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Chapter IV

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Soil conditions and vegetation on gyttia lands in the Masurian Lakeland

DEFINITION OF GYTTJA AND GYTTJA SOILS

Gyttja is a freshwater deposit (mud) consisting of organic and mineral matter found at the bottom or near the shores of lakes. The term was originally defined by the Swedish scientist Hampus von Post in 1862, as a light-colored coprogenic deposit consisting of a mixture of plankton particles, mollusk shells, chitin remains from the exoskeletons of insects, pollen and spores of higher plants, and mineral particles, formed in eutrophic water bodies (MYŚLIŃSKA 2001). The term “gyttja” (meaning “slime” in Swedish) proposed by von Post is currently used in international classification systems. Gyttja sediments have been defined and categorized in many different ways by the specialists representing different research areas, who applied different methods and criteria in their studies. According to Rzepecki (1983), this terminological chaos seems to be caused by the fact that lake deposits are highly unique and complex as regards their mineral, chemical and biological composition.

The term gyttja (sapropel) refers to the sediment formed at the bottom of open water bodies, composed of dead phytoplankton and zooplankton mixed with inorganic constituents. Under anaerobic conditions, organic matter undergoes partial bacterial decomposition, leading to the formation of structureless, jelly-like mass which often contains fat, wax and protein substances (BERGLUND 1996).

Detrital (organic) gyttja is olive green to dark brown in color. It accumulates as a gelatinous precipitate, but when exposed on the surface and dried it contacts and hardens showing vertical cracks and fissures. Clayey-detrital and calcareous-detrital gyttja is termed mixed gyttja or mineral-organic gyttja due to high content of mineral substance. It is slimy in the damp state, but becomes crumble when drying and more gelatinous when richer in organic matter. Mineral gyttja comprises clay-calcareous, calcareous and clay deposits which are hard and compact. Their grey or white color is due to the presence of calcium carbonate or gleyey clay (TOBOLSKI 2000).

Gyttja sediments were originally deposited during the Late Pleistocene (Younger Dryas substage) and the Early Holocene (Preboreal stage). Gyttja accumulation takes place underwater, following the deposition of suspended matter contained in water and in the surface run-off from the catchment. Organic (detrital) gyttja is formed in hollows and depression with no inflow or outflow, fed by nutrient-poor water. It is predominantly composed of dead planktonic organisms (including algae, the external skeletons of crustaceans, single diatom cells), small benthic invertebrates (living in the benthic zone of water bodies) and metabolites produced by aquatic organisms that settle on the bottom. Homogenous organic matter is accompanied by chemical precipitates (mostly calcium carbonate) and mechanically deposited non-carbonate minerals (silt, clay and sand fractions) (MYSLIŃSKA 2001). Calcareous sediments are deposited as a result of biological water decalcification. This process is observed most often in shallow water bodies rich in dissolved acidic calcium carbonate. Changes in water temperature and carbon dioxide concentrations also favor calcium carbonate precipitation (STASIAK 1971; TOBOLSKI 2000).

The rate of sedimentation is affected by the primary production of organic matter in a water body, the physical properties of water, the external input of organic matter, as well as by the size and weight of sedimenting particles. The allogenic genesis of bottom deposits is determined by the processes of fluvial and eolic translocation, and chemical and mechanical denudation in the catchment. The accumulation of deposit components of local (intrabasinal) origin is known as an autogenic process. The formation of bottom deposits is greatly influenced by catchment conditions (UGGLA 1964; ILNICKI 2002). The effect of catchment characteristics on deposit formation results from several factors. A key role is played by the local climate, in particular by the total amount, intensity and distribution of precipitation, temperature and wind. Other important parameters are surface features, geological structure of the catchment, hydrological and hydrographic relations, and vegetation development.

As a result of the natural processes of lake terrestrialisation, or controlled reclamation, gyttja sediments were exposed on the surface and provided the parent material for gyttja soils. Following their exposure to atmospheric and biospheric interactions, they were transformed into subareal soils (OKRUSZKO 1976, 1998; UGGLA 1962, 1971). Land improvement projects and drainage practices have led to the development of gyttja lands where the thickness of bottom sediments varies widely from several centimeters to a dozen meters or so. Gyttja soils developed from detrital gyttja are most common. Soils of this type are not used for agricultural purposes and they are usually classified as wasteland. They should be left in their natural state and put under protection. Calcareous gyttjas, in the form of bog lime (lacustrine chalk), are encountered less frequently. They are the parent material for Quaternary rendzina soils (UGGLA 1976).

ANTHROPOGENIC TRANSFORMATIONS OF WATER BODIES

Lake disappearance is a natural consequence of the evolution of water bodies. It results from changes in water-level caused by reduced inflow intensity and the accumulation of sediments delivered from the catchment. The rate of this process is determined by lake type, catchment geology, hydrological network development, climatic conditions and vegetation cover (KALINOWSKA 1961; LOSSOW 1996). Another crucial factor is human activity.

Intensive drainage and land reclamation, including the removal of water from lakes by artificial means, was carried out in former East Prussia (today Warmia and Mazury) in the second half of the 19th c. and at the beginning of the 20th c. It involved the widening and deepening of river-beds, constructing canals, drainage ditches and pumping stations. As a result, the water-level dropped by several meters (SROKOWSKI 1930), the surface area of some lakes decreased, while some other lakes ceased to exist. Drained peatlands surrounding the lakes and the drained bottoms of lakes were later used as grasslands. The entire process has been documented – archival maps show lakes (Ehemaliger Dimmer See, Stammsee) which were converted into meadows (Dimmernwiese = Dymer Meadows – Łąki Dymerskie, Stasswinner Wiesen = Staswiny Meadows – Łąki Staświńskie).

The interruption of the natural process of water body development contributed to the formation of gyttja lands with exposed gyttja sediments (CHMIELESKI et al. 2004; ILNICKI 2002), which management often posed serious problems due to the limited technical capabilities of enterprises at that time. The specific features of gyttja and changes in hydration resulted either in shrinkage, subsidence and crack formation or in expansion, uplift and clogging of drains. Organic gyttja, which is a highly hydrated colloid, filled the ditches and thus slowed down drainage. According to literature data (OLKOWSKI 1970), the same gyttja lands were reclaimed several times. In many cases the attempts to drain selected water bodies were unsuccessful, and some drained lakes started to fill with water again within a few years. The efforts made to convert gyttja lands into grasslands did not bring the expected results, either. Due to secondary bogging, many former meadows turned into wetlands. The lack of maintenance and progressive silting of drainage systems contributed to the restoration of water bodies, with their hydrophilic and littoral vegetation. Today the majority of gyttja lands are not used for agricultural production, but they are known for their high natural values and environmental benefits (ŁACHACZ 1996).

RESEARCH AREA AND METHODS

According to the physico-geographical regionalization of Poland (KONDRACKI 2000), the Masurian Lakeland is a geomorphological unit of north-eastern Poland. This macroregion has a total area of approximately 13 180 km^2, and it comprises 7 mesoregions (Fig. 1). The early post-glacial landscape in the Masurian Lakeland owes its origin to the Vistulian glaciation. The features that contribute to the specific character of this landscape are latitudinal morainal sequences, numerous lakes and wetlands. Another distinguishing feature of the region is the presence of dense forest complexes, including old-growth forest stands (ŁACHACZ 1996). Wetlands occupy 107 161 ha, i.e. 8.1% of the total area of the Masurian Lakeland. Despite major transformations in the 19th c., many natural environmental components of wetlands remained unchanged. Lake deposits occurring on the surface form unique wetlands that add up to the overall diversity of the Masurian Lakeland. Gyttja lands (excluding the gyttja deposits covered by peats) cover a total area of approximately 8 000 ha in this region, and the number of separate gyttja beds is 189 (OLKOWSKI 1971).

Three typical, extensive gyttja lands situated in the Masurian Lakeland were investigated in the study. All of them were drained to pumping stations and used as grasslands until World War II. Then they are gradually turned into a wetland ecosystem again, and reed rushes developed in their central parts. These gyttja lands had been studied (land reclamation, soils, vegetation cover) in the 1950s and 1960s to determine whether they could be used for agricultural purposes (UGGLA 1964, 1968, 1969, 1971; OLKOWSKI 1970, 1971). Recent research has focused on their protection (ŁACHACZ 1996) and habitat reconstruction as part of the study of regional prehistoric settlement (GUMIŃSKI 2008; WACNIK, RALSKA-JASIEWICZOWA 2008).

In order to characterize the local habitat conditions, a total of 25 soil pits were excavated in the three investigated gyttja lands, and an analysis of vegetation cover was performed. Phytosociological data were collected in relevés, according to the Braun-Blanquet method (MATUSZKIEWICZ 2001). Soil profiles were grouped in 6 transects, which enabled to determine the spatial diversity of soil cover. The distribution of soil profiles along each transect was similar, from mineral soils on the edge to organic soils towards the middle of the former lake basin. They were situated perpendicularly to the main drainage channel. The depth and geographical coordinates of soil profiles were determined using the Asus MyPal A639 PDA with a built-in GPS receiver. Gyttja samples were analyzed by conventional methods applied in Poland in studies of organic soils (SAPEK, SAPEK 1997):

- the color of soil formations was determined based on the Munsell atlas (OYAMA, TAKEHARA 1992);
- pH in water and potassium chloride was measured with a potentiometer;
- carbonate content was estimated by the Scheibler method (MYŚLIŃSKA 200l);
- sorption capacity: exchangeable cations were determined following extraction with 1 M CH_3COONH_4 (pH 7.0), total exchangeable acidity was determined following extraction with BaCl – TEA (pH 8.0);
- organic matter content was estimated based on weight loss during roasting at 550°C;
- organic carbon content was measured with a spectrophotometer following oxidation with potassium dichromate;
- total nitrogen content was determined by the Kjeldahl method.

The age of organic soil formations was estimated by the radiocarbon method (^{14}C) – AMS (Accelerator Mass Spectrometry) at the Radiocarbon Dating Laboratory in Poznań (GOSLAR 2008).

The Łąki Staświńskie gyttja land

The Łąki Staświńskie gyttja land is situated in the south-eastern part of the powiat (county) of Giżycko, in the mesoregion of Great Masurian Lakes (Fig. 1). This mesoregion has the largest total water area of all mesoregions in the Masurian Lakeland (302 km^2, which accounts for 20% of the total area). Peatlands occupy approximately 16% of the total area in this region, and 43 gyttja lands cover a total area of 1780 ha (GOTKIEWICZ et al. 1995). The Łąki Staświńskie gyttja land is located on ground moraine, 160-180 m a.s.l. The terminal moraine south of the gyttja land has an altitude of 120-200 m a.s.l. Luvisols and Cambisols developed from moraine clay dominate in the areas surrounding the gyttja land studied.

