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IDENTIFICATION AND ARRANGEMENT OF DEFORMED FOREST ASSOCIATIONS IN THE KABACKI FOREST RESERVE NEAR WARSAW

ABSTRACT: The paper presents results of syntaxonomic identification and numerical arranging (by means of detrended correspondence analysis) in deformed forest associations of the Kabacki Forest reserve near Warsaw. Results of arranging provided grounds for estimating the degree of homogeneity distinctness of distinguished actual and potential vegetation units. Also the relation of many ecological factors (soil properties, structural development, parameters of phytocenoses) with vegetation differentiation at present was examined.

KEY WORDS: Detrended correspondence analysis, identification, Kabacki Forest, arrangement, anthropogenous vegetation.

1. INTRODUCTION

At the present stage of development of phytosociology in Poland the majority of phytosociologists deal with the problem of identification, i.e. recognition of plant communities as types and proper syntaxonomic determination of phytocenoses examined (Matuszkiewicz 1981). This problem is of special significance in case of communities transformed under the influence of anthropogenous factors. Degenerative changes in species composition, natural structure and the characteristic apperance of phytocenoses (Faliński 1966) cause that when identifying vegetation types, especially of potential natural vegetation (Tuxen 1956) and also when estimating and interpreting ecologically the distinguished units, there is a relatively high margin of uncertainty and subjectivism.

For a long time there have been attempts in phytosociology to diminish the subjective element mainly by using statistical methods in data analysis (Motyka 1947, Matuszkiewicz 1948, Matuszkiewicz and Polakowska 1955, Faliński 1960, Kulczyński 1972). Recently there have been also attempts to use statistical methods in classification of deformed communities (Olaczek 1972, Jakubowska-Gabera 1985). According to above mentioned authors the mathematical methods alow to select and arrange quite precisely and objectively the group of records presenting various forms of community degeneration.

Here the procedure was slightly different. First of all the deformed oak-hornbeam communities in the Kabacki Forest reserve near Warsaw were identified using "classic" methods. Results of this identification were compared with results of arranging communities by statistical method. The newest and most frequently used numerical method of multidimensional arranging was applied, the so-called detrended correspondence analysis (Hill 1979, Hill and Gauch 1980). Results of numerical analyses were also used in an attempt of ecological interpretation of main floristic gradients characterizing plant communities examined.

2. OBJECT OF INVESTIGATIONS AND RESEARCH MATERIAL

Kabacki Forest which has been acknowledged since 1980 as a forest-landscape nature reserve is the biggest forest complex in the Warsaw area. Its total surface area is 918.02 ha, of which 95% is covered by forest associations.

Kabacki Forest is on a plain slightly undulated surface of Warsaw Upland (up to 110.5 m a.s.l.), connected from the north-east an almost 20 m slope with the Vistula ice-marginal valley. Sands, muddstones of various origin, and glacial drifts dominate in the reserve. Out of these formations different types of soils have been formed, among which the most frequently occurring ones are rusty soils formed of medium sands, pseudogley soils formed of silts loams and loams, degraded meadow black earth and leached brown soils formed of medium sands, because of fertile soils oak-hornbeam communities dominate in Kabacki Forest, but they are greatly transformed as a result of long lasting interference of man. The forest stands are mostly of artificial origin, and despite oak-hornbeam sites they consist mainly of Scots pine occupying over 58% of the reserve's area being 49% of total stand volume in the forest stand reserve. On the second place is the oak, first of all pedunculate oak with an area rate 31% and total stand volume 25%. Among the remaining species the most significant are: silver birch (7 and 11%), european aspen (2 and 5%) and hornbeam (1 and 4%). The age structure of forest stands is also not good enough, because the greatest surface area (47%) is covered by relatively young forest stands, 30–50 years old. Older forest stands cover only 17% (100 years and more). Because of such age structure the majority of forest stands has a single layer structure and only the older forest stands have usually the lower tree layer consisting mainly of hornbeam.

