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The causes of soil and vegetation variability in the area of the designed "Dybowo" nature reserve near Toruń

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Abstract. The aim of the present paper is to elucidate the variability of soils and vegetation in the designed nature reserve "Dybowo" near Toruń. The studied area is a slope of north-east aspect where ordered horizontal and vertical variability of soils and vegetation was found. Horizontal variability of soils is mainly caused by deluvial processes and vertical variability by type of parent material. A close relationship between the variability of soils and plant communities was found. The occurrence of *Tilio cordatae-Carpinetum betuli* association on a sandy slope of the Vistula VI terrace near Dybowo is possible due to the increase in habitat value of the soils occurring there. The factors resulting in this increase are: 1 – a thick cover of deluvia (sometimes exceeding 100 cm) enriched with humus, developed on almost all the area of the slope under investigation; 2 – the north-east aspect of the slope and direct vicinity of a large water body (river) resulting in better humidity conditions. Parent material of the soils is the factor differentiating vegetation of the designed "Dybowo" reserve at sub-association level. *Tilio-Carpinetum corydaletosum* sub-association demanding good site conditions developed in the slope area, where loamy material admixture occurs in the substratum.

Key words: habitat, phytocenosis, deluvial soil, slope, *Tilio-Carpinetum*.

1. Introduction

The area of the designed "Dybowo" nature reserve including *Tilio cordatae-Carpinetum betuli* occurs in the Toruń Basin (Kotlina Toruńska) on the slope of VI left-bank Vistula terrace, about 10 km west of Toruń in the vicinity of Zielona-Vistula river confluence (fig. 1). It extends from Dybowo toward Przyłubie for about 6 km. The total area of the designed reserve amounts about 17.5 ha (Rutkowski 1998). Most of the area belongs to National Forests (Cierpiszewo Forest Division, Dybowo Forestry). Private forest occupies only a small area.

The Toruń Basin is an area where relatively poor forest podzol soils dominate, and are overgrown with pine forest, so-called the Bydgoszcz Primeval Forest. For many years botanists were interested in the occurrence of *Tilio cordatae-Carpinetum betuli* association in the Dybowo vicinity (Cyzman 1996; Fiedorek 2000; Kępczyński & Cyzman 1991;

Rutkowski 1998). The reasons for the forest at a site of relatively demanding habitat requirements were considered. It was supposed that such a state was a result of environmental elements, in particular the soil properties. The aim of the present work is to elucidate the cause of variability of soils and vegetation on the slope of VI Vistula terrace near Dybowo, taking into account biotic as well as abiotic elements of the environment.

Figure 1. Localization of the investigated area

2. Objectives and methods

Studies were performed in the eastern part of the designed reserve on two transects with north-east aspect. They represent different but zone-repetitive vegetation systems. It was assumed that different vegetation communities reflect the differentiation of environmental variables.

Four soil pits were located along transect I (forest section 30f), maximum gradient about 31°, height 28 m (35–63 m above sea level) and 49 m long (profiles 1–4). Transect II (forest section 46d) located 450 m south-east from transect I, on a slope with maximum gradient of about 36°, 21 m in height (36–57 m above sea level) and 33 m long is represented by 3 soil pits (profiles 5–7). Samples for laboratory analyses were taken from all profiles. The following properties were determined for the samples: particle-size composition by the hydrometer method according to Bouyoucos as modified by Casagrande and by Prószyński (sand and gravel were separated on sieves); the soil reaction (pH in H_2O and pH in 1M KCl) by glass electrode; organic carbon (OC) in mineral samples by the Tiurin method and in organic samples by the Alten method (oxidation with potassium dichromate); nitrogen (N) by the Kjeldahl method; and $CaCO_3$ by the Scheibler method. The soil colours were determined by reference to Munsell Soil Color Charts (1971).

Vegetation studies were performed using the Braun-Blanquet method. Plant associations were defined according to W. Matuszkiewicz (2002). Latin names of plant species are given using Mirek et al. (2002).

3. Results

3.1. Soils

The soil in profile 1, located in transect I in the upper part of the slope, regarding its morphology (O-A-Bv-C) and properties (tab. 1) corresponds to the criteria accepted in the "Systematics of Polish Soils" (1989) for rusty soils. It is the only one among the soils investigated which does not exhibit deluvial enrichment with humus. It is characterized with the least favourable humidity conditons. Plant growth conditions here are the worst among the soils under investigation.