The Łąki Staświńskie gyttja land covers an area of around 700 ha, and the total area of this gyttja land and adjacent peatlands is 2500 ha (OLKOWSKI 1970; GUMIŃSKI 2008). The peatland boundary follows level line 134 m a.s.l. During the Holocene, the altitude of the water-level in the former Lake Staświńskie was approximately 133 m a.s.l., with oscillations of up to 1.5 m (GUMIŃSKI 2008). The thickness of bottom deposits is 7.0 m. The sedimentation of bottom deposits in Lake Staświńskie started at the late glacial stage of the Vistulian glaciation, approximately 11 500 years ago (WACNIK, RALSKA-JASIEWICZOWA 2008). In the years 1825-1836 the water-level in Lake Staświńskie was decreased by 2.2 m, which contributed to the development of an extensive swamp. The area was reclaimed for the first time in the years 1910-1920. Excess water was drained off by the Staświnka River to Lake Wojnowo, west of the gyttja land. After World War II, gradual gyttja subsidence and lack of maintenance of drainage systems resulted in secondary bogging, and the land was reclaimed again in 1962. Today the edges of the gyttja land are used as grasslands, and the central part is occupied by reed rushes surrounded by sedges.

The first transect, located in the south towards the former lake-basin, comprises 5 soil profiles (Fig. 2). The first type of soil on this transect was muckous soil found at the site farthest from the former lakeshore and at the highest altitudes, compared with the remaining sites. The next three soil profiles represent gyttja-muck soils situated at the former lake boundary, as indicated by the sequence of soil horizons. Surface soil horizons are dominated by gyttja muck with an organic matter content above 60% (Table 1). Gyttja muck is underlain by gelatinous organic gyttja. The low thickness of this formation in profile 2 (15 cm) suggests that it was the littoral zone of the lake. Profiles 3 and 4, with a similar arrangement of soil horizons, have thicker gyttja sediments. Based on radiocarbon dating, organic gyttja started to accumulate in profile 4 (at a depth of 99-100 cm) 1690 ± 30 years BP (Sub-Atlantic stage). Thus, an estimated gyttja accumulation rate was around 0.6 mm per year. The last profile (5) is located within the former water body. The groundwater level is at the soil surface, and the surface horizon consists of coarse detrital gyttja overgrown with the roots of marsh plants, but with no symptoms of muck-forming process. The thickness of the organic formation is 270 cm, and it is underlain by clay-calcareous gyttja.

The second transect comprises three soil profiles located in the south-eastern part of the gyttja land. Profile 6 is proper gley soil, and profile 7 – mineral-muck soil underlain by light loam. The lowest-lying profile 8 consists of gyttja-muck soil.

