

A. Zieliński (ed.)
Interdisciplinary researches in natural sciences
Institute of Geography
Jan Kochanowski University
Kielce, 2011, s. 105-122.

RELATION BETWEEN VEGETATION AND SOIL IN TIMBER FOREST ON EXAMPLE OF PERMANENT STUDY AREA IN CZARNY BRYŃSK (NE POLAND)

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Abstract

The aim of this study was to examine connections between vegetation and soil distributions in permanent study area located in Urszulewska Plain mesoregion (NE Poland). Based on detailed cartographic soil and vegetation documentation referenced to the network of 270 study plots (cartogram method), a canonical correspondence analysis (CCA) was performed (Canoco program).

The analysis of real vegetation and soils distribution revealed that plant communities distribution depend mainly on peat soils and soils lessivés and to a lower extent – on podzolized rusty soils. Similar results were obtained for potential natural vegetation – soil relation.

CCA ordination diagram for potential vegetation and soils results in a clear connection of plant communities with soil types. Whereas in case of real vegetation and soils analysis relations are not so evident on account of the existence of degeneration and regeneration forms of forest communities.

Distribution of the majority of coniferous forest species is correlated with occurrence of podzolized rusty soils. Nevertheless, some of the species are not connected with specific soil type and they occur in entire permanent area.

Key words: *Tilio-Carpinetum*, *Quercus roboris-Pinetum*, podzol soils, brown forest soils, canonical correspondence analysis (CCA), timber forest

Słowa kluczowe: *Tilio-Carpinetum*, *Quercus roboris-Pinetum*, gleby bielicoziemne, gleby brunatnoziemne, kanoniczna analiza zgodności (CCA), las gospodarczy

Introduction

Plant cover diversity is often a reflection of soil heterogeneity. Mutual vegetation and soil relations are important both from a scientific and practical points of view. They are particularly essential in forest ecosystems, where soil constitutes a basic habitat element for forest habitat type assessment (Puchalski, Prusinkiewicz 1990). In turn, habitat type of forest decides about development of a proper treestand and thereby development of a determined plant community, which is particularly important in timber forests.

„Vegetation – soil” mutual relations research is carried out mainly in forests of a natural character (Prusinkiewicz 1961, Pritchett 1979, Bednarek et al. 2005), as well as in timber forests (Ceitel 1999, Sewerniak et al. 2009). In this paper authors used a detailed cartographic documentation of permanent study area in timber forest aiming at a demonstration of correlation of vegetation distribution and partially flora distribution with soils. The permanent area delimited in study plots enables detailed natural, including complex and interdisciplinary research.

Area of research

The object of the research constitutes permanent study area known as Research-Education Area in Czarny Bryńsk (Zaluski et al. 1998, Paszek 2002). It is situated in forest complex in Urszulewo Plain mesoregion (NE Poland) within Górzno-Lidzbark Landscape Park. It is an outwash plain with a diversified relief, soils and vegetation. The permanent area have circa 25 hectares of timber forest delimited in 270 study plots (ca 30 x 30 m each), which gave an opportunity to carry out detailed soil science and geobotanical research by cartogram method (Fig. 1).

Permanent study area occupies a relatively small area but it is diversified in terms of soil (Fig. 2). Soil cover correlates strictly with geomorphology of the examined area. Location in proximal part of Dobrzyń outwash plain causes that podzol soils dominate. Main type constitute rusty soils which occupy over 80% of the area. They occur in three subtypes: proper rusty soils, podzolized rusty soils and brownish rusty soils. Considerably smaller area

is occupied by browned soil lessivés (circa 7%) occurring in north-eastern part of the object.

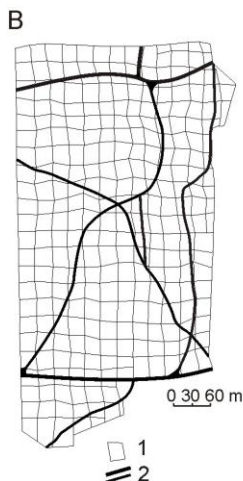
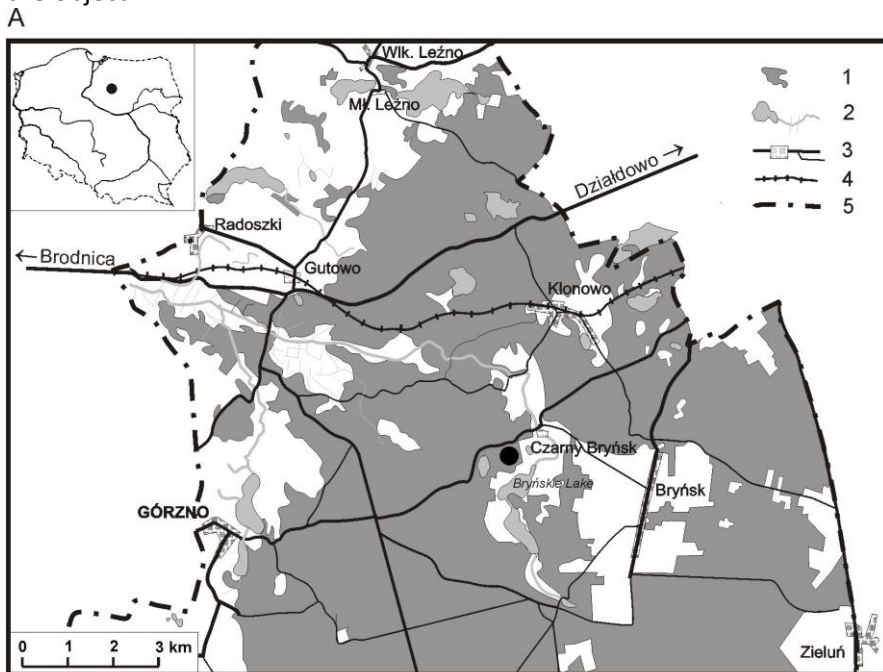


Fig. 1. Study area:

A – location of study area: 1 – forests, 2 – surface waters, 3 – towns and major roads, 4 – railway, 5 – boundary of the Górzno-Lidzbark Landscape Park, B – network of plots of permanent study area: 1 – basic study plot, 2 – roads.