Within periodical works in forest arrangement in 1987 a first attempt was made as regards a complex phytosociological analysis of forest communities in Kabacki Forest. It was based on 58 records for chosen patches of vegetation consistently with Braun-Blanquet's method. For 30 of these records there were additional data on

Table 1. Cefficients of rectilinear correlation between coordinates of records on 4 first DCA axes and 16 soil parameters

Soil parameters	No. of arranging axis (DCA)			
	1	2	3	4
Content of particle of a diameter 1.0–0.1 mm	−0.22	−0.03	0.11	0.04
Content of particle of a diameter 0.1–0.02 mm	0.18	0.02	0.14	0.05
Content of particle of a diameter <0.02 mm	0.25	0.04	0.05	−0.18
pH in H_2O	−0.02	−0.10	−0.36*	0.09
pH in KCl	−0.06	−0.01	0.27	0.04
Ca^{++} content	0.12	0.19	−0.26	−0.13
Mg^{++} content	0.27	0.18	0.05	−0.08
K^{+} content	0.46**	0.15	−0.31	−0.27
Na^{+} content	−0.12	0.12	0.15	−0.21
Sum of basic cations (S)	0.13	0.22	−0.20	−0.15
Hydrolytic acidity (Hh)	−0.28	−0.10	−0.16	−0.35*
Sorptive capacity (T=S+Hh)	−0.19	−0.01	−0.21	−0.35*
$V=S/T \cdot 100\%$	0.24	0.32	−0.08	0.02
C_{org}	−0.21	−0.01	−0.22	−0.35*
N	−0.10	−0.16	−0.03	−0.16
C/N	0.26	−0.01	0.42	−0.23

$*0.01 < p \leq 0.05$, $**p \leq 0.01$; n=30.

the variability of some soil properties at different genetic levels of soil profiles obtained in the direct vicinity of these records. Table 1 presents the soil parameters taken into consideration in these studies.

3. STATISTICAL ANALYSIS OF DATA

In statistical analysis of floristic and soil data the method called detrended correspondence analysis (DCA) elaborated by Hill (1979), also Hill and Gauch (1980) was used. DCA is an improved version of the earlier method of reciprocal averaging (Hill 1973, 1974, also Brzeziecki 1984). DCA is one of the most frequently used arranging methods which is a modern, multidimensional improvement on earlier ordination techniques, including among others the commonly used in Poland Czekanowski's method and of Wrocław dendrite. Generally these methods try to arrange experimental surface (representing vegetation patches) in the coordinate system with axes corresponding to environmental factors having the greatest influence on vegetation under given conditions. But this requires a reduction of multidimensional phytosociological data, frequently including hundreds of species and experimental surfaces, and finding a two- and three-dimensional representation of these data for direct analysis and interpretation (Brzeziecki 1977a).

Arranging records by DCA method included all plant species as well as trees and bushes counted separately for each vegetation layer. Before starting the proper calculations the floristic data underwent initial transformation by substituting symbols from the 7-degree Braun-Blanquet quantitative scale by numerical values (Kuhn 1983).

After calculating the indices of record arranging by means of coefficient of rectilinear correlation, the strength of relation was determined between floristic trends indicated by four first DCA axes and chosen soil parameters, some structural characters of patches and mean ecological numbers (Zarzycki 1984). The latter were calculated for particular records on the basis of their species composition.

The records were arranged by DCA method using the programme DECORANA written by Hill (1979) and installed in computer Riad at the Calculation Centre of Academy of Agriculture. Other calculations were made using standard statistical programmes.

4. RESULTS

4.1. ACTUAL FOREST COMMUNITIES

In Kabacki Forest the following communities and forest associations were distinquished:

– Pino-Quercetum Kozł. 1925 – mid-Polish mixed forest covering some 5 ha of the poorest rusty soils in the reserve formed of shallow hardly medium sands deposited on shifting sands. This association is formed by 50 years old mixed forest stands with dominating Scots pine. The undergrowth is poorly developed and the herb layer does not have species of the Querco-Fagetea class.