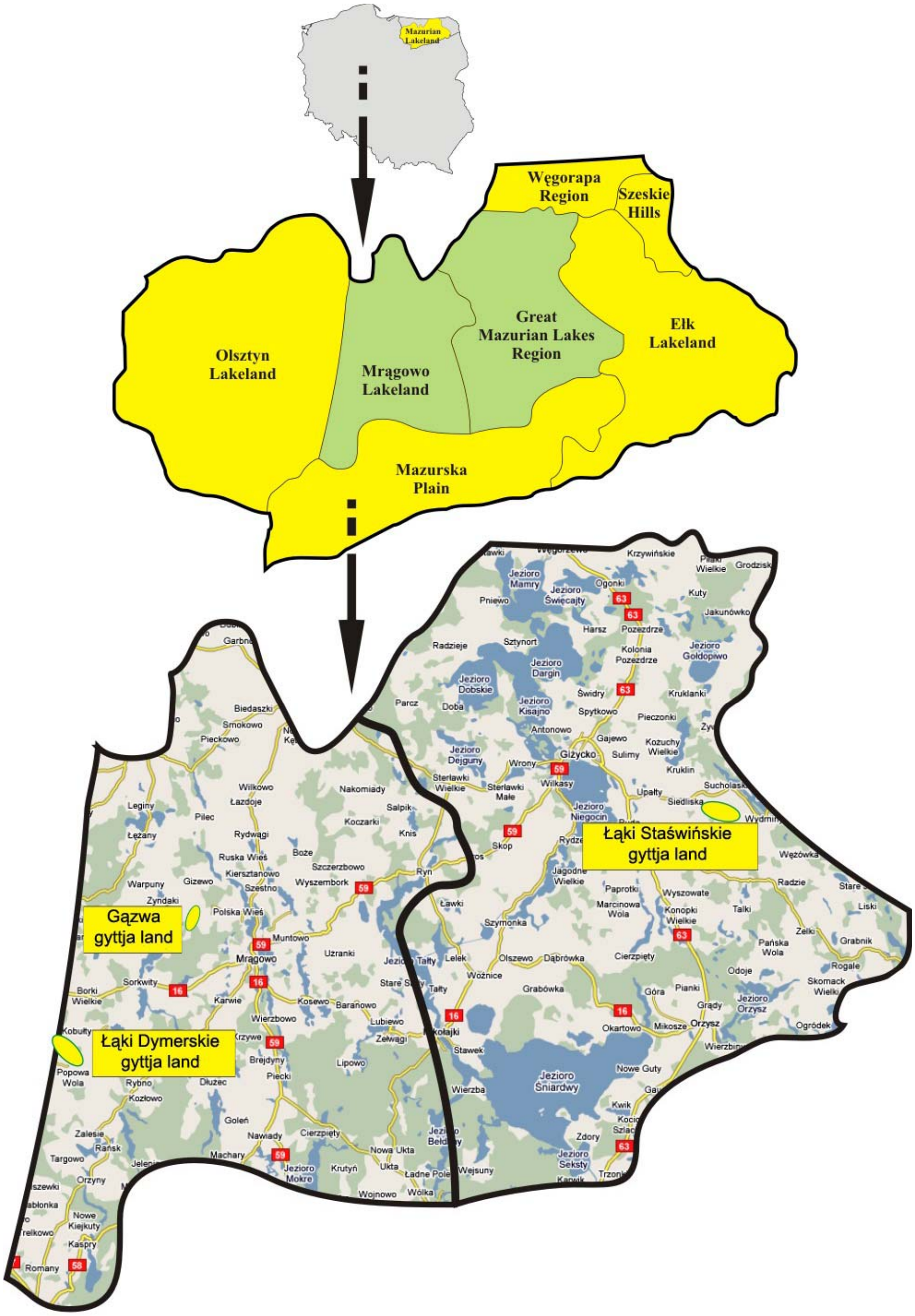

Fig. 1. Location of the gyttja lands studied

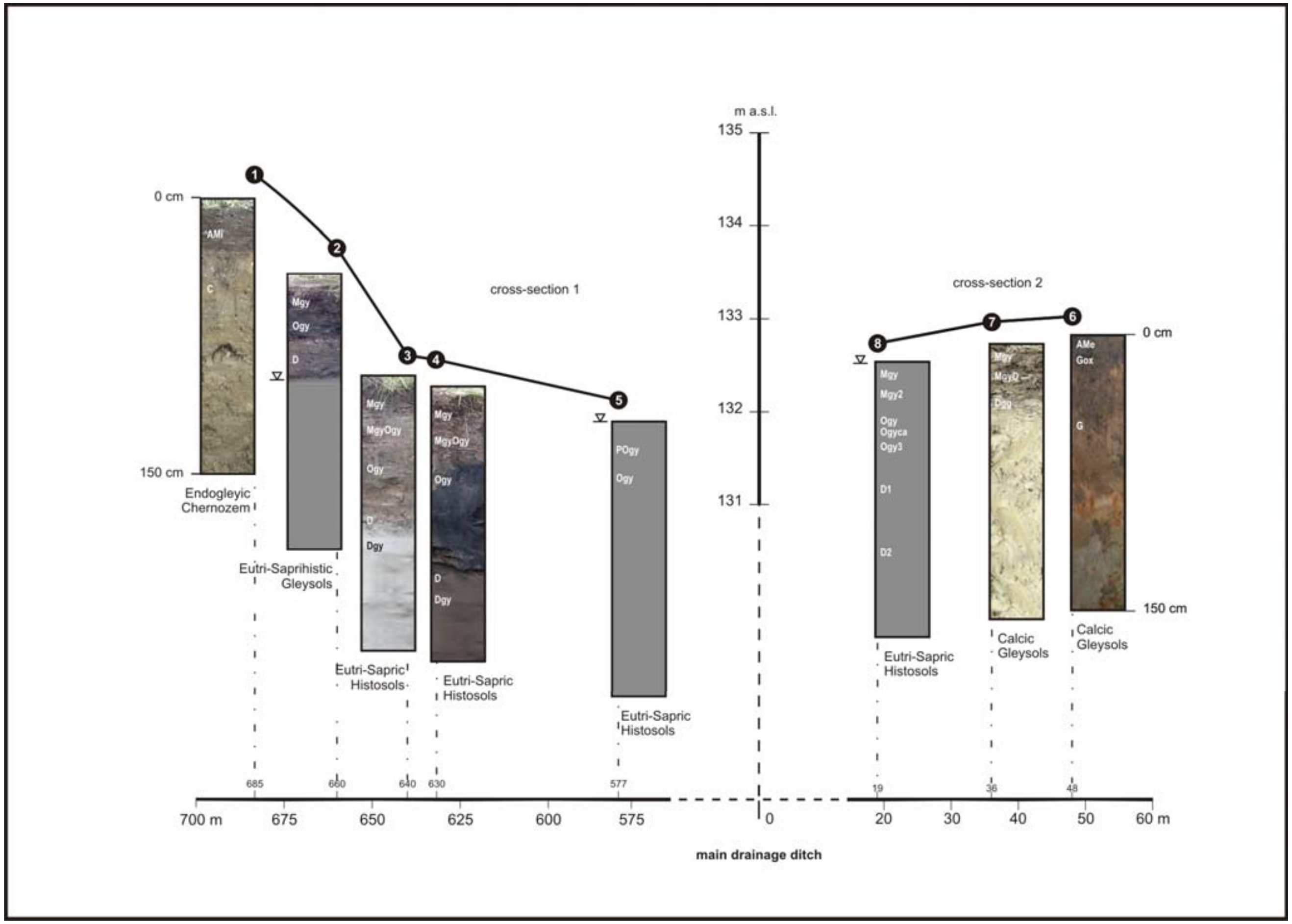

Fig. 2. A cross-section of Łąki Staświńskie gyttja land

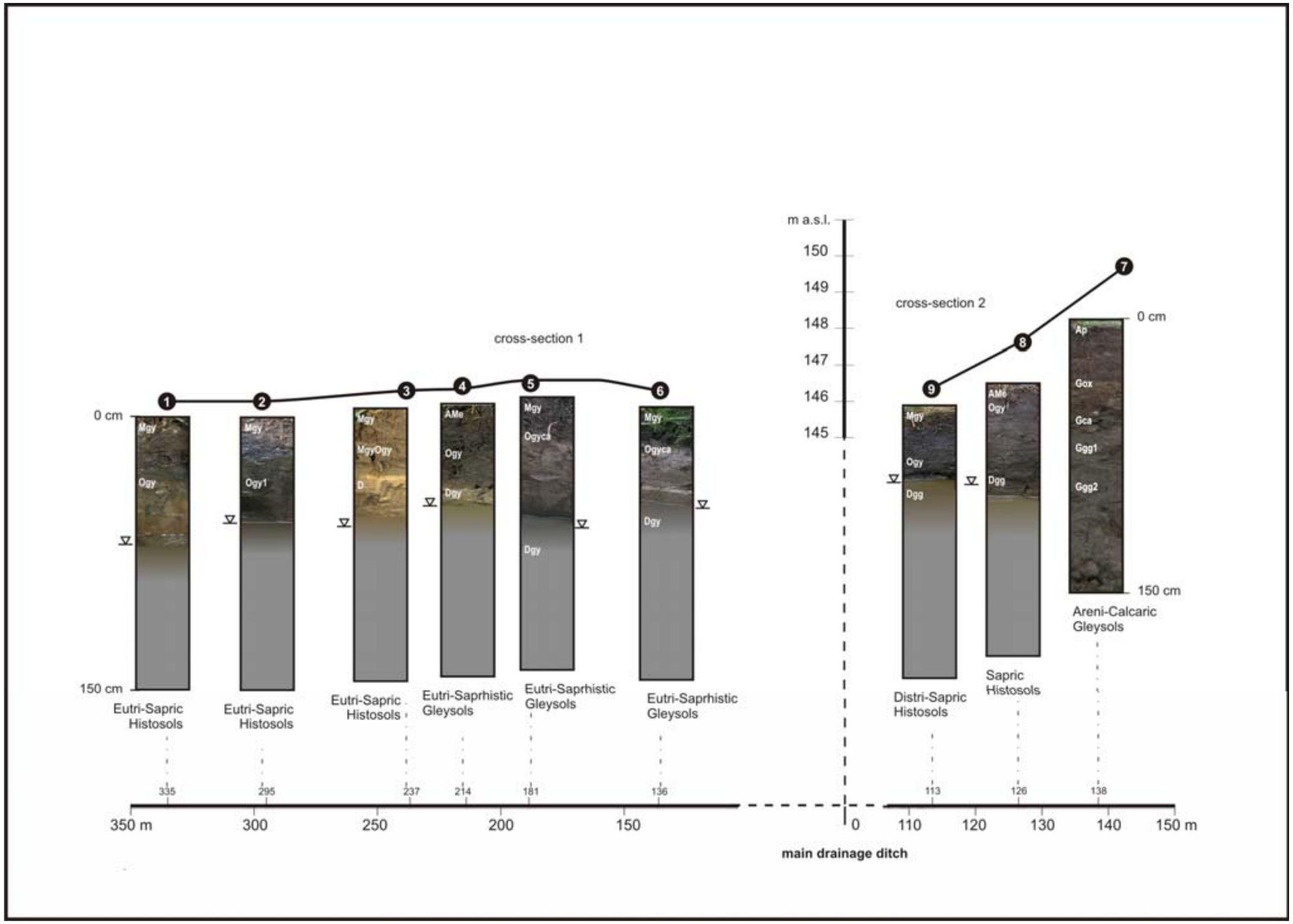

Fig. 3. A cross-section of Gązwa gyttja land

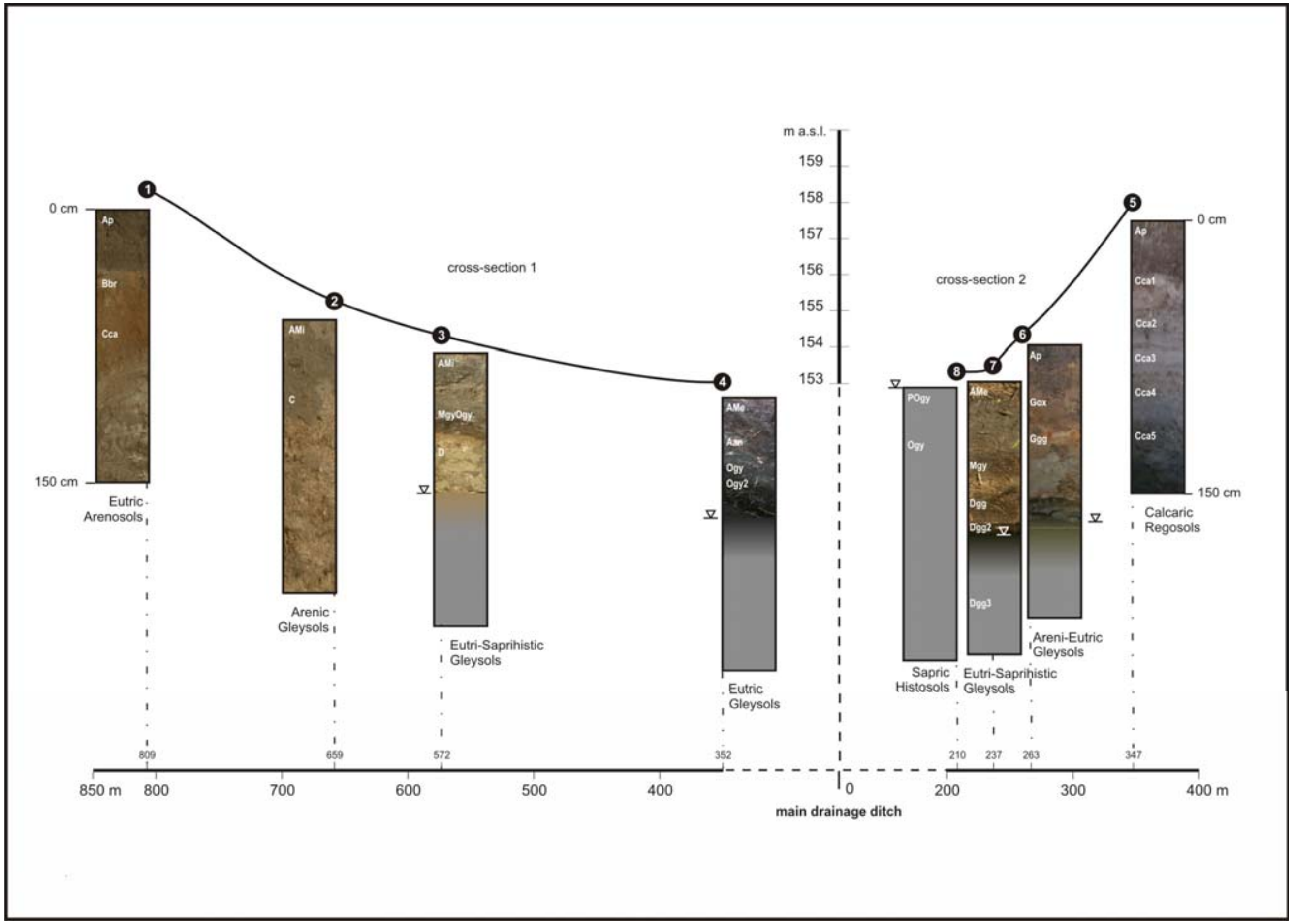

Fig. 4. A cross-section of Łąki Dymerskie gyttja land

Table 1

Description of soil profiles studied

Profile No	Gyttja sample No*	Depth [cm]	Soil horizon**	LOI [%]	$CaCO_3$ [%]	Munsell soil colour		Soil formation	Soil taxonomy	
						dry	wet		Polish (1989)**	WRB (2006) ***
1	2	3	4	5	6	7	8	9	10	11
Łąki Staświńskie gyttja land										
1		0-28 28-52 52-150	AMi AC Cca	9.53 1.53 0.35	3.49 7.38 13.11	10YR 4/2 5Y 6/3 5Y 6/2	10YR 2/1 5Y 5/3 5Y 5/3	humous sand (muckous) sandy loam loamy sand	muckous soil	Endogleyic Chernozem
2	1 2	0-20 20-35 35-150	Mgy Ogy Dca	60.72 75.52 0.64	0.00 0.00 9.56	10YR 2/1 10YR 4/2 5Y 6/2	10YR 1.7/1 10YR 2/1 5Y 5/3	gyttja muck coarse detrital gyttja loamy sand	gyttja-muck soil	Eutri-Saprihistic Gleysols
3	3 4 5 6	0-20 20-43 43-76 76-81 81-180	Mgy MgyOgy Ogy D Dgy	61.74 59.04 58.39 0.93 1.66	0.00 0.00 0.00 4.43 21.57	10YR 1.7/1 10YR 4/1 10YR 4/2 10YR 6/2 5Y 7/1	10YR 1.7/1 10YR 2/1 10YR 3/1 10YR 5/2 5Y 5/2	gyttja muck mucking gyttja fine detrital gyttja loose sand clay-calcareous gyttja	gyttja-muck soil	Eutri-Sapric Histosols
4	7 8 9 10	0-23 23-40 40-100 100-108 108-180	Mgy MgyOgy Ogy D Dgy	67.61 74.51 72.59 1.79 3.42	0.00 0.00 0.00 0.00 12.89	10YR 2/1 10YR 4/2 10YR 4/1 10YR 6/2 5Y 7/1	10YR 1.7/1 10YR 3/2 10YR 2/2 10YR 5/2 5Y 5/2	gyttja muck mucking gyttja coarse detrital gyttja loose sand clay gyttja	gyttja-muck soil	Eutri-Sapric Histosols
5	11 12 13	0-28 28-270 270-430	POgy Ogy Dgy	72.51 72.75 2.49	0.00 0.00 22.67	10YR 3/1 10YR 4/1 5Y 7/1	10YR 2/1 10YR 3/1 5Y 5/2	coarse detrital gyttja coarse detrital gyttja clay-calcareous gyttja	gyttja soil	Eutri-Sapric Histosols
6		0-10 10-45 45-150	AMe Gox G	18.14 1.84 2.29	2.68 16.56 20.99	10YR 4/1 2.5Y 6/3 2.5Y 7/3	10YR 1.7/1 2.5Y 5/3 2.5Y 5/3	mucky (muck-like) silty loam heavy loam (silty)	proper gley soil	Calcic Gleysols
7	14	0-15 15-28 28-150	Mgy MgyD Dgg	26.61 15.66 0.54	22.46 40.98 16.86	10YR 4/1 10YR 6/1 5Y 7/2	10YR 2/1 10YR 5/2 5Y 5/2	gyttja muck sand with gyttja admixture light loam	mineral-muck soil (developed from clay-calcareous gyttja)	Calcic Gleysols

