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CHANGING LAND USE IN RECENT DECADES AND ITS IMPACT ON PLANT COVER IN AGRICULTURAL AND FOREST LANDSCAPES IN POLAND

Abstract: The objective of this paper is to present the effects of general changes in land use in recent decades on plant cover structure in Poland. The paper is focused on spontaneous processes that occur in agricultural and forest areas being no longer under human pressure. Studies carried out in different geobotanical regions of Poland demonstrated that the directions and range of dynamic changes in plant cover are similar across the country. The formation of secondary forest phytocenoses, on the lands delivered from human activity is a common ecological process observed today in the agricultural landscape. In the dynamics of forest vegetation the basic process is regeneration after ceased use, and the introduction of legal protection.

Key words: cultural landscape, human disturbance, land use changes, regeneration, secondary succession, vegetation dynamics processes

1. INTRODUCTION

Over the last several thousand years the natural environment on the Earth has been transforming particularly rapidly due to the growing needs of a single species – *Homo sapiens*. Currently, the human pressure on our planet is so strong that the name of a new epoch – the anthropocene – is being used more and more frequently (CRUTZEN 2002; CRUTZEN, STEFFEN 2003; ZALASIEWICZ *et al*. 2008). The beginning of the 20th century can be assumed as the starting point of this period, when

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population size and consumption rate rapidly increased, and humans dominated nature and became the major factor shaping ecological systems.

The intensity of human activity fluctuates depending on historical period and geographical region (SUKOPP 1972; FOLEY *et al.* 2005). Because of surges of civilization changes, natural areas previously seized by humans recover their former status during periods of economic slowdown or because of advances in technology. Therefore, the present vegetation cover is a mosaic comprising patches which undergo dramatic changes, and those where succession and regeneration lead to the naturalization of ecological systems (FALIŃSKI 1986a; ELLENBERG 1988; VAN DER MAAREL 1988).

The objective of this paper is to present the effects of general changes in land use in recent decades on plant cover structure in Poland. Due to the extensive range and complexity of the discussed problem this paper is focused solely on general transformations in agricultural and forest areas, without reference to urban and industrial areas. Major interest is focused on spontaneous processes that occur in land being no longer under human pressure. Our article was inspired by papers on various aspects of dynamic transformation in plant cover in Poland, published in the current volume of *Folia Biologica et Oecologica* no. 7/2011.

2. GENERAL DIRECTIONS OF LAND USE CHANGES IN EUROPE OVER THE LAST TWO CENTURIES

Over about 5,000 years of agricultural history in Europe, the anthropogenic transformation of natural woodlands into mosaic landscapes with agricultural and semi-natural habitats has had the considerable side-effect of enhancing the diversity of vascular plants, biocoenoses and ecosystems (SUKOPP 1972; WALDHARDT *et al.* 2003). The highest diversity of plant cover in Europe was recorded in the 18^{th} and early 19^{th} centuries (SUKOPP 1972; ELLENBERG 1988; BAKKER 2005). Various extensive forms of use resulted in the permanent preservation of meadows, grasslands, pastures, forest edge communities and thermophilous forests (BAKKER 2005). In farming and forest areas unaffected by urbanization and industry, plant cover adapted to the specific way of use, which involved periodically repeated forms of human pressure (OLACZEK 1972). However, in those times human pressure did not yet result in significant changes in general environmental conditions, water and soil regime, or climate (SUKOPP 1972; KORNAŚ 1977).

In the middle of the twentieth century, the situation changed dramatically. Traditional and diverse management practices, which had been the main driving forces for the increase and preservation of biodiversity, were given up and were replaced by modern agriculture. Intensification of agriculture through the use of high-yielding crop varieties, fertilization, irrigation, and pesticides has contributed substantially to tremendous increases in food production over the past 50 years (MATSON *et al*. 1997). At the same time, many marginal areas with an unfavourable climate, topography and poor soils are threatened by abandonment. Such rural landscapes, with a traditional small-scale mosaic of grassland and arable fields, and thus a high diversity of habitats, have undergone radical change since crop production has been widely replaced by extensively managed grasslands or even forests in the past few decades (WALDHARDT *et al*. 2003).

These opposing processes have led to a decrease in biodiversity, which continues to be observed today, particularly in Western Europe (ELLENBERG 1988; BAKKER 2005; HODGSON *et al*. 2005; POSCHLOD *et al*. 2005; PETIT, FIRBANK 2006; REIDSMA *et al*. 2006; NIEDRIST *et al*. 2009).

In Europe the end of the 20th century brought further human-induced changes which had a significant effect on land use (POSCHLOD *et al*. 2005). The availability of inexpensive food imported from distant countries, changes in life style, and migration of people from rural to urban areas in search of jobs, have been causing the abandonment of areas formerly under human use (ELLENBERG 1988). These areas have became forested, or used for the construction of new residential estates, holiday resorts, or for public, transport and industrial infrastructure. Such a process has certain effects on the structure and dynamics of plant cover. Grasslands, arable fields and meadows become covered with trees, and young and secondary forests are formed, which are difficult to classify to the existing phytosociological units. Species banks in the landscape change, and the surface of grassland and meadow communities – remnants of former use – are reduced, until total decline occurs. The isolation of semi-natural vegetation patches has become a considerable problem (PETIT, FIRBANK 2006). The restoration of floristically rich meadows and grasslands is today greatly inhibited due to the limited migration opportunities of plants which were formerly dispersed by, e.g. domestic animals (POSCHLOD *et al*. 1998; BĄBA 2003; DZWONKO, LOSTER 2007).

In the middle of the 20th century some changes in European forest ecosystems have been caused by abandonment of use. Forests were no longer used for grazing, the collection of litter and faggots, or controlled burning (ELLENBERG 1988; FALIŃSKI 1986 a, 1988 a; BENGTSSON *et al.* 2000; ZERBE 2002).

At present after decades of executing technical and economic forest management, e.g. cultivation of coniferous monocultures, the so-called biological rationalisation methods are being introduced. Not only the answer for the question: "What to do to forge a sustained, stabile, biologically diverse and efficient forest?" is being sought but also "What not to do yet to achieve this target?" (PALUCH 2006).

Changes in silviculture theory and practice today result in the observed spontaneous regeneration of forest communities, reflected in such processes as increased share of deciduous trees and shrubs, and number of species characteristic for mesophilous and shady habitats. The encroachment of broad-leaved tree species and habitat fertilization often cause a decline in thermophilous and heliophilous species, whose occurrence may be connected with the management of forests in the past (e.g. TYBIRK, STRANDBERG 1999). Regeneration mainly occurs in protected forest areas where use is limited or has completely ceased (FALIŃSKI 1986 a).

When the above-described changes in agricultural and forest landscapes occur simultaneously over large areas they lead to a change in regional species polls, which may significantly influence the future formation of new species compositions (BENGTSSON *et al.* 2000; NAAF, WOLF 2011).

3. NATURE OF CHANGES IN LANDSCAPE MANAGEMENT IN THE 20TH CENTURY IN POLAND

The formation of plant cover in Poland has been under the influence of various natural and cultural factors (SZAFER 1977). Plant cover is highly diversified and includes: almost primeval communities, semi-natural and markedly anthropogenic communities. In general, the natural environment in Poland is preserved in a better condition than in other parts of the Central European Plain, and biodiversity in Poland has one of the highest levels in Europe (ANDRZEJEWSKI, WEIGLE 2003). This is influenced both by natural conditions and, different from other European countries, the nature of human pressure, for example uneven distribution of industrial and urban areas in Poland, as well as extensive farming on a large scale. The cultural landscape of the Polish countryside is unique on European scale because historical circumstances prevented Polish agriculture from doctrine-based collectivisation or large-acreage farming driven by the free market.

Changes that occurred in the Polish natural environment in recent centuries have been unevenly distributed and determined by political and social factors. On the land annexed by Prussia changes in plant cover caused by the developing civilization were similar to those in Western Europe, while in other regions they occurred with delay. This particularly refers to eastern and south-eastern regions of Poland, where the structure of farming land is highly fragmented, and where traditional farming methods continue to be used.

The transformations that occurred in Poland after World War II had a significant effect on intensified changes in land use. In Poland, under a new system, the migration of people and changes in land use took forms unknown before (CIOŁKOSZ, POŁAWSKI 2006). Abandoned and fallow lands were not uncommon in Poland in the period between the wars, yet the acreage of arable fields, meadows and pastures has been rapidly decreasing since 1938 (Fig. 1). The dramatic decrease in acreage occurred during and after WWII. In the 1940s, because of war damage and migration of people, fallow lands covered a considerable part of Poland, particularly in Regained Territories. In the 1950s and 1960s, during post-war reconstruction and development, the reduction in agricultural acreage was inhibited (Fig.1). Further reduction in agricultural acreage, and the emergence of lands left fallow for social and economic reasons, was associated with social and economic transformations that had led to the migration of people from rural to urban areas, and which continued gradually until as late as the 1980s (BAŃSKI 1997).

Another phase of growth in fallow land area followed the transformation of the political system between the end of the 1980s and the early 1990s (Fig. 1). This process was determined by various factors, e.g. economic, financial, poor soil quality and high fragmentation of farms (NOWICKI *et al*. 1998).

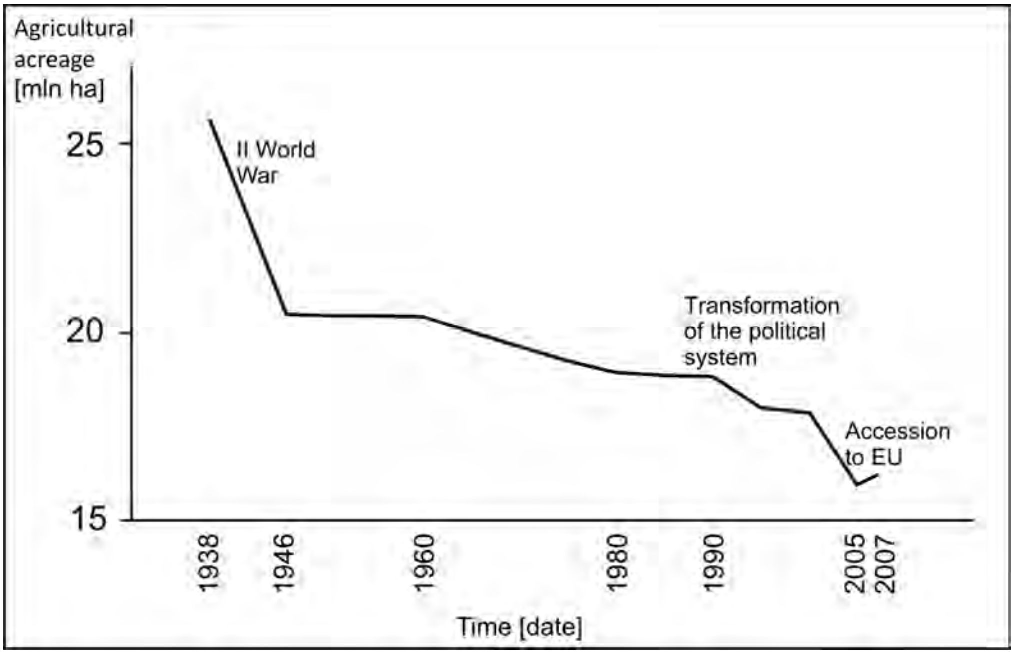

Fig. 1. Changes in agricultural area between 1938 and 2007 in Poland (based on data from URBAN 2009).