Podzol soils occur in two small complexes (ca 5% of the area), mainly on hills in south-western part of the study area. In small depression without outflow, an occurrence of pseudogley soils was noted. Whereas in the swamp, located in kettle depression, peat soils developed. Mucky soils dominate in the swamp surroundings (Markiewicz 2000).

Oak-linden-hornbeam forests of *Tilio-Carpinetum* (Fig. 3) with large share of *Carpinus betulus* in subcanopy layer (a_2) of treestand dominate in examined area (Fedorowicz 1997). Within this association lower level units were distinguished. Phytocoenoses of *Tilio-Carpinetum typicum* subassociation have the largest area in north-eastern part of the discussed object, in addition to which local forms with dominance of oak in the treestand (*Tilio-Carpinetum typicum*, form with *Quercus robur*) and with pine share in treestand (*Tilio-Carpinetum typicum*, form with *Pinus sylvestris*) were distinguished. Very often in different parts of the permanent area phytocoenoses of *Tilio-Carpinetum calamagrostietosum* occur where in the upper layer (a_1) of treestand almost always *Pinus sylvestris* dominates and in herb layer (c) marks a share of typical for coniferous forest species. The central part of the object composes floristically poorer pine-oak forests *Quercus roboris-Pinetum*, locally diversified in typical form (*Quercus roboris-Pinetum*, typical form) and form with introduced beech (*Quercus roboris-Pinetum*, form with *Fagus sylvatica*). In kettle hole focus mainly different plant communities of *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances (northern part of the swamp) and *Caricion lasiocarpae* alliance (southern part of the swamp).

The map attached (Fig. 3) shows a vegetation state from 1997 when the majority of forest area was occupied by typically developed phytocoenoses with appropriately dense treestand. Neither, development stadia nor degeneration stadia of both *Tilio-Carpinetum* subassociations occupy a large area at that time. In examined object different development stadia spatial range of forest plant communities currently has increased distinctly which is an effect of natural or artificial forest restocking introduction within planned forest management.

For permanent research area, also in analogical period (1997), full vascular plant flora was performed. It is rich and encompasses over 400 species (Paszek 1997, Załuski et al. 1998).

General vegetation diversity is shown in potential natural vegetation map (Fig. 4). In forest complex three units were distinguished: *Tilio-Carpinetum typicum*, *Tilio-Carpinetum calamagrostietosum* and *Quercus roboris-Pinetum*. In case of the swamp potential and real vegetation units are identical.