Table 1 continued

1	2	3	4	5	6	7	8	9	10	11
8	15	0-20	Mgy	61.09	0.00	10YR 2/1	10YR 1.7/1	gyttja muck	gyttja-muck soil	Eutri-Sapric Histosols
	16	20-30	Mgy2	54.34	0.09	10YR 2/1	10YR 1.7/1	gyttja muck		
	17	30-35	Ogy	39.29	32.91	10YR 5/2	10YR 3/2	detrital-calcareous gyttja		
	18	35-45	Ogyca	28.36	51.75	2.5Y 6/2	2.5Y 5/2	calcareous gyttja		
	19	45-65	Ogy3	38.97	30.49	10YR 4/1	10YR 2/1	detrital-calcareous gyttja		
		65-103	D1	2.67	5.55	10YR 5/2	10YR 3/2	loose sand		
		103-150	D2	4.44	13.09	5Y 6/1	5Y 4/2	loamy sand (silty)		
		150-250	D3	2.41	21.87	5Y 7/1	5Y 5/2	clay		
Gązwa gyttja land										
1	20	0-28	Mgy	84.48	0.00	10YR 4/2	10YR 2/2	gyttja muck	gyttja-muck soil	Eutri-Sapric Histosols
	21	28-150	Ogy	82.72	0.00	10YR 3/2	10YR 2/1	algal gyttja		
2	22	0-27	Mgy	20.56	0.00	10YR 4/1	10YR 2/1	gyttja muck	gyttja-muck soil	Eutri-Sapric Histosols
	23	27-160	Ogy1	87.75	0.00	10YR 3/2	10YR 2/2	algal gyttja		
	24	160-245	Ogy2	67.09	0.00	10YR 2/1	10YR 1.7/1	coarse detrital gyttja		
	25	245-325	Dgy	1.08	9.20	5Y 4/2	5Y 3/2	clay gyttja		
3	26	0-18	Mgy	20.94	0.27	10YR 3/1	10YR 1.7/1	gyttja muck	gyttja-muck soil (shallow)	Eutri-Sapric Histosols
	27	18-42	MgyOgy	49.00	0.53	10YR 4/2	10YR 2/1	mucking gyttja		
		42-150	Dca	8.93	25.76	10YR 6/3	10YR 4/3	loamy silt		
4		0-25	AMe	13.76	0.00	10YR 5/2	10YR 3/1	mucky (muck-like)	gyttja-muck soil	Eutri-Saprihistic Gleysols
	28	25-48	Ogy	58.95	0.48	10YR 4/2	10YR 2/1	fine detrital gyttja		
	29	48-150	Dgy	2.61	38.60	5Y 6/2	5Y 5/2	clay-calcareous gyttja		
5	30	0-18	Mgy	32.94	0.82	10YR 3/1	10YR 1.7/1	gyttja muck	gyttja-muck soil	Eutri-Saprihistic Gleysols
	31	18-80	Ogyca	23.08	66.30	10YR 6/2	10YR 5/2	calcareous gyttja		
	32	80-150	Dgy	8.25	35.12	10YR 6/2	10YR 3/2	clay-calcareous gyttja		
6	33	0-22	Mgy	31.49	2.84	10YR 3/1	10YR 1.7/1	gyttja muck	gyttja-muck soil	Eutri-Saprihistic Gleysols
	34	22-60	Ogyca	20.13	67.46	10YR 7/1	10YR 5/2	calcareous gyttja		
	35	60-150	Dgy	7.65	33.01	10YR 6/2	10YR 3/2	clay-calcareous gyttja		

Table 1 continued

1	2	3	4	5	6	7	8	9	10	11
7		0-32	Ap	3.44	0.00	10YR 5/2	10YR 3/2	humous loose sand	proper gley soil	Areni-Calcaric
		32-52	Gox	1.95	2.42	10YR 5/3	10YR 4/3	loamy sand		Gleysols
		52-67	Gca	0.84	12.35	10YR 6/2	10YR 4/3	loamy sand		
		67-88	Ggg1	0.28	8.21	10YR 6/2	10YR 4/3	loose sand		
		88-150	Ggg2	0.23	5.66	10YR 6/2	10YR 4/3	loose sand		
8		0-11	AMe	16.22	0.00	10YR 5/2	10YR 2/1	mucky (muck-like)	gyttja-muck soil	Sapric Histosols
	36	11-50	Ogy	44.49	0.00	10YR 4/2	10YR 2/1	fine detrital gyttja	(shallow)	
		50-150	Dgg	2.35	4.25	2.5Y 6/3	2.5Y 4/3	sandy loam (silty)		
9	37	0-27	Mgy	67.00	0.00	10YR 4/1	10YR 2/1	gyttja muck	gyttja-muck soil	Distri-Sapric
	38	27-45	Ogy	62.11	0.00	10YR 3/2	10YR 1.7/1	coarse detrital gyttja	(shallow)	Histosols
		45-150	Dgg	1.00	0.13	2.5Y 6/2	2.5Y 4/2	loamy sand		
Łąki Dymerskie gyttja land										
1		0-29	Ap	2.95	0.51	10YR 4/2	10YR 2/2	humous loose sand	brown pararendzina	Eutric Arenosols
		29-65	Bbr	0.69	0.27	10YR 5/4	10YR 4/4	loose sand		
		65-150	Cca	0.50	10.49	10YR 7/2	10YR 6/2	loose sand		
2		0-38	AMi	6.18	0.00	10YR 4/1	10YR 2/1	humous sand (muckous)	muckous soil	Arenic Gleysols
		38-57	AC	3.67	0.00	10YR 5/2	10YR 3/1	loose sand (humous)		
		57-150	Cgg	0.34	0.45	10YR 6/3	10YR 4/3	loose sand		
3		0-30	AMi	6.21	1.49	10YR 4/1	10YR 3/1	humous sand (muckous)	gyttja-muck soil	Eutri-Saprihistic
	39	30-51	MgyOgy	45.12	0.00	10YR 4/2	10YR 2/1	mucking gyttja	(shallow)	Gleysols
		51-150	Dca	0.55	5.73	2.5Y 6/2	2.5Y 5/3	loose sand		
4		0-22	AanMe	11.10	0.00	10YR 3/2	10YR 2/1	mucky (muck-like)	gyttja soil with	Eutric Gleysols
		22-37	Aan	3.14	4.39	10YR 5/2	10YR 4/1	humous sand	anthropogenic top	
	40	37-44	Ogy	52.98	0.00	10YR 4/1	10YR 2/1	fine detrital gyttja	layer of mucky	
	41	44-150	Ogy2	61.19	0.00	10YR 3/1	10YR 1.7/1	coarse detrital gyttja	character	

Table 1 continued

1	2	3	4	5	6	7	8	9	10	11
5		0-24	Ap	1.97	1.28	10YR 5/3	10YR 3/2	humous loose sand	proper pararendzina	Calcaric Regosols
		24-51	Cca1	0.29	8.19	10YR 7/2	10YR 6/3	loose sand		
		51-69	Cca2	0.32	10.64	10YR 7/2	2.5Y 6/3	loose sand		
		69-88	Cca3	0.19	6.03	10YR 7/2	10YR 6/3	loose sand		
		88-112	Cca4	0.26	8.49	10YR 7/3	10YR 5/3	loose sand		
		112-150	Cca5	0.25	8.38	10YR 8/2	10YR 6/3	loose sand		
6		0-24	Ap	4.46	0.45	10YR 5/2	10YR 1.7/1	humous loose sand	proper gley soil	Areni-Eutric Gleysols
		24-45	Gox	1.22	0.82	10YR 5/4	10YR 3/4	loose sand		
		45-150	Ggg	0.32	4.79	2.5Y 7/3	10YR 5/3	loose sand		
7		0-39	AMe	11.10	0.00	10YR 5/2	10YR 2/1	mucky (muck-like)	mucky soil with gyttja layer	Eutri-Saprihistic Gleysols
	42	39-61	Mgy	22.01	0.00	10YR 3/2	10YR 1.7/1	gyttja muck		
		61-76	Dgg	4.95	0.00	10YR 5/2	10YR 2/2	sand with humus admixture		
		76-115	Dgg2	8.57	0.00	10YR 3/2	10YR 1.7/1	sand with humus admixture		
		115-150	Dgg3	1.13	0.00	10YR 6/2	10YR 4/2	loose sand		
8	43	0-29	POgy	40.91	0.00	10YR 3/2	10YR 2/1	fine detrital gyttja	gyttja soil	Sapric Histosols
	44	29-150	Ogy	40.76	0.00	10YR 3/1	10YR 1.7/1	fine detrital gyttja		

LOI – loss-on-ignition
* – as presented on triangle, Fig. 5
** – according to Systematics of Polish Soils (1989)
*** – according to World Reference Base for Soil Resources (2006)

Gązwa gyttja land

The Gązwa gyttja land is situated in the powiat (county) of Mrągowo, in the mesoregion of Mrągowo Lakeland (Fig. 1). It covers a total area of 104 ha (OLKOWSKI 1970) and is located on end moraines deposited during the Vistulian glaciation. The extensive catchment area is surrounded by sandy soils. Boulder clays are found only in the northern and north-eastern parts of the gyttja land. The investigated object is situated at an altitude of 146-148 m a.s.l., and the altitude of adjacent areas is higher than 160 m a.s.l. In the south the studied area borders on a high peat bog protected as the "Gązwa" nature reserve. The gyttja land is all that remained of the former Lake Stama which was artificially drained after 1860 (UGGLA 1968). Immediately after draining, the land was an unmanageable swamp. Around the year 1910 the area was reclaimed. A dense network of 20 m spaced drainage ditches, 0.4-0.8 m in width, connected with the main ditch in the central part of the gyttja land, was constructed. Due to the lack of routine maintenance of the drainage system after World War II, the land underwent secondary bogging (UGGLA 1968). Today the central part of the gyttja land, characterized by the highest groundwater level, is covered by wetland vegetation and the higher parts are used as hay meadows and pastures.

The first transect comprises 6 similar soil profiles situated at a comparable altitude (Fig. 3). According to the Taxonomy of Polish Soils (1989), they were classified as gyttja-muck soils. The estimated age of gyttja formations in profile 2 (at a depth of 235-236 cm) is 10720 ± 60 years BP, and bottom sediments were deposited at a depth of 244-245 cm 11250 ± 60 years BP (late glacial stage). Thus, the rate of organic gyttja accumulation in this profile was around 0.2 mm per year. The floor layers of the examined lake deposits for which radiocarbon dates older than Holocene were obtained, probably contain admixtures of carbon from organic formations that accumulated during Pleistocene interstadials. As a result of ice-sheet activity, these formations could reach the lake basin, where they participated in the process of deposit sedimentation at the bottom (UGGLA 1969; GOSLAR 2008).