In the early 21st century further significant changes in the structure of agricultural areas were observed in Poland (Fig. 1). The accession of Poland to the European Union, and previous economic problems in Polish agriculture (e.g. decline of state-owned farms), compelled fallowing on a considerable area of agricultural land (PLAN ROZWOJU 2004-2006; PROGRAM ROZWOJU 2007-2013). After the accession of Poland to the EU the area of meadows and pastures increased slightly (Fig. 1), due to the introduction of EU direct subsidies and agri-environmental programmes, but, unfortunately, lands recovered to use are not in general as valuable in terms of natural features as those which have been lost within the past several decades.

Elimination of land from agricultural use triggers secondary succession, which is one of the major threats to the existence of valuable semi-natural communities in the landscape. In certain regions previously dominated by meadows and pastures farming was completely eliminated, while in others agriculture moved to more fertile soils, e.g. those located in drained areas. This has led to the decline of many patches of semi-natural meadow, moor and marshy communities (see: JASNOWSKI *et al*. 1968; JASNOWSKI 1972; FALKOWSKI 1983; KORNAŚ, DUBIEL 1990; OLACZEK *et al*. 1990; BARABASZ 1994; HERBICHOWA 1998; KUCHARSKI 1999). For similar reasons grazing on thermophilous grasslands, whose existence is dependent on extensive use, was abandoned (see: MICHALIK 1990 a; SENDEK, BABCZYŃSKA-SENDEK 1990; FIJAŁKOWSKI, ŚWIERCZYŃSKA 1991; DZWONKO, LOSTER 1998; WALDON 1999).

Another process parallel to fallowing is intensified agricultural practice (PROGRAM ROZWOJU 2007-2013), which, combined with land integration, leads to a further decrease in mosaic habitats, a reduction in the area of semi-natural communities, and elimination of woodstands, ponds and boundary strips, as well as the isolation of populations of stenotopic species.

Reduction in the area of semi-natural meadows and grasslands in the 20th century occurred with the simultaneous increase in forested areas and those intended for settlement and industrial use. After the period of 'hunger for wood and land' in the 19th century, which led to considerable deforestation (OLACZEK 1972), the area of forests increased by over 15,000 km^2 in 1930-2000, and the forestation rate in Poland increased from 20.8% in 1945 to 29.2% in 2010 (GUS 2010). These changes had a clearly regional nature and occurred mainly in north-western and south-eastern parts of Poland (Fig. 2). The forestation rate increased significantly in such regions as the Bieszczady Mountains and their vicinity (WOLSKI 2007), and in Regained Territories in western and northern Poland. This was associated with political transformations and the massive resettlement of people after Word War II (JUTRZENKA-TRZEBIATOWSKI 1999; CIOŁKOSZ, POŁAWSKI 2006; WOLSKI 2007).

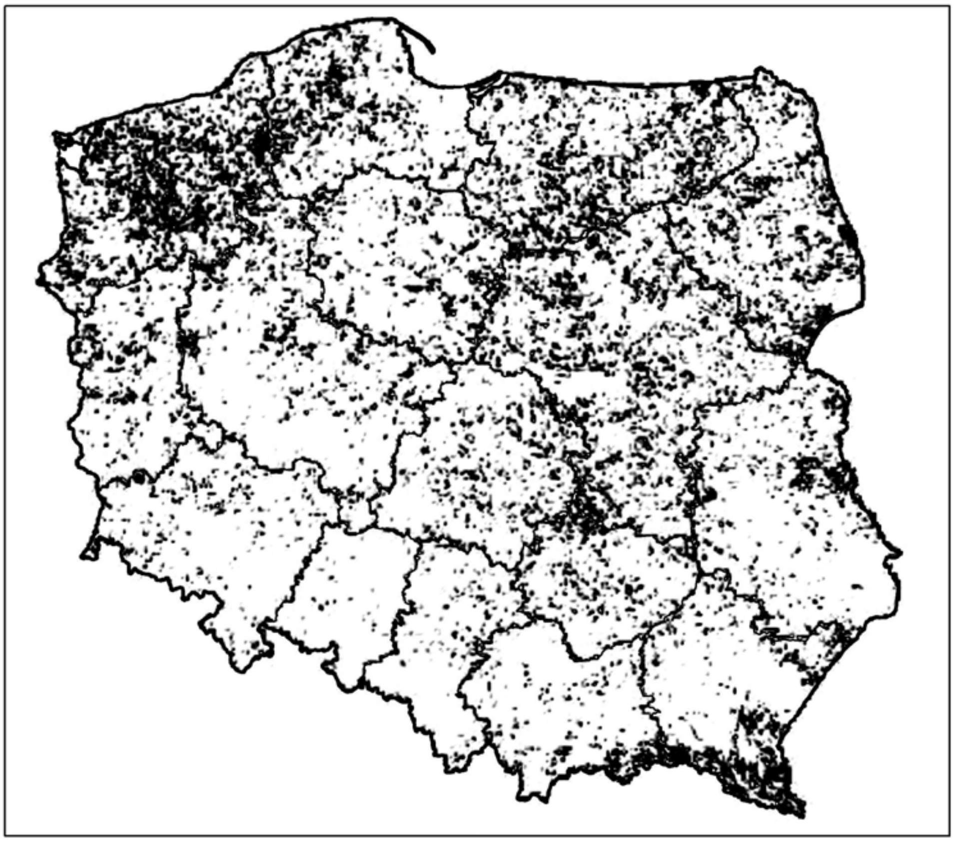

Fig. 2. Areas of recorded increase in forest cover in Poland 1930-2000 (after CIOŁKOSZ, POŁAWSKI 2006, modified).

A question of whether areas eliminated from agricultural use should be aforested or instead left until the spontaneous forest return is more and more frequently raised (WÓJCIK 1996; BALCERKIEWICZ 1997; KUJAWA-PAWLACZYK, PAWLACZYK 1997; SZWAGRZYK 1997; JERMACZEK 2008; MATYSIAK, DEMBEK 2008). Forestation causes a permanent change in land use, requires considerable financial input, and is time-consuming and labour-intensive (REWUCKI 2008; SKOLUD 2008). On the other hand, several hundred years may be needed for spontaneous forest return (FALIŃSKI 1986a,b; BOMANOWSKA, ADAMOWSKI 2007, 2009), and this process does not always lead to the recovery of the former forest community (GRINN-GOFROŃ 2007; KUJAWA-PAWLACZYK, PAWLACZYK 1997; ŁASKA 1997). The species composition in secondary forests established during spontaneous or assisted succession depends, for example, on the availability of diaspores of ancient forest species. Therefore, the ability of plants to migrate within the landscape is the key factor determining the time needed for regeneration and naturalization of the discussed natural systems (DZWONKO, LOSTER 1992; ORCZEWSKA, FERNES 2011). Many authors (RICHARDSON *et al*. 1994; FALIŃSKI 1998b; REJMÁNEK 1999; BARABASZ-KRASNY 2002; MEINERS *et al*. 2002; ADAMOWSKI, BOMANOWSKA 2007, 2008) also draw attention to the fact that fallow lands are susceptible to invasion by alien species.

Methods of use of forest ecosystems have also changed over recent decades. In the early 20th century traditional forms of use such as grazing and litter removal, were eliminated in forests, although in some regions they remained as an occasional practice until the 1980s. These changes resulted from the implementation of relevant regulations, and also from civilization progress and reduced demand for "historical forest services". The early 20th century brought the dominance of forest management giving preference to the establishment of coniferous monoculture and limiting the use of selection-cutting system (OLACZEK 1976).

An essential stage of changing forest use was ‘ecological forest management’, introduced by legislation in early 1990s. New principles for forest-growing included, e.g. better adjustment of tree species composition to habitats, wider use of complex felling, withdrawal of clearcutting in certain habitats, and limitation of use in so-called special forestry management units, including the gradual restructuring of coniferous tree monocultures established in past times. In the current understanding of the environmental role of forests the older methods, such as selection-cutting are gaining in importance again (PALUCH 2006).

The ecological effects of these changes can be observed in many forms today. One of their symptoms is the common regeneration of hornbeam forests, *Carpinion*, and beech forests, *Fagion*, (see: CZEREPKO 2004; KUROWSKI 2004; MACIEJEWSKI 2011) and the disappearance of some communities from the Polish forest landscape. The area covered by thermophilous oak forest *Potentillo albae-Quercetum*, subboreal mixed forest *Serratulo-Pinetum,* and pine forests with pasque-flowers *Peucedano-Pinetum pulsatilletosum,* is decreasing. All this leads to a decrease in the internal diversification of vegetation units (JAKUBOWSKA-GABARA 1993; MATUSZKIEWICZ 2007). It turns out that not only substitute communities described as degenerated forms (OLACZEK 1972), but also some well-known forest associations have developed and enlarged their area under long human pressure. There is only a difference in the time needed to initiate the transformation.

