the depth of 200 cm. Such deep or even lack of *gleyic* properties is due to strong drainage works carried out in the studied area as early as the 19th century (Sulimierski et al., 1880; Makowski 1998). Within the alluvial plain of the lower Vistula, the groundwater table declined by an average of about 1,3–1,5 m since the mid-19th century (Babiński, 2005). In many pedons distinct relict gleyic features (mainly iron or iron-manganese concentrations) were visible. Accumulation of several different iron forms in the oxidation-reduction horizon in which the active gley soil-forming process occurs was described by many authors (e.g. Chojnicki 2001; Kalembasa et al., 2001). The high concentration of iron in most of alluvial soils is certainly due to the influence of groundwater. Nevertheless, in many of investigated profiles concentrations of iron were formed in the period before the regulation of the river bed and melioration (drainage) of the alluvial plains. Currently, many of studied soils are not actively influenced by groundwater. However, such relict accumulations of iron and manganese are very similar to active gleyic features. They slightly differ from them because occur not mainly around the root canals and on surfaces or shallowly below the surface of aggregates, but can be found in various positions independent of the current shapes and surfaces of the aggregates. Moreover, relict gleyic concretions are mostly surrounded by mineral matrix which brownish/rusty colour indicates biochemical weathering in well-aerated conditions. It led to the formation of kambik or siderik (Bw/Bv) horizons in places (depths) where originally strong gleyic conditions prevailed (Kawałko et al., 2021). Domination of residual, fixed in silicate structures fractions of iron in alluvial soils from the River Vistula valley was also noticed by Dąbkowska-Naskręt (2000) which may be evidence of post-sedimentation processes. Due to the morphologically dominant gleyic features (i.e. the fact that they are relict), these Bw/Bv horizons can often be misclassified. Described issue is presented on the example of GS 21 and GS 11 profiles (Table 1, Fig. 4). It should place emphasis on the precise recognition of the degree of their transformation already at the stage of field research.

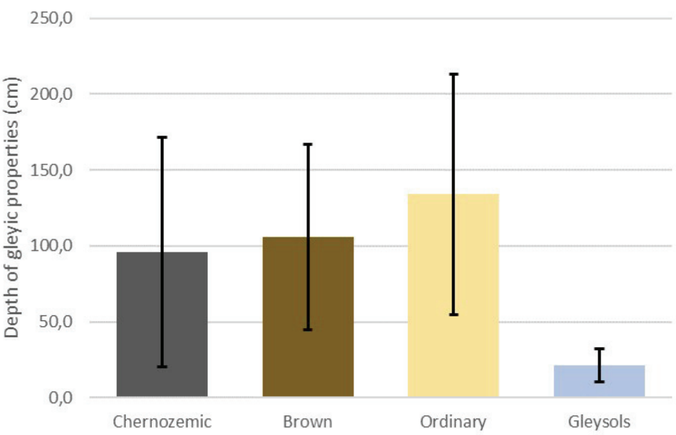

Fig. 5. Average depth to *gleyic* properties

On the other hand, in 19 soil profiles of alluvial types (8 – chernozemic, 8 – brown; 3 – ordinary) and all investigated gleysols (7 profiles), groundwater appears at a depth of less than 1 m (at least in part of the year), and the gleyic properties occurred at a depth of up to 50 cm. In gleysols it is an obvious feature and its occurrence is already highlighted in the rank of soil type. In alluvial soils (all three types), such a strong influence of groundwater should be expressed in the rank of the soil subtype – analogous to the black earths type, where the waterlogged subtype can be distinguished. This is especially important in the type of **chernozemic alluvial soils** where such a shallow influence of groundwater was recorded in as much as 40% of cases. Moreover, many alluvial soils without diagnostic humus horizons but with shallow influence of groundwater are classified according to the PSC (2019) as gleysols (e.g. profile DM 8 – Table 1, Fig. 4). The alluvial genesis is not noticed in such soils at rank of type or subtype. To solve this problem, order of gleyzemic soils should include the type of gleyic alluvial soils, or the subtype of alluvial gleysols should be add to the type of gleysols. It should be noted that similar suggestions for distinguishing "gleyic alluvial soils" have been appearing in Polish literature for a long time (e.g. Rytelewski, 1965)