In profiles 2, 3 and 4, organic matter content was considerably lower in surface muck horizons (20.6%, 20.9% and 13.8% respectively) than in deeper layers (Table 1). Since the studied land is flat, the sandy formations could not originate from water erosion. It seems that the sand was brought in to improve the physical properties of gyttja soils. Profiles 4, 5 and 6 have a shallow organic horizon and therefore have been classified as Eutri-Saprihistic Gleysols according to the World Reference Base for Soil Resources (WRB 2006). In profile 4, samples of organic (fine detrital) gyttja for radiocarbon dating were collected at a depth of 35-36 cm and 45-46 cm. It was found that these sediments were deposited 8590 ± 50 and 9290 ± 50 years BP, which corresponds to the Early Holocene (Boreal and Preboreal stage). The above dates were obtained for relatively shallow layers in the profile. Similarly to profile 2, the analyzed sediments contained admixtures of carbon from organic formations that accumulated during Pleistocene interstadials.

The second transect consists of proper gley soil (profile 7) and shallow gyttja-muck soil (profiles 8 and 9). All soil profiles within this transect are located in the northern part of the gyttja land. Profile 7 of proper gley soil is situated at an altitude of 149.69 m a.s.l., while profile 8 of shallow gyttja-muck soil can be found at a distance of 12 m from profile 7. The rapid lowering of the ground and the presence of gyttja in the profile are indicative of the boundaries of the former water body. The surface horizon consists of muckous formation containing 16% organic matter. In this case the occurrence of sandy surface formations can be associated with water erosion, as the fall of the land is substantial and the higher-lying areas are ploughed. Profile 9 is also shallow gyttja-muck soil.

The Łąki Dymerskie gyttja land

The Łąki Dymerskie gyttja land is situated in the powiat (county) of Olsztyn, in the western part of the mesoregion of Mrągowo Lakeland (Fig. 1). It is located on ground moraine, at an altitude of 152-155 m a.s.l. The plateau surrounding the gyttja land is composed of sand and gravel, and it reaches an altitude of 165-170 m a.s.l. The total area of the analyzed site is approximately 400 ha, including 242 ha of the gyttja land (OLKOWSKI 1971), its width ranges from 500 to 1000 m, and its length is around 5 km. Until 1876, the examined object was known as Lake Dymer (German: Dimmer See). Following the canalization and deepening of the Dymer River bed, Lake Dymer and nearby lakes (Czarne, Gisielskie, Szczepańskie, Rumowskie) were drained of water in order to reclaim the adjacent peatlands (BIENIEK 1988). The system of drainage channels contributed to a 3 m decrease in the water-table of Lake Dymer, but water still remained on the surface. To facilitate reclamation works, sluices and pumping stations were constructed. A network of drainage ditches, connected to the main 5-10 m wide channel in the middle of the lake, was also built. Lake management began when gyttia (up to 10 m thick) had a semi-liquid consistency. In 1945, progressive silting of drainage ditches and pumping station failure caused secondary bogging of the Łąki Dymerskie gyttja land, and a water body developed in the central part of the site. The renovation of drainage facilities, carried out over the years 1954-1955, did not bring the expected results. Today the Łąki Dymerskie gyttja land is an extensive, rush-covered wetland. Only the higher-lying marginal parts are used as grasslands. The central part of the gyttja land is occupied by rush and sedge communities. Since 1993 the Łąki Dymerskie gyttja land has been protected as a site of ecological interest (500 ha) and of particular importance for birds.

The following soil types were found along the transect: brown pararendzina, muck soil and two profiles of gyttja-muck soil (Fig. 4). Profile 3 represents shallow gyttja-muck soil. The surface horizon is a muck formation containing 6.2% of organic matter, which developed when sand was brought in to the gyttja land. Mucking gyttja lies at a depth of 30-51 cm, and it is underlain by loose sand (Table 1). The presence of gyttja in profile 3 shows that it was the boundary of the former water body. Profile 4 represents an interesting sequence of soil horizons. The surface layer is made up of two humus sub-horizons of anthropogenic origin. The first of them, 0-22 cm in thickness, consists of muck-like formation with an 11.1% of organic matter content, while the other one (22-37 cm) developed from loose sand containing 3.1% of organic matter. They are underlain by a thin (37-44 cm) gyttja layer whose organic matter content is 53%. Also in this case the surface horizon developed from sand that had been brought in to this area from nearby excavation pits. The process of covering gyttja soils with sand in the Łąki Dymerskie gyttja land, by the Rimpau method, has been described by Ermert (1963).

The second transect comprises four profiles. Profile 5 is made up of proper pararendzina. Profile 6, of proper gley soil, is situated at an altitude of 154.36 m a.s.l. It has a 24 cm thick surface humus horizon composed of loose sand. Profile 7 is mucky soil with a gyttja layer. The surface horizon consists of muck formations that developed from sand brought in by man. Profile 8 is gyttja soil, with the groundwater level at the ground surface. To a depth of 150 cm, the soil formation consists of organic (fine detrital) gyttja. It is overgrown with plant roots in the surface layer, but remains jelly-like in consistency.

GYTTJA CLASSIFICATION SYSTEMS

Lake bottom deposits are classified according to many different systems. They can be divided based on their origin, morphological features, physical and chemical properties. However, in the majority of classification systems bottom deposits are grouped by origin and lithology (HORAWSKI 1971; MYŚLIŃSKA 2001; BORÓWKA 2007). In the first classification system, proposed by von Post (1862), gyttja was divided into three types: carbonate, clayey and sandy. As regards the site of deposit formation, gyttja was divided into lacustrine, fluvial, pond and spring. The classifications of Lundquist (1927) and von Bülow (1929) account not only for the percentage content of main deposit-forming components, but also for the presence of biotic elements (TOBOLSKI 2000). In Polish literature, the first classification scheme for bottom deposits was proposed by Stangenberg (1938) who divided them into silicate deposits, organic deposits, deposits with a high calcium carbonate content and mixed deposits.

Most of the gyttja classification systems developed for the purpose of soil studies are based on the content of three main components, i.e. organic matter (determined as weight loss upon roasting), calcium carbonate and non-calcareous mineral fraction (ash). In Poland such division systems were proposed by Okruszko (1976), Ilnicki (1979) and Markowski (1980). All of them are similar and agenetic in nature. The introduction of three main classification parameters resulted in the three-element structure characteristic of all schemes based on the system proposed by Lundquist (RZEPECKI 1983). The classification system developed by Markowski (1980), applied in this study, is presented in table 2.

The gyttja classification system of Markowski (1980) is commonly applied in Poland, and it refers to the division of carbonate sedimentary rocks. The projection of this division is an equilateral triangle (Fig. 5) which indicates that the proposed classification is insufficient – six surface areas remain unclassified (they have no names and are denoted by question marks). Among a total of 44 bottom deposit samples analyzed in the study, as many as 31 did not contain $CaCO_3$ or contained only small amounts of this compound. They were classified as fine detrital gyttja and coarse detrital gyttja.

Table 2

Gyttja classification according to Markowski (1980)

Type and kind of gyttja	Organic matter (loss-on-ignition) [%]	Calcium carbonate [%]	Mineral matter without $CaCO_3$ [%]
A. Organic gyttja:			
1. algal gyttja	> 80	< 10	< 20
2. coarse detrital gyttja	60-90	< 20	< 40
3. fine detrital gyttja	35-75	< 20	< 65
B. Calcareous gyttja:			
4. calcareous mud (lacustrine chalk)	< 20	> 80	< 20
5. calcareous gyttja	< 40	50-80	< 40
6. detrital-calcareous gyttja	> 30	20-50	< 40
7. clay-calcareous gyttja	< 30	20-50	< 60
C. Non-calcareous mineral gyttja:			
8. clay gyttja	5-35	< 20	> 65
9. sand-clay gyttja	5-35	< 20	> 65
10. diatomaceous-clay gyttja	5-35	< 20	> 65

Three samples with the highest organic matter content were categorized as algal gyttja, while five – as clay gyttja. The group of clay gyttja sediments was also inclusive of two samples (No. 10 and 25) that did not fall into any of the categories proposed by Markowski (1980), and whose properties resembles those of the above group. Mixed gyttja sediments, containing comparable amounts of all three components, are represented by clay-calcareous gyttja and detrital-calcareous gyttja. Again, the group of clay-calcareous gyttja sediments was inclusive of two samples (No. 6 and 13) that did not fall into any of the categories proposed by Markowski (1980), and whose properties resembles those of the above group. Samples 18, 31 and 34, classified as calcareous gyttja sediments, contained more than 50% of $CaCO_3$. Calcium carbonate content did not exceed 80% in any of the samples, which would qualify them as calcareous mud. The domination of detrital gyttja in the investigated area results from the fact that the analyzed soils developed along the shorelines of former lake basins. Gyttja with a higher content of mineral matter (ash) and $CaCO_3$ usually makes up deeper layers of bottom deposits. Similar proportions of gyttja types in this region were reported by other researchers (OLKOWSKI 1971; UGGLA 1971).

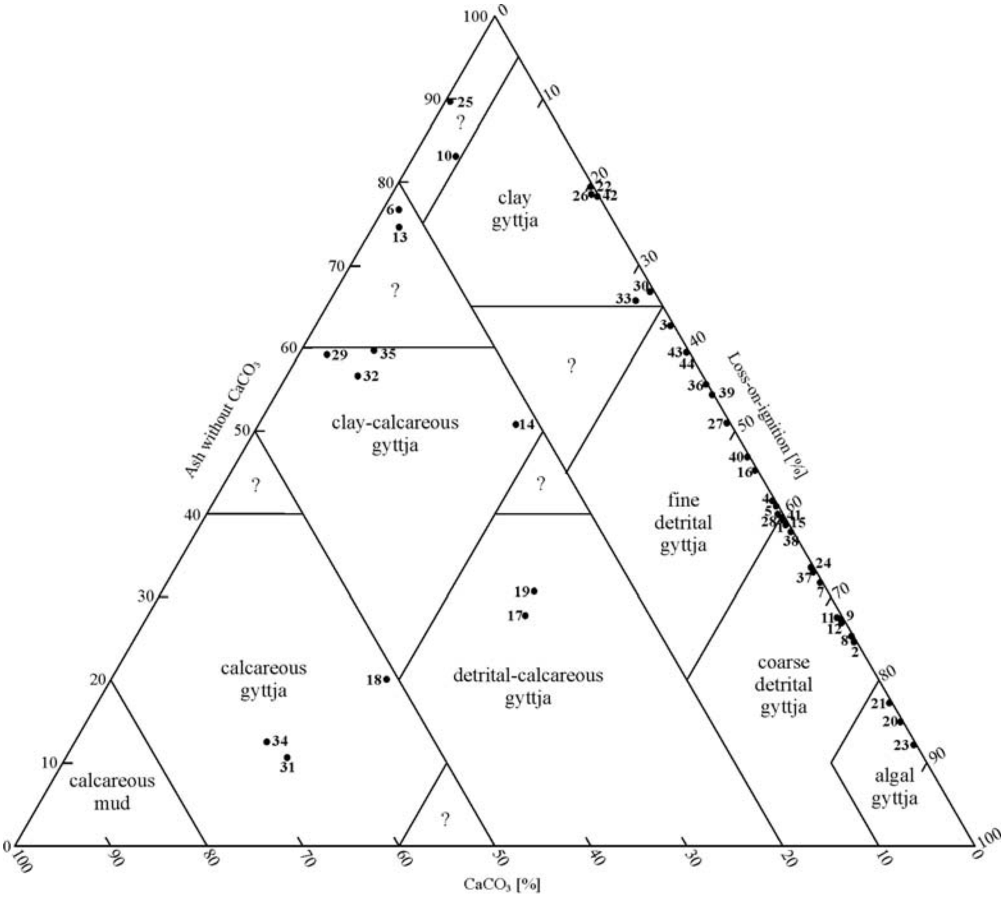

Fig. 5. Classification of gyttja samples studied based on the ash, calcium carbonate and organic matter contents. Gyttja types according to the classification proposed by Markowski (1980).