Agricultural or forest management has also ceased in areas with valuable natural features, those under legal protection, or in their direct neighbourhood (KUJAWA-PAWLACZYK, PAWLACZYK 1997; ADAMOWSKI, BOMANOWSKA 2008; MATYSIAK, DEMBEK 2008; MICHALSKA-HEJDUK, BOMANOWSKA 2009). Today there are ten forms of nature conservation in Poland established by law. National parks and reserves cover about 1.6% of Poland's area, while landscape parks and protected landscape areas account for over 30% (GUS 2010). In these areas human pressure has been largely limited. Recently a significant impact on the increase in the surface of protected areas has been attributed to the European network of Natura 2000 sites, which in total covers about 20% of Poland and partly overlaps the national system for nature conservation. In protected areas where forest or agriculture management ceased, transformations in plant cover also contribute most frequently to a retreating of heliophilous species typical for grasslands, meadows and thermophilous forests (see: MICHALIK 1990b; JAKUBOWSKA-GABARA 1991; KAŹMIERCZAKOWA, GRODZIŃSKA 2007; MICHALSKA-HEJDUK, BOMANOWSKA 2009). Active conservation measures, which are expensive and demand regular use, are implemented for the protection of these sites. Protected sites are also good testing grounds for studies on spontaneous ecological processes (see: FALIŃSKI 1986a; SZWAGRZYK 1994).

In summary, the agricultural and forest landscape of Poland has been considerably transformed over recent decades. Naturalization and increased human pressure coexist, and their effects are difficult to separate (BALON, GERMAN 2001). With respect to plant cover, their effects occur after different periods of time, but are widely present and have a clearly defined direction. For example, a decrease in areas of semi-natural grasslands and meadows, and dry coniferous and thermophilous forests is observed, as well as a decline in habitats with plants typical for these formations. Diversity of plant cover is decreasing, and mesophilous species, common and having high dispersion and growth potential, are spreading. Stenotopic species having poor competitive features and limited dispersion potential are declining. These transformations occur in parallel with the invasion of geographically alien species which take advantage of newly formed ecological niches. Both in agricultural and forest landscapes anthropophytes often play a significant role in the transformation of plant cover on abandoned sites where human pressure has ceased.

4. EXAMPLES OF CURRENT GEOBOTANICAL STUDIES INDICATING CHANGES IN FLORA AND VEGETATION IN THE LANDSCAPE OF POLAND

Changes in the intensity of land use have far-going consequences for the dynamics of flora and vegetation in Poland, and their registration and interpretation is a vital ecological subject. This gives botanists and ecologists an incentive to undertake detailed studies on the contemporary dynamic changes of plant cover in Polish landscape.

This volume of *Folia Biologica et Oecologica* contains papers on regional research (e.g. DZWONKO 2011; TOWPASZ, STACHURSKA-SWAKOŃ 2011; ZAŁUSKI 2011) and reports on studies carried out on specific objects, analyzing transformations in their flora and vegetation in various aspects and at various levels of organization.

Studies carried out in different geobotanical regions of Poland demonstrated that the directions and range of dynamic changes in plant cover are similar across the country. This is confirmed by studies in southern Poland (DZWONKO 2011; SKOWRONEK *et al.* 2011; ŚWIERCZ 2011; TOWPASZ, STACHURSKA-SWAKOŃ 2011; WILCZEK *et al.* 2011), south-eastern (CWENER, NOWAK 2011) and central (KIEDRZYŃSKI *et al.* 2011, KUROWSKI *et al.* 2011; WOZIWODA, AMBROŻKIEWICZ 2011; WOZIWODA, KOMPERDA 2011; WOZIWODA, MICHALSKA-HEJDUK 2011) as well as north and western regions of Poland (ADAMOWSKI, BOMANOWSKA 2011; RATYŃSKA *et al.* 2011; ZAŁUSKI 2011).

The formation of secondary forest phytocenoses, spontaneous or human-assisted, is a common ecological process observed today in the landscape.

Therefore, the process of secondary succession is one of the most frequently studied problems in the presented papers. Detailed data on changes in species composition during secondary succession were obtained from permanent study plots (ADAMOWSKI, BOMANOWSKA 2011; DZWONKO 2011). Data from multi-annual observational series presented in the listed papers are highly valuable, as they explain in detail the reasons for and mechanisms of dynamics in contemporary plant cover on various scales, and also enable the development of models and the testing of ecological hypotheses. They are also unique because they require the process to be followed for decades longer than the lifespan of a single researcher, and therefore such studies are undertaken quite rarely.

Much more popular studies on secondary succession employ a chronosequence method based on the description of floristic compositions developed at a certain time or in a predicted time. Interesting conclusions on this type of study were made based on the analysis of changes in plant cover carried out using transects established on the patches abandoned in different periods (WOZIWODA, AMBROŻKIEWICZ 2011; WOZIWODA, MICHALSKA-HEJDUK 2011). Valuable information on general directions of succession were provided by floristical and phytosociological studies repeated after several decades on the sites of semi-natural protected communities (CWENER, NOWAK 2011; DZWONKO 2011). Study results confirmed the decline of precious meadow and grassland communities, associated with extensive management, even on the scale of entire regions (DZWONKO 2011; ZAŁUSKI 2011). This results in local and a regional decrease in floristical diversity and the formation of secondary forest and brushwood communities of lower floristical value.

An important group of papers is focused on changes in forest vegetation. Transformations of forest communities result, among other things, from regeneration after ceased use, and the introduction of legal protection (KIEDRZYŃSKI *et al*. 2011). Changes are also caused by the introduction and invasion of alien species (RATYŃSKA *et al*. 2011; SKOWRONEK *et. al*. 2011; TOWPASZ, STACHURSKA-SWAKOŃ 2011). Advancing fragmentation of the landscape, and isolation of old forest patches is a vital aspect in the formation of species composition in forest phytocenoses (DZWONKO 2011; WILCZEK *et al*. 2011). Interesting results were provide the application of new measures and analysis methods of floristic transformations in forest phytocoenoses (WILCZEK *et al*. 2011; SKOWRONEK *et. al*. 2011). Dynamic changes in forests, reflected by the increasing share of mesophilous species, can lead to changes in the range of communities across regions. Communities formed by heliophilous and thermophilous species decline, and the area of coniferous forest communities decreases (ZAŁUSKI 2011).

Dynamic changes in vegetation are also influenced by anthropogenic modification in soil conditions, like drainage (KUROWSKI et al. 2011; WOZIWODA, MICHALSKA-HEJDUK 2011) or alkaline dust pollution (ŚWIERCZ 2011). Soil drainage leads to the decline of many hygrophilous forest communities and moors (ZAŁUSKI 2011). If habitats are at risk of damage, sites of valuable protected species require metaplantation to preserve the complete genetic pool of the native flora (KUROWSKI *et al*. 2011).

The above-listed examples confirm the nature of changes in the plant cover of Poland, and are a sample of current studies on the dynamics and structure of vegetation in Poland. As with papers on the dynamics of flora in protected areas (HOLEKSA, SZWAGRZYK 2006), the study results contained in this volume of *Folia Biologica et Oecologia* contribute to the better understanding of the directions of changes. The detailed ecological and biological mechanisms driving these processes still remain a challenge for Polish geobotanists.

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EFFECT OF CHANGES IN LAND USE DURING THE 20TH CENTURY ON WOODLAND AND CALCAREOUS GRASSLAND VEGETATION IN SOUTHERN POLAND

Abstract: In the modern agricultural landscape major threats to plant species diversity are loss and fragmentation of habitats and communities. During the last century natural and semi-natural communities have faced also cessation of tradition management and increased load of nutrients. This paper presents a survey of studies on vegetation dynamics of woodlands in the northern part of the Carpathian foothills and of calcareous grasslands on limestone hills near Kraków. The causes of far-going changes observed in communities of these types and possible management for their conservation are discussed. The nature conservation value of woods can be assessed by means of ancient woodland plant species indicators.

Key words: literature review; nature conservation; permanent plots; species diversity; vegetation change

1. INTRODUCTION

Landscape transformation due to land use changes is one of the main reasons for decline in species diversity in natural and semi-natural habitats in the 20th century. In central Europe changes in land use have occurred since the first Neolithic settlements about 7000-9000 years ago. The first types of land use were grazing of woodlands and alternating arable field-pasture farming (KRUK, MILISAUSKAS 1999; POSCHLOD *et al*. 2005). Since that time the variety of land use types increased until

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the 19th century causing a high diversity of habitats and species. The highest plant species diversity occurred probably in the first half of the 19th century. From that period changes in land use have caused a decrease in biodiversity. The novel land use changes have included among other: the intensification of arable field farming due to development of mineral fertilizers, the land consolidation, the drainage of peatlands and wetlands, the abandonment of low-intensity grazing systems, and afforestation with non-indigenous trees (POSCHLOD, BONN 1998; POSCHLOD *et al*. 2005). These changes continued during most decades of the 20th century. Particularly deterioration and fragmentation of habitats have created major extinction threats as they reduce the availability of suitable habitats for many species. Decreasing population sizes lead to an enhanced extinction risk among species with poor dispersal ability, especially when they occur in isolated sites where local extinctions are not counterpoised by colonisations. In a traditional man-made landscape there was the highest diversity of dispersal processes connected with a great diversity of land use practices. In the modern agricultural landscape most of these processes became lost or changed (POSCHLOD, BONN 1998). Many semi-natural grasslands, originating from traditional agriculture and grazing, are nowadays threatened also by habitat degradation due to agricultural or atmospheric inputs or due to secondary succession occurring after land abandonment.

Vegetation changes can be studied in two ways. The first is the space-for-time substitution approach where different phases of a succession are studied in different sites and it is assumed that the changes observed are time-dependent. This approach has been applied most often. It is emphasized that although this approach may be useful for qualitative description and for hypothesis generation, it is unreliable for a deeper understanding of successional changes because site history is also important, and the assumption of similar habitats of different successional phases may not be valid. The second approach is to continuously study vegetation applying some formal monitoring system – above all long-term permanent plot observations. Vegetation changes measured in this way can be related directly to time in combination with other treatments imposed on it. Therefore hypotheses of causes and mechanisms of changes in species composition of communities can be tested in permanent plot experiments. Long-term monitoring, by using permanent plots is the most appropriate method to distinguish between trends and fluctuations in vegetation dynamics, and, in nature preservation, to evaluation whether the applied management is in accordance with the conservation goal (BAKKER *et al*. 1996; BAKKER *et al*. 2002).

Some examples of vegetation changes resulting from different changes in land use in southern Poland between the 1950s and the 1980s were presented and discussed by KORNAŚ (1990). They concerned vegetation in the Gorce Mts. and in the Ojców National Park and were based also on the results of phytosociological studies in which relevés were repeated on marked plots and mapping of the actual vegetation was repeated in the same area. The present paper discusses the causes, rate and direction of changes and possible management for conservation of woodland vegetation in the northern part of the Carpathian foothills, and of calcareous grassland vegetation on limestone hills near Kraków, based on detailed studies including permanent plot observations and experiments.