4.3. Subsurface AB or A/B horizons

The accumulation of humus in alluvial soils has a complex genesis resulting from their allochthonous nature. Fluvial material is very often rich in highly decomposed organic matter at the time of its deposition (Hein et al., 2003; Zehetner et al., 2008; Bullinger-Weber at al., 2014). As a result, alluvial soils very often have humus horizons down to considerable depths. In aggradation environments, i.e. flood plains or foot slopes (Świtoniak 2015) former surface humus horizons are gradually covered with younger A horizons and become subsurface parts of pedons. Post-sedimentation soil-formation processes (i.e. biochemical weathering, bioturbations) gradually change it into ABw or ABv horizons. After some time, such materials are still relatively rich in humus, but at the same time meet all the criteria for kambik or siderik horizons (e.g. profiles Czarnowo 10 and Czarnowo 11 – Table 1, Fig. 4). Well-developed, biochemically weathered B horizons with significant OC content (over 1%) are a common feature in alluvial soils (e.g. Niedźwiecki et al., 2010a; 2010b; Mendyk et al., 2016). However, soil-surveyors often treat such horizons only as A, ignoring their post-sedimentative pedogenesis. In cases where AB or A/B horizons meet the diagnostic criteria for A mollik / umbrik, advanced pedogenesis is highlighted at the level of type – chernozemic alluvial soils (Fluvic Phaeozems or Fluvic Chernozems in WRB). In soils where the A surface and AB or A / B subsurface horizons do not meet the diagnostic criteria for mollik/umbric all information about advanced pedogenesis in such soils is lost in the name of soil. This is confirmed by the entries on soil-classification maps where the tested brown alluvial soils (Fluvic Cambisols or Fluvic Brunic Arenosols in WRB) were classified as weakly developed ordinary alluvial units (Fluvisols in WRB).

4.4. Stagnic properties

Stagnic properties were visible only in few investigated soils. This diagnostic property can be connected with the fine-textural texture of soils (Kawałko et al., 2021) In some cases this diagnostic property may be a result of water stagnation on barriers formed by relict gleyic process of iron and manganese compounds accumulation. This is confirmed by the presence of *stagnic properties* in the upper part of some Bv horizons developed as weathering of relict iron concretions formed due to changes in redox conditions (Fig. 4). In addition, in some cases the compaction in the sub-arable horizons as a result of agricultural cultivation and the formation of a plow pan was recorded. Development of stagnic properties just under the Ap horizons due to compaction of fine sands or silty alluvial deposits by the usage of heavy machinery was recorded in the floodplain of Mississippi Delta (Iqbal et al., 2005) .

4.5. Eluviation

The leaching (eluviation) processes are very common in the soils of the described region. Among autogenous soils (not subject to a strong influence of groundwater), lessivage processes dominate in fine-grained soils (Radziuk and Świtoniak 2021; Świtoniak 2021) or podzolization in sandy materials (Jankowski, 2014; Sewerniak et al., 2017). Leaching processes are also noticed in alluvial soils in many parts of the World (e.g. Cipriano-Silva et al., 2020; Suther and Leigh, 2020) and Poland (Terelak, 1967; Banaszuk, 1987). However, such processes were not recorded in the investigated soils. This may be due to the high pH values found in most soils, resulting from the influence of groundwater and fertilization. The activation of strong leaching processes in alluvial soils is often associated with pine plantings (Banaszuk, 1987), while the studied soils were generally under agricultural cultivation or covered with riparian forests.