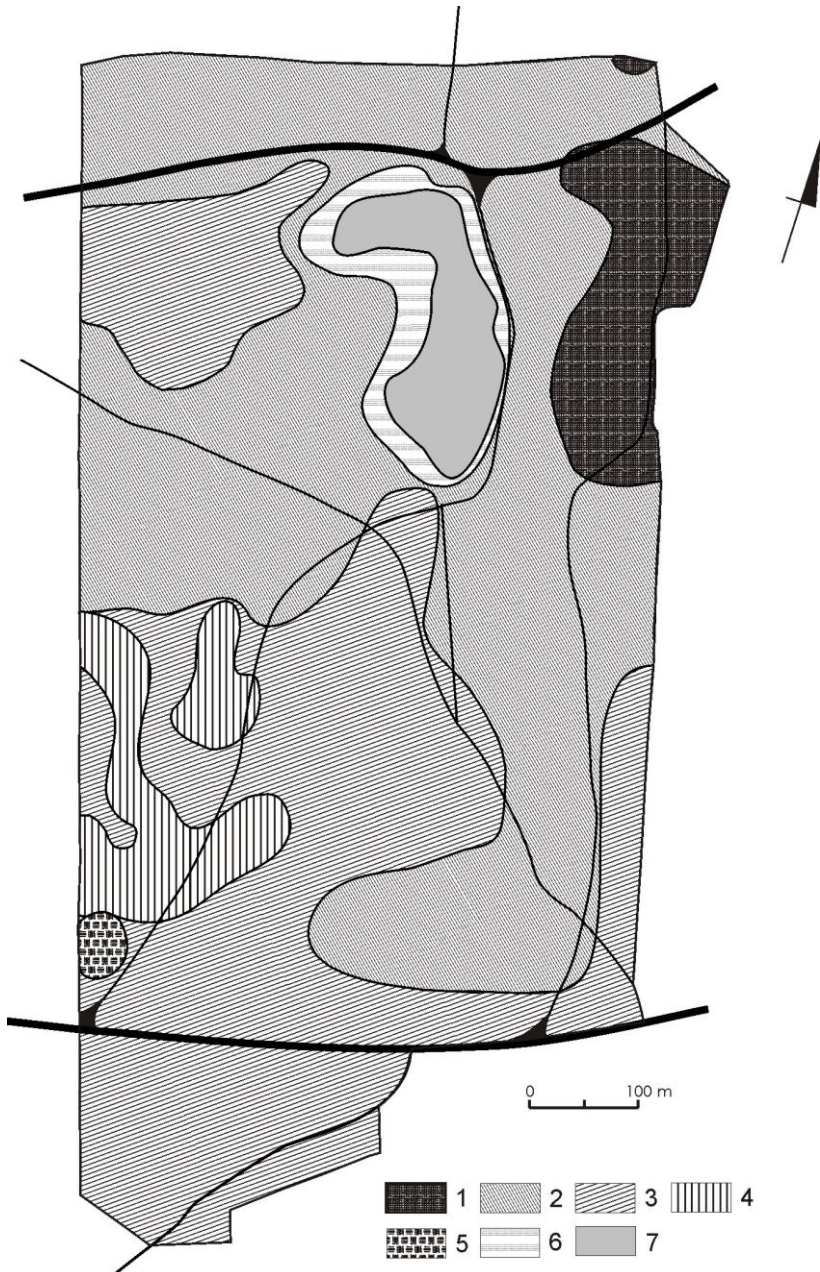


Fig. 2. Soil types distribution in permanent study area (Markiewicz 2000, modified):

1 – browned soil lessivés, 2 – complex of proper rusty and brownish rusty soils, 3 – podzolized rusty soils, 4 – podzol soils, 5 – pseudogley soils, 6 – complex of mucky and peat soils, 7 – peat soils.

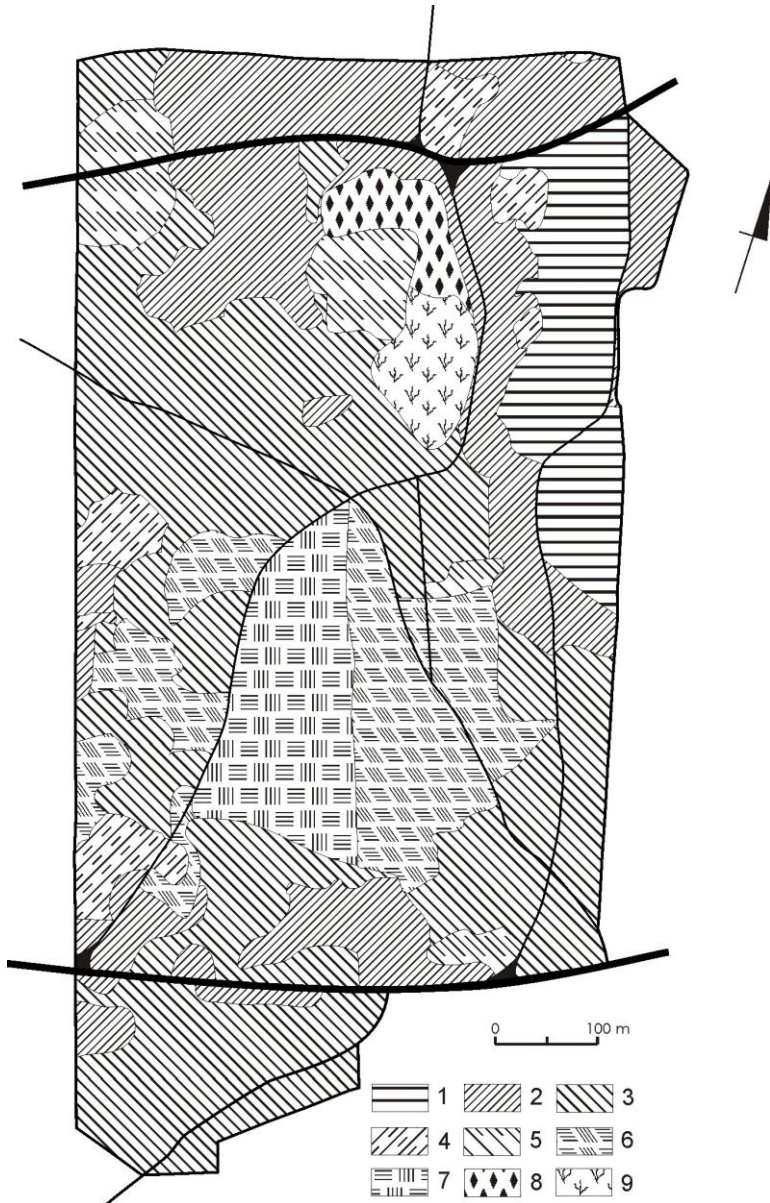


Fig. 3. Real vegetation of permanent study area (Fedorowicz 1997, modified):

- 1 – *Tilio-Carpinetum typicum*, form with *Quercus robur*, 2 – *Tilio-Carpinetum typicum*, form with *Pinus sylvestris*, 3 – *Tilio-Carpinetum calamagrostietosum*, 4 – *Tilio-Carpinetum typicum*, development and degeneration stadia, 5 – *Tilio-Carpinetum calamagrostietosum*, development and degeneration stadia, 6 – *Quercus roboris-Pinetum*, typical form, 7 – *Quercus roboris-Pinetum*, form with *Fagus sylvatica*, 8 – complex of communities of *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances, 9 – communities of *Caricion lasiocarpae* alliance.