2. CHANGES IN SPECIES RICHNESS AND COMPOSITION OF WOODLANDS AND THE ASSESSMENT OF THEIR CONSERVATION VALUE

In the present-day agricultural landscapes of southern Poland the ancient deciduous woodlands frequently occupy small, isolated areas, similarly as in other parts of temperate Europe. For example in the northern part of the foothills of the Carpathians only a few woodlands cover large areas, several dozen hectares, while the others are small patches of woods, from several dozen square metres to several hectares, in places unsuitable for agriculture, such as on steep slopes of stream valleys and on hill slopes too steep for cultivation. Most of these woodlands are remnants of primary forests which still covered the greater part of this area during the Middle Ages. Only a few originated later, on land which had previously been in agricultural use. The remnants of ancient forests represent such associations as: *Tilio cordatae-Carpinetum betuli*, *Dentario glandulosae-Fagetum*, *Pino-Quercetum*, and seldom *Carici remotae-Fraxinetum*. As it is difficult to prove that any particular wood is primary it is more useful to discuss ancient woods, which are defined as woods in existence before some date selected on the basis of available historical documents – opposed to those which are more recent. In southern Poland a specified date may be appointed by Mieg's map from 1779-1783. Many authors have pointed out that woodlands which are isolated in an agricultural landscape are habitat islands. The Carpathian foothills were colonized gradually. In some parts intensive colonization began already in the fifteenth century, and most woodland islands currently existing were formed by fragmentation of former large forests earlier than in other parts of this area. The woodlands in the areas colonized earlier and in a much greater extent are often more isolated and also more anthropogenically disturbed because of grazing, trampling, rubbish dumping and the like.

Detailed analyses in the Wierzbanówka valley (Pogórze Wielickie) – a typical fragment of the northern part of the Carpathian foothills, showed that the number of plant species in woodland islands was related to their area, isolation, shape and habitat diversity. Compared with the more recently isolated and less disturbed woodlands, those isolated for longer periods and more anthropogenically disturbed were found to have fewer species, including fewer woodland species, i.e. species characteristic of the classes *Querco-Fagetea* and *Vaccinio-Piceetea*, and some other species closely associated with woodland conditions. On the other hand, significantly more non-woodland species were present here. It was also found that groups of small ancient woods (0.008-2.16 ha) support more woodland species than do single woods equal in area (DZWONKO, LOSTER 1988, 1989). These results indicate that preservation of many small woodland remnants in an agricultural landscape may be of great importance for the maintenance of local species richness and the protection of woodland species. The vegetatively propagating long-lived perennials predominate among the woodland species of temperate deciduous forests. Such species can persist for a very long time in small ancient woods, which may become lasting refuges for many of them if they are not subjected to too strong anthropogenic pressure, including grazing, trampling, and rubbish dumping.

Ancient deciduous woodlands are, as a rule, considerably richer in woodland species than the recent woods and plantations on abandoned fields, meadows and grasslands (PETERKEN, GAME 1984; DZWONKO, LOSTER 1989; WULF 1997; HONNAY *et al*. 1998; HERMY *et al*. 1999). Recent studies have shown that natural regeneration of woodland communities is very slow and it is possible only in sites immediately adjacent to ancient woodlands - the sources of woodland species diaspores (PETERKEN, GAME 1984; DZWONKO 1993; DZWONKO, GAWROŃSKI 1994; MATLACK 1994; BRUNET, VON OHEIMB 1998; BOSSUYT, HERMY 2000). The soil seed banks cannot be sources of diaspores even in the sites agriculturally used for a short period since a majority of the woodland vascular plant species form only transient or short-term persistent seed banks and their seeds do not survive in the soil longer than few years (JANKOWSKA-BŁASZCZUK, GRUBB 1997; BEKKER *et al*. 1998). Even in the soil seed banks in ancient woods many woodland species are scarce or absent; shade-intolerant species, representing earlier stages of succession predominate there generally (PIROŻNIKOW 1983; WARR *et al*. 1994; JANKOWSKA-BŁASZCZUK 1998).

At present natural regeneration of full floristic composition of woodland communities in sites spatially isolated from ancient woodlands is impossible because of poor dispersal ability of many woodland species (WHITNEY, FOSTER 1988; DZWONKO, LOSTER 1989, 1992; MATLACK, 1994; GRASHOF-BOKDAM, GEERTSEMA 1998). Even recent woods adjacent to ancient woodlands are very slowly colonised by woodland species. Migration rates of woodland species to such recent woods varied in general from 0.0 to 1.2 m year^{-1}, and rarely exceed 1.5 m year^{-1} (Table 1). It seems that the secondary woods are generally most quickly colonized by endozoochores and hovering and flying anemochores and most slowly by heavy anemochores, myrmecochores and barochores. The results of detailed studies suggest that in the present-day landscapes, species-rich woodland communities can be maintained first of all in the remnants of ancient woodlands and these woods should be protected in the first place. Recent woods may be more effectively colonised by woodland species only when they are directly adjacent to ancient woodlands, and are dominated by broad-leaved trees with quickly decomposing litter, and if these relationships will be stable for a relatively long period.

Table 1. Frequency of woodland species on the plots in an oak-hornbeam ancient wood (AW, 24 plots) and in an adjacent 52-year old pine wood (RW, 36 plots) in the Skołczanka reserve, and mean migration rates (m year^{-1}) of species in the pine wood based on the farthest individuals. For comparison, mean migration rates of species in recent deciduous woods in the Carpathian foothills (CF), southern Sweden (SS; Brunet, von Oheimb 1998), and central Belgium (CB; Bossuyt *et al*. 1999; Honnay *et al*. 1999) are given. An – anemochore, Au – autochore, B – barochore, En – endozoochore, M – myrmecochore, V – vegetative reproduction. After Dzwonko (2001).

			Frequency		Migration rate			
Species			AW	RW	RW	CF	SS	CB
Species more frequent in the ancient wood								
Convallaria majalis	En	V	22^{***}	10	0.18	-	0.43	0.45
Melica nutans	M	V	22^{***}	9	0.29	-	0.42	-
Lamiastrum galeobdolon	M	V	22^{***}	3	0.27	2.28	0.50	1.15
Viola reichenbachiana	M		21^{***}	13	0.24	1.00	0.67	-
Anemone nemorosa	M	V	20^{***}	6	0.21	2.09	0.85	0.55
Mercurialis perennis	M	V	18^{***}	2	0.05	-	0.73	0.28
Polygonatum multiflorum	En	V	15^{*}	10	0.24	2.09	0.63	0.25
Ajuga reptans	M	V	8^{***}	0	0.00	-	-	-
Aegopodium podagraria	B	V	6^{**}	0	0.00	0.95	-	-
Carex digitata	M		3	0	0.00	-	0.00	-
Lilium martagon	An		3	0	0.00	-	-	-
Species more frequent in the recent wood								
Rubus hirtus	En	V	6	36^{***}	>0.53	-	0.88	-
Mycelis muralis	An		14	30^{+}	>0.53	-	-	-
Dryopteris carthusiana	An		2	26^{***}	>0.53	1.57	0.44	-
Hieracium murorum	An		0	6^{*}	-	-	-	-
Vaccinium myrtillus	En	V	0	5^{+}	-	-	-	-
Other species								
Geranium robertianum	Au		20	33	>0.53	-	-	-
Moehringia trinervia	M		13	17	>0.53	1.29	-	-
Luzula pilosa	M		8	13	0.38	0.72	-	-
Solidago virgaurea	An		2	4	0.34	-	-	-

$^{+}$ 0.1 > P > 0.05; * 0.05 > P > 0.01; ** 0.01 > P > 0.001; *** P < 0.001.

Woodland plant species unable to colonise isolated recent woods may be considered as indicators of ancient woodlands, because their presence suggests a long continuous history for the habitat patch, and because they may be indicative of more original woodland conditions. A list of 155 ancient woodland species was generated for Poland on the basis of survey the list of ancient woodland species in north-western and central Europe (HERMY *et al*. 1999), and taking into account ecological characters of vascular plant species associated with deciduous woodlands in Poland (DZWONKO, LOSTER 2001; DZWONKO 2007). This list includes many still common species, e.g. *Anemone nemorosa*, *Asarum europaeum*, *Carex digitata*, *C. sylvatica*, *Convallaria majalis*, *Dryopteris filix-mas*, *Festuca gigantea*, *Lathyrus vernus*, *Luzula pilosa*, *Melica nutans*, *Poa nemoralis*, *Polygonatum multiflorum*, *Stachys sylvatica* and *Viola reichenbachiana*. Ancient woodland species indicators are of high importance for woodland conservation and vegetation studies, because spontaneous restoration of woodland communities in new sites takes centuries. Hence, these plant species indicators may be used for assessing the nature conservation value of woodlands, and to distinguish ancient woodland communities from recent woods. Forest management should aim at favouring ancient woodland species by maintaining traditional deciduous forest management systems.

Eutrophication, just like acidification, has been one of the most often observed processes occurring in woodland ecosystems in many European countries in the last decades of the 20th century (cf. PEARSON, STEWART 1993; BOBBINK *et al.* 1998). An increase in the number or frequency of nitrophilous species in deciduous and mixed woodlands in western, north-western and central Europe has been noted by various authors (FALKENGREN-GRERUP 1986; TYLER 1987; THIMONIER *et al.* 1994; BRUNET *et al*. 1997). Moreover, decline and extinction of acidophilous species were observed in deciduous, coniferous and mixed woods growing on less fertile soils (FANGMEIER *et al*. 1994; VAN TOL *et al*. 1998). MEDWECKA-KORNAŚ and GAWROŃSKI (1990) showed that in the Ojców National Park (established in 1956, about 22 km NNW of Kraków) changes in the structure and composition of the *Pino-Quercetum*, the only acidophilous forest in this area, are so great that most of its stands do not represent this community any more. An evident retreat during 30 years (1958-1988) of such acidophilous woodland species as *Vaccinium myrtillus*, *Luzula luzuloides*, *Majanthemum bifolium*, *Melampyrum pratense*, *Orthilia secunda*, *Veronica officinalis*, *Lycopodium annotinum*, *Polytrichum formosum* and *Pleurozium schreberi* was noted there. Similar changes have been observed also on other sites in southern Poland. In consequence, species richness of many woodlands and local diversity of woodland communities decrease. Considerable increase in air-borne nitrogen and sulphur, observed in the last decades of the 20th century, has been invoked as responsible for eutrophication of woodland communities in most studies.