5. Conclusions

The conducted research makes it possible to propose several improvements in the Polish Soil Classification with regard to soils developed from alluvial material:

1) the criterion of the minimum thickness of fluvic material and the depth of its occurrence should be introduced when classifying soils as alluvial soils. The rules adopted in the WRB could be applied here;
2) "Humic" subtype should be revised. In the case of materials that do not meet (except thickness) the mollik criteria – a greater minimum thickness or organic carbon content should be introduced here – preferably compatible with the "humic" qualifier in WRB. The current criteria are so undemanding that almost all alluvial soils can be classify as "humic";
3) In order of gleyzemic soils new type should be added – gleyic alluvial soils or in type of gleysols the subtype of alluvial gleysols should be added;
4) Waterlogged subtype should be introduced – it is most important in case of chernozemic alluvial soils.

In addition to the above proposals, there is also an important issue of B horizons – both their genesis (weathering of relictigleyic features) and the designation of AB horizons not as only humus but also diagnostic kambik or siderik. This aspect requires further research. Moreover, it should be noted that soil-agricultural maps are a good source of the range of occurrence of soils developed from alluvial materials.

References

Andrzejewski, L., 1984. Dolina Zgłowiączki – jej geneza oraz rozwój w późnym glacjale i holocenie. Dokumentacja Geograficzna 3, IGiPZ PAN.

Babiński, Z., 2005. Renaturisation of the lower Vistula valley using the hydrotechnical method. Przegląd Geograficzny 77(1), 21–36. (in Polish with English abstract)

Banaszuk, H., 1987. Dependence of the spatial arrangement of the lithological formation and profile features of alluvial soils on the geomorphologic structure of the flooded valley of lowland rivers as exemplified by a sector of the Narew river valley. Roczniki Gleboznawcze – Soil Science Annual 38(3), 103–119.

Bednarek, R., Prusinkiewicz, Z., 1997. Geografia gleb. PWN, Warszawa.

Bullinger-Weber, G., Le Bayon, R.-C., Thébault, A., Schlaepfer, R., Guenat, C., 2014. Carbon storage and soil organic matter stabilisation in near-natural, restored and embanked Swiss floodplains. Geoderma 228–229, 122–131. https://doi.org/10.1016/j.geoderma.2013.12.029

Cappuyns, A., Swennen, R., 2007. Classification of alluvial soils according to their potential environmental risk: a case study for Belgian catchments. Journal of Environmental Monitoring 9, 319–328. https://doi.org/10.1039/B616959G

Chojnicki, J., 2001. Iron forms in alluvial soils of central Vistula valley. Roczniki Gleboznawcze – Soil Science Annual 52 (supl.), 97–107. (in Polish with English abstract)

Chojnicki, J., 2002. Soil-forming processes in alluvial soils of central Vistula valley and Żuławy. Fundacja Rozwój SGGW, Warsaw. (In Polish with English summary).

Cieśla, W., Dąbkowska-Naskręt, H., Dymińska, M., Owedyk, J., 1988. Preliminary results of investigations of the mineralogic composition of clay fraction of selected Vistula alluvial soils. Roczniki Gleboznawcze – Soil Science Annual 39(3), 209–212. (in Polish with English abstract)

Cipriano-Silva, R., Valladares, G.S., Azevedo, A.C., Anjos. L.H.C., Pereira. M.G., Pinheiro Junior, C.R., 2020. Alluvial soil formation in the plains of northeastern Brazil. Revista Brasileira de Ciencia do Solo 44, 1–18. https://doi.org/10.36783/18069657rbcs20190110

Dąbkowska-Naskręt, H., 1994. The content of total and DTPA-extractable microelements in selected alluvial soils of Fordon Valley and Unisław Basin. Zeszyty Problemowe Postępów Nauk Rolniczych 414, 99–104. (in Polish with English abstract)

Dąbkowska-Naskręt, H., 2000. Status of iron in alluvial soils from the Wisła River Valley, Poland. Journal of Plant Nutrition 23(11–12), 1549–1557. https://doi.org/10.1080/01904160009382123

Driessen, P.M., Deckers, J., Spaargaren, O., 2001. Lecture notes on the major soils of the world. (World Soil Resources Reports: FAO; Vol. 94). Rome: Food and Agriculture Organization of the United Nations (FAO).