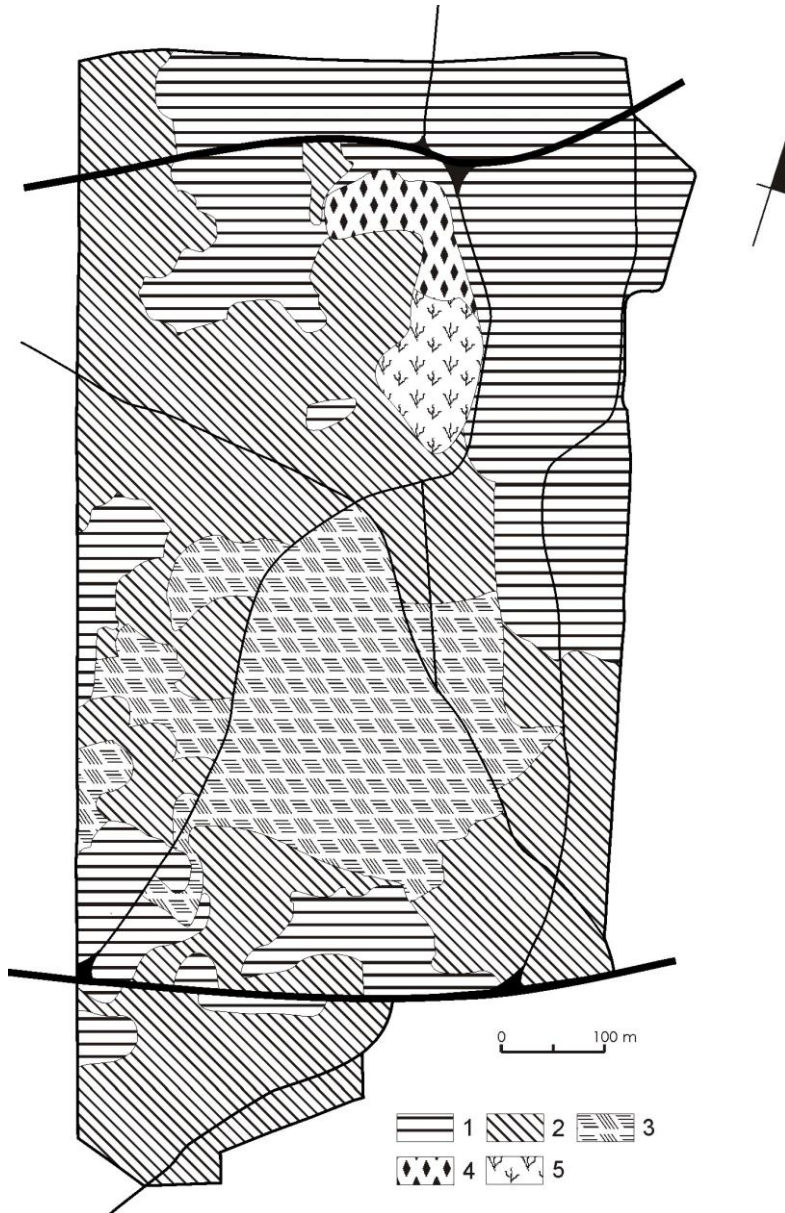


Fig. 4. Potential natural vegetation of permanent study area:

- 1 – *Tilio-Carpinetum typicum*, 2 – *Tilio-Carpinetum calamagrostetosum*, 3 – *Quercroboris-Pinetum*,
- 4 – complex of communities of *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances,
- 5 – communities of *Caricion lasiocarpae* alliance.

Material and methods

A cartographic documentation concerning soil, vegetation and flora distribution in permanent study area constitutes a basic material for studying the correlation between vegetation and soils. This documentation displays vegetation and flora state from 1997 and soils – from 2000. The justification of analyses of material from 1997-2000 carried out is a fact that the majority of forest area was at that time occupied by typical forest phytocoenoses and not their degeneration and development stadia.

The criteria included in Systematics of Polish Soils (1989) constituted the basis of the classification and delimitation of soil types and subtypes.

Forest vegetation units at association and subassociation level were delimited according to Matuszkiewicz (2007a), whereas non-forest vegetation units – according to Brzeg and Wojterska (2001). Potential natural vegetation map (Fig. 4) was drawn up on a basis of Tüxen's conception (Matuszkiewicz 2007b). In flora's examination a quantitative cartogram method according to Faliński (1990) in addition to which species cover values in study plots were expressed in five-degree scale.

Subsequently, output data to numerical analysis were prepared. After superimposing the network of research plots on soil map a share of delimited soil types and subtypes in respective area units was read off. This share was expressed in ten-degree scale by giving values from 0.5 to 5.0. Obtained data were entered in a working table (Excel program) which constituted an output material for further analyses. Analogically, the share of real and potential natural vegetation units in all research plots was calculated and two subsequent working tables were created.

Moreover, in analogical way coverage values (in five-degree scale) of typical for coniferous forests i.e. characteristic for *Vaccinio-Piceetea* class (mainly according to Matuszkiewicz 2005) were set out. Coniferous forest species were analysed because they were admitted as essential factors of podzolization process.

Obtained data were processed with numerical analysis by using Canoco program (ter Braak 1986, ter Braak, Šmilauer 2002). In order to determine the correlation of real and potential vegetation and selected coniferous forest species distribution against the background of soils the canonical correspondence analysis (CCA) was performed. In analysis concerning soil and plant species lowered weight of rare species was used. For each analysis the permutative Monte Carlo test was performed.

Results

Canonical correspondence analysis (CCA) of real vegetation against the background of soils revealed that plant communities distribution is determined mainly by peat soil (correlation coefficient with the first axis 0.99) and browned soil lessivé (correlation coefficient with the second axis 0.91). Influence on vegetation type distribution to a lower extent has a podzolized rusty soil, of which correlation coefficient value with the second axis is -0.58 (Fig. 5).