– Populo tremulae-Quercetum Sokoł. 1980 – moist mixed coniferous, growing on 11 ha of pseudogley soils formed of shallow medium sands on a different (most frequently sandy loams) substrata. The association is formed by mixed stands from self-sown plants and offshoots, with dominant pedunculate oak and European aspen. Alder buckthorn dominates in udergrowth, whereas in the herb layer-species from the Vaccinio-Piceetea class and tussock grass (*Deschampsia caespitosa* (L.) P.B.), sedge (*Carex brizoides* L.) and common oosestrife (*Lysimachia vulgaris* L.).

– Tilio Carpinetum Tracz. 1962 – subcontinental hornbeam forest which covers the remaining surface area of the reserve. Because of strong and long-lasting anthropopressure patches of this association are greatly transformed and thus the following forms (mostly degenerative) of this associaton were distinguished:

a. T.-C. form with *Vaccinium myrtillus* L. including patches of 40–50 years old mixed stands with pine as a dominant species. They grow on fresh sandy loams and loamy slightly moist soils similar to leached brown soils, lessive and pseudogley soils.

This form has an averagely developed undergrowth where pedunculate oak (in drier places) and alder buckthorn (in more moist places) dominate. In the herb layer apart from *Vaccinium myrtillus* the most abundant are species of the Vaccinio-Piceetea class and *Festuca ovina* L. and *Agrostis vulgaris* With.

b. T.-C. initial form including patches of young (30–50 years old) mixed stands (partly offshoots and partly self-sown) growing on fertile and little permeable pseudogley soils and leached brown soils. In the strongly developed undergrowth alder buckthorn dominates, whereas in the poor herb layers – *Agrostis vulgaris* and species of the class Vaccinio-Piceetea. The contribution of species of the Querco--Fagetea is very small.

c. T.-C. form with *Rubus* sp. growing almost under all soil-site conditions in the reserve. Occurs in patches of different size in forest stands of all age classes. However, it occurs most frequently in thinned 60–100 years old single layer stands where Scots pine dominates. Usually the undergrowth is well developed and in the herb layer, apart from genus *Rubus*, there are frequently species of classes Vaccinio-Piceetea and Querco-Fagetea and a considerable group of mezo- and eutrophic accompanying species.

d. T.-C. typical form including patches with the oldest double-layer forest stands. In the top layer Scots pine and pedunculate oak dominate, and in the bottom one – hornbeam. This form, similarily as the previous one grows on various sandy loams (rarely silt soils), leached brown, lessive and pseudogley soils. The undergrowth and herb layer, depending on hornbeam density in the bottom tree layer vary as to the cover. In this form species of the class Querco-Fagetea occur more abundantly, whereas those of the Vaccinio-Piceetea class – less frequently. The most frequent accompanying species is *Oxalis acetosella.*

e. T.-C. form with *Urtica dioica* L. growing on patches of the most moist sites, mainly degraded meadow black earth. In young (30–50 years old) stands there are first of all black alder, Scots pine and to a smaller extent pedunculate oak. In the undergrowth, black elder, bird cherry and alder buckthorn dominate. *Urtica dioica* dominates in the herb layer.

4.2. POTENTIAL NATURAL VEGETATION

On the basis of soil-site conditions, present and expected vegetation development trends in the reserve, following units of potential natural vegetation have been distinguished:

– Pino-Quercetum and Populo tremulae-Quercetum described in subchapter 4.1. among units of present vegetation.

– Tilio-Carpinetum for which the following subassociations and ecological variants are distinguished:

a. T.-C. calamagrostietosum including poorer fresh-moist sites with characteristic rusty soils and leached brown soils formed of coarse sandy soils and light medium sands on loose sandy and coarse sandy soils.

b. T.-C. typicum fresh variant covering the biggest area of Kabacki Forest.

Proper lessive and leached brown soils of sandy loams and silt loams are characteristic for this unit.

c. T.-C. typicum fresh-moist variant is the second phytosociological unit in the reserve as regards the surface area occupied. It occurs mainly on proper pseudogley soils formed of silt loams and loams which during spring maintain moisture for a long – time.

d. T.-C. stachyetosum occurs sporadically in small patcheson pseudogley proper soils and on degraded meadow black earth formed of sandy fractions on loams and glacial drift.