CHEMICAL PROPERTIES OF GYTTJA SOILS

Organic gyttja has a high total nitrogen content due to its origin – phytoplankton is abundant in protein and therefore also in nitrogen (CIEŚLEWICZ 2007; MEYERS 1990). According to Uggla (1971), gyttja may contain as much as 5% of total nitrogen, which is why the carbon to nitrogen ratio was narrow in the studied formations, e.g. 5.9-7.6 in profile 8 in the Łąki Staświńskie gyttja land (Table 3). The carbon to nitrogen ratio in plankton ranges from 4 to 10 (CIEŚLEWICZ 2007). In the investigated formations this ratio was within the 10-20 range. Cieślewicz (2007) demonstrated that the carbon to nitrogen ratio of 13-14 in surface lake deposits is indicative of a mixture of similar amounts of vascular plant detritus and algal detritus. This shows that in vascular plants the values of the above ratio are equal to or higher than 20. The OC:TN ratio is usually narrower in surface muck horizons than in deeper horizons (Table 3), due to organic matter mineralization and the conversion of organic carbon compounds to CO_2, as well as nitrogen accumulation in humus compounds.

Fig. 6. *Caricetum distichae* plant association on Łąki Staświńskie gyttja land

Fig. 7. Pomping station on Gązwa gyttja land

Fig. 8. *Phragmites australis* on the former shore of Stama lake (Gązwa gyttja land)

Fig. 9. Reed rushes on Gązwa gyttja land

Fig. 10. Cultivated meadows and reed rushes in the background (Łąki Dymerskie gyttja land)

Fig. 11. Sedge communities from the *Magnocaricion* alliance on Łąki Dymerskie gyttja land (all photos by A. Łachacz)

The reaction of the analyzed soil formations was strongly correlated with their calcium carbonate content (Table 3). The pH of gyttja containing more than 20% of $CaCO_3$, measured in water, was higher than 8.0. The pH of non-calcareous gyttja was lower, within the range of 4.6-5.5. The sorption capacity of the studied formations was determined by the content of both calcium carbonate and organic matter which occurs in humus form and has the character of organic acid. In all formations, the predominant cation was calcium whose quantity in the sorption complex increases along with an increase in calcium carbonate content. The formations containing calcium carbonate had a low (often close to zero) exchangeable hydrogen content, and the sorption complex saturation with basic cations (Σ Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) exceeded 95% or approached 100%. The base saturation was below 50% only in three formations, which pointed to their dystrophic character – according to WRB (2006), their diagnostic properties were described as dystric. It should be noted that in calcareous gyttja calcium cations dominate over magnesium cations (Table 3). The Ca^{2+} to Mg^{2+} ratio is often very wide, greater than 30 or even 100.

The effect of the catchment area on the chemical properties of the examined soils, in particular on their reaction and sorption capacity, was reflected in the inflow of calcium cations to the low-lying gyttja lands. In general, the analyzed gyttja sediments should be classified as eutrophic, as confirmed by the type of their vegetation cover.

VEGETATION COVER IN GYTTJA LANDS

The use of drained lake basins as grasslands, followed by spontaneous plant colonization and succession, resulted in the concentric arrangement of plant communities in the investigated gyttja lands. Their central parts are usually occupied by open water surfaces, while reed rushes develop closer to the shores, covering the largest area in the studied gyttja lands. The association of *Phragmitetum australis* developed under conditions of annual flooding. It is dominated by common reed, and the contribution of other species is low (Table 4). Phytosociological data on the floristic composition of reed rushes was collected in relevés: S8 (Łąki Staświńskie), G1,2 (Gązwa), D4 (Łąki Dymerskie).

Communities of the class *Phragmitetea* that require seasonal flooding or water-logging are found nearer the edge of the gyttja land. They comprise sedges *Carex disticha* and *Carex gracilis*. The association of *Caricetum distichae* occurs in the Łąki Dymerskie gyttja land and the Łąki Staświńskie gyttja land. *Carex gracilis* grows in the Gązwa gyttja land, but it does not form an association there. In general, sedges *Caricetum gracilis* are common in the gyttja lands in the Masurian Lakeland (OLKOWSKI 1970, 1971). The grass species *Phalaris arundinacea* is also encountered relatively frequently in the investigated gyttja lands. In the Gązwa gyttja land and the Łąki Staświńskie gyttja land it forms the association of *Phalaridetum arundinaceae*. Its presence points to the eutrophic character of surface waters whose level shows significant fluctuations throughout the year (MATUSZKIEWICZ 2001).

Table 3

Some chemical properties of soils studied

Profile No	Depth [cm]	Soil horizon	OC [%]	TN [%]	OC:TN	pH		Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	H^{+}	SBC	BS [%]	Ca^{2+}/Mg^{2+}
						H_2O	KCl	$cmol(+) \cdot kg^{-1}$							
Łąki Staświńskie gyttja land															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0-28	AMi	2.83	0.368	7.7	7.87	7.22	33.97	2.84	0.18	0.79	0.94	37.78	97.57	11.96
	28-52	AC	0.19	0.014	13.6	8.65	7.66	38.69	1.00	0.15	1.50	0.05	41.43	99.88	38.69
	52-150	Cca	-	-	-	8.62	7.73	36.32	0.72	0.12	0.83	0.00	37.99	100.00	50.44
2	0-20	Mgy	36.25	2.257	16.1	6.56	6.29	37.97	2.50	0.33	1.70	4.18	42.50	91.04	15.19
	20-35	Ogy	45.05	2.377	19.0	7.31	7.02	82.46	2.07	0.11	2.18	3.05	86.82	96.61	39.84
	35-150	Dca	0.16	0.010	16.0	8.60	7.79	30.99	0.66	0.10	1.49	0.00	33.24	100.00	46.95
3	0-20	Mgy	35.97	1.963	18.3	6.68	6.55	53.72	3.04	0.29	1.54	4.86	58.59	92.34	17.67
	20-43	MgyOgy	38.20	2.229	17.1	7.55	7.34	85.58	1.85	0.06	2.22	8.59	89.71	91.27	46.26
	43-76	Ogy	37.76	2.542	14.9	7.61	7.38	85.07	2.02	0.06	2.08	8.23	89.23	91.55	42.11
	76-81	D	0.75	0.039	19.2	8.50	7.96	27.32	0.50	0.02	1.20	0.05	29.04	99.83	54.64
	81-180	Dgy	0.53	0.064	8.3	8.28	7.42	39.01	1.20	1.34	1.73	0.00	43.28	100.00	32.51
6	0-10	AMe	6.82	0.792	8.6	7.56	7.00	33.59	3.90	0.23	1.38	4.70	39.10	89.27	8.61
	10-45	Gox	0.81	0.058	14.0	8.40	7.40	37.87	1.36	0.24	1.58	0.00	41.05	100.00	27.85
	45-150	G	0.49	0.050	9.8	8.51	7.51	30.08	1.36	0.20	1.73	0.00	33.37	100.00	22.12
7	0-15	Mgy	7.95	0.974	8.2	7.74	7.25	70.45	1.88	0.30	2.08	2.40	74.71	96.89	37.47
	15-28	MgyD	7.69	0.676	11.4	8.08	7.50	90.39	1.87	0.10	2.25	0.00	94.61	100.00	48.34
	28-150	Dgg	-	-	-	8.74	7.75	38.44	0.93	0.16	1.56	0.00	41.09	100.00	41.33
8	0-20	Mgy	17.47	2.343	7.5	6.20	5.92	65.64	4.28	0.19	1.70	20.24	71.81	78.01	15.34
	20-30	Mgy2	13.70	1.834	7.5	6.67	6.39	45.42	3.52	0.10	1.54	11.14	50.58	81.95	12.90
	30-35	Ogy	10.12	1.706	5.9	7.64	7.37	102.92	3.54	0.12	3.10	5.20	109.68	95.47	29.07
	35-45	Ogyca	8.86	1.159	7.6	7.91	7.53	83.96	2.18	0.07	2.43	0.20	88.64	99.77	38.51
	45-65	Ogy3	11.59	1.683	6.9	7.64	7.43	93.84	2.56	0.12	2.84	0.25	99.36	99.76	36.66
	65-103	D1	1.38	0.130	10.6	8.18	7.71	32.05	0.74	0.04	1.42	0.07	34.25	99.80	43.31
	103-150	D2	1.99	0.179	11.1	7.95	7.45	77.24	1.86	0.20	1.92	0.54	81.22	99.34	41.53
	150-250	D3	0.74	0.084	8.8	8.26	7.45	43.94	1.36	1.41	1.73	0.00	48.44	100.00	32.31