On the basis of field studies and the analysis of results (tab. 1, 2) all remaining profiles were classified as deluvial soils. Their morphology is as follows: O – organic horizon, A – humic horizon, most frequently dual (A1, A2), A2C – transitional horizon and C – parent material. Soil-habitat conditions are improved along with lower location on the slope. It is a result of an increase in the thickness of deluvial material enriched with humus along with better humidity conditions in the lower positions of the slope. An effect of enrichment is that deluvial material of both transects is characterized with black or brownish black colour (Munsell colour, moist 10YR 2/1, 10YR 2/2).

Beside common features of the profile structure, there are clear differences in the thickness and organic material decomposition and humic horizon thickness in deluvial soils of both transects. Chemical properties of these soils in the studied transects are also somewhat different. They are particularly noticeable when comparing soil profiles 3 and 6, located in both transects at similar height (tab. 3).

Table 1. Some properties of soils in transect I

Horizon	Depth [cm]	OC [%]	Nt [%]	C/N	pH H$_2$O	pH KCl	Munsell colour: Dry sample	Munsell colour: Moist sample	Particle-size distribution [%]: >1.0 [mm]	1.0–0.5 [mm]	0.5–0.25 [mm]	0.25–0.1 [mm]	0.1–0.05 [mm]	0.05–0.02 [mm]	0.02–0.005 [mm]	0.005–0.002 [mm]	<0.002 [mm]
Rusty soil (profile no. 1)																	
Ol	6–5	49.5	1.118	44	4.5	4.0	–	–	–	–	–	–	–	–	–	–	–
Ofh	5–3	40.5	1.348	30	4.6	3.9	–	–	–	–	–	–	–	–	–	–	–
Of	3–0	30.3	1.009	30	4.2	3.3	–	–	–	–	–	–	–	–	–	–	–
A	0–15	2.00	0.102	19	4.2	3.3	10YR 4/2	10YR 2/1	0.0	2	23	64	6	3	1	1	0
Bv	15–70	0.14	–	–	5.3	4.2	10YR 6/4	10YR 4/4	0.0	1	22	70	5	1	1	0	0
C	70–130	0.06	–	–	5.8	4.5	10YR 7/4	10YR 4/4	0.0	1	21	73	4	1	0	0	0
Medium-deep deluvial soil (profile no. 2)																	
Ol	4–2	44.4	1.407	32	4.7	4.2	–	–	–	–	–	–	–	–	–	–	–
Ofh	2–0	25.4	1.139	22	4.4	3.7	–	–	–	–	–	–	–	–	–	–	–
A	0–15	1.34	0.076	18	4.4	3.6	10YR 3/2	10YR 2/1	0.0	1	26	62	6	4	1	0	0
A2	15–45	0.34	0.022	15	5.1	4.2	10YR 4/3	10YR 2/3	0.1	1	24	67	6	2	0	0	0
A2C	45–100	0.19	–	–	5.9	4.6	10YR 5/3	10YR 3/3	0.1	1	24	67	7	1	0	0	0
C	100–180	–	–	–	6.2	5.0	10YR 6/4	10YR 4/4	0.1	1	23	68	7	1	0	0	0
Deep deluvial soil (profile no. 3)																	
Ol+Ofh	2–0	44.1	1.304	34	4.6	4.1	–	–	–	–	–	–	–	–	–	–	–
A1	0–10	1.19	0.064	19	4.2	3.3	10YR 4/2	10YR 2/1	0.0	1	27	65	5	1	1	0	0
A2	10–70	0.41	0.022	19	4.6	3.9	10YR 3/3	10YR 2/1	0.1	1	26	68	3	1	1	0	0
A2C	70–110	0.17	0.010	17	5.5	4.3	10YR 5/3	10YR 3/3	0.0	1	24	71	3	1	0	0	0
C	110–150	–	–	–	5.7	4.4	10YR 7/4	10YR 5/4	0.1	1	22	73	3	1	0	0	0
Deep deluvial soil (profile no. 4)																	
Ol	2–0	38.8	1.326	29	5.2	4.8	–	–	–	–	–	–	–	–	–	–	–
A	0–20	2.29	0.188	12	6.4	5.4	10YR 4/2	10YR 2/2	0.1	1	13	33	15	21	8	5	4
IIA1	20–60	0.72	0.069	10	7.5	6.5	10YR 3/2	10YR 2/1	0.0	1	19	63	7	3	3	2	2
IIA2	60–160	0.71	0.068	10	7.8	6.6	10YR 3/3	10YR 2/1	0.1	1	24	63	5	3	3	1	0