– Circaceo-Alnetum Oberd. 1953 covers a narrow belt in the lowest part of the reserve (the Vistula ice-marginal valley) on dried fen soils and degraded meadow black earth.

4.3. ARRANGING RECORDS BY DCA METHOD

Results of arranging records by DCA method are presented graphically in Figures 1 and 2. Each record is indicated in the system of two first axes of multidimensional arrangement taking into consideration the highest per cent of data variability. Figure 1 shows the affiliation of records to units of actual vegetation. One can observe that units of actual vegetation distinguished within the Tilio-Carpinetum association have a similar degree of inside homogenity. This is indicated by the surface area of diagram occupied by particular units which seem to be only the

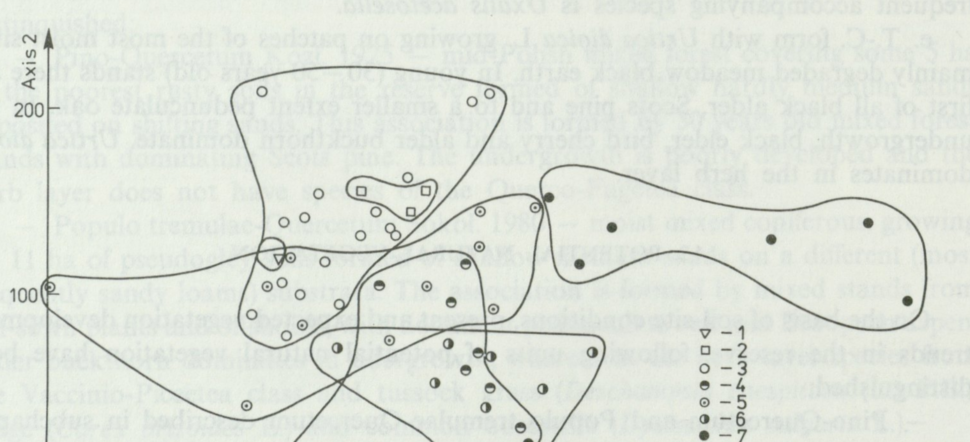

Fig. 1. Arranging of units of actual vegetation in the system of two first axes arrangement, calculated by DCA method

Units of vegetation: 1 — Pino-Quercetum, 2 — Populo tremulae-Quercetum, 3 — Tilio-Carpinetum form with *Vaccinium myrtillus*, 4 — T.-C. initial form, 5 — T.-C. form with *Rubus* sp., 6 — T.-C. typical form, 7 — T.-C. form with *Urtica dioica*

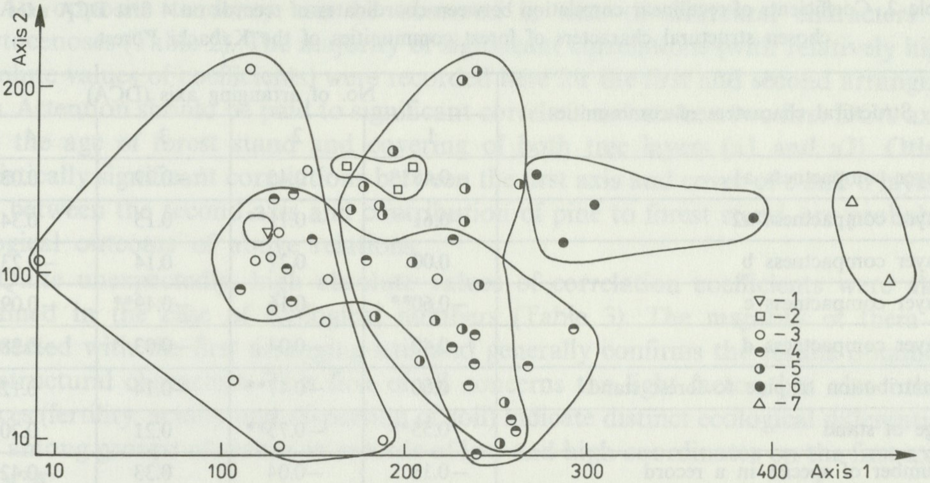

Fig. 2. Position of units of potential vegetation in the system of first axes of arrangement, calculated by DCA method