Table 3 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gązwa gyttja land															
1	0-28	Mgy	49.23	3.520	14.0	6.99	6.86	37.11	2.09	0.04	1.48	6.86	40.72	85.58	17.76
	28-150	Ogy	46.88	3.501	13.4	6.80	6.67	31.92	1.98	0.04	1.29	3.96	35.23	89.89	16.12
3	0-18	Mgy	13.19	1.338	9.9	6.91	6.45	28.18	1.63	0.10	0.95	6.64	30.86	82.29	17.29
	18-42	MgyOgy	28.44	1.592	17.9	7.15	6.80	26.72	1.58	0.08	1.19	8.56	29.57	77.55	16.91
	42-150	D	4.41	0.292	15.1	7.96	7.36	89.91	1.86	0.19	2.25	1.22	94.21	98.72	48.34
5	0-18	Mgy	21.99	1.454	15.1	6.59	6.54	39.01	1.84	0.27	1.42	11.88	42.54	78.17	21.20
	18-80	Ogyca	11.19	0.840	13.3	7.86	7.55	68.28	1.83	0.09	2.72	0.00	72.92	100.00	37.31
	80-150	Dgy	3.58	0.301	11.9	7.54	7.23	97.24	1.51	0.12	2.01	0.00	100.88	100.00	64.40
6	0-22	Mgy	18.33	1.420	12.9	7.35	7.00	49.55	1.50	0.10	1.48	5.37	52.63	90.74	33.03
	22-60	Ogyca	10.88	0.715	15.2	7.90	7.56	64.48	1.52	0.06	2.36	0.00	68.42	100.00	42.42
	60-150	Dgy	4.31	0.366	11.8	7.58	7.34	97.36	1.61	0.15	2.10	0.00	101.22	100.00	60.47
7	0-32	Ap	1.76	0.128	13.8	5.56	4.58	11.25	0.33	0.02	0.15	6.20	11.75	63.34	34.09
	32-52	Gox	0.86	0.038	22.6	7.04	6.96	10.31	0.57	0.05	0.59	4.28	11.52	72.91	18.09
	52-67	Gca	-	-	-	8.45	7.61	38.84	0.68	0.04	1.32	0.00	40.88	100.00	57.12
	67-88	Ggg1	-	-	-	8.93	7.98	32.53	0.48	0.03	1.27	0.00	34.31	100.00	67.77
	88-150	Ggg2	-	-	-	8.66	8.02	28.76	0.45	0.03	1.14	0.00	30.38	100.00	63.91
8	0-11	AMe	6.58	0.559	11.8	4.00	3.33	22.92	1.21	0.24	0.12	18.20	24.49	57.37	18.94
	11-50	Ogy	22.21	1.392	16.0	4.62	4.05	29.65	0.79	0.05	0.43	28.04	30.92	52.44	37.53
	50-150	Dgg	0.98	0.091	10.8	7.93	7.21	33.56	2.53	0.09	0.82	0.16	37.00	99.57	13.26
9	0-27	Mgy	32.39	2.301	14.1	4.63	4.24	17.30	1.16	0.09	0.27	31.92	18.82	37.09	14.91
	27-45	Ogy	36.62	2.538	14.4	5.39	4.80	18.45	1.00	0.07	0.55	26.96	20.07	42.67	18.45
	45-150	Dgg	-	-	-	6.99	6.07	3.37	0.58	0.07	0.10	2.16	4.12	65.60	5.81
Łąki Dymerskie gyttja land															
1	0-29	Ap	1.02	0.121	8.4	7.41	6.86	10.21	0.46	0.04	0.29	1.80	11.00	85.94	22.20
	29-65	Bbr	-	-	-	7.58	7.06	4.61	0.10	0.06	0.22	0.16	4.99	96.89	46.10
	65-150	Cca	-	-	-	8.84	8.01	35.48	0.31	0.05	0.91	0.00	36.75	100.00	114.45

Table 3 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	0-38	AMi	2.99	0.247	12.1	6.13	5.56	6.67	0.61	0.07	0.24	7.08	7.59	51.74	10.93
	38-57	AC	1.79	0.131	13.7	5.81	4.77	4.79	0.45	0.03	0.21	6.92	5.48	44.19	10.64
3	0-30	AMi	3.11	0.274	11.4	7.39	7.04	21.05	0.88	0.04	0.57	2.06	22.54	91.63	23.92
	30-51	MgyOgy	23.76	2.820	8.4	4.84	4.33	18.73	0.39	0.06	0.63	12.04	19.81	62.20	48.03
	51-150	Dca	-	-	-	8.37	7.78	28.23	0.37	0.04	0.80	0.00	29.44	100.00	76.30
4	0-22	AanMe	8.90	0.798	11.2	6.46	6.11	29.42	1.33	0.09	0.92	13.52	31.76	70.14	22.12
	22-37	Aan	1.94	0.111	17.5	7.55	7.33	39.08	1.37	0.07	1.24	6.33	41.76	86.84	28.52
	37-44	Ogy	31.30	2.130	14.7	6.07	5.81	44.46	0.74	0.06	1.29	16.74	46.55	73.55	60.08
	44-150	Ogy2	36.29	3.860	9.4	6.01	5.80	40.37	2.28	0.06	1.38	19.54	44.09	69.29	17.71
5	0-24	Ap	0.97	0.100	9.7	8.06	7.45	15.05	0.28	0.29	0.38	0.15	16.00	99.07	53.75
	24-51	Cca1	-	-	-	8.96	8.00	26.51	0.34	0.03	0.75	0.00	27.63	100.00	77.97
	51-69	Cca2	-	-	-	8.89	8.01	23.85	0.30	0.05	0.76	0.00	24.96	100.00	79.50
	69-88	Cca3	-	-	-	8.96	8.05	22.79	0.37	0.06	0.75	0.00	23.97	100.00	61.59
	88-112	Cca4	-	-	-	8.93	8.16	26.61	0.40	0.04	0.76	0.00	27.81	100.00	66.52
	112-150	Cca5	-	-	-	8.91	8.08	28.33	0.37	0.05	0.73	0.00	29.48	100.00	76.57
6	0-24	Ap	2.46	0.223	11.0	7.17	6.78	12.18	1.57	0.12	0.54	2.24	14.41	86.55	7.76
	24-45	Gox	0.72	0.067	10.7	8.12	7.60	9.35	0.13	0.03	0.26	0.10	9.77	98.99	71.92
	45-150	Ggg	-	-	-	8.65	8.04	23.69	0.20	0.04	0.73	0.00	24.66	100.00	118.45
7	0-39	AMe	6.76	0.484	14.0	6.31	6.21	22.01	0.92	0.04	0.54	18.72	23.51	55.67	23.92
	39-61	Mgy	11.41	0.674	16.9	6.01	5.76	31.79	0.75	0.09	0.78	25.42	33.41	56.79	42.39
	61-76	Dgg	2.39	0.126	19.0	6.43	6.17	8.52	0.35	0.02	0.26	2.72	9.15	77.08	24.34
	76-115	Dgg2	4.57	0.286	16.0	5.84	5.74	14.87	1.09	0.02	0.41	2.61	16.39	86.26	13.64
	115-150	Dgg3	0.80	0.059	13.6	6.44	6.38	1.37	0.09	0.01	0.09	1.20	1.56	56.52	15.22
8	0-29	POgy	21.81	1.580	13.8	5.53	5.44	41.43	1.51	0.04	1.19	38.92	44.17	53.16	27.44
	29-150	Ogy	21.64	1.510	14.3	5.31	5.24	40.21	1.30	0.02	0.98	39.21	42.51	52.02	30.93

Explanations:
OC – organic carbon
TN – total nitrogen
SBC – sum of base cations
BS – base saturation

Table 4

Plant communities on gyttja lands studied

Succesive number of record	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Occurrence
Code of localities	D3	D5	D2	D1	G5	S2	D6	S1	S6	G7	G9	G8	G3	G4	G6	S3,4	S5	D7	D8	D4	G1,2	S8	S7	
Cover of herbaceous plants [%]	100	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	100	100	100	
Cover of bryophytes [%]	0	1	1	10	0	1	0	1	1	2	2	0	2	0	15	1	0	0	1	0	0	0	0	
Number of species in the record	13	27	32	23	23	22	22	29	23	40	26	14	29	15	20	14	14	16	12	9	11	9	14	
Area of sample plot [m^2]	30	20	20	20	15	30	20	20	20	15	30	20	20	50	30	20	50	50	50	50	40	50	50	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ch. Molinio-Arrhenatheretea																								
Deschampsia caespitosa	·	·	·	·	·	5	1	1	+	·	+	3	1	+	·	+	·	+	·	·	+	·	·	11
Poa pratensis	·	2	1	2	·	1	1	1	2	2	·	+	+	·	·	1	·	·	·	·	·	·	·	11
Galium mollugo	1	1	1	1	1	·	+	+	+	·	·	·	+	·	·	·	·	+	·	·	·	·	·	10
Lythrum salicaria	·	·	·	·	·	·	·	·	·	·	1	·	+	1	+	+	1	+	+	·	·	·	+	9
Potentilla anserina	·	·	·	·	1	1	1	·	+	1	·	·	1	1	+	2	·	·	·	·	·	·	·	9
Dactylis glomerata	+	1	·	2	1	·	3	2	1	3	·	·	·	·	·	·	·	·	·	·	·	·	·	8
Phleum pratense	·	2	·	+	3	+	·	+	+	1	·	·	1	·	·	·	·	·	·	·	·	·	·	8
Achillea millefolium	·	1	1	·	2	·	1	2	2	1	·	·	·	·	·	·	·	+	·	·	·	·	·	8
Taraxacum officinale	+	1	2	1	1	·	1	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	7
Equisetum palustre	·	·	·	·	+	·	·	·	·	·	1	·	·	4	·	+	+	+	·	1	·	·	·	7
Galium uliginosum	·	·	·	·	·	+	·	·	·	·	·	·	2	1	1	·	·	1	+	·	1	·	·	7
Agrostis gigantea	·	·	+	·	·	1	·	·	·	2	·	1	1	+	·	·	·	·	·	·	·	·	·	6
Arrhenatherum elatius	2	+	4	4	·	·	·	+	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	6
Cerastium holosteoides	·	·	1	·	+	+	·	1	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5
Ranunculus repens	·	·	+	·	+	+	·	·	·	·	·	·	+	·	·	1	·	·	·	·	·	·	·	5
Vicia cracca	·	·	·	·	+	·	+	·	·	1	·	·	·	·	·	·	·	+	·	·	+	·	·	5
Festuca rubra	·	1	1	·	1	1	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5
Juncus effusus	·	·	·	·	·	·	·	·	·	·	2	+	1	+	·	·	·	·	·	·	+	·	·	5
Trifolium repens	·	·	1	·	·	·	2	2	4	+	·	·	·	·	·	·	·	·	·	·	·	·	·	5
Carex hirta	·	·	·	·	·	+	·	·	·	·	+	+	+	·	·	·	·	·	·	·	·	·	·	4
Festuca pratensis	·	·	·	·	1	·	·	1	2	1	·	·	·	·	·	·	·	·	·	·	·	·	·	4
Lathyrus pratensis	·	·	·	·	·	+	+	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4