Faust, D., Olmo, F.D., Escudero, R.B., 2000. Soils in the Holocene alluvial sediments of the Rio Fraja Valley, Spain: in situ or soil-sediments? Catena 41, 1–3, 133–142. https://doi.org/10.1016/S0341-8162(00)00112-0

Głąb, T., Gondek, K., 2013. The influence of soil compaction on chemical properties of Mollic Fluvisol soil under Lucerne (Medicago sativa L.). Polish Journal of Environmental Studies 22(1), 107–113.

Hein, T., Baranyi, C., Herndl, G.J., Wanek, W., Schiemer, F., 2003. Allochthonous and autochthonous particulate organic matter in floodplains of the River Danube: the importance of hydrological connectivity. Freshwater Biology, 48, 220–232. https://doi.org/10.1046/j.1365-2427.2003.00981

Hewelke, P., Hewelke, E., Oleszczuk, R., Kwas, M., 2018. The application of pedotransfer functions in the estimation of water retention in alluvial soils in Żuławy Wiślane, northern Poland. Soil Science Annual 69(1), 3–10. https://doi.org/10.2478/ssa-2018-0001

Hikmatullah, A., Al-Jabri, M., 2007. Soil properties of the alluvial plain and its potential use for agriculture in Donggala Region, Central Sulawesi. Indonesian Journal of Agricultural Science 8(2), 67–74. https://doi.org/10.21082/ijas.v8n2.2007.67-74

Holmes, R.S., Hearn, W.E., 1942. Chemical and Physical Properties of Some of the Important Alluvial Soils of the Mississippi Drainage Basin. Technical Bulletin 833, 1–82.

Hulisz, P., Michalski, A., Dąbrowski, M., Kusza, G., Łęczyński, L., 2015. Human-induced changes in the soil cover at the mouth of the Vistula River Cross-Cut (northern Poland). Soil Science Annual 66, 67–74. https://doi.org/10.1515/ssa-2015-0021

Iqbal, J., Thomasson, J.A., Jenkins, J.N., Owens, P.R., Whisler, F.D., 2005. Spatial Variability Analysis of Soil Physical Properties of Alluvial Soils. Soil Science Society of America Journal 69, 1338–1350. https://doi.org/10.2136/sssaj2004.0154

Intergovernmental Panel on Climate Change (IPCC), 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Egglestone, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.). Intergovernmental Panel on Climate Change (IPCC), IPCC/IGES, Hayama, Japan.

IUSS Working Group WRB, 2007. World Reference Base for Soil Resource 2006. World Soil Resources Reports No. 103, Food and Agriculture Organization of the United Nations, Rome.

IUSS Working Group WRB, 2015. World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Report No. 106, FAO, Rome, Italy.

Jankowski, M., 2014. The evidence of lateral podzolization in sandy soils of Northern Poland. Catena 112, 139–147. https://doi.org/10.1016/j.catena.2013.03.013

Jonczak, J., 2015. Geneza, ewolucja i właściwości gleb dolin rzek źródłowych w młodoglacjalnych obszarach zastoiskowych. Wyd. Naukowe Akademii Pomorskiej, Słupsk, 758.

Jonczak, J., Parzych, A., Sztabkowski, K., 2022. Soil-forming processes and properties of soils developed from fluvic materials in the headwater river valleys of Middle Pomerania, north Poland: A case study of the Kamienna stream. Soil Science Annual 73(3), 156044. https://doi.org/10.37501/soilsa/156044

Kabała, C., Gałka, B., Jezierski, P., Bogacz, A., 2011. Transformation of fluvisols caused by river regulation and long-term farming – a case study from the Dobra River valley in the Silesian Lowland. Roczniki Gleboznawcze – Soil Science Annual 62(2), 141–153. (in Polish with English abstract)

Kabała, C. et al., 2019. Polish Soil Classification, 6th edition – principles, classification scheme and correlations. Soil Science Annual 70(2), 71–97. https://doi.org/10.2478/ssa-2019-0009

Kalembasa, D., Becher, M., Pakuła, K., 2001. Gleby z poziomami żelazistymi w dolinie rzeki Liwiec. Roczniki Gleboznawcze – Soil Science Annual 52, 71–78.