Syntaxonomic units: 1 – Pino-Quercetum, 2 – Populo tremulae-Quercetum, 3 – Tilio-Carpinetum calamagrostietosum, 4 – T.-C. typicum fresh variant, 5 – T.-C. typicum fresh-moist variant, 6 – T.-C. stachyetosum, 7 – Circaeo-Alnetum

function of the number of records qualified to a given unit. An exception here is only the unit determined as T.-C. initial form, which covers a considerable fragment of area ordination despite a relatively small number of records (as compared with T.-C. typical form and T.-C. form with *Rubus* sp.).

The measure of distinct character of distinguished syntaxonomic units may be also the extent of overlapping of area covered by particular units. For example, initial T.-C. form has common parts with three other units. The differentiation is also very small between the typical form and that with *Rubus* sp. T.-C.; both units cover the major part of the same fragment of diagram. However, a distinct character has the T.-C. form with *Urtica dioica* connected with positive extremum of the first arranging axis.

Figure 2 shows the position of units of potential vegetation in the system of two first DCA axes. The majority of distinguished units, i.e. T.-C. calamagrostietosum, T.-C. typicum fresh-moist variant, T.-C. stachyetosum and Circaeo-Alnetum, form a distinct ecological order along the first arranging axis. The only exception is the fresh-moist variant of T.-C. typicum. Records of this units do not cover an independent area in the diagram but overlap with two order units (T.-C. calamagrostietosum and T.-C. typicum fresh-moist variant).

Coordinates of records on arranging axes (four first axes are taken into consideration) were also used to estimate the strength of relation between main

Table 2. Coefficients of rectilinear correlation between coordinates of records on 4 first DCA axes and chosen structural characters of forest communities of the Kabacki Forest

Structural characters of communities	No. of arranging axis (DCA)			
	1	2	3	4
Layer compactness a1	−0.48**	0.45	−0.29	0.03
Layer compactness a2	0.61**	−0.71**	0.15	0.34
Layer compactness b	0.00	0.27	0.14	−0.23
Layer compactness c	−0.60**	0.16	−0.49**	−0.09
Layer compactness d	−0.40	−0.04	−0.03	−0.28
Contribution of pine to forest stand	0.00	−0.47**	−0.14	0.12
Age of stand	0.55**	−0.75**	0.21	0.20
Number of species in a record	−0.18	−0.04	0.33	−0.42*

$^*0.01 < p \leqslant 0{,}05$: $^{**}p \leqslant 0.01$; $n = 30$,

floristic trends revealed by arranging and some soil properties (Table 1) and selected structural-development parameters of phytocenoses examined (Table 2).

In the first case (soil properties) a great majority of correlations proves statistically insignificant. The only exception is the significant correlation between arrangement of records on the first axis and the content of potassium cations. Positive sign of the coefficient is that records on the right side of diagram generally have a higher content of potassium cations. Generally, in case of soil parameters, there is a tendency towards stronger correlations for further arranging axes (third and fourth). But as these axes take into consideration a relatively small part of data variability the information provided by these correlations is small.

Table 3. Coefficients of rectilinear correlation between coordinates of records on 4 first DCA axes and the indicatory ecological numbers (average for records)

Ecological factors	No. of arranging axis (DCA)			
	1	2	3	4
Light (L)	−0.75**	0.38*	−0.38*	−0.31
Moisture (M)	0.09	0.33	−0.35*	−0.32
Fertility (F)	0.84**	−0.02	0.45*	0.32
Soil acidity (R)	0.56**	0.18	0.52**	0.40*
Soil dispresion (D)	0.71**	−0.03	0.21	0.45**
Organic matter (H)	0.18	0.02	−0.31	0.22

$^*0.01 < p \leqslant 0{,}05$; $^{**}p \leqslant 0.01$; $n = 30$.