Table 2. Some properties of soils in transect II

Horizon	Depth [cm]	OC [%]	Nt [%]	C/N	pH		Munsell colour		Particle-size distribution [%]								
					H_2O	KCl	Dry sample	Moist sample	>1.0 [mm]	1.0–0.5 [mm]	0.5–0.25 [mm]	0.25–0.1 [mm]	0.1–0.05 [mm]	0.05–0.02 [mm]	0.02–0.005 [mm]	0.005–0.002 [mm]	<0.002 [mm]
Medium-deep deluvial soil (profile no. 5)																	
Ol	3–0	41.2	1.430	29	5.0	4.5	–	–	–	–	–	–	–	–	–	–	–
A1	0–15	1.75	0.134	13	4.7	3.6	10YR 3/2	10YR 2/1	0.0	2	17	64	12	4	1	0	0
A2	15–45	0.47	0.029	16	5.6	4.4	10YR 3/2	10YR 2/1	0.1	2	19	68	9	1	1	0	0
A2C	45–65	0.25	–	–	5.4	4.2	10YR 5/4	10YR 3/3	0.1	1	20	71	7	1	0	0	0
C	65–120	–	–	–	5.9	4.5	10YR 6/4	10YR 4/4	0.0	1	13	78	8	0	0	0	0
Medium-deep deluvial soil (profile no. 6)																	
Ol	3(5)–0	40.3	1.462	28	4.9	4.5	–	–	–	–	–	–	–	–	–	–	–
A1	0–10	1.32	0.087	13	5.0	3.8	10YR 4/1	10YR 2/1	2.0	4	22	62	7	3	1	1	0
A2	10–40	0.56	0.041	14	5.8	4.5	10YR 3/2	10YR 2/1	2.9	3	21	67	6	1	1	1	0
A2C	40–60	0.21	–	–	5.9	4.7	10YR 4/2	10YR 2/3	2.5	3	27	63	5	1	1	0	0
C	60–120	–	–	–	*6.8	6.2*	10YR 6/4	10YR 4/3	7.7	16	49	32	2	1	0	0	0
Deep deluvial soil (profile no. 7)																	
Ol	2–0	35.0	1.320	26	5.7	5.3	–	–	–	–	–	–	–	–	–	–	–
A1	0–28	1.88	0.157	12	6.3	5.5	10YR 3/1	10YR 2/1	3.9	10	34	44	3	3	3	2	1
A2	28–65	0.43	0.042	10	7.2	6.3	10YR 4/2	10YR 2/2	4.2	4	28	58	3	3	2	1	1
A3	65–115	0.48	0.046	10	7.7	6.5	10YR 3/2	10YR 2/1	2.5	5	29	55	5	2	2	1	1
C	115–150	0.17	–	–	*7.8	6.5	7,5YR 4/4	10YR 3/4	3.8	17	46	26	2	0	1	2	6

* – traces of CaCO3

The soils of transect II, compared with transect I soils, are characterized by higher biological activity that is reflected in narrower C/N ratios. Forest humus is of mull type and occurs at all slope positions, whereas in the soils of transect I forest humus of moder type dominates. Enrichment with humus extends deeper in profiles of transect I than in transect II. In contrast, organic carbon content is higher in the soils of transect II. The soils in transect I are more acid and are characterized by greater selection of mineral material than soils in transect II. The differences mentioned above point to more favourable soil-habitat conditions occurring in transect II.