The analysis revealed different connection degrees of distinguished plant communities with soil types (Fig. 5). Strongly connected with peat and mucky soils is aquatic and helophytic vegetation of *Caricion lasiocarpae*, *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances. Connection with podzolized rusty and podzol soils have pine-oak forests (*Quercus robur*-*Pinetum* typical form and *Quercus robur*-*Pinetum* form with *Fagus sylvatica*) and also poorer oak-linden-hornbeam forms – *Tilio-Carpinetum calamagrostietosum*. Distinctly correlated with browned soil lessivés is an occurrence of a richer oak-linden-hornbeam form – *Tilio-Carpinetum typicum* form with *Quercus robur*. Development and degeneration stadia of *Tilio-Carpinetum typicum* are more connected with browned soil lessivés and with proper rusty and brownish rusty soil complex rather than with other soil types.

Comparable results were obtained with potential natural vegetation – soil relation analysis (Fig. 6). On potential vegetation distribution distinctly influences peat soil (correlation coefficient with the first axis 0.99), podzolized rusty soil (correlation coefficient with the second axis -0.72) and browned soil lessivé (correlation coefficient with the second axis 0.70).

More apparent, rather than in case of real vegetation, is a connection of potential plant communities with soil types (Fig. 6). Strongly connected with peat soils is an occurrence of *Caricion lasiocarpae*, *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances. With browned soil lessivés, pseudogley soils and complex of proper rusty and brownish rusty soils an occurrence of *Tilio-Carpinetum typicum* is distinctly correlated. Whereas connection with podzolized rusty and podzol soils reveal *Quercus robur*-*Pinetum* and *Tilio-Carpinetum calamagrostietosum*.

Typical for coniferous forests species distribution, i.e. characteristic for *Vaccinio-Piceetea* class, determines in study area an occurrence of mucky and peat soil complex (correlation coefficient with the first axis is respectively 0.76 and 0.70), podzolized rusty soils (correlation coefficient with the first axis

-0.70) and browned soil lessivés (correlation coefficient with the second axis 0.66) (Fig. 7).

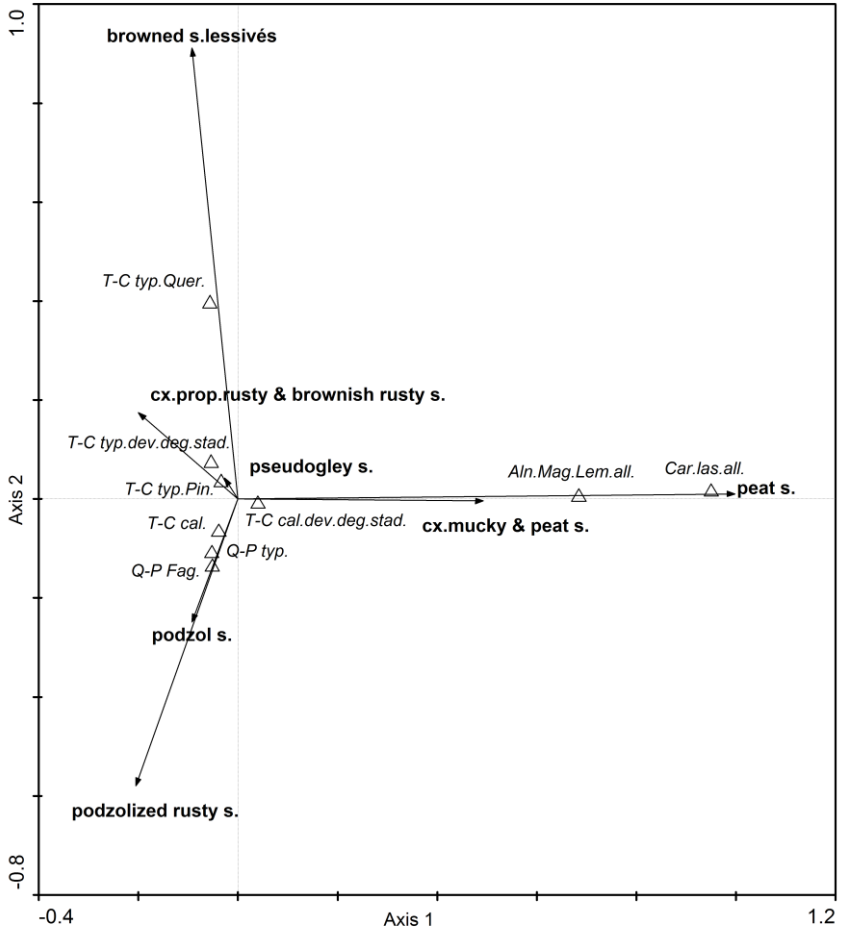


Fig. 5. CCA ordination diagram – correlation between real vegetation and soil types:

