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FOREST COMMUNITIES AND THEIR TRANSFORMATIONS IN THE MARGINAL ZONE OF THE CARPATHIAN FOOTHILLS

Abstract: The paper presents the basic results of phytosociological studies carried out in the north-eastern part of the Wieliczka Foothills (part of the Carpathian Foothills). The basic forest communities of the investigated area (alder-ash carrs, oak-hornbeam forests, beech forests, mixed oak-pine forests and fir forests), identified using numerical classification, are characterized. Particular attention is focused on transformations in the communities described. The main causes of observed alterations are the inadequate forest management procedures leading to an impoverishment of the floral composition, decline of plant associations' character species and the induced expansion of *Carex brizoides* and *Rubus hirtus*.

1. Introduction

The living natural environment is a result of the complex interactions of many different factors, such as climate conditions, and geological and edaphic factors. The historical course of events linked with human activities in this area is also significant. Human activities alter the environment many times faster than natural environmental processes. Nature remaining under constant human pressure undergoes transformations. An understanding of the mechanisms of these transformations, identification of their main causes and trends, is an important tool in maintaining biodiversity and in planning reasonable natural resource management policies.

The area of the study covers a part of the Carpathian Foothills which, due to such qualities as its relief, soils and water network has always been attractive to humans. Traces of human presence in the Carpathian Foothills area date back to seven thousand years ago (Pietrzak, 1995a). This long-term, though irregular, course of human activity has determined the transformations of the natural environment. This is particularly evident in the case of vegetation cover. Two-thirds of the area investigated is covered by residential construction, roads, fields and grassland (Pietrzak, 1995b). Natural plant communities mainly occupy areas that are not suitable for agricultural use due to their relief or humidity. The distribution of forests is scattered (Fig. 1). Forests grow on the

Fig. 1. Distribution of forests in the research area.

Ryc. 1. Rozmieszczenie lasów na terenie badań.

steepest slopes and at sites that are strongly sectioned with incisions, ravines and stream valleys. Despite the continuous pressure of human activities they play a very significant role in the natural environment, creating habitats for many species of plants and animals (Hobbs, 1988; Hansen di Castri, 1992).

This article presents the basic results of a doctoral thesis defended at the Department of Plant Ecology of the Institute of Botany, Jagiellonian University (Stachurska, 1996). The full text of this thesis is being prepared for publication (Stachurska, 1998).

2. Area of study and methodology

The research carried out from 1993 to 1996 concerns the north-eastern part of the Wieliczka Foothills, covering the marginal area of the Carpathians between the valleys of the Raba and Uszwica rivers. According to the physiogeographical classification of Starkel (1988), this area covers the Brzesko Foothills and the Okocim Hills. According to geobotanical division it is part of the Loess Foothills in the subdivision of the Western Carpathians (Szafer, 1966). The geological structure of the marginal zone of the Carpathians is complex due to the overlapping of the flysch and Miocene formations (Olewicz, 1973). The geological structures are covered with thick quaternary formations (fine-grained loess-like deposits) and protrude to the surface only in individual spots (Kaszowski, Święchowicz, 1995). The soil cover is 80% *Haplic Luvisol* and *Stagnic Luvisol* (Skiba et al., 1995). In terms of climate conditions, the area is located within a moderately warm climate stage, with an average annual temperature of 8.6^{0}C (Angiel, Cisowska, 1995; Obrębska-Starklowa, Leśniak, 1988). An extensive characterization of the abiotic environment in the area investigated is given in the volume entitled 'Dynamika i antropogeniczne przeobrażenia progu Karpat między Rabą a Uszwicą' ('Dynamics and anthropogenic transformations of the natural environment of the edge zone of the Carpathian Foothills between the Raba and Uszwica rivers') (ed. by Kaszowski, 1995). Phytosociological records (375) were made using the Braun-Blanquet method (Braun-Blanquet, 1964; Szafer, 1966). The types of

forest communities and their diversity were identified based on results of numerical classification and ordination (SYNTAX 5 - Podani 1993; DCA, CANOCO - ter Braak 1988). Thorough investigations of the cartographic materials and inventory protocols led to the determination of the main factors causing their transformation. A complete description of the investigation methods is given by Stachurska (1996).

3. Results

The varied relief of the areas covered by forests and the related diversity of humidity and edaphic conditions influence the significant differentiation of forest communities over a relatively small area. The natural diversity is further increased by the effects of human activities, both direct ones, such as forest management and forest land use patterns, and indirect ones, such as airborne pollution, which significantly affects the condition and health of trees.

Twenty-eight forest communities were identified, including both natural and transformed communities (Tab. 1). Among them are the alder-ash carrs, oak-hornbeam forests, beech forests, mixed oak-pine forests and fir forests.