Table 4 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Rumex acetosa	·	+	·	·	1	+	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	4
Trifolium pratense	·	·	·	·	·	·	·	1	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Avenula pubescens	·	·	·	·	·	·	·	1	2	+	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Alopecurus pratensis	·	·	·	·	·	·	·	·	·	·	+	1	·	·	·	·	·	1	·	·	·	·	·	3
Heracleum sibiricum	·	·	·	·	+	·	1	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	3
Centaurea jacea	·	·	·	·	·	·	+	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Cirsium palustre	·	·	·	·	·	·	·	·	·	·	·	·	+	·	1	·	·	·	+	·	·	·	·	3
Lysimachia vulgaris	·	·	·	·	·	·	·	·	·	·	2	·	·	·	1	·	·	·	·	·	1	·	·	3
Ranunculus acris	·	·	·	·	·	1	1	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Rumex crispus	·	·	·	·	·	·	·	+	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	3
Tragopogon pratensis	+	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Agrostis stolonifera	·	·	·	·	·	·	·	·	·	·	·	·	+	·	2	·	·	·	·	·	·	·	·	2
Plantago lanceolata	·	·	·	·	·	·	·	·	·	1	·	·	1	·	·	·	·	·	·	·	·	·	·	2
Festuca arundinacea	·	4	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Lotus uliginosus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	+	·	·	·	·	2
Myosotis palustris	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	+	·	2
Poa trivialis	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	2
Rumex thyrsiflorus	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Campanula patula	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Carum carvi	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Geranium pratense	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Climacium dendroides d	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	1
Holcus lanatus	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	1
Knautia arvensis	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Leontodon autumnalis	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Leucanthemum vulgare	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Lotus corniculatus	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Lychnis flos-cuculi	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	1
Plantago major	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1

Table 4 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Prunella vulgaris	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Scirpus sylvaticus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	1
Trifolium dubium	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Ch. Phragmitetea																								
Phalaris arundinacea	·	·	·	·	·	+	·	·	·	+	2	2	2	4	·	·	·	·	·	·	4	2	5	9
Phragmites australis	·	·	·	·	·	·	·	·	·	·	·	·	1	·	1	·	·	2	3	5	4	5	1	8
Galium palustre	·	·	·	·	·	·	·	·	·	·	+	·	·	·	1	2	·	·	·	1	·	·	+	5
Carex disticha	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5	4	4	3	·	·	·	4
Carex gracilis	·	·	·	·	·	·	·	·	·	·	2	·	2	·	·	·	+	·	·	·	·	·	·	3
Carex vesicaria	·	·	·	·	·	·	·	·	·	·	2	·	·	·	·	·	1	·	·	·	·	·	1	3
Carex rostrata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	+	·	·	·	·	·	·	2
Iris pseudacorus	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+	·	2
Peucedanum palustre	·	·	·	·	·	·	·	·	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·	2
Rorippa amphibia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	2
Alisma plantago-aquatica	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	1
Carex pseudocyperus	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	1
Equisetum fluviatile	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	1
Lysimachia thyrsiflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	1
Poa palustris	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	1
Scutellaria galericulata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	1
Sium latifolium	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	1
Typha latifolia	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	1
Ch. Artemisietea																								
Cirsium arvense	+	+	+	·	+	1	+	1	+	+	·	·	·	·	·	·	·	2	+	·	·	·	·	11
Urtica dioica	2	·	1	·	+	1	·	·	·	·	·	1	·	+	·	·	·	1	1	·	+	·	1	10
Anthriscus sylvestris	1	·	1	·	+	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4
Melandrium album	+	+	+	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4
Artemisia vulgaris	·	+	+	+	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	4

Table 4 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Glechoma hederacea	·	·	·	·	1	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	3
Artemisia absinthium	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Cirsium vulgare	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Linaria vulgaris	·	·	·	·	+	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	2
Picris hieracioides	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Tanacetum vulgare	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Epilobium parviflorum	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Ch. Scheuchzerio-Caricetea nigrae																								
Carem nigra	·	·	·	·	·	·	·	·	·	·	+	·	2	+	+	1	+	·	·	·	·	·	·	6
Calamagrostis stricta	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4	4	+	·	·	+	·	·	+	5
Drepanocladus polycarpus d	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	+	·	·	+	·	·	·	·	3
Comarum palustre	·	·	·	·	·	·	·	·	·	·	1	·	·	·	+	·	·	·	·	·	·	·	·	2
Stellaria palustris	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	2
Juncus articulatus	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	1
Triglochin palustre	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	1
Ch. Koelerio-Corynephoretea																								
Hypochoeris radicata	·	·	+	+	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Brachythecium albicans d	·	+	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Potentilla argentea	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Trifolium arvense	·	+	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Ceratodon purpureus d	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Helichrysum arenarium	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Other species																								
Polygonum amphibium	·	·	·	·	+	·	·	·	·	·	+	1	1	4	1	·	+	·	+	+	1	·	+	11
Brachythecium rutabulum d	·	+	+	1	·	+	·	·	+	1	·	·	+	·	·	·	·	·	·	·	·	·	·	7
Medicago lupulina	·	·	+	+	·	+	+	+	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	7
Veronica chamaedrys	·	1	+	·	1	1	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	6
Stellaria graminea	·	·	+	·	·	·	·	·	·	+	·	+	+	·	·	·	·	·	·	·	·	·	·	4
Agropyron repens	·	·	·	·	·	·	·	+	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	3

Table 4 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Alchemilla sp.	·	·	·	·	+	·	·	·	+	1	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Arenaria serpyllifolia	·	+	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Calamagrostis epigeios	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	3	1	·	·	·	·	3
Campanula rotundifolia	+	1	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Epilobium palustre	·	·	·	·	·	·	·	·	·	·	+	·	·	·	1	·	+	·	·	·	·	·	·	3
Galeopsis bifida	·	·	·	·	·	·	·	·	·	·	+	2	·	·	·	·	1	·	·	·	·	·	·	3
Lemna minor	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	+	·	+	·	3
Silene vulgaris	+	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Vicia angustifolia	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Centaurea scabiosa	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Plantago media	+	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Anthoxanthum odoratum	·	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·	·	·	·	·	·	·	·	2
Calliergonella cuspidata d	·	·	·	·	·	·	·	·	+	·	·	·	·	·	2	·	·	·	·	·	·	·	·	2
Cardamine dentata	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·	2
Erigeron annuus	·	·	+	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Geum rivale	·	·	·	·	·	·	·	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	2
Hypericum perforatum	·	+	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Lycopus europaeus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	+	·	·	2
Medicago falcata	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Pimpinella saxifraga	·	·	·	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Plagiomnium ellipticum d	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	+	·	·	·	·	2

Sporadic species: 1 – *Bromus inermis* (5); 2 – *Crataegus monogyna* c (+), *Pinus sylvestris* c (+); 3 – *Myosotis arvensis* (+), *Vicia tetrasperma* (+), *Viola arvensis* (+), *Senecio jacobea* (1); 4 – *Conyza canadensis* (+), *Echium vulgare* (+), *Hieracium pilosella* (+); 7 – *Equisetum arvense* (+); 8 – *Capsella bursa pastoris* (+), *Plagiomnium elatum* d (+); 9 – *Agrostis capillaris* (+); 10 – *Sonchus arvensis* (+), *Vicia hirsuta* (+), *Convolvulus arvensis* (+), *Plagiomnium affine* d (+), *Rhytidiadelphus squarrosus* d (+); 11 – *Bidens cernua* (+), *Riccia fluitans* d (1), *Salix cinerea* (+), *Utricularia vulgaris* (2); 12 – *Agropyron caninum* (+), *Carex leporina* (+); 15 – *Calliergon giganteum* d (+); 17 – *Solanum dulcamara* (+), *Symphytum officinale* (+); 18 – *Mentha arvensis* (+); 20 – *Calamagrostis canescens* (2); 23 – *Bidens tripartita* (+), *Polygonum hydropiper* (+).

Code of localities: S – Łąki Staświńskie gyttja land (soil profiles No. 1-8); G – Gązwa gyttja land (soil profiles No. 1-9); D – Łąki Dymerskie gyttja land (soil profiles No. 1-8).

The sites distant from ditches with running water provide habitat for mesotrophic and dystrophic species typical of transitional moors of the class *Scheuchzerio-Caricetea nigrae*. The above species are not abundant in the analyzed gyttja lands, but attention should be paid to the grass *Calamagrostis stricta* which forms emersion (floating) communities of boreal character. Communities dominated by *Calamagrostis stricta* can be found in the Łąki Staświńskie gyttja land (S3,4) and in the Gązwa gyttja land (G6). Communities of that type are rare in Poland, and they occur primarily in gyttja lands that have not been drained completely.

Meadow communities of the class *Molinio-Arrhenatheretea* developed on the edges of the studied gyttja lands. This group of communities is widely diverse with respect to water relations, trophic conditions and management types. The following grass species dominated among them: *Deschampsia caespitosa*, *Poa pratensis*, *Dactylis glomerata*, *Phleum pratense*, *Arrhenatherum elatius*, *Agrostis gigantea*, *Festuca rubra*, *F. pratensis* and *F. arundinacea*. Meadow communities on organic formations that undergo muck-forming process have an admixture of ruderal (nitrophilous) species of the class *Artemisietea*, such as *Cirsium arvense*, *Urtica dioica* and *Anthriscus sylvestris*. Higher-lying sites, not affected by the groundwater level, are occupied by pastures whose species composition includes members of the class *Koelerio-Corynephoretea*.

A large group of species without phytosociological affinity (referred to as “other species”) shows that the analyzed communities are instable and simply represent a certain stage of succession. It is a result of frequent changes in water conditions observed in the investigated gyttja lands during the last 150 years, which contributed to their colonization by diverse plant species from adjacent areas.

SUMMARY

Gyttja lands are a specific type of wetlands. Despite their lacustrine origin, gyttja lands are characterized by habitat conditions and vegetation cover typical of lowland bogs. Due to high content of calcareous rock fragments in soil formations in the catchment, calcareous gyttja sediments were relatively common at the investigated sites, gyttja soils contained numerous calcium cations in their sorption complex and were classified as eutrophic. The artificial drainage of gyttja lands, their utilization as grassland as well as secondary bogging contributed to the concentric arrangement of soil and vegetation cover. The central parts of gyttja lands are occupied by water bodies, while common reed grows in wide belts on the surrounding gyttja soils. The process of rush peat accumulation currently takes place in the above habitats. Gyttja-muck soils showing symptoms of secondary conversion of gyttja into muck can be found in the littoral zone of the former lakes. The soils are covered with sedge rushes and meadow communities. Muck-like (muckous) soils and proper gley soils are located in the zone affected by the groundwater level, whereas pararendzinas containing a significant amount of calcareous rock fragments are situated in the zone surrounding the studied gyttja lands.

The specific properties and uniqueness of bottom deposits make gyttja lands environmentally valuable areas which – due to secondary bogging – became hardly accessible and therefore are not threatened by agricultural expansion. Although they cover small areas, gyttja lands are valuable biocenoses known for their exceptional landscape qualities. They provide habitat for rare and protected plant and animal species, including those threatened with extinction.

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