T-C typ.Quer. – *Tilio-Carpinetum typicum*, form with *Quercus robur*, T-C typ.Pin. – *Tilio-Carpinetum typicum*, form with *Pinus sylvestris*, T-C cal. – *Tilio-Carpinetum calamagrostietosum*, T-C typ.dev.deg.stad. – *Tilio-Carpinetum typicum*, development and degeneration stadia, T-C cal.dev.deg.stad. – *Tilio-Carpinetum calamagrostietosum*, development and degeneration stadia, Q-P typ. – *Quercus roboris-Pinetum*, typical form, Q-P Fag. – *Quercus roboris-Pinetum*, form with *Fagus sylvatica*, Aln.Mag.Lem.all. – complex of communities of *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances, Car.las.all. – communities of *Caricion lasiocarpae* alliance, brownd s.lessivés – browned soil lessivés, cx.prop.rusty & brownish rusty s. – complex of proper rusty and brownish rusty soils, podzolized rusty s. – podzolized rusty soils, podzol s. – podzol soils, pseudogley s. – pseudogley soils, cx.mucky & peat s. – complex of mucky and peat soils, peat s. – peat soils

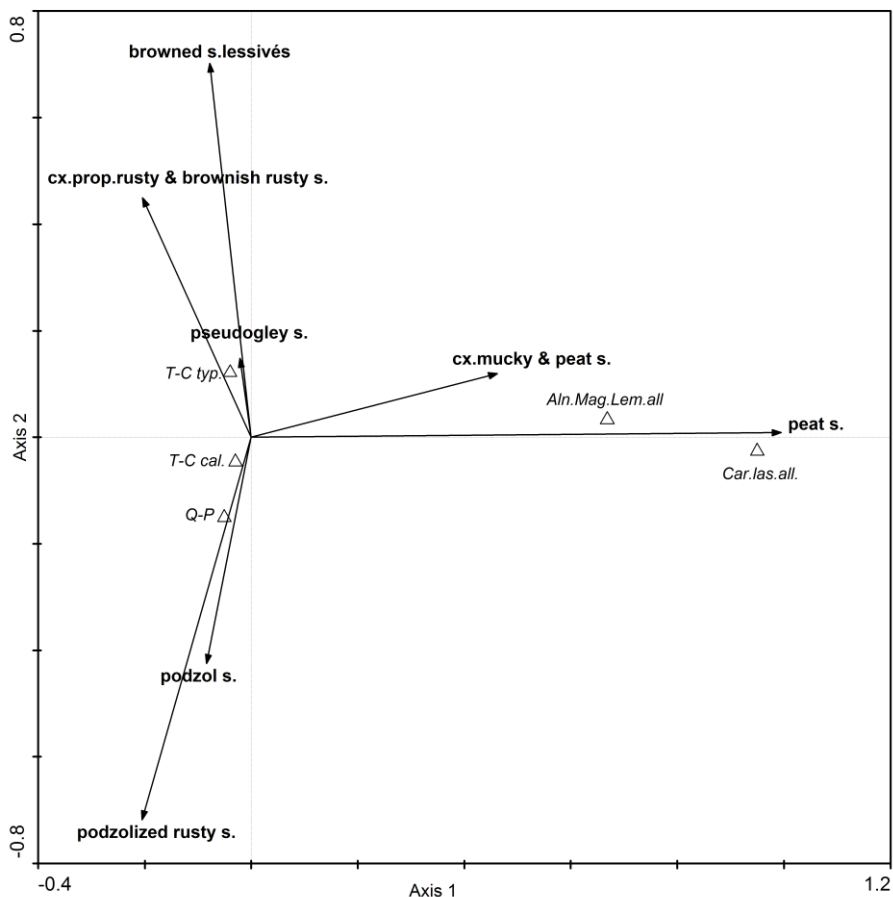


Fig. 6. CCA ordination diagram – correlation between potential natural vegetation and soil types:

T-C typ. – *Tilio-Carpinetum typicum*, T-C cal. – *Tilio-Carpinetum calamagrostietosum*, Q-P – *Quercus robur*-*Pinetum*, Aln. Mag. Lem. all. – complex of communities of *Alnion glutinosae*, *Magnocaricion* and *Lemnion minoris* alliances, Car. las. all. – communities of *Caricion lasiocarpae* alliance, browned s. lessivés – browned soil lessivés, cx. prop. rusty & brownish rusty s. – complex of proper rusty and brownish rusty soils, podzolized rusty s. – podzolized rusty soils, podzol s. – podzol soils, pseudogley s. – pseudogley soils, cx. mucky & peat s. – complex of mucky and peat soils, peat s. – peat soils

Also a correlation of some species and soils were shown (Fig. 7). With peat and mucky soils *Pinus sylvestris* in b layer and *Lycopodium annotinum* are connected. With podzolized rusty soils the most correlated is *Monotropa hypopitys* and *Chimaphila umbellata* occurrence. A distinct connection with

this soil types reveal also *Pinus sylvestris* in a₂ layer, *Juniperus communis* in b layer and *Diphasiastrum complanatum*. Less apparent is a correlation of soil mentioned above with *Vaccinium vitis-idaea* and with *Juniperus communis* in c layer. In turn, with podzol soils an occurrence of *Trientalis europaea* is connected. Whereas *Dryopteris dilatata* and *Picea abies* in a₁ layer reveal a slight connection with mucky and peat soils.