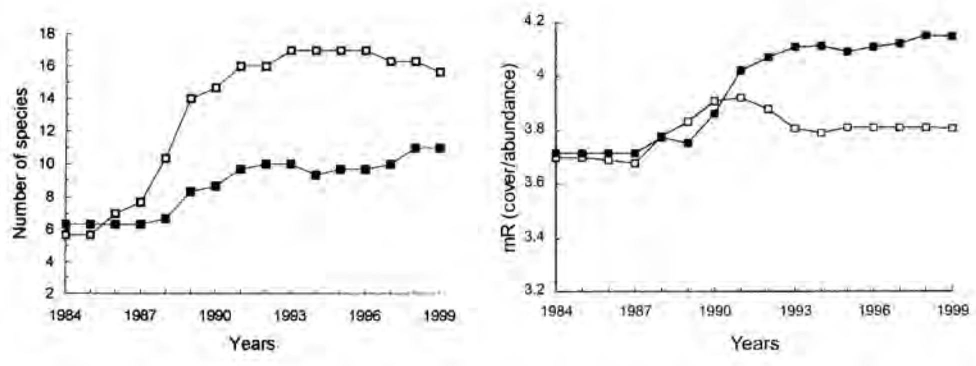

Fig. 1. Mean number of species in the field layer and the mean ELLENBERG indicator values for reaction (mR) in three pairs of the litter removal (☐) and control (■) permanent plots in an oak-pine mixed woodland in the Wierzbanówka valley, during 1984-1999. In the course of 16 years abundance of *Vaccinium myrtillus*, *Majanthemum bifolium* and *Luzula pilosa* considerably decreased in the control plots, while abundance such species as *Carex brizoides*, *Milium effusum* and *Rubus hirtus* increased distinctly. After DZWONKO and GAWROŃSKI (2002).

Extinction of acidophilous species in woodlands and their eutrophication may also arise from other processes. For hundreds of years woods in central Europe have been strongly influenced by human activities. Still in the first half of the 20th century farmers removed litter and grazed domestic animals in many woods (MIKLASZEWSKI 1928; ELLENBERG 1988). Regular litter removal resulted in substantial impoverishment of soils in nitrogen and other nutrients and could lead to considerable reduction of woodland productivity. According to ELLENBERG (1988), as a consequence of material removal, woodland soils in central Europe became less fertile and more acid than they were originally. Yet during the first few decades after World War II litter was removed and animals were grazed in deciduous woods in various parts of Poland (JAKUBOWSKA-GABARA 1993). Cessation of these traditional methods of management coincided with the beginning of air pollution growth. It is possible then that changes in species composition of mixed woods also arose from the accumulation of organic matter and occurrence of thick litter layer. Decomposition of larger quantities of matter enriched soil in nutrients, and thick litter layer could restrict seed germination and development of many species. This opinion is supported by the results of 16-year litter removal experiment in an acidophilous mixed oak-pine woodland in the Wierzbanówka valley (DZWONKO, GAWROŃSKI 2002). It was found that litter removal resulted in substantial impoverishment of soil. Vascular plant species and bryophytes colonized the litter removal plots much more frequently. Within 16 years species richness increased in the field layer of these plots, but abundance of dominant species and character of vegetation remained unchanged, while vegetation of the control plots changed from acidophilous to neutrophilous (Fig. 1).

3. CHANGES IN CALCAREOUS GRASSLAND VEGETATION AND MANAGEMENT FOR ITS CONSERVATION

For several centuries semi-natural calcareous grasslands have been characteristic elements of the agricultural landscapes in the hilly regions of southern Poland. They were composed of species-rich and geographically differentiated communities. Many grassland species reached this area in long time as migratory waves from the southeast and south of Europe. Today, in xerothermic calcareous grasslands of southern Poland occur many Pontic and Pontic-Pannonian plant species, e.g. *Adonis vernalis*, *Campanula sibirica*, *Carex humilis*, *Carlina onopordifolia*, *Chamaecytisus albus*, *Cirsium pannonicum*, *Echium russicum*, *Inula ensifolia*, *Iris aphylla*, *Linum flavum*, *L. hirsutum*, *Scorzonera purpurea*, *Stipa joannis*, *S. pulcherrima* and *Thymus praecox*. Most of these species usually appear in form of rare, isolated populations. Patches of calcareous grasslands represent some associations from the *Festuco-Brometea* class, like: *Inuletum ensifoliae*, *Sisymbrio-Stipetum capillatae*, *Koelerio-Festucetum rupicolae*, *Thalictro-Salvietum pratensis* and *Origano-Brachypodietum*. The first two associations are most common (MEDWECKA-KORNAŚ, KORNAŚ 1966; MICHALIK, ZARZYCKI 1995).

For long time, the grasslands on limestone and chalk hill slopes as well as those on calcareous loess were regularly grazed by domestic animals, most often by sheeps and goats, and their development and maintenance was primarily linked with this type of land use. During the two decades after World War II, the traditional methods of management had been ceased and most of the calcareous grasslands abandoned. Today, remnants of these grasslands, ranging from several dozen square metres to several hectares, are isolated by fields and meadows. The distances between them are from several hundred metres to several kilometres. Only some of abandoned calcareous grasslands have been set aside as nature reserves. The remnants of old grasslands in southern Poland like in other parts of central, western and northern Europe are the only refuges for many grassland and xerothermic species of plants and small animals (MORTIMER *et al*. 1998; DOLEK, GEYER 2002; WAALLISDE VRIES *et al*. 2002). Thus, maintaining grassland communities is of utmost importance to the conservation of local and regional biodiversity.

Unmanaged grasslands have changed as a result of secondary succession. Abandoned grasslands situated in the vicinity of woodlands are often overgrown by shrubs and trees. In many places the effect of this process has been a considerable decrease of the area occupied by grassland communities and its fragmentation into small, often isolated patches (Fig. 2). An increase in tree and shrub cover results in a decrease in the number and cover of grassland species and may lead to their local extinction within decades. In many grasslands after cessation of management practices the cover of tall grasses and forbs with larger leaves as well as of species reproducing vegetatively (e.g. *Arrhenatherum elatius*, *Phleum phleoides*, *Vincetoxicum hirundinaria* and *Galium mollugo*) increases rapidly. They reduce light penetration to lower layers of the grasslands and restrict the development of shorter species. The dominance of tall grasses and non-removal of organic matter lead to the formation of a thick litter layer, which hinder germination and growth of seedlings. A thick litter layer in the dense grassland impedes also seed germination

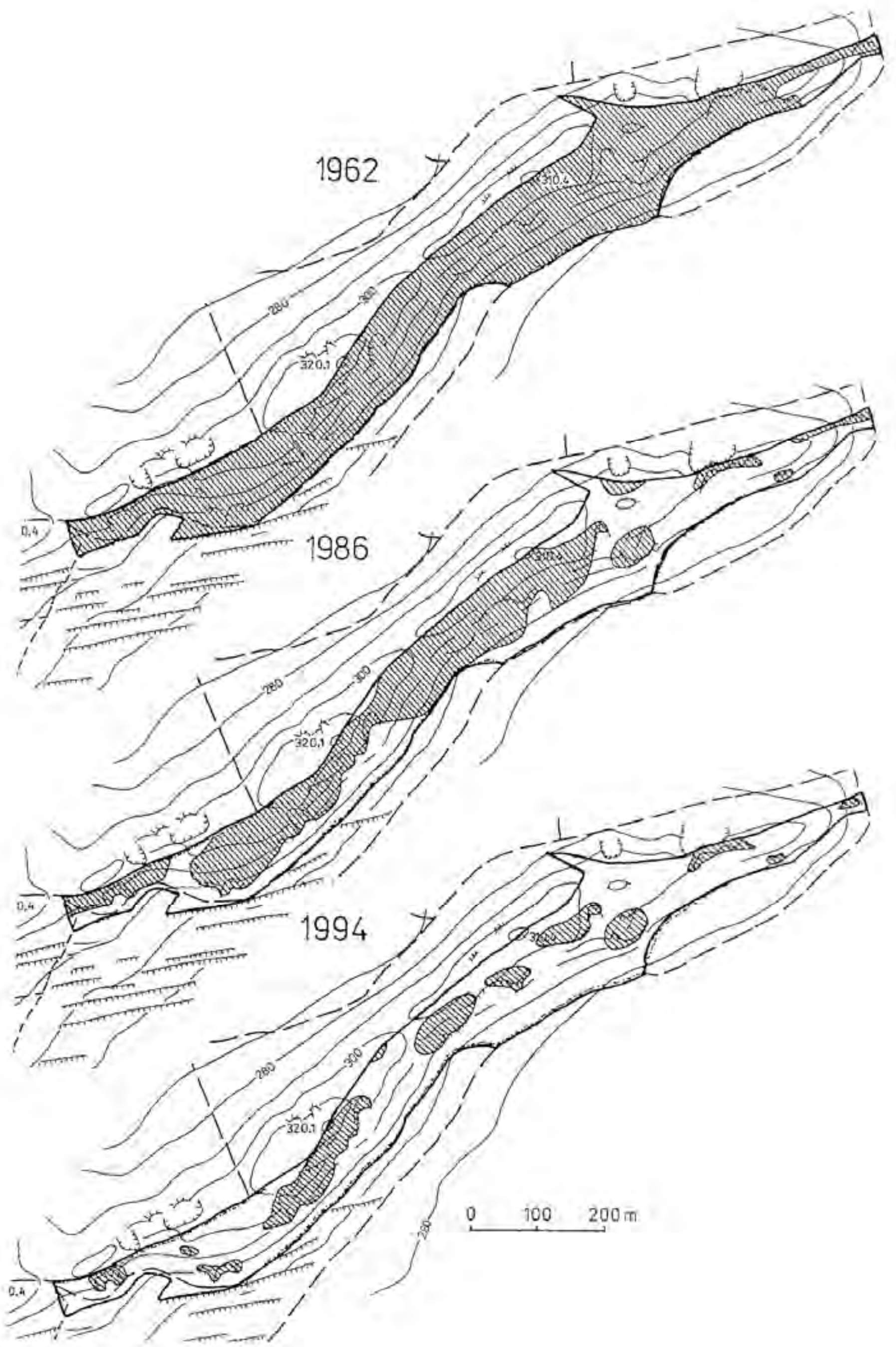

Fig. 2. Changes of area and fragmentation of xerothermic calcareous grassland (shaded) in the Kajasówka reserve near Kraków, during 1962-1994, after cessation of grazing. The reserve (12 ha) was established in 1962. After MICHALIK and ZARZYCKI (1995).

and seedling development of shrubs and trees, thus causing the succession to wood to proceed much slower than in more open grasslands. Such changes, usually with decrease in species diversity, have been observed in abandoned grasslands in different parts of central and western Europe (WILLEMS 1983; WARD, JENINGS 1990; DZWONKO, LOSTER 1998a, 2008; KAHMEN, POSCHLOD 2004).