An opposite tendency can be observed in case of structural characters of phytocenoses (Table 2). The majority of significant correlations (with relatively high absolute values of coefficients) were recorded here for the first and second arranging axis. Attention should be paid to significant correlations between two first DCA axes and the age of forest stand and covering of both tree layers (a1 and a2). Other statistically significant correlations between the first axis and cover of c and d layers, and between the second axis and contribution of pine to forest stand, are probably a logical outcome of above relations.

Quite unexpectedly, high absolute values of correlation coefficients were also obtained in the case of ecological numbers (Table 3). The majority of them is connected with the first arranging axis and generally confirms the results obtained for structural characters. This first of all concerns the light factor, but also other indices (fertility, acidity and dispersion of soil) indicate distinct ecological differentiation among groups of species in records of low and high coordinates on the first axis of DCA.

5. DISCUSSION

Deformation of structure and species composition of the majority of modern phytocenoses causes problems when identifying these phytocenoses to syntaxons by traditional methods. Thus, phytosociologists have to find other than classic methodical solutions. However, it frequently results in forming new syntaxonomic units not always fully justified (e.g., Jutrzenka-Trzebiatowski 1980, Pacyniak 1981). The results of this research are also systems of degenerative phases and forms (Faliński 1966, Olaczek 1972, 1974). Although such systems allow to understand better general mechanisms of degenerative changes in phytocenoses, they do not solve problems connected with phytosociological analysis of specific, deformed communities. It seems that modern numerical methods may contribute to solution of these problems.

The DCA method used in present paper allowed, amongst other things, to estimate the homogeneity degree of distinguished syntaxonomic units. Such estimation may be used, for example, to find less specific units covering little isolated fragments of arranging diagrams, although it has to be remembered that defined units are fragments of multidimensional agglomeration and that two-dimensional diagram gives only an approximate locality of records. DCA method allows only to reduce deformations being a result of projection of multidimensional space on plane (two-dimensional space) to the minimuum but does not eliminate them. For example, the analysed here typical T.-C. form and form with *Rubus* sp. of this association in reality can be more isolated in multidimensional space than shown by the presented diagram.

Attention should be paid also to the schedule of units of potential natural vegetation obtained by DCA. It meets the increasing moisture and to some extent at least the increasing fertility of the site. A similar image was obtained under conditions of little deformed phytocenoses (Brzeziecki 1987b) which suggests that units of potential vegetation determined in Kabacki Forest were probably interpreted correctly. The fact that in the already mentioned ecological sequence there was no place for the unit determined as fresh-moist variant of T.-C. typicum indicates perhaps that this variant did not have to be distinguished. But it can not be excluded that if regeneration of phytocenoses takes place in the future the distinguished units will spread on the arranging diagram and each will have an independent position.

As it has been pointed out by some authors (Scamoni 1967, Olaczek 1972) one should distinguish anthropogenous associations from natural ones, but it is not enough to classify them, their ecology should be thoroughly and broadly studied. Thus, as positive effects connected with the use of DCA one should include the possibility of using indices of record arranging to determine ecological factors the most under correlated given conditions with vegetation differentiation. This shows that in the case of deformed communities soil factors are of smaller significance than some structural characters and development state of phytocenosis. Main trends of variability of soil conditions (as e.g., in little deformed communities examined by Matuszkiewicz (1974) and Wierzchowska (1981) but correspond to the transition from the most deformed communities (the youngest with one-layer and frequently monospecific forest stand) to those most resembling the natural ones. It can be expected that vegetation and soil variability will be consistent no sooner than at the end of regeneration and after the development of natural structure and species composition of phytocenoses.

Finally, it is worth pointing out the results obtained by mean of ecological numbers. Faliński (1966) suggests that degeneration of plant communities most frequently results in agglomerations of plants in the form of mixture of species of different ecology. In the case of communities of Kabacki Forest, even under conditions of advanced changes in phytocenosis, particular vegetation patches consist of species similarly related to environmental factors. In analysed communities the differences in ecology of species were big enough to confirm their significance by statistical methods.

