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Soil Genesis

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TRANSFORMATIONS OF SOILS AND FOREST COMMUNITIES IN THE AREAS OF EARLY-MEDIEVAL STRONGHOLDS (EXAMPLES FROM CHEŁMNO LAND)***

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Abstract. The research concerned transformations of soils in the areas of Early-Medieval strongholds and connected differences in floristic composition between forest communities from strongholds and non-synanthropic habitats. The study focused on two areas where Early-Medieval strongholds were situated – Gronowo and Płutowo (Chełmińska Upland, Northern Poland) – surrounded by various types of soils: rusty soils and black earths, respectively. Detailed pedological and floristic-phytosociological investigations were carried out in the sites and their vicinity. Transformations of *Tilio-Carpinetum corydaletosum* phytocoenoses were performed with respect to the specificity of soils at the settlements and their anthropogenic enrichment in biogenic elements (C, N, P) to a considerable depth.

Anthropogenic lands, in particular strongholds and mounds, for many years have attracted naturalists' interests. Pedologists deem important soils from territories of ancient settlements, which analysed in detail provide information on their origin and age as well as purpose and degree of transformations of the soil environments on the strength of ancient anthropopressure [1-3, 10-12, 14, 15]. Botanists in the first place pay attention to different kind of flora compared to

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grounds in the direct vicinity of anthropogenic forms [4-6, 8, 16, 17, 20]. Early-Medieval strongholds of Chełmno Land have not been so far subject to integrated pedological and botanical research. The aim of this paper is to describe transformations of soil environment and forest floral assemblies in the places of Early-Medieval settlements in Chełmno Land in comparison to soils and floral assemblies from the closest vicinity.

STUDY AREA

Two Early-Medieval strongholds in the Chełmno Land, situated on different form of relief, were chosen for the investigations (Fig. 1). The Gronowo stronghold is located on the edge of a small outwash area made of sand-gravel deposits. The total surface area of the stronghold is 4900 m^2, whereas the yard itself is 1500 m^2 [7]. From the north and east the settlement is undercut by a stream (Struga Rychnowska) flowing in a subglacial valley.

The Płutowo stronghold is situated on the edge of a morainic plateau made of boulder clay, on a headland formed by an erosional dissection of the Wysoczyzna Chełmińska. The area of the stronghold is approx. 4500 m^2 including the yard of approx. 3100 m^2 [18].

The areas of both strongholds and their vicinity were deforested at the time when they were in use. Then, after the strongholds had been abandoned, the forest assemblies with natural characteristics underwent regeneration. The area of Płutowo stronghold and the adjacent erosion valley are protected as a woodland reserve called 'Płutowo'. Here there is a dry-ground forest of *Tilio-Carpinetum* Tracz. 1962 in the subtype with *Corydalis cava*, which forms a kind of mosaic with *Tilio-Carpinetum stachyetosum* on the valley slopes [17]. At Gronowo the slopes

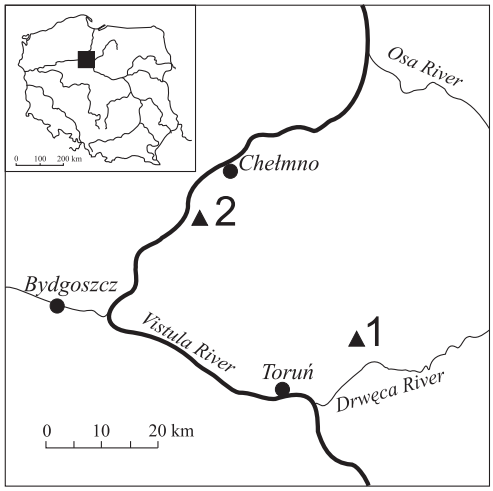

Fig. 1. Localization of research objects: 1 – Gronowo, 2 – Płutowo.

of ramparts and part of the settlement yard are covered with a patch of the *Tilio-Carpinetum corydaletosum* subassociation, whereas the slopes of the Struga Rychnowska valley are grown with the dry ground forests *Tilio-Carpinetum*.

METHODS

During integrated pedological and phytosociological studies in the patches of *Tilio-Carpinetum* Tracz. 1962, growing in the strongholds under investigation, six phytosociological relevés were taken by the classic Braun-Blanquet's approach. The relevés were compared with literature data (20 relevés) concerning patches of the same assemblage from their natural habitats in the vicinity [16, 17]. The phytosociological relevés were then subjected to agglomerative hierarchical clustering by the unweighted pair group method with arithmetic averages, using the Jaccard's coefficient.