Various studies revealed that most of the grassland species have poor dispersal ability and cannot, without grazing animals acting as dispersal vectors, re-colonize isolated grasslands nor colonize isolated open sites (GIBSON *et al*. 1987; POSCHLOD, BONN 1998; POSCHLOD *et al*. 1998). The above cited studies showed that herbivores moving between grasslands could disperse enormous numbers of seeds during a year. When grazing is ceased the dispersal of most grassland species is limited to several metres or even to several dozen centimetres (VERKAAR *et al*. 1983; STAMPFLI, ZEITER 1999; KALAMEES, ZOBEL 2002). Species-rich grasslands cannot be restored from soil seed bank because relatively few species of these communities form persistent seed bank in the soil, and seeds of many grassland species have a short life span in soil (DUTOIT, ALARD 1995; BEKKER *et al*. 1997; WILLEMS, BIK 1998; STAMPFLI, ZEITER 1999). Experimental studies suggest that even though the seeds of grassland species do occur in seed rain or soil seed bank, successful restoration of species-rich grasslands may still require additional management such as grazing or mowing in order to facilitate the development of suitable species seedlings (HUTCHINGS, BOOTH 1996). Observation by KARLÍK and POSCHLOD (2009) in southwestern Germany has showed that species composition of ancient calcareous grasslands (i.e. patches continuously used as pasture at least since the first half of the 19th century) differed considerably from that of recent grasslands (no more then 150 years old), and it was possible to identify species indicating the historical status of the grasslands. Regional indicators of ancient grasslands included among others: *Aster amellus*, *Brachypodium pinnatum*, *Carex caryophyllea*, *Carlina vulgaris*, *Hieracium pilosella*, *Linum catharticum*, *Scabiosa columbaria*, and *Vincetoxicum hirundinaria*. Cited authors found that a part of the regional calcareous grassland species pool was restricted to recent grasslands which also contained rare and/or endangered species. Therefore, also these grasslands may have a high conservation value.

Many studies have pointed out that the best way to maintain the species richness and composition of semi-natural grasslands is to re-introduce traditional methods of management i.e. controlled grazing and mowing (Tab. 2; cf. GIBSON *et al*. 1987; GIBSON, BROWN 1991; MOOG *et al*. 2002). In Poland they have been seldom used for both economic and organizational reasons. In many cases periodic cutting of trees and shrubs is the only available and applied conservation management aimed at preservation or regeneration of grassland vegetation.

A 12-year observation in the Skołczanka reserve near Kraków showed that the richness and composition of the restored calcareous grasslands depended significantly on the community composition before tree and shrub cutting (DZWONKO, LOSTER 2007, 2008). This study has suggested that periodical tree cutting enables the maintenance of a temporal-spatial mosaic of scrub-grassland communities and the preservation of local species diversity. But, in practice, cutting trees and shrubs in sites where most grassland species have already vanished, without additional management, such as grazing, mowing, formation of gaps or even sowing seeds is not sufficient to restore grasslands rich in xerothermic species, even though old grassland – a potential source of diaspores is in closed vicinity (Fig. 3). The cited study has showed that developing shrubs and trees can significantly hinder regeneration of xerothermic calcareous grasslands and should be cut more often than in ten years – presumably every five or six years, before their covers increase to about 30%. Long-term monitoring of the vegetation dynamics is crucial in such cases. However, this treatment alone will not stop the changes to communities with the dominance of tall and vegetatively spreading grasses and forbs.

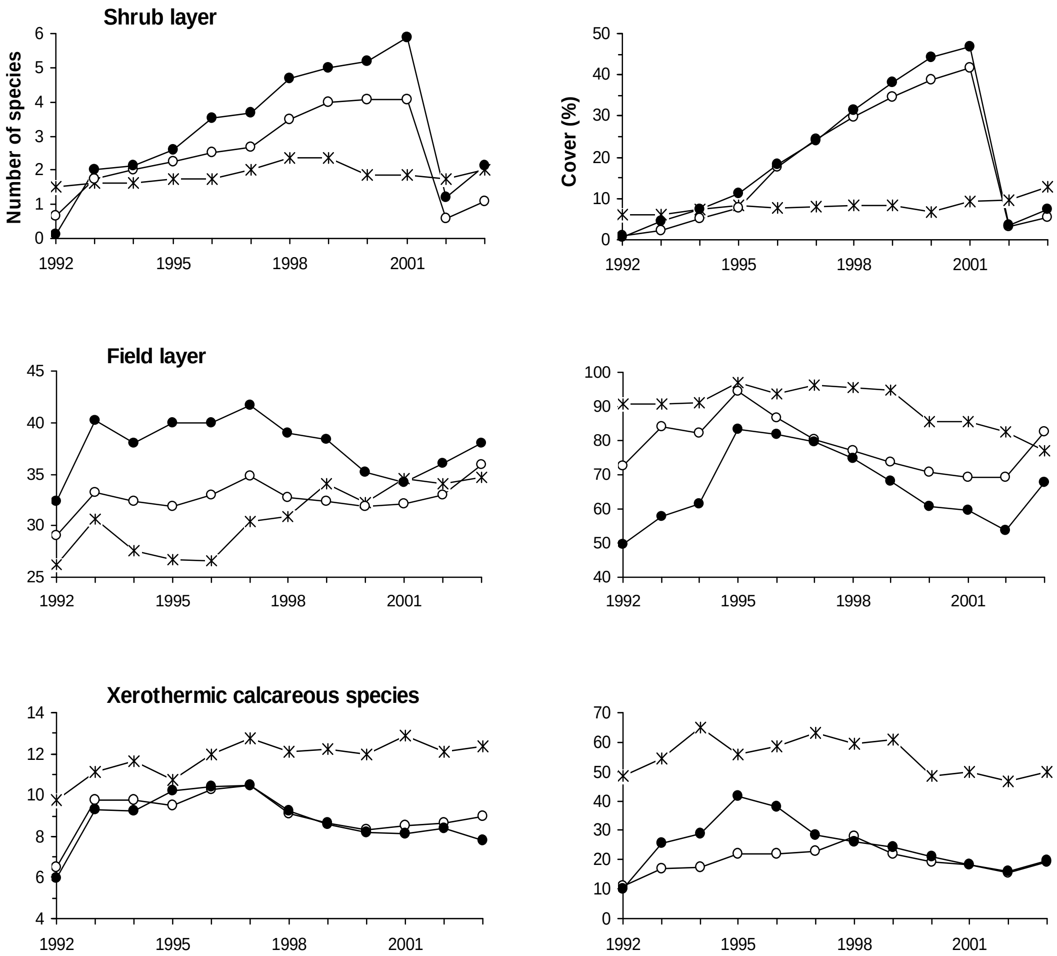

Fig. 3. Mean number and cover of species in shrub and field layers and of xerothermic calcareous species in the permanent plots on the old grassland (∗, 8 plots) and on the grasslands restored in the former open (○, 12 plots) and closed (●, 15 plots) woods, in the Skołczanka reserve close to Kraków, during 1992-2003. The reserve (36 ha) was established in 1957. In 1992 all trees and shrubs overgrew former grasslands were felled. They were cut again in 2002. After DZWONKO and LOSTER (2008).

Table 2. Factors and processes restricting species richness in abandoned calcareous grasslands. After DZWONKO and LOSTER (1998b).

Scale	Factors and processes	Direct causes	Conservation management
Landscape	Isolation	Poor dispersal ability of species	Protection of isolated populations. Sowing and reintroduction of plants.
Community	Transient and short-term persistent soil seed bank of many species.	Poor regeneration ability of many species.	Grazing under control. Mowing. Cutting of trees and shrubs.
	Dominance of tall grasses and forbs.	Reduction of light in lower layers of grassland. Suppression of plants with other growth forms.	
	Thick layer of litter.	Reduction of light near soil. Reduction of seed germination and growth of seedlings and runners.	
	Development of shrubs and trees.	Reduction of light. Suppression of plants with smaller growth forms.	

4. CONCLUSIONS

- Small remnants of ancient woodlands in an agricultural landscape are refuges of numerous woodland species. Therefore, the preservation of such woods carries great weight in the maintenance of local/regional species richness and the protection of woodland species.
- Ancient deciduous woodlands are, as a rule, significantly richer in woodland species than isolated recent woods and plantations because of poor dispersal ability of many woodland species.

- Natural regeneration of woodland communities is very slow and at present it is possible only in sites immediately adjacent to ancient woodlands – the sources of woodland species diaspores.
- The nature conservation value of woodlands can be easily assessed by means of ancient woodland plant species indicators.
- The disappearance of acidophilous species in mixed woodlands of southern Poland may result in a high degree from the cessation of traditional methods of management, above all regular litter removal.
- After abandonment semi-natural calcareous grasslands are overgrown by tall grasses and forbs as well as by shrubs and trees, in consequence, the species-rich communities with many regionally rare and endangered species are vanishing.
- Limited availability of seeds seems the principal reason for the weak regeneration of xerothermic calcareous grasslands.
- Periodical tree and shrub cutting, before their covers increase to about 30%, makes it possible to maintain a temporal-spatial mosaic of species-rich grassland-scrub communities in isolated habitats, and to preserve local species diversity.
- Cutting trees and shrubs in sites where most grassland species have already vanished, without additional managements supporting their dispersal, seedling recruitment and development, is not sufficient to restore calcareous grasslands rich in xerothermic species.

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FOREST RETURN ON AN ABANDONED FIELD – SECONDARY SUCCESSION UNDER MONITORED CONDITIONS

Abstract: The secondary succession pattern observed on an arable field abandoned since 1974 in *Tilio-Carpinetum* habitat is described and disscussed. Results obtained during 36 years of study confirm that succession on an abandoned field leads from a typical segetal community to the formation of a juvenile treestand composed of pioneer species. Our study supports the view that succession is a process which is largely dependent on the initial conditions and surrounding vegetation. The results indicate that some species can modify the course of this process, accelerating or slowing it down. Limitations of the method and prognosis of future vegetation development are also discussed.