The alder-ash carrs (an intermediate community between *Circaeo-Alnetum* and *Carici remotae-Fraxinetum*) form along streams and on periodically flooded terraces. The dominant species of this kind of tree stand is the common alder (*Alnus glutinosa*), with the addition of the European ash (*Fraxinus excelsior*). The multi-layered undergrowth of this community is very rich. It contains species such as *Carex remota*, *Chaerophyllum hirsutum*, *Equisetum telmateia* and *Lycopus europaeus*. The alder-ash carrs often transform due to the lowering of groundwater table. The reduced habitat humidity is reflected by the lack of hydrophilous species. These processes can also lead to the expansion of species such as *Carex brizoides* (community *Alnus glutinosa-Carex brizoides*).

A characteristic association of the foothill stage is the oak-hornbeam forest, which dominates the majority of aforested areas. This community forms phytocoenoses belonging to many subcommunities and forms, differing in the specific floral composition of their undergrowth. This is linked with the fertility and humidity of the habitat. The tree layer of the oak-hornbeam forest may include species such as hornbeam (*Carpinus betulus*), oak (*Quercus robur*), lime (*Tilia cordata*), sycamore (*Acer pseudoplatanus*) and birch (*Betula pendula*).

The richest community (in terms of floral composition) is the *Tilio-Carpinetum stachyetosum* forming in damp and fresh habitats. It is characterized by the occurrence of alder-carr-specific species and hydrophilous species such as *Aegopodium podagraria*, *Circaea lutetiana*, *Ranunculus ficaria*, *Stachys sylvatica* and others. The most frequent oak-hornbeam subassociation is a typical community *Tilio-Carpinetum typicum* with dominant *Lamiastrum galeobdolon*, *Polygonatum multiflorum* and *Anemone nemorosa*. The subassociation *Tilio-Carpinetum caricetosum pilosae* occurs on the southern slopes. A character species for this plant community is *Carex pilosa*.

The transformation of oak-hornbeam forests in the area investigated is the result of inadequate forest management procedures. The introduction of pine (*Pinus sylvestris*) often leads to the acidification of soil and occurrence of acidophilous species such as

Tab. 1 Forest communities of north-eastern part of Wieliczka Foothills.

Tab. 1. Zbiorowiska leśne północno-wschodniej części Pogórza Wielickiego.

Class: *Querco-Fagetea* B.-Bl. et Vlieg. 1973
- Order: *Fagetalia* (Pawł. 1928 n. n.) R. Tx. et Diemont 1936
- Alliance: *Alno-Padion* Knapp 1942
  - community: alder-ash carr between associations *Circaeo-Alnetum* Oberd. 1953 and *Carici remotae-Fraxinetum* Koch 1926
  - community: *Alnus glutinosa – Carex brizoides*
- Alliance: *Carpinion betuli* Oberd. 1953
  - Association: *Tilio-Carpinetum* Traczyk 1962
    - Subassociation: *T.-C. stachyetosum, T.-C. caricetosum pilosae*, *T.-C. typicum*
- Alliance: *Fagion silvaticae* Pawł. 1928
  - Suballiance: *Eu-Fagion* Oberd. 1957
    - Association: *Dentario glandulosae-Fagetum* Klika 1927 em. 1964
  - Suballiance: *Luzulo-Fagion* Lohm. et Tx. 1954
    - Association: *Luzulo nemorosae-Fagetum* (Du Rietz 1923) Markgr. 1932 em. Meusel 1937
    - Association: *Luzulo pilosae-Fagetum* Mat. 1973
    - community: *Fagus sylvatica – Rubus hirtus*
    - community: *Fagus sylvatica – Carex brizoides*

Class: *Vaccinio-Piceetea* Br.-Bl. 1939
- Order: *Vaccinio-Piceetalia* Br.-Bl. 1939
- Alliance: *Vaccinio-Piceion* Oberd. 1957
  - Suballiance: *Vaccinio-Abietion* Oberd. 1962
    - Association: *Abietetum polonicum* (Dziub. 1928) Br.-Bl. et Vlieg 1939
    - community: *Abies alba – Rubus hirtus*
    - community: *Abies alba – Carex brizoides*
- Alliance: *Pino-Quercion* Medw.-Korn. 1959
  - Association: *Pino-Quercetum* Kozł. 1925 em. Mat. et. Pol. 1955
    - Subassociation: *P.-Q. typicum*

Vaccinium myrtillus. It also causes an impoverishment of the herb layer's floral diversity and the disappearance of mesophilous species characteristic for the oak-hornbeam forests. Partial clearing allows for the growth of photophilous species. This type of forest management policy leads to the formation of deciduous forests with a dominant percentage of birch (*Betula pendula*). The clearing of the tree crown could effect in the expansion of *Carex brizoides*. This extremely expansive species competes with most other vascular plants.