Table 3. Comparision of selected properties of deluvial soils in transect I and II

Profile no. and transect no.	Horizon	Depth [cm]	OC [%]	C/N	pH H_2O	Percentage content of fraction		Type of forest humus
						> 1 mm	< 0.1 mm	
3 I	A1	0–10	1.19	19	4.2	0.0	7	Moder
	A2	10–70	0.41	19	4.6	0.1	5	
	A2C	70–110	0.17	17	5.5	0.0	4	
	C	110–150	–	–	5.7	0.1	4	
6 II	A1	0–10	1.32	13	5.0	2.0	12	Mull
	A2	10–40	0.56	14	5.8	2.9	9	
	A2C	40–60	0.21	–	5.9	2.5	7	
	C	60–120	–	–	6.8	7.7	3	

Soil materials in profiles 1–3 are highly sorted and characteristic of aeolian sands. Our studies has shown that transect I of the slope is built up by dune material, which covers terrace VI. Aeolian material has been deposited over the terrace edge and covers almost all the slope in transect I up to a depth of 320 cm. As a result, in transect I, deluvial material is of humus enriched aeolian sediment.

Profile 4 is in the range of high river stage of Vistula and Zielona and this is reflected in its soil morphology and particle-size composition. The near-surface soil horizon (A) is composed of alluvial material as it contains relatively high proportion of silt and clay. The horizons located below (IIA1 and IIA2) are composed of deluvia of aeolic origin and are secondarily enriched with small grain-size fractions washed out of the A horizon.

The soils of transect II show different particle-size composition to the soils of transect I. In profiles 5–7 there occurs a greater content of the fraction > 1 mm (up to 7.7%), coarse sand (up to 17%) and (neglecting profile 4) the silt fraction, than in transect I profiles. Our results show that greater grain-size variability in transect II is due to lithological causes. Varigrain sands of terrace VI play an important role in the structure of the slope under investigation. Aeolian material participation is low, as at the top of this terrace a small-size dune occurs. In the lower half of the slope, in transect II, local occurrence of morainic materials (loamy sand, loam) was found. The presence of this material was determined on the basis of borings performed in the vicinity of the analysed profiles. The heterogenous lithological structure of the slope in its middle and lower part in transect II (profiles 6 and 7) is reflected by a greater content of the fraction > 1 mm and the fraction < 0.1 mm in comparison with the upper part of the transect (profile 5, tab. 2). As a result deluvial material, comprising soils in transect II, is a mixture of different materials (terrace, aeolian and morainic material). It can be assumed that parent material of soils in transect II creates better conditions for the development of soils with higher habitat value.

3.2. Vegetation

The results of vegetation studies are shown in table 4. Horizontal and vertical vegetation variability is closely related to soils variability (figs 2 and 3). At the foot of both transects, where the richest soils occur the most demanding vegetation has developed. In contrast, on the upper part of the slope, plant species characteristic of poorer habitats are found. In the area under investigation trees about 65 years old dominate.

Table 4. Vegetation of the investigated transects

	TRANSECT II			TRANSECT I		
Soil profile number	7	6	5	4	2–3	1
Association, sub-association:	A	B	C	D	C	E
Species						
Trees, shrubs:						
Alnus glutinosa	–	–	–	(+)	–	–
Cornus sanguinea	–	–	–	(+)	–	–
Ulmus laevis	+	+	+	+	+	–
Carpinus betulus	+	+	+	+	+	–
Quercus robur	(+)	+	+	+	+	+
Quercus petraea	+	+	+	–	–	+
Pinus sylvestris	–	–	–	(+)	+	+
Frangula alnus	–	–	–	–	+	+
Sorbus aucuparia	–	–	–	–	+	+
Betula pendula	–	–	–	–	–	+
Corylus avellana	–	–	–	–	–	+
Berberis vulgaris	–	–	–	–	–	+
Herbs / Cover of herb layer %	50	30	5	50	30	30
Corydalis cava	+	–	–	–	–	–
Ficaria verna	+	–	–	+	–	–
Gagea lutea	+	–	–	+	–	–
Pulmonaria obscura	+	–	–	+	–	–
Asarum europaeum	+	(+)	–	–	–	–
Glechoma hederacea	+	–	–	+	–	–
Aegopodium podagraria	+	–	–	+	–	–
Lamium maculatum	–	–	–	+	+	–
Dryopteris filix-mas	+	+	(+)	–	+	+
Convallaria majalis	+	+	+	–	+	+
Polygonatum odoratum	–	–	–	–	+	+

Association, sub-association:
A *Tilio cordatae-Carpinetum betuli corydaletosum*
B *Tilio cordatae-Carpinetum betuli typicum*
C *Tilio cordatae-Carpinetum betuli calamagrostietosum*
D *Ficario-Ulmetum minoris*
E *Querco roboris-Pinetum*