Soil samples for laboratory analyses were taken from four profiles. Profiles 1 and 3 represented the soils of the Early-Medieval strongholds (Gronowo and Płutowo respectively), whereas profiles 2 and 4 exposed soils near them (respectively Gronowo and Płutowo). The following properties were determined for the samples: particle-size distribution by hydrometer method according to Bouyoucos as modified by Casagrande and by Prószyński (sand and gravel were separated on sieves); the soil pH by glass electrode in 1:2.5 soil/water and 1:2.5 soil/KCl suspensions of concentrations 1 mol dm^{-3}; organic carbon (OC) by oxidation with potassium dichromate; total nitrogen (N_t) by Kjeldahl method; phosphorus (P) by Bleck method as modified by Gebhardt [9]; and carbonates by Scheibler method. The colours of dry and moist samples were keyed to the Munsell Soil Colour Charts. Taxonomic position of the investigated soils was described according to the *Systematics of Polish Soils* [19] and according to the WRB classification system [21].

RESULTS AND DISCUSSION

The principal characteristics of the examined soils are shown in Tables 1 and 2.

Near the Gronowo stronghold rusty soils (Brunic Arenosols, Profile 1) emerged in the outwash deposits, originally grown by the mixed forest vegetation (*Querco roboris-Pinetum*) [22], in the situation of endopercolative water regime. These soils belong to acid soils. They are sandy, poor in mineral colloids and easily permeable. They are characterised by modest thickness of the topsoil (A horizon), usually rich in organic carbon and nitrogen. Right below it, in the Bv horizon, the content of biogenic elements is a few times smaller. The thickness of the mineral portion of the soil, which provides the vegetation with nutrients, is only 25 cm. Due to not very favourable environmental conditions biological activity of the soil is low, as evident in the C/N ratio (Table 1).

TABLE 1. PROPERTIES OF INVESTIGATED SOILS IN GRONOWO

Horizon or layer	Depth (cm)	Colour		Particle-size distribution (%)				OC	N_t	C:N	pH		$CaCO_3$	P
		dry sample	moist sample	gravel >2	sand 2-0.05	silt 0.05-0.002	clay <0.002				H_2O	KCl		
				(mm)				(%)					(%)	(mg kg^{-1})
Profile 1. Rusty soil (Brunic Arenosol) in Gronowo														
A	0-6	10YR 3.5/1	10YR 2/1	2.9	90	8	2	3.12	0.122	26	3.9	3.1	-	159
ABv	6-23	10YR 5/3	10YR 2.5/3	3.8	93	5	2	0.50	0.028	18	4.4	3.6	-	258
Bv	23-67	10YR 6/4	10YR 4/4	3.5	97	1	2	n.d.	n.d.	n.d.	5.2	4.2	-	138
C	67-150	10YR 7/4	10YR 5/4	0.7	98	1	1	n.d.	n.d.	n.d.	6.4	5.0	-	203
Profile 2. Anthropogenic soil (Terric Anthrosol) in Gronowo														
Aan	0-75	10YR 4/1	10YR 1.7/1	3.3	94	3	3	0.55	0.040	14	6.9	6.5	0.24	398
Wanh1	75-86	10YR 3/1	10YR 1.7/1	4.1	87	11	2	1.42	0.094	15	7.4	7.0	0.54	2329
Wan2	86-95	10YR 3.5/1	10YR 2/1	2.2	95	3	2	0.49	0.030	16	7.9	7.3	0.51	518
Wan3	95-120	10YR 5/2	10YR 3/1.5	3.3	96	3	1	0.32	0.019	17	8.1	7.6	0.68	449
Wanh4	120-165	10YR 4/1	10YR 2/1	2.6	94	4	2	0.52	0.032	16	8.0	7.4	0.61	533
Wanh5	170-180	10YR 4/1	10YR 2/1	3.3	94	4	2	0.62	0.033	19	7.9	7.4	0.61	618
Wan6	180-200	10YR 4.5/1	10YR 2/1	2.8	94	4	2	0.44	0.022	20	8.0	7.5	0.65	553
Wanh7	200-250	10YR 4/1	10YR 2/1	2.6	92	4	4	0.91	0.060	15	7.8	7.2	0.27	580
Wan8	250-280	10YR 6/5	10YR 4/3.5	3.5	93	4	3	n.d.	n.d.	n.d.	8.2	7.5	0.45	342

n.d. – not determined, Wan – anthropogenic layer, Wanh – anthropogenic layer enriched in humus.