There are also some patches of secondary larch forest planted on former oak-hornbeam forest sites. They are characterized by a very poor herb layer.

The main type of beech forest occurring in the north-eastern part of the Wieliczka Foothills is the poor beech forest. The occurrence of two communities of poor beech forests - *Luzulo pilosae-Fagetum* typical of the lower parts and *Luzulo nemorosae-Fagetum* typical of the foothill stage - results from the fact that this area is the northernmost physical and geographical unit of the Carpathians, a site where plant species specific to lowlands and foothills overlap. The poor beech forests do not have a rich flora. Often, their tree layer is only composed of beech (*Fagus sylvatica*) and the herb layer of bundles of woodrush (*Luzula pilosa* or *Luzula nemorosa*) and a few species of vascular plants and mosses. In a few areas of particular geomorphological conditions (shaded and humid northern slopes) there are phytocoenoses of *Dentario glandulosae-Fagetum*, the main community of the upper forest zone (its character herb layer species is *Dentaria glandulosa*).

One of the transformations of the beech forests is the formation of phytocoenoses with a high percentage share of *Carex brizoides* or *Rubus hirtus*. These species expand very intensively under cleared crowns of beech trees. In a few sites there are also fragments of beech forest. The syntaxonomical position of these phytocoenoses is not clearly identified due to the lack of character species.

The mixed oak-pine forest (*Pino-Quercetum*) is relatively often transformed in the area investigated. It is characterized by multi-species tree stands with the pine *Pinus sylvestris*, a relatively well-developed shrub layer and the occurrence of the bog whortleberry (*Vaccinium myrtillus*), bracken (*Pteridium aquilinum*) and moss *Polytrichum attenuatum*. The appearance of phytocoenoses of this community is very diversified. Its natural character in this area is still questioned. Transformed mixed oak-pine forest phytocoenoses are often occurring in this area. They are characterized by either the domination of a single species in the herb layer (*Carex brizoides*, *Rubus hirtus*) or the lack of character species.

The group of mixed oak-pine forest communities also includes an distinctive form with artificially introduced *Quercus rubra*. The floral composition of the herb layer in this community (with a percentage of species characteristic for *Vaccinio-Piceetea*) indicates acidification of the habitat.

There are occasional occurrences of fir forests (*Abietetum polonicum*), representing a type of shaded moss-fern forest with dominant firs (*Abies alba*). Other species of the stand include the spruce (*Picea abies*) and beech (*Fagus sylvatica*). A characteristic feature of the fir forest is the rigorously regenerating fir and the occurrence of several species of ferns such as *Blechnum spicant*, *Dryopteris dilatata* and the interrupted club moss

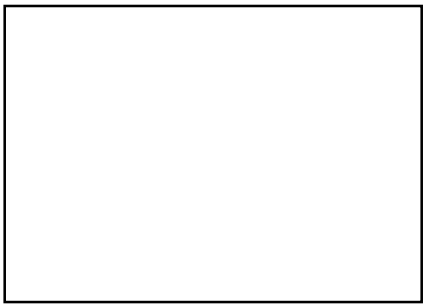

Fig. 2. Share of phytosociological records in the syntaxonomical units of forest communities:
A - association and typical lower units,
B - phytocoenoses dominated by *Carex brizoides* or *Rubus hirtus*,
C - other form of the association's deformation,
D - phytocoenoses of simplified forest communities.

Ryc. 2. Procentowy udział zdjęć fitosocjologicznych w grupach syntaksonomicznych zbiorowisk leśnych:
A - zespoły i jednostki niższe typowe,
B - fitocenozy z dominacją *Carex brizoides* lub *Rubus hirtus*,
C - inne formy zniekształcenia zespołów,
D - zdjęcia reprezentujące fragmenty zespołów.

(*Lycopodium annotinum*). As in all the previous cases, the transformation of these phytocoenoses is mainly reflected by a massive expansion of *Carex brizoides* or *Rubus hirtus* in the herb layer. This phenomenon is very often connected with clearing of the tree crowns.

The forest communities of the investigated part of the Wieliczka Foothills are currently transformed to a significant extent. Of the performed phytosiociological records, 54% describe transformed stands (Fig. 2). This problem applies to all the communities identified.