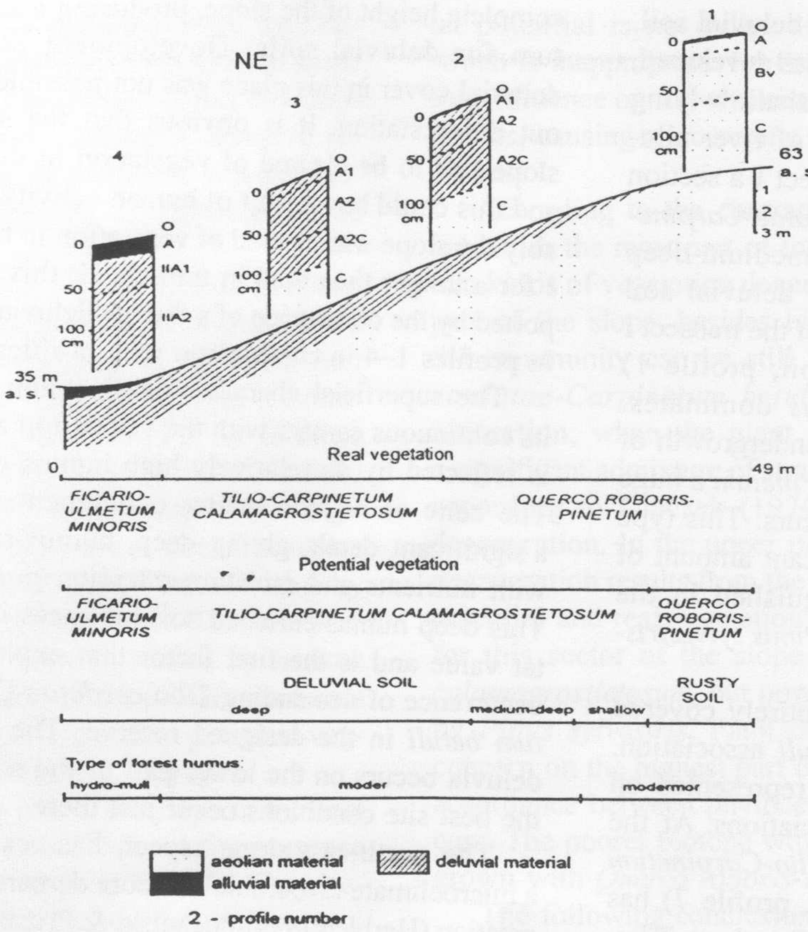

Figure 2. Variability of soils and vegetation – transect I

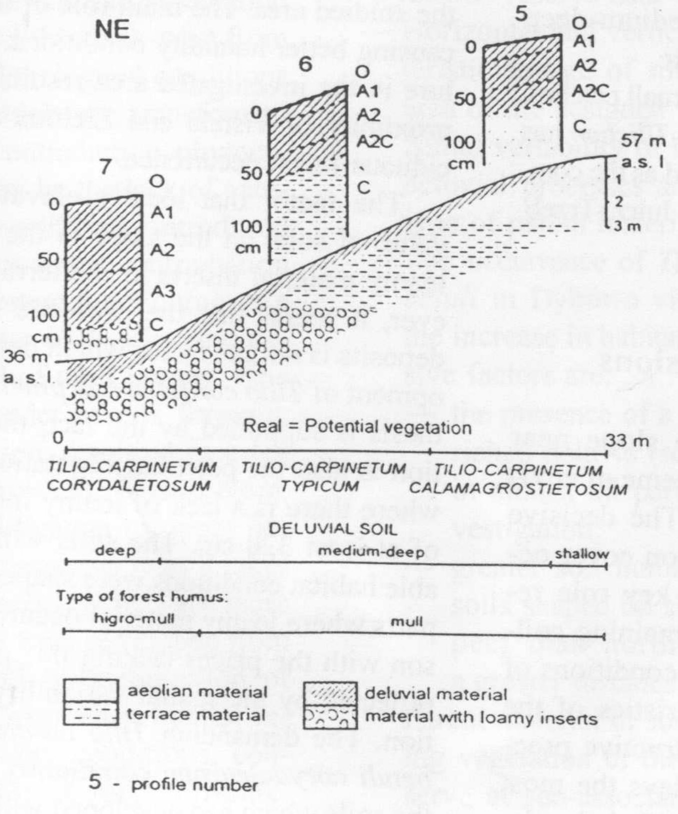

Figure 3. Variability of soils and vegetation – transect II

At the bottom of transect I (deep deluvial soil, profile 4) *Ficario-Ulmetum minoris* has developed, whose presence is connected with shallow-lying ground water level and occurrence of river alluvia. Above this association, in transect I a section of highly pine-influenced *Tilio cordatae-Carpinetum calamagrostietosum* occurs (medium-deep deluvial soil – profile 2 and deep deluvial soil – profile 3). From about the middle of the transect I *Querco roboris-Pinetum* (rusty soil, profile 1) occours in which *Pinus sylvestris* dominates. It should be mentioned that in the undergrowth of the low part of the *Querco roboris-Pinetum* a huge amount of *Dryopteris filix-mas* occurs. This type of plant community, with a significant amount of *Dryopteris filix-mas*, was distinguished in the Toruń Basin by Cyzman (1991) as *Pinus sylvestris-Dryopteris filix-mas*.

In transect II the slope is entirely covered by *Tilio cordatae-Carpinetum betuli* association. *Tilio-Carpinetum* of transect II is represented on the slope by three plant sub-associations. At the bottom a fertile sub-association *Tilio-Carpinetum corydaletosum* (deep deluvial soil, profile 7) has developed, on the middle part of the slope *Tilio-Carpinetum typicum* (medium-deep deluvial soil, profile 6) is found, and on the upper part *Tilio-Carpinetum calamagrostietosum* (medium-deep deluvial soil, profile 5) is characteristic.

It must be mentioned that, locally in small patches, in the area of the designed reserve *Aceri-Tilietum* has developed (Cyzman 1996) – now regarded as the community *Acer platanoides-Tilia cordata* Jutrz.-Trzeb. 1995 em. W. Matuszkiewicz 2002.

4. Discussion and conclusions

The research conducted on the slope near Dybowo enabled us to establish a scheme of environmental functioning in this area. The decisive factors of the slope soil and vegetation cover occurrence are slope processes. Their key role results from clear modelling of the remaining soil-forming factors, modelling soils and conditions of plant growth. The gradient characteristics of the slope favours the occurrence of destructive processes, amongst which slope wash plays the most important role. This process has enabled the development of a thick