Kalinowski, A., Burandt, P., Glińska-Lewczuk, K., 2011. Effect of hydrological factors on temperature and oxygen distribution in floodplain lakes. A case study of the Drwęca floodplain. Proceedings of ECOpole 5, 1, 245–250. (in Polish with English abstract)

Kanno, I., Honjo, Y., Arimura, S., Kuwano, Y., 1965. Characteristics and classification of an unirrigated anthropogenic-alluvial soil found in the Kumamoto Plain, Soil Science and Plant Nutrition 11(1), 14–23. https://doi.org/10.1080/00380768.1965.10431147

Kawałko, D., Jezierski, P., Kabała, C., 2021. Morphology and Physicochemical Properties of Alluvial Soils in Riparian Forests after River Regulation. Forests 12, 329. https://doi.org/10.3390/f12030329

Kejna, M., Hildebrandt, K., Kartanas, E., Pius, B., Rutkowski, L., Sobota, I., Solarczyk, A., Sulik, S., Uscka-Kowalkowska, J., Wojtczak. H., 2020. Raport z realizacji programu badawczo-pomiarowego Zintegrowanego Monitoringu Środowiska Przyrodniczego w Stacji Bazowej Pojezierze Chełmińskie (Koniczynka) w 2019 roku. Toruń.

Kobierski, M., Banach-Szott, M., 2022. Organic Matter in Riverbank Sediments and Fluvisols from the Flood Zones of Lower Vistula River. Agronomy 12, 536. https://doi.org/10.3390/agronomy12020536

Kondracki, J., 2009. Geografia regionalna Polski. Wydawnictwo Naukowe PWN, Warszawa.

Kordowski, J., Gamrat, W., Gierszewski, P., Kubiak-Wójcicka, K., Szmańda, J.B., Tyszkowski, S., Solarczyk, A., 2014. Record of fluvial and biogenic sedimentation processes in sediments of the Lower Vistula Valley floor. Landform Analysis 25, 77–93. (in Polish with English abstract). https://doi.org/10.12657/landfana.025.007

Kottek, M., Grieser, J., Beck, C., Rudolf, B., Rubel, F., 2006. World Map of Köppen-Geiger Climate Classification updated. Meteorologische Zeitschrift 15, 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Laskowski, S., 1986. Origin, evolution and the properties of alluvial soils from the middle Odra river valley. Zeszyty Naukowe Akademii Rolniczej we Wrocławiu 56. (in Polish with English abstract)

Łabaz, B., Kabała, C., 2016. Human-induced development of mollic and umbric horizons in drained and farmed swampy alluvial soils. Catena 139, 117–126. https://doi.org/10.1016/j.catena.2015.12.013

Łachacz, A., Nitkiewicz, S., 2021. Classification of soils developed from bottom lake deposits in north-eastern Poland. Soil Science Annual 72(2), 1–14. https://doi.org/10.37501/soilsa/140643

Makowski, J., 1998. Dolna Wisła i jej obwałowania: historyczne kształtowanie, obecny stan i zachowanie w czasie znacznych wezbrań. Część II. Odcinek od Torunia do Białej Góry. Wydawnictwo IBW PAN, Gdańsk. s. 81–84.