TABLE 2. PROPERTIES OF INVESTIGATED SOILS IN PŁUTOWO

Horizon or layer	Depth (cm)	Colour		Particle-size distribution (%)				OC	N_t	C:N	pH		$CaCO_3$	P
		dry sample	moist sample	gravel >2	sand 2-0.05	silt 0.05-0.002	clay <0.002				H_2O	KCl		
				(mm)				(%)					(%)	(mg kg^{-1})
Profile 3. Black earth (Mollic Gleysol) in Płutowo														
Ap	0-35	10YR 2.5/1	10YR 1.7/1	1.1	60	31	9	1.86	0.168	11	7.7	6.9	0.5	3985
ApC	35-65	10YR 4/3	10YR 3/3	0.6	62	20	18	0.42	0.054	8	8.1	6.9	0.1	930
Coxgg	65-90	10YR 6/4	10YR 4/4	3.0	73	12	15	0.18	n.d.	n.d.	8.2	7.1	0.3	1018
IICgg	90-118	2.5Y 6/3	2.5Y 3/3	4.4	78	13	9	n.d.	n.d.	n.d.	8.6	7.8	5.4	1260
IIICgg1	118-130	2.5Y 6.5/4	2.5Y 4.5/4	3.8	60	26	14	n.d.	n.d.	n.d.	8.6	7.6	9.2	1117
IIICgg2	130-150	2.5Y 6.5/3	2.5Y 5/3.5	4.1	62	29	9	n.d.	n.d.	n.d.	8.8	7.8	7.2	757
Profile 4. Anthropogenic soil (Terric Anthrosol) in Płutowo														
Aan	0-80	10YR 3.5/2	10YR 1.7/1	3.5	60	37	3	2.16	0.190	11	8.1	7.4	5.1	4870
Wanh1	80-125	10YR 3.5/1	10YR 1.7/1	2.6	58	36	6	2.02	0.189	11	8.4	7.6	4.6	7150
Wan2	125-165	10YR 5/3	10YR 3/3	3.1	47	39	14	0.82	0.072	11	8.6	7.8	10.6	6210
Wanh3	165-190	10YR 4/1	10YR 2/1	4.9	50	40	10	2.12	0.084	25	8.5	7.9	11.2	5920
Wan4	190-200	10YR 6/4	10YR 4/4	1.8	62	25	13	0.20	0.023	9	8.8	8.1	9.4	3890
Wanh5	200-260	10YR 4.5/2	10YR 2.5/2	0.8	56	35	9	1.25	0.132	9	8.6	7.8	6.6	7940

Explanations as in Table 1.

The soil found in the stronghold area (Profile 2) is anthropogenic (Terric Anthrosol). Its composition and properties are distinctly different from those of the rusty soil present in the proximity of the settlement. The soil has a specific morphological feature, i.e. there are layers which differ in colour, the content of organic carbon, nitrogen, carbonates and the pH values (Table 1). The granulometric composition of the material in individual layers is similar and it corresponds to the characteristics of the material found in the rusty soil. Therefore, it means that the material used for the construction and reinforcement of the stronghold during subsequent phases of colonisation was taken from outwash deposits. The anthropogenic soil found in the stronghold, in comparison with the rusty soil from its closest vicinity, is enriched with organic carbon, nitrogen and phosphorus to a substantial depth of 250 cm. It also reveals a clearly narrower C/N ratio, the presence of carbonates and a slightly alkaline reaction.

At Płutowo, on the till deposits of a flat moraine plateau (containing $CaCO_3$) black-earths are found with ground water deposited at moderate depth (Mollic Gleysols; Profile 3). They are characterised by a quite thick topsoil layer, a considerable content of organic carbon and nitrogen, a narrow C/N ratio and a slightly alkaline reaction (Table 2). The analysed profile of the black earth was located in the area of an non fortified settlement, which had not been earlier documented by archaeologists. Obtained results of this soil phosphorus content were up to twenty times higher than standard values for the soils that have not been transformed by human activity.

The soil in the yard of the Płutowo settlement, like the one at Gronowo, belongs to anthropogenic soils (Terric Anthrosol; Profile 4). It differs from the black earth found in the vicinity because its enrichment with organic matter extends much deeper, the content of OC, N_t, P_t and carbonates is higher, just like the pH values. The profiled variation of particle-size distribution and chemical characteristics in this profile showed no regularity typical of soils that have not been transformed by human activity.

On the basis of the results of analyses shown herein it may be claimed that the granulometric composition of the soil material in both settlements reveals origin in the closest vicinity. Despite the differences in particle size distribution of the anthropogenic soils, their chemical properties are similar. They are enriched with biogenic elements (C, N, P) to a considerable depth (250-260 cm); they reveal a major biological activity; they contain carbonates and their reaction is slightly alkaline.

A numerical analysis of the phytosociological relevés shows that there are distinct variations in the floristic composition of the *Tilio-Carpinetum corydaletosum* associations in the stronghold areas as compared with associations from non-anthropogenic habitats.