deluvial layer on almost the complete height of the slope, producing a substratum for deluvial soils. Development of deep deluvial cover in this place was not possible without deforestation. It is obvious that the studied slope had to be cleared of vegetation in the past, and this could be a result of human activity. Probably the slope was cleared of vegetation in transect I for a longer time than in transect II; this is supported by the occurrence of a thicker deluvial cover in profiles 1–4 in comparison with profiles 5–7.

The superficial character of deluvium causes its continuous contact with the vegetation and this is reflected by its relatively high humus content. The zone of organic matter enrichment reaches a significant depth, giving deep, humus-rich soil with nutrients and moisture retention properties. This deep humus-enriched soil increases its habitat value and is the first factor that explains the occurrence of demanding *Tilio cordatae-Carpinetum betuli* in the designed reserve. The deepest deluvia occurs on the lower part of the slope and the best site conditions occur just there.

The north-east slope aspect, has resulted in a microclimate favourable for more demanding vegetation (Herbich 1994; Puchalski & Prusinkiewicz 1990) and is the second factor conditioning the existence of *Tilio cordatae-Carpinetum betuli* in the studied area. The main role of this factor is in causing better humidity conditions. Greater moisture in the investigated area results also from the proximity of Vistula and Zielona rivers and deciduous forest occurrence.

The factor that locally elevates the habitat value of soils on the slope is the occurrence of loamy material inserts in the terrace sand. However, it seems that the presence of such heavy deposits is not the factor which determines development of *Tilio cordatae-Carpinetum betuli*. This thesis is supported by the fact, that this association is also the potential vegetation of transect I, where there is a lack of loamy inserts to a depth of at least 320 cm. The soils with more favourable habitat conditions were shaped in those slope parts where loamy material occurred, in comparison with the places lacking this material. This is reflected by the spatial variability of the vegetation. The demanding *Tilio cordatae-Carpinetum betuli corydaletosum* community was shaped on the soils which had developed with a greater share of heavy material.