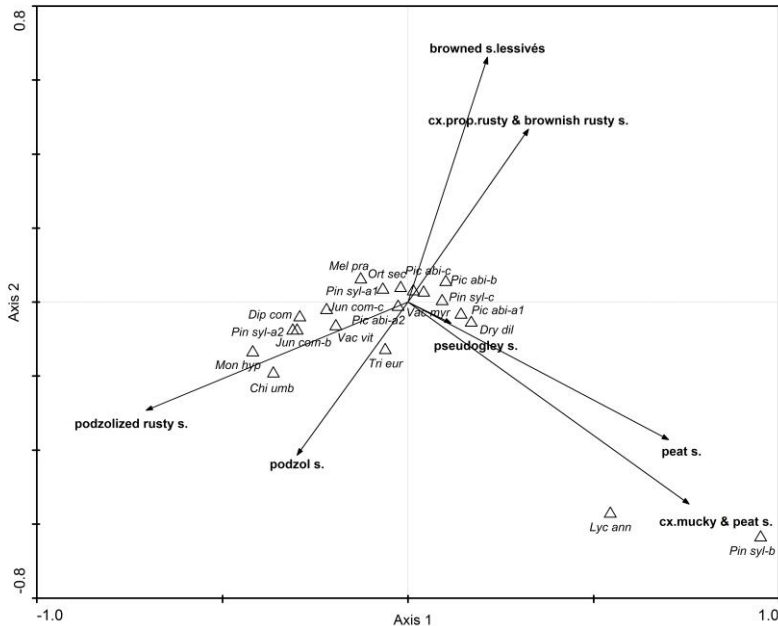


Fig. 7. CCA ordination diagram – correlation between coniferous forest species and soil types:

Chi umb – *Chimaphila umbellata*, Dip com – *Diphasiastrum complanatum*, Dry dil – *Dryopteris dilatata*, Jun com-b – *Juniperus communis* in layer b, Jun com-c – *Juniperus communis* in layer c, Lyc ann – *Lycopodium annotinum*, Mel pra – *Melampyrum pratense*, Mon hyp – *Monotropa hypopitys*, Ort sec – *Orthilia secunda*, Pic abi-a1 – *Picea abies* in layer a₁, Pic abi-a2 – *Picea abies* in layer a₂, Pic abi-b – *Picea abies* in layer b, Pic abi-c – *Picea abies* in layer c, Pin syl-a1 – *Pinus sylvestris* in layer a₁, Pin syl-a2 – *Pinus sylvestris* in layer a₂, Pin syl-b – *Pinus sylvestris* in layer b, Pin syl-c – *Pinus sylvestris* in layer c, Tri eur – *Trientalis europaea*, Vac myr – *Vaccinium myrtillus*, Vac vit – *Vaccinium vitis-idaea*, browned s. lessivés – browned soil lessivés, cx.prop.rusty & brownish rusty s. – complex of proper rusty and brownish rusty soils, podzolized rusty s. – podzolized rusty soils, podzol s. – podzol soils, pseudogley s. – pseudogley soils, cx.mucky & peat s. – complex of mucky and peat soils, peat s. – peat soils.

An analysis carried out revealed also that some of the species are not connected with a specific soil type or subtype (Fig. 7). *Vaccinium myrtillus* and *Orthilia secunda* should be mentioned here. They occur in entire

permanent area on different soils.

A carried out permutative Monte Carlo test revealed that soil types have a substantial influence on distribution of distinguished real and natural potential vegetation units and also on distribution of species characteristic for coniferous forests within examined permanent area ($p < 0.05$).

Discussion and conclusions

Research carried out revealed that different elements of vegetation and flora are spatially are more or less correlated with distinguished soil types and subtypes.

Admittedly, the most apparent is a connection of helophytic and aquatic vegetation with peat and mucky soils (Fig. 5-6), but it is an evident fact on account of swamp ecosystem ecological identity. Whereas mutual relations of vegetation and flora with soil in forest complex in mineral substratum require interpretation.

Drawn up CCA ordination diagrams (Fig. 5-7) present relations of examined elements in relation to axis 1, which indicates humidity and axis 2 illustrating trophic gradient of examined habitats.

Relatively high soil variability in study area is caused i.a. by a high diversity of soil parent material, from sands to loams and clays (Markiewicz 2000). Examined object is situated in outwash plain area with enclaves of morainic material (Wysota 1997). Textural diversity of soil material undoubtedly influences character of soil forming processes.

Also a percolative water regime occurring in the vast majority of Poland favouring nutrient leaching out of the soil profile affects soil variability (Bednarek, Prusinkiewicz 1997). It is shown in podzol soils forming and revealing podzolization process.

Carried out numerical analyses (Fig. 5, 6) result in a distinct connection of mixed coniferous forests (*Quercus robur*-*Pinetum*) and poorer forms of oak-linden-hornbeam forests (*Tilio-Carpinetum calamagrostietosum*) with podzolized rusty and podzol soils. The specificity of these plant communities is a distinct share of coniferous trees, mainly *Pinus sylvestris*, less often *Picea abies*. Share of coniferous trees is usually larger than deciduous trees which locally distinguishes communities of *Tilio-Carpinetum typicum*, form with *Pinus sylvestris* mentioned above (Fedorowicz 1997).

Large share of coniferous forest species has an essential effect on soil forming processes which was documented many times (Bublinec 1973, Biały 1997, Załuski et al. 1997, Pokojska et al. 1998). A podzol soils forming process

and rusty soils podzolization form a consequence thereof. Stress should be put on a fact that the object is surrounded by timber forests and species composition control is possible, which, in turn, can affect soil forming processes (cf. Biały 1999).

Moreover, a clear correlation of oak-linden-hornbeam forest typical form – *Tilio-Carpinetum typicum*, form with *Quercus robur* with browned soil lessivés was shown (Fig. 5). It is also justifiable because soils mentioned above developed from more fertile loamy sands lying on loam (Markiewicz 2000), creating typical for deciduous forests habitat.