6. SUMMARY

The paper presents results of phytosociological and ecological analysis of forest communities in the Kabacki Forest reserve near Warsaw. On the basis of 58 records from chosen vegetation patches and using Braun-Blanquet method the communities were identified syntaxonomically distinguishing 4 units at an association level: Pino-Quercetum Kozł. 1925, Populo tremulae-Quercetum Sokoł. 1980, Tilio-Carpinetum Tracz. 1962 and Circaeo-Alnetum Oberd. 1953. And additionally within the Tilio-Carpinetum association 5 units of present vegetation were distinguished: a form with *Vaccinium myrtillus*, initial form, a form with *Rubus* sp., typical form and a form with *Urtica dioica* and 4 units of potential vegetation: T.-C. calamagrostietosum, T.-C. typicum fresh variant, T.-C. typicum fresh-moist variant and T.-C. stachyetosum. Results of syntaxonomic identification were confronted with results of record arranging by the method of detrended correspondence analysis, which allowed to estimate the degree of homogeneity and the distinct character of distinguished present (Fig. 1) and potential (Fig. 2) vegetation units.

Coordinates of records on the first four axes of multidimensional arrangement were used to estimate the strength of relation between main floristic trends and chosen soil parameters (Table 1) and some structural characters of phytocenoses (Table 2). A significant relation has been observed between the position of records along two first arranging axes and the structure of forest stand and development state of community.

On the basis of indicatory numbers of ecological species (Table 3) it has been determined that despite the anthropogenous character of vegetation particular patches are composed of species having similar site requirements, which shakes the thesis about the ecological heterogeneity of anthropogenous communities.

7. POLISH SUMMARY

Praca zawiera wyniki analizy fitosocjologicznej i ekologicznej zniekształconych zbiorowisk leśnych, występujących w rezerwacie Las Kabacki k. Warszawy. Na podstawie 58 zdjęć fitosocjologicznych, wykonanych w wybranych płatach roślinności zgodnie z metodą Brauna-Blanqueta, dokonano identyfikacji przynależności syntaksonomicznej zbiorowisk, wyróżniając cztery jednostki w randze zespołu: Pino-Quercetum Kozł. 1925, Populo tremulae-Quercetum Sokoł. 1980, Tilio-Carpinetum Tracz. 1962 i Circaeo-Alnetum Oberd. 1953. Dodatkowo w ramach zespołu Tilio-Carpinetum wyróżniono 5 jednostek roślinności aktualnej: postać z *Vaccinium myrtillus*, postać inicjalna, postać z *Rubus* sp., postać typowa i postać z *Urtica dioica* oraz 4 jednostki roślinności potencjalnej: T.-C. calamagrostietosum, T.-C. typicum wariant świeży, T.-C. typicum wariant świeżo-wilgotny i T.-C. stachyetosum.

Wyniki identyfikacji syntaksonomicznej skonfrontowano z rezultatami porządkowania zdjęć metodą detrended correspondence analysis, co pozwoliło na ocenę stopnia homogenności i odrębności wyróżnionych jednostek roślinności aktualnej (rys. 1) i potencjalnej (rys. 2).

Współrzędne zdjęć fitosocjologicznych na pierwszych czterech osiach wielowymiarowego porządkowania wykorzystano do obliczenia siły związku między głównymi trendami florystycznymi oraz wybranymi parametrami glebowymi (tab. 1) i niektórymi cechami strukturalnymi fitocenoz (tab. 2). Stwierdzono istotną zależność między położeniem zdjęć wzdłuż dwóch pierwszych osi porządkowania a budową drzewostanu i statusem rozwojowym zbiorowiska.

Na podstawie wskaźnikowych liczb ekologicznych gatunków (tab. 3) ustalono, że mimo antropogenicznego charakteru roślinności poszczególne płaty zbudowane są z gatunków o zbliżonych wymaganiach siedliskowych, co podważa tezę o niejednorodności ekologicznej zbiorowisk antropogenicznych.

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