Provided that deluvial soil enrichment with humus and specific microclimate of the studied slope enable *Tilio cordatae-Carpinetum betuli* development, the type of parent material is decisive regarding the occurrence of particular sub-associations of this community. This dependence can be seen from figure 3.

In the end, the role of the accordance between phytocenosis and habitat on the studied area should be emphasized. Real vegetation in the lower part of transect I and in the whole of transect II corresponds to potential vegetation (figs 2, 3). In those slope sections deciduous forest controls a mild microclimate, favourably influencing habitat conditions. Leaf-fall undergoes quick decomposition. Forest humus is of mull type, characterized by small thickness of organic horizons. The soil possesses high biological activity, shown by narrow C/N ratios. In those parts of the investigated area where real vegetation corresponds to potential vegetation, ecosystem functioning is proper.

Pine trees covering part of the slope in transect I were introduced by man. However the presence of *Dryopteris filix-mas* (typical for *Tilio-Carpinetum)* indicates that *Tilio-Carpinetum calamagrostietosum* is a natural sub-association in the prevailing length of transect I. Such a thesis is supported by the development of this sub-association at a distance of 200 m toward the north-west from transect I, under analogous lithological conditions (aeolian material >320 cm thickness, transformed by deluvial process). The contradiction phytocenosis-habitat is supported also by the lack of natural pine tree restocking under artificially introduced tree stands. As a result of this stated contradiction some abnormalities in ecosystem functioning take place. This is shown by wider C/N ratios and development of moder instead of mull humus. Pine leaf-fall, participating in moder humus forming, undergoes slow decomposition, resulting in a lag in element cycling in the ecosystem. What is more, this leaf-fall causes the acidification of upper horizons. This is a dangerous phenomenon as it takes place in sandy soils of transect I, which are more degradation-susceptible than those developed from heavier material. Inappropriate introduction of *Pinus sylvestris* into *Tilio-Carpinetum* habitat results in worsening of humidity conditions, connected with coniferous forest microclimate. As a result, in potential *Tilio-Carpinetum* sections that are presently overgrown with pine trees, habitat potential is not fully utilized. Phytocenosis which is inappropriate for the habitat, has a negative influence on soil chemistry and humidity conditions, causing a worsening of plant growth conditions.

According to the contradiction phytocenosis-habitat in the most part of transect I, there can be two kinds of vegetation degeneration. In the lower part of the slope, besides high pine-tree impact, the community can be still ascribed to the *Tilio cordatae-Carpinetum betuli* association. Such a situation, when the plant community contains a significant admixture of strange species, is called, according to Olaczek (1974), plant association degeneration. In the upper part of the slope plant degeneration results from the discrepancy between potential and real vegetation. Potential vegetation for this sector of the slope is *Tilio-Carpinetum calamagrostietosum*, but now it is covered mainly by *Pinus sylvestris*. Plant degeneration is of no concern on the highest part of the slope, where an accordance between phytocenosis and habitat occurs. The poorer biotope with a rusty soil is overgrown with *Querco roboris-Pinetum*.

The following conclusions can be drawn from the research performed on a sandy slope of the Vistula terrace VI, in the area of the designed "Dybowo" reserve near Toruń:

- Horizontal and vertical variability is a characteristic feature of soils and vegetation in the area of the designed "Dybowo" reserve. Horizontal variability of soils is mainly caused by deluvial processes and vertical variability by type of parent material.
- The occurrence of *Tilio cordatae-Carpinetum betuli* in Dybowo vicinity is possibly due to the increase in habitat value of soils. The decisive factors are:
  - the presence of a thick layer of humus-enriched deluvia (sometimes above 100 cm) in almost all parts of the slope under investigation;
  - greater soil humidity in comparison with soils shaped on slopes with a different aspect than north-east and occurring at a greater distance from the Vistula river.
- Parent material of soils is a factor differentiating vegetation of the designed "Dybowo" reserve at sub-association level. Demanding as to its habitat conditions *Tilio cordatae-Carpinetum betuli corydaletosum* has devel-

oped in those slope positions which contain loamy material inserts in the substratum.

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