Inadequate forest management procedures are the main reason of the transformation of forest communities (Fig. 3). Introduction of tree species which are alien to the local natural habitats leads to changes in the floral composition of the herb layer and in the quantitative proportions of vascular plants. The alien tree species are *Larix decidua*, *Pinus sylvestris* and *Quercus rubra*. Their presence may cause impoverishment of the floral diversity or increase the percentage of acidophilous species such as *Vaccinium myrtillus*, *Oxalis acetosella* or *Pteridium aquillinum*. Unfavorable consequences for biodiversity may also result from the economic protection of certain tree species aimed at the generation of a high growth mass of timber. Due to such activities, the natural renewal of a multi-species tree stand is difficult. This also leads to the impoverishment of the floral composition of the undergrowth. This process leads to the formation of phytocoenoses with unclear syntaxonomical classification. Various forest management procedures favor the infiltration and expansion of some herbaceous plant species such as for example *Impatiens parviflora*. This is particularly discernible along forest roads. Such microsites have their own specific species composition, often significantly different from the stands of communities the roads cross.

The lighting of tree crowns, being a consequence of clearings and airborne pollution, favors the expansion of two plant species: *Carex brizoides* and *Rubus hirtus*. These species are a natural component of the undergrowth, but due to the increased access to light they colonize the available space. A dramatic effect of this phenomenon is the occurrence of stands of communities where the dominant component of a uniform undergrowth is one of the two species mentioned above.

Fig. 3. The influence of human activities on oak-hornbeam forests.

Ryc. 3. Wpływ oddziaływań człowieka na zbiorowiska grądowe.

4. Discussion

Forest management is considered to be one of the direct factors presently modeling the forest communities (Sokołowski, 1972; Rodwell, 1991; Medwecka-Kornaś, 1994). Management procedures, mainly clearing management, lead to significant structural changes in the communities. The species composition of clearings (both resulting from the cutting of trees and from natural clearing) depends on the ability of particular species to colonize (Matlack, 1994). The growth and vegetative propagation of two species (*Carex brizoides* and *Rubus hirtus*) frequently allow these species to dominate the herb layer in the area investigated. They are accompanied by anemochores and endozoochores. A positive correlation of the species composition of secondary forests with seeding methods is described by Dzwonko and Loster (1992).

Pinus sylvestris, the most frequently planted tree species in forest areas, together with its monocultures has been the subject of numerous observations (Olaczek, 1972, 1974; Kurowski, 1979; Jakubowska-Gabara, 1994). The results of this study confirm the presence of pine in oak-hornbeam forest habitats and the resulting impoverishment of the herb layer and occurrence of acidophilous species. The literature, however,

lacks data on studies of the influence of other introduced species. Therefore observations of the effects of *Larix decidua* or *Quercus rubra* broaden our knowledge of the problem of the influence of introduced species on forest undergrowth.

The low percentage of oligotrophic plant species in the herb layer of mixed oak-pine forests and fir forests and the high percentage of mesophilous species in all the types of forests identified is most probably an effect of the eutrophication of habitats caused by long range transport of airborne pollutants. The phenomena of vanishing acidophilous species and expansion of nitrophilous species were observed in both pine and deciduous forests (Kuhn, 1989; Medwecka-Kornaś, Gawroński, 1991; Sokołowski, 1991; Falkengren-Grerup, Tyler, 1991; Kwiatkowska, 1994; Thimonier et al., 1994). Experimental studies based on the changes of particular factors indicate a direct reaction of the herb layer (Becker et al., 1992; Mitka, 1993).

It is currently impossible to identify a single major factor responsible for the vegetation transformations observed. The dynamic transformations are a result of the complex impacts of human pressure, reactions of the abiotic environment and the resistance and flexibility of the components of plant communities.

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Zbiorowiska leśne i ich przekształcenia na progu Pogórza Karpackiego

Streszczenie

Praca przedstawia wyniki badań fitosocjologicznych prowadzonych w północno-wschodniej części Pogórza Wielickiego. Podano krótką charakterystykę głównych zbiorowisk leśnych występujących na badanym obszarze. Należą do nich: łęgi (zbiorowisko pośrednie między *Circaeo-Alnetum* i *Carici remotae-Fraxinetum*), grądy (*Tilio-Carpinetum*), kwaśne buczyny (*Luzulo pilosae-Fagetum* i *Luzulo nemorosae-Fagetum*), żyzne byczyny (*Dentario glandulosae-Fagetum*), kontynentalny bór mieszany (*Pino-Quercetum*), wyżynny jodłowy bór mieszany (*Abietetum polonicum*) (tab. 1). Zbiorowiska te zostały wyróżnione z zastosowaniem klasyfikacji i ordynacji numerycznej. Szczególną uwagę poświęcono przekształceniom zbiorowisk leśnych. Fitocenozy tych zbiorowisk stanowiły 54% zdjęć fitosocjologicznych (ryc. 2). Główną przyczyną obserwowanych zaburzeń jest gospodarka człowieka - zarówno jej bezpośredni wpływ poprzez gospodarkę leśną, jak również skutki zanieczyszczeń atmosferycznych (ryc. 3).