By performing a comparison of numerical analyses executed for real vegetation (Fig. 5) and for potential natural vegetation (Fig. 6) with soil types, apparent is that a clearer image of mutual connections gives a potential vegetation and soil analysis. Against a background of soils both subassociations of *Tilio-Carpinetum* have distinguished distinctly (Fig. 6). Real vegetation and soil correlation (Fig. 5) is additionally complicated by an occurrence of anthropogenic forest communities with treestand being formed by forest management.

Specific correspondences were shown for coniferous forest species – soil relations (Fig. 7). The majority of analysed species is to a higher or lower extent connected with podzolized rusty soils. Part of them is connected with mucky and peat soil complex a few do not reveal a correlation with definite soils. With regard to humidity and trophy factors discussed species comprise a compact group (Fig. 7) with no clear preference to fairly dry, meso- and oligotrophic habitats. It is theoretically at variance with their habitat preferences (cf. Zarzycki et al. 2002, Rothmaler et al. 2005) and thereby indicates a large extent of local occurrence in different soil types.

In order to illustrate different distribution type of discussed species 2 demonstration cartograms in study area were put (Fig. 8). One of them presents distribution of *Vaccinium vitis-idaea* – a species with distribution correlated with podzolized rusty soils a thereby spatially limited. The second example is a cartogram of *Vaccinium myrtillus* – a species which reveals no local correlation between distinguished soil types with numerous localities in entire area. Spatial species distribution may be then a confirmation of habitat factors (cf. Faliński 2001).

On example of examined area it can be generally stated that canonical correspondence analysis (CCA) may reveal main spatial correlations between vegetation and flora with soils in timber forests. However, an anthropogenic forest character causes a less distinct image of mutual relation rather than in case of natural vegetation.

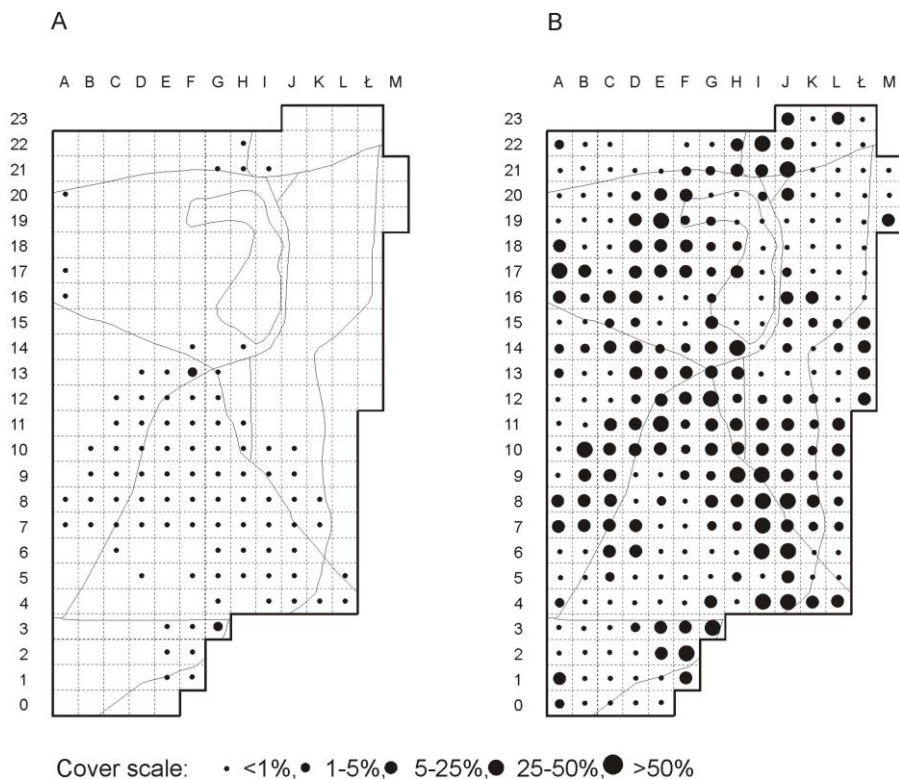


Fig. 8. *Vaccinium vitis-idaea* (A) and *Vaccinium myrtillus* (B) distribution in permanent study area (Paszek 1997, modified).

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Streszczenie

Celem pracy było zbadanie powiązań między rozmieszczeniem roślinności i rozmieszczeniem gleb na stałej powierzchni badawczej, leżącej w mezoregionie Równiny Urszulewskiej (NE Poland). Na podstawie szczegółowej dokumentacji kartograficznej gleb i roślinności, odniesionej do sieci 270 pól badawczych (metoda kartogramu), wykonano kanoniczną analizę zgodności CCA (program Canoco).

Analiza występowania roślinności rzeczywistej i gleb wykazała, że rozmieszczenie zbiorowisk roślinnych determinuje głównie gleba torfowa i gleba płowa zbrunatniała, a w mniejszym stopniu – gleba bielocowo-rdzawa. Podobne wyniki uzyskano dla relacji:

potencjalna roślinność naturalna – gleba.

Z diagramu ordynacyjnego CCA dla roślinności potencjalnej i gleb wynika wyraźne przywiązanie zbiorowisk roślinnych do typów gleb. Natomiast w przypadku analizy roślinności rzeczywistej i gleb zależności nie są tak ewidentne, w związku z istnieniem postaci degeneracyjnych i regeneracyjnych zbiorowisk leśnych.

Rozmieszczenie większości gatunków borowych jest skorelowane z występowaniem gleb biellicowo-rdzawych. Jednak niektóre gatunki nie są związane z konkretnym typem gleby i występują na całej stałej powierzchni.