Key words: abandoned field, long-term study, permanent plots, species turnover, vegetation succession, Białowieża Forest, Poland

1. INTRODUCTION

Secondary succession, i.e. the restoration of forest communities after their destruction by natural factors or anthropogenic activity, is one of the most frequently analysed problems in studies on vegetation dynamics. Two principal methods are used to study this process. The first, and most popular, is that of chronosequence based on a description of floristic compositions developed at a certain time or at a

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predicted time (e.g. CONELL, SLATYER 1977; VANKAT, SNYDER 1991; BRADY, NOSKE 2010); the second, less popular method is based on the long-term observation of permanent plots (FALIŃSKI 2003; BORNKAMM 2007). Both research approaches have their theoretical and practical limitations (see CONELL, SLATYER 1977; FOSTER, TILMAN 2000; FALIŃSKA 2003; JOHNSON, MYIANISHI 2008), which is why some authors strongly recommend their complementary use (BAKKER *et al.* 1996; FOSTER, TILMAN 2000; BORNKAMM 2007; MYSTER, MALAHY 2008). The integration of the two methods is difficult owing to the shortage of data obtained from a many-years' observation series, as such a study requires follow-up of the process for twenty plus years or even centuries, which is longer than a researcher's life (CONELL, SLATYER 1977; FALIŃSKI 2001, 2003).

Regardless of these difficulties, such studies are conducted because permanent plot studies with precise documentation of vegetation changes over long periods of time are thus of great interest in the testing of ecological models and hypotheses (BAKKER *et al.* 1996; FALIŃSKI 2003; BLATT *et al.* 2005; SCHMIDT 2006).

An example of these long-term studies on secondary succession are studies conducted since 1974 on permanent plots at the Experimental Ecological Garden of the Białowieża Geobotanical Station, Warsaw University, initiated and coordinated for many years by Professor Janusz Bogdan Faliński (FALIŃSKI 1986, 2002). According to the authors' knowledge, this is the longest series of direct observations of old-field succession in Poland, and one of very few as long in Europe (PICKETT 1982; OSBORNOVÁ *et al.* 1990; DEBUSSCHE *et al.* 1996; BALCERKIEWICZ, PAWLAK 2006; DÖLLE *et al.* 2008).

Results of the studies conducted in Białowieża have been partly published (FALIŃSKI 1986; ADAMOWSKI, KNOPIK 1996; FALIŃSKI *et al.* 2004; ADAMOWSKI, BOMANOWSKA 2007a, 2007b, 2007c; BOMANOWSKA, ADAMOWSKI 2007a, 2007b, 2009). The main objectives of the current study are: i) to identify a successional pathway characterised by a sequence of different stages; ii) to indicate factors influencing change in the pathway of the studied process which do not occur, or whose intensity is different, during the succession undisturbed by anthropogenic activity.

2. MATERIAL AND METHODS

The Experimental Ecological Garden of the Białowieża Geobotanical Station (BGS) of Warsaw University is located in the central part of the Białowieża Clearing, in typical subcontinental oak-hornbeam forest *Tilio-Carpinetum typicum* habitat. This area had been in agricultural use since the late 17^{th} century, up to the moment of its acquisition by the BGS (FALIŃSKI 1986). The Garden came into existence in 1974 on an area of 1.2 ha in the location of a former arable field and mown meadow. The last cultivation, in 1973, were potatoes and cabbage, which were accompanied by a segetal community, *Echinochloo-Setarietum*, while the meadow was described as belonging to the *Arrhenatheretum elatioris* association (FALIŃSKI 1986, 2002). The garden is surrounded by a fence and divided into sectors connected by roads with a hardened surface.

Two sectors were selected for long-term observations on the initiation and progress of secondary succession on an abandoned field and meadow under monitored conditions: sectors C and E, each with an area of 400 m^2. Both permanent study areas are divided into 22 basic plots, each with an area of 10 m^2 (6.25 m x 1.6 m), separated by paths with a width of 30 cm. The plots are surrounded by an isolating belt which is 120-220 cm wide. A detailed description of the site of the experiment, its habitat conditions and the treatments used can be found in earlier papers by FALIŃSKI (1977, 1986, 2002), ADAMOWSKI and KNOPIK (1996) as well as BOMANOWSKA and ADAMOWSKI (2007a).

Regular observations have been conducted (since 1974) once a year, around the end of June and the beginning of July. Until 1995 all the observations were carried out by Prof. Aurelia U. WARCHOLIŃSKA, and are continued at present by the authors of this paper. The following features were recorded: overall species composition, structure of the plant community, appearance of seedlings and juvenile individuals of woody species (all seedlings were marked and mapped during the first 21 years). To fulfil this goal, a phytosociological relevé was recorded from each basic plot by the classical Braun-Blanquet method, while cover for each species was assessed in the numerical scale of Braun-Blanquet and in the decimal scale of Londo (DZWONKO 2007). Since 2000 the occurrence of spring geophytes has been recorded at the end of April or the beginning of May. Since 1984, additional observations have been conducted in sector F, which is used to evaluate the effects of the anthropogenic modification of the secondary succession process by controlled mowing (FALIŃSKI 2002; ADAMOWSKI, BOMANOWSKA 2009).

The data used in this work were collated in the BGS archive and obtained from sector C (former arable field). Data from 17 observation plots were included in the analysis (=170m^2) because in the five remaining ones (C1 – C3, C12 and C13) since 1984 plants have been mown each year after observation and the biomass was removed from the plot.

The total cover of plants was calculated from the cover index values for individual species, estimated using Londo scale. The following conversion factors for Londo scale were adopted: 0.1 – 0.5% cover, 0.2 – 2%, 0.4 – 5%, 1 – 10%, 2 – 20%, 3 – 30%, etc.

The succession pattern was established based on observation data (see above), as well as literature data regarding the maximum age of individual tree species and their role in forest communities (ZARZYCKI 1979; FALIŃSKI 1997, 1998; FALIŃSKI, PAWLACZYK 1991, 1993; DANIELEWICZ, PAWLACZYK 2006).

The Latin names of vascular flora were used according to MIREK *et al.* (2002).

3. RESULTS

1. During 36 years of observation in the experimental area, 224 vascular plant species classified to 46 families were recorded in total (Fig. 1). Families represented by the highest number of species included: *Asteraceae* (34 species), *Poaceae* (27) and *Rosaceae* (23).
2. During individual years of the experiment, the number of recorded species ranged from 80 to 107 (Fig. 2). The lowest number of species was recorded in year 13 of the study, and the highest number in year 31 of the study.

3. Initially, species composition was dominated by short-lived plants associated with arable lands, which were quickly replaced by perennials and later by woody species. The number of perennials reached its maximum in year 7 of observation (Fig. 2).
4. During the first years of the experiment an important role among short-lived plants was played by segetal species remaining after the primary community. During the first year of observation 36 segetal species were recorded, but their number rapidly decreased, and only 6 species were recorded in year 6 of observation. The cover of this species group decreased rapidly along with the progress of secondary succession from approximately 35% in the first year to 1% in year 6 (Fig. 3).
5. Three *Vicia* species were an exceptional case in this group (*Vicia angustifolia*, *V. hirsuta* and *V. tetrasperma*), and they reached a maximum cover rate as late as in years 7 and 10 of observation (Fig. 3). Up to the present time they demonstrate significant frequency, and flower and produce fruits.
6. Between the second and fourth observation year the study site was dominated by *Elymus repens*, which attained over 40% of cover (Fig. 4).
7. After the withdrawal of short-lived species during the following dozen or more years (especially between years 5 and 16 of the experiment) a significant role was played by perennials, including grasses. The two most frequent meadow species (*Leontodon hispidus* and *Dactylis glomerata*) had the highest cover rate in years 15 and 16 of observation respectively, which was followed by their withdrawal (Fig. 5).
8. Despite the withdrawal of the vast majority of perennial meadow species, the cover of two grass species (*Arrhenatherum elatius* and *Poa palustris*; Fig. 6) still continues to increase.
9. In total, 55 tree and shrub species have occurred on experimental plots during the 36 years of observation. The first seedlings (*Betula, Populus, Salix, Acer, Fraxinus*) emerged early, in year 2 of observation, but for many years their share in the herb layer cover was insignificant.

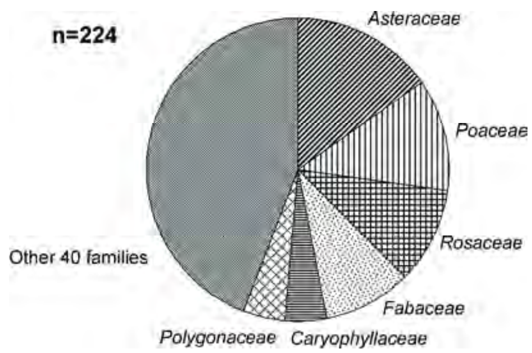

Fig. 1. Taxonomical spectrum of species found in the course of secondary succession.

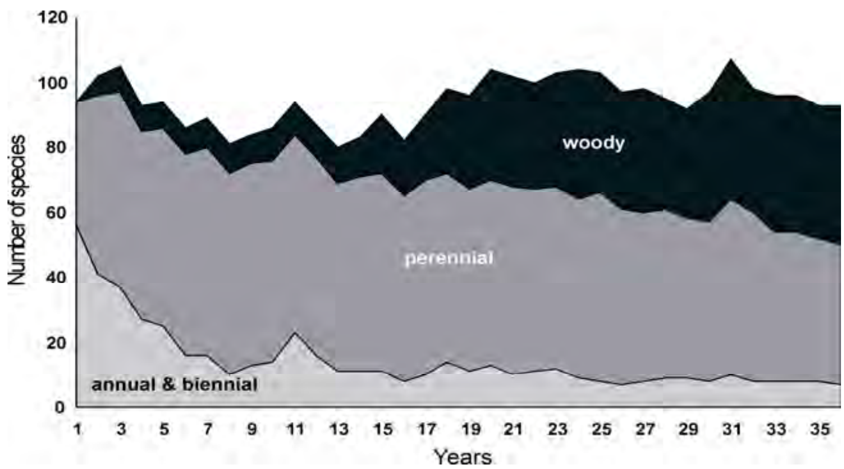

Fig. 2. Number of species observed in the course of secondary succession.