Marks, L., 2012. Timing of the Late Vistulian (Weichselian) glacial phases in Poland. Quaternary Science Reviews 44, 81–88. https://doi.org/10.1016/j.quascirev.2010.08.008

Mayer, S., Kölbl, A., Völkel, J., Kögel-Knabner, I., 2019. Organic matter in temperate cultivated floodplain soils: Light fractions highly contribute to subsoil organic carbon. Geoderma 337, 679–690. https://doi.org/10.1016/j.geoderma.2018.10.014

Mendyk, Ł., Świtoniak, M., Bednarek, R., Falkowski, A., 2015. Genesis and classification of the soils developed from the sediments of the former Oleszek mill pond basin (the Chełmińskie Lakeland, N Poland). Soil Science Annual 66(1), 29–35. https://doi.org/10.1515/ssa-2015-0016

Mendyk, Ł., Hulisz, P., Kusza, G., Świtoniak, M., Gersztyn, L., Kalisz, B., 2016. Sediment origin and pedogenesis in the former mill pond basin of Turznice (north-central Poland) based on magnetic susceptibility measurements. Bulletin of Geography. Physical Geography Series 11, 55–69. http://dx.doi.org/10.1515/bgeo-2016-0015

Michalski, A., 2013. The problem of protection of organic carbon stocks in plough soils of the Lower Vistula floodplain. Episteme 18, 329–337.

Młynarek, Z., Stefaniak, K., Wierzbicki, J., 2012. Geotechnical Parameters of Alluvial Soils from in-situ Tests. Archives of Hydro-Engineering and Environmental Mechanics 59(1–2), 63–81. https://doi.org/10.2478/v10203-012-0005-1

Munsell Soil Color Charts, 2000. GreagMacbeth, New Windsor.

Myga-Piątek, U., Nita, J., Papińska, E., Rodzik, J., Strzyż, M., Terpiłowski, S., Ziaja, W., 2018. Physico-geographical mesoregions of Poland: Verification and adjustment of boundaries on the basis of contemporary spatial data. Geographia Polonica 91(2), 143–170. https://doi.org/GPol.0115

Niedźwiecki, E., Meller, E., Malinowski, R., Sammel, A., Sobczyńska, E., 2010a. The diversity of habitat conditions and plant communities in the Ina River valley near Sowno. Part II. Soil chemical properties and macro-element content in grassland sward. Water-Environment-Rural-Areas 10, 1(29), 145–155. (in Polish with English abstract)

Niedźwiecki, E., Winkler, L., Wojcieszczuk, M., Jarnuszewski, G., 2010b. Selected properties of variably used alluvial soils located in the Ina river valley near the Krąpiel river mouth to the north of Stargard Szczeciński. Part I. Hydrological conditions and morphological features of soils. Roczniki Gleboznawcze – Soil Science Annual 61(4), 171–177. (in Polish with English abstract)

Niewiarowski, W., 1959. Glacial forms and types of deglaciations on the moraine plateau of Chełmno (Bydgoszcz district). Studia Societatis Scientiarum Torunensis Sectio C. 1. 4. Toruń. (in Polish with English summary)

Niewiarowski, W., 1986. Morphogenesis of the Brodnica outwash on the background of ther glacial landforms of Brodnica Lake District. Acta Universitatis Nicolai Copernici sec. Geografia 19(60), 3–30. (in Polish with English summary)

Niewiarowski, W., Wysota, W., 1986. Moraine plateau levels of the Brodnica Moraine Plateau and their genesis. Acta Universitatis Nicolai Copernici sec. Geografia 19(60), 39–46. (in Polish with English summary)

Paluszek, J., 2004. Comparison of aggregation and aggregate water stability in Luvisols, Phaeozems and Fluvisols. Roczniki Gleboznawcze – Soil Science Annual 55(1), 181–191. (in Polish with English abstract)

Polish Soil Classification (Systematyka gleb Polski), wyd. 2, 1959. Roczniki Gleboznawcze – Soil Science Annual 7(2).

Polish Soil Classification (Systematyka gleb Polski), wyd. 3, 1974. Roczniki Gleboznawcze – Soil Science Annual 25(1).