A detailed floristic analysis shows a higher constancy and higher coverage values obtained in the stronghold areas by nitrophilous species: *Urtica dioica* L. and *Sambucus nigra* L. The occurrence of *Astragalus glycyphyllos* L. is also noteworthy as this species is not listed in the patches of the association in question in Chełmno Land. On the other hand, the strongholds show a puzzling lack of certain species which frequently occur in natural habitats: *Corydalis intermedia* (L.) Mérat, *Gagea minima* (L.) Ker Gawl., *Stellaria holostea* (L.) and *Padus avium* Mill. There are also considerable differences in the specific composition of the tree stands. Although in the patches describing natural habitats the tree stand is formed by *Carpinus betulus* L., *Tilia cordata* Mill., *Ulmus glabra* Huds. and *Ulmus minor* Mill. Emend. Richens, the tree stand at the Płutowo stronghold is formed by *Quercus robur* L. and *Fraxinus excelsior* L. whereas at Gronowo – by *Acer platanoides* L. with a minor participation of *Tilia cordata*. The differences might be a result of both anthropogenic transformations of the habitat and changes in the succession processes in the areas that have been exposed to prolonged human activity, as well as of intentional forest husbandry.

The patches of forest plant communities were determined as the *Tilio-Carpinetum* Tracz. 1962 association in the subtype with *Corydalis cava* Schweigg and Körte. This decision is justified by the specific composition of the undergrowth, including the presence of *Corydalis cava,* the species which distinguishes the subassociation [17].

The analysis of the floristic composition of phytocoenoses from the area of the strongholds shows that they lack a number of species which are very frequent in the patches from natural habitats. Other characteristics include higher coverage values and a higher constancy of nitrophilous species, as well as the presence of species which are not listed in natural habitats. The transformations result from anthropogenic enrichment of the soil with nutrients to considerable depth. Consequently, the phytocoenoses of *Tilio-Carpinetum corydaletosum,* a subassociation covering richest habitats [13], developed in the areas which once might have been the habitats of a poorer and dryer forest.

CONCLUSIONS

1. The soils occurring in the vicinity of the strongholds represent two typologically different systematic units. In the Gronowo stronghold it is the rusty soils, characterised by sandy texture, acid reaction and low biological activity, whereas at Płutowo the stronghold is adjacent to very fertile, biologically active black earths.

2. The soil conditions around the stronghold provided relevant development of forest communities: at Gronowo it is the tree stand of the *Querco roboris-Pinetum* mixed coniferous forest type and the dry-ground forests of *Tilio-Carpinetum*; whereas at Płutowo it is the dry-ground forest of *Tilio-Carpinetum* in the subtype with *Corydalis cava* and *Stachys sylvatica*.

3. The soils in the strongholds (Profiles 2, 4) are anthropogenic (Terric Anthrosol). Despite the differences in the granulometric composition of the soil material their chemical properties are similar and consist in the enriched content of organic carbon, nitrogen and phosphorus down to considerable depths (250-260 cm), significant biological activity, the presence of carbonates and the slightly alkaline reaction.

4. In both strongholds phytocoenoses of the *Tilio-Carpinetum corydaletosum* occurred.

5. A comparison of the phytocoenoses from the strongholds and natural habitats revealed differences in the floristic composition. The stronghold phytocoenoses lack a number of species which are otherwise frequent in the patches from natural habitats (*Corydalis intermedia*, *Gagea minima*, *Stellaria holostea* and *Padus avium*); their coverage values are higher, just like the constancy of nitrophilous species (*Urtica dioica* and *Sambucus nigra*); and there are species which are not listed in the natural habitats (*Astragalus glycyphyllos*).

6. The transformations observed in the composition of phytocoenoses from the stronghold are a consequence of the anthropogenic origin of the habitats and resulting enrichment of the soil with nutrients to the depth of 250-260 cm due to continued human colonisation. This stimulated the development of the phytocoenoses of *Tilio-Carpinetum corydaletosum,* a subassociation that occurs in the richest habitats.

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PRZEKSZTAŁCENIA GLEB I ZBIOROWISK ROŚLINNYCH NA OBSZARACH WCZESNOŚREDNIOWIECZNYCH GRODZISK (PRZYKŁADY Z ZIEMI CHEŁMIŃSKIEJ)

Badania dotyczyły przekształcenia gleb w miejscach dawnego osadnictwa i związane z nimi różnice w składzie gatunkowym fitocenoz z grodzisk i siedlisk naturalnych. Do badań wybrano wczesnośredniowieczne grodziska w Gronowie i Płutowie (ziemia chełmińska, północna Polska), w otoczeniu których występują różne typy gleb, odpowiednio: gleby rdzawe i czarne ziemie. Na badanym terenie wykonano szczegółowe badania gleboznawcze i florystyczno-fitosocjologiczne. Wykazano przekształcenia fitocenoz *Tilio-Carpinetum corydaletosum* w powiązaniu ze specyfiką gleb na grodziskach i ich antropogenicznym wzbogaceniem w pierwiastki biogenne (C, N, P) do znacznej głębokości.