Polish Soil Classification (Systematyka gleb Polski), wyd. 4, 1989. Roczniki Gleboznawcze – Soil Science Annual 40.

Polish Soil Classification (Systematyka gleb Polski), wyd. 5, 2011. Roczniki Gleboznawcze – Soil Science Annual 62(3).

Polish Soil Classification (Systematyka gleb Polski), wyd. 6, 2019. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, Polskie Towarzystwo Gleboznawcze, Komisja Genezy Klasyfikacji i Kartografii Gleb. Wrocław – Warszawa.

Pranagal, J., Ligeza, S., 2011. Retention of Fluvisols on a present-day floodplain of the Vistula river near Puławy. Roczniki Gleboznawcze – Soil Science Annual 62(2), 335–340. (in Polish with English summary)

Radziuk, H., Świtoniak, M., 2021. Soil erodibility factor (K) in soils under varying stages of truncation. Soil Science Annual, 72(1), 134621. https://doi.org/10.37501/soilsa/134621

Rennert, T. et al., 2021. Does soil organic matter in mollic horizons of central/east European floodplain soils have common chemical features? Catena 200, 105192. https://doi.org/10.1016/j.catena.2021.105192

Rytelewski, J., 1965. Typology of the alluvial soils of Łyna valley. Roczniki Gleboznawcze – Soil Science Annual 15, 1, 91–109. (in Polish with English summary)

Schaetzl, R., Anderson, S., 2005. Soils. Genesis and Geomorphology. Cambridge University Press.

Sewerniak, P., Jankowski, M., Dąbrowski, M., 2017. Effect of topography and deforestation on regular variation of soils on inland dunes in the Toruń Basin (N Poland). Catena 149(1), 318–330. https://doi.org/10.1016/j.catena.2016.10.008

Sheremet, B.V., 2006. Soil horizons as the basis for classification of alluvial soils. Eurasian Soil Science 39, 127–133. https://doi.org/10.1134/S1064229306020025

Soil Survey Staff, USDA. Soil Taxonomy. 1999. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Washington DC, 745.

Solon, J., et al., 2018. Physico-geographical mesoregions of Poland: Verification and adjustment of boundaries on the basis of contemporary spatial data. Geographia Polonica 91(2), 143–170. https://doi.org/10.7163/GPol.0115

Suther, B.E., Leigh, D.S., 2020. Soil morphology of an alluvial chronosequence from the Little River, North Carolina Coastal Plain, USA. Geomorphology 351, 106921. https://doi.org/10.1016/j.geomorph.2019.106921

Strzemski, M., 1955. The typology of Polish alluvial soils. Roczniki Gleboznawcze – Soil Science Annual 4, 180–191. (in Polish)

Sulimierski, F., Chlebowski, B., Walewski, W., 1880. Słownik geograficzny Królestwa Polskiego i innych krajów słowiańskich. Tom II, s. 724. Druk Wieku. Warszawa.

Sykuła, M., Jankowski, M., Mendyk, Ł., Dąbrowski, M., Jasińska, J., Michalak, J., Michalski, A., Pindral, S., Bednarek, R., 2019. Wczoraj i dziś Mapy gleb Polski 1 300 000 – próba adaptacji do Systematyki gleb Polski 2019 (SGP6). [w:] 30. Kongres Polskiego Towarzystwa Gleboznawczego – Gleba źródłem życia, Bartmiński P., Dębicki R. (red.). Uniwersytet Marii Curie-Skłodowskiej w Lublinie, Lublin, 108–109.

Świtoniak, M., 2015. Issues relating to classification of colluvial soils in young morainic areas (Chełmno and Brodnica Lake District, northern Poland). Soil Science Annual 66(2), 57–66. https://doi.org/10.1515/ssa-2015-0020

Świtoniak, M., 2021. Rustification as a collateral process in clay-illuvial soils of northern Poland. Soil Science Annual 72(4), 143444. https://doi.org/10.37501/soilsa/143444

Świtoniak, M., Kabała, C., Podlasiński, M., Smreczak, B., 2019. Proposal of the correlation between cartographic units on the agricultural soil map and types and subtypes of Polish Soil Classification (6th edition, 2019). Soil Science Annual 70(2), 98–114. https://doi.org/10.2478/ssa-2019-0010

Terelak, H., 1967. Kwaśne mady eluwialno-iluwialne. Pamiętnik Puławski 30.

Weckwerth, P., Przegiętka, K., Chruścińska, A., Woronko, B., Oczkowski, H.L., 2011. Age and sedimentological features of fluvial series in the Toruń Basin and the Drwęca Valley (Poland). Geochronometria 38(4), 397–412. https://doi.org/10.2478/s13386-011-0038-1

Yilmaz, I., Karacan, E., 1997. Geotechnical properties of alluvial soils: An example from South of Sivas (Turkey). Bulletin of the International Association of Engineering Geology 55, 159–165. https://doi.org/10.1007/BF02635418

Zehetner, F., Lair, G.J., Maringer, F.J., Gerzabek, M.H., Hein, T., 2008. From sediment to soil: floodplain phosphorus transformations at the Danube River. Biogeochemistry 88, 117–126. https://doi.org/10.1007/s10533-008-9198-3

Pozycja systematyczna gleb aluwialnych – zagadnienia problematyczne na przykładach z Pojezierzy Południowobałtyckich, Polska północna

Słowa kluczowe

Mady
Równiny aluwialne
Systematyka gleb Polski
Gleby gruntowo-glejowe
Kambik, Siderik

Streszczenie

Gleby wytworzone z materiałów aluwialnych stanowią bardzo zróżnicowaną grupę. Dotyczy to zarówno ich genezy, jak i wynikających z niej większości podstawowych właściwości np. zawartości węgla organicznego, cech związanych z oglejeniem opadowo lub gruntowo wodnym, obecności poziomów B czy uziarnienia. Zróżnicowanie omawianych gleb odzwierciedla ich pozycja systematyczna. W najnowszym wydaniu Systematyki gleb Polski (2019) gleby wytworzone z materiałów aluwialnych mogą należeć do trzech typów mad: czarnoziemnych, brunatnych lub właściwych. W przypadku braku poziomów diagnostycznych, ale przy silnym wpływie wody mogą być też klasyfikowane jako gleby gruntowo lub opadowo-glejowe. Celem przeprowadzonych badań była weryfikacja kryteriów jak i kompletności jednostek w randze typów i podtypów gleb aluwialnych wydzielonych w najnowszym wydaniu Systematyki gleb Polski (2019). Badania przeprowadzono w dolinach rzecznych Polski północnej objętej ostatnim zlodowaceniem Wisły. Łącznie przebadano 87 profili glebowych. 18 gleb zostało zaklasyfikowanych jako mady czarnoziemne. Najbardziej powszechne, bo reprezentowane aż przez 48 przypadków, były mady brunatne. Mady właściwe odnotowano 11 razy. Ponadto 7 gleb wytworzonych z materiałów aluwialnych należało do gleb gruntowo-glejowych. 3 pozostałe przypadki zostały zaklasyfikowane jako gleby organiczne i deluwialne. Na podstawie uzyskanych wyników badań opracowano kilka propozycji zmian w Systematyce gleb Polski. Dotyczą one konieczności wprowadzenia kryterium minimalnej miąższości materiału fluvic przy wydzielaniu mad, podniesienia wymogów dla podtypu gleb próchnicznych oraz rozszerzenia gamy typów w glebach glejoziemnych lub podtypów gleb gruntowo-glejowych o mady gruntowo-glejowe oraz typu mad czarnoziemnych o gleby podmokłe. W artykule podjęto też problematyczne kwestie określania genezy poziomów B w glebach aluwialnych. Ponadto badania potwierdziły dużą przydatność map glebowo-rolniczych w określaniu zasięgów występowania gleb aluwialnych.