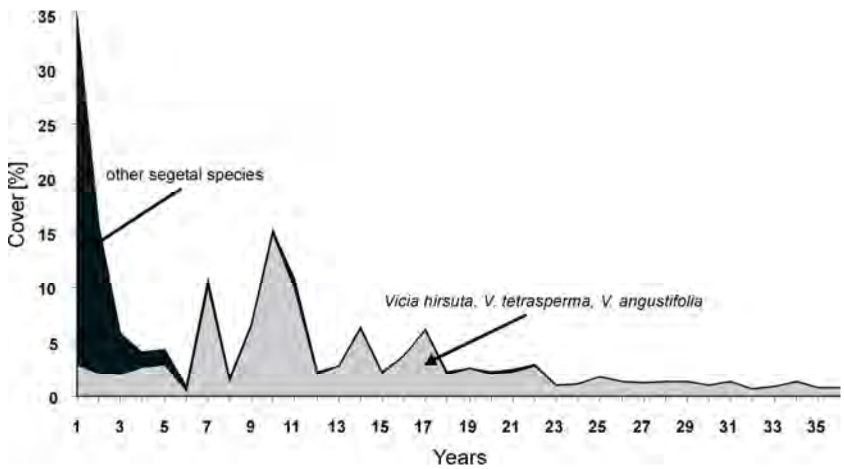

Fig. 3. Percentage cover of segetal species in the course of secondary succession.

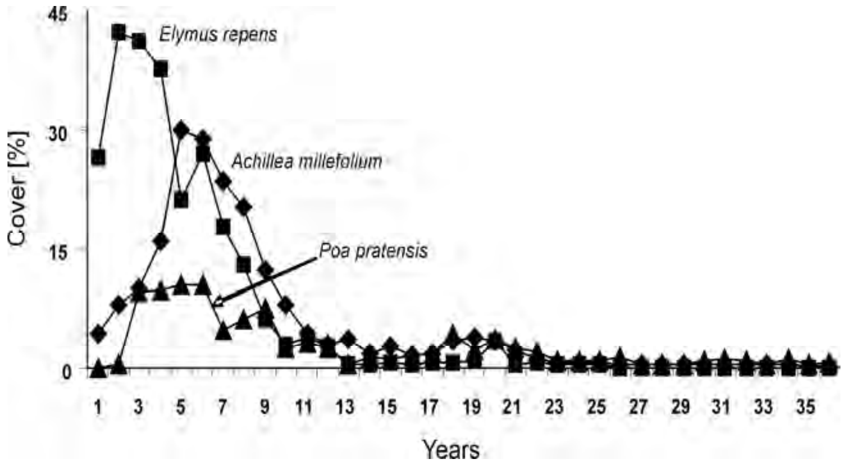

Fig. 4. Percentage cover of fallow species in the course of secondary succession.

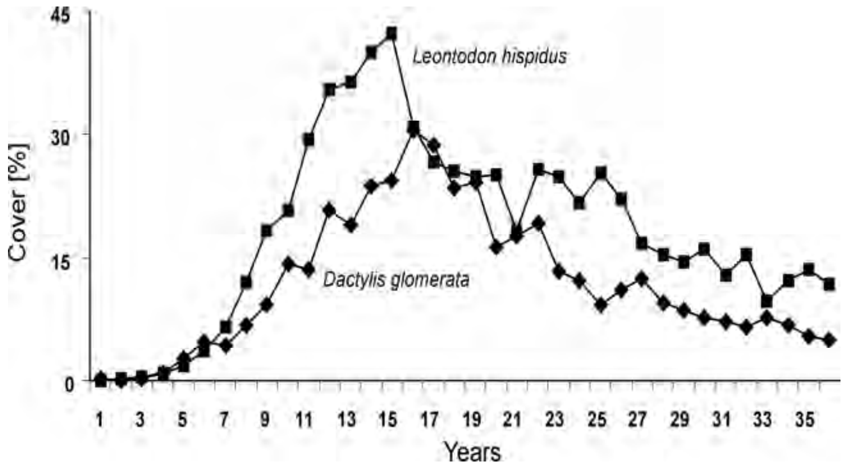

Fig. 5. Percentage cover of meadow species in the course of secondary succession.

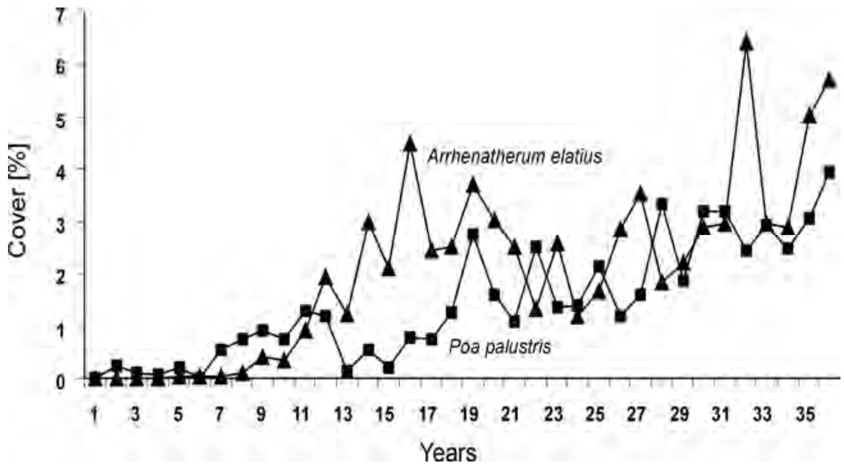

Fig. 6. Percentage cover of expansive grasses in the course of secondary succession.

10. The first individuals of arborescent species outgrew herbaceous plants in year 11 of observation. In recent years the shrub layer reached an average of 20-25% cover (Fig. 7, 8). The shrub layer was mainly formed by trees, initially pioneer species (*Salix caprea*, *Betula pendula*), and currently, to a larger extent, by permanent forest components (*Tilia cordata*, *Carpinus betulus*; Fig. 8). So far, *Salix aurita*, has been the only shrub species with a high rate of cover in this layer.
11. The presence of a tree layer was first recorded in year 13 of observation. In year 21 it had a 50% cover, and after year 23 the canopy cover stabilised at a level of 60-65%. Initially, it was formed exclusively by pioneer species (*Salix caprea*, *Betula pendula*, *Populus tremula*), but currently also contains *Acer platanoides* and *Tilia cordata* (Fig. 9). Observations from recent years have demonstrated a gradual withdrawal of *Salix caprea*.
12. Between year 14 and 20 of observation the number of recorded tree species increased rapidly (1987 – 12, 1993 – 34). The majority of trees and shrubs observed for the first time during that period are species dispersed by birds (Fig. 10a), and *Sorbus aucuparia* was the first ornithochorous species, two seedlings of which emerged on experimental plots in year 14 of observation.
13. *Melampyrum nemorosum*, the most frequent pre-forest species, had the highest share in year 29 of observation (Fig. 11).
14. The share of juvenile specimens of tree species in the herb layer significantly increased after the formation of treestand, to reach 18.5% in year 36 of observation (Fig. 11).
15. In recent years the first forest herbaceous plants have occurred under the tree canopy (*Convallaria majalis* in year 26 of observation, *Anemone nemorosa* in year 29, *Isopyrum thalictroides* and *Carex digitata* in year 34); however, so far their role in the herb layer has been insignificant, due to their very low frequency and rate of cover.

4. DISCUSSION

Forest return on abandoned fields has been described by many authors, and the obtained data demonstrates that the course of this process is diversified, and many secondary succession patterns developed based on empirical studies to a larger or smaller extent vary from succession theoretical model (OSBORNOVÁ *et al.* 1990; GLENN-LEVIN 1992; MCCOOK 1994; BARABASZ-KRASNY 2002; FALIŃSKA 2003; BALCERKIEWICZ, PAWLAK 2006).

This results, among other things, from the fact that succession is a process strongly determined by starting conditions and surrounding vegetation (GLENN-LEVIN 1992; MCCOOK 1994; FALIŃSKA 2003). The course of succession can also be modified by disturbances occurring during this long process, even if they are accidental or highly infrequent (TURNER *et al.* 1998; VON OHEIMB, BRUNET 2007). It has been demonstrated that the turnover of species and appearance of diverse floristic compositions in the long-term process of succession cannot always be predicted, even in the same object (OSBORNOVÁ *et al.* 1990; FALIŃSKA 2003, BLATT *et al.* 2005).

4.1. Limitations

In the Experimental Garden, the course of succession is influenced by factors which do not occur, or whose intensity is different, during a secondary succession which is undisturbed by man's influence. The most important of them are (ADAMOWSKI, KNOPIK 1996, supplemented):

1) an increased availability of ornithochorous species propagules, caused by the presence in the immediate vicinity of the plots of a considerable number of tree and shrub species producing fruits eaten by birds. This is one of the indirect causes of the ornithochore seedling "boom" observed in the plot (Fig. 10a). Data by PABJANEK (2003), also obtained from Białowieża Clearing as in our study, demonstrated how significant this increased availability of propagules is. In brushwood forests of several hundred to thousands of square meters in area, and distant from human dwellings, PABJANEK (2003) observed the occurrence of single ornithochorous

Fig. 7. Percentage cover of treestand, shrub layer and ground layer in the course of secondary succession (after BOMANOWSKA, ADAMOWSKI 2009, supplemented).

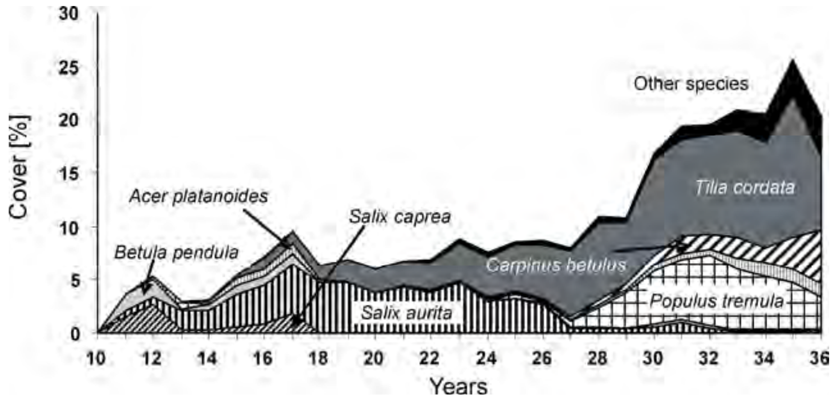

Fig. 8. Composition of the shrub layer in the course of secondary succession (after BOMANOWSKA, ADAMOWSKI 2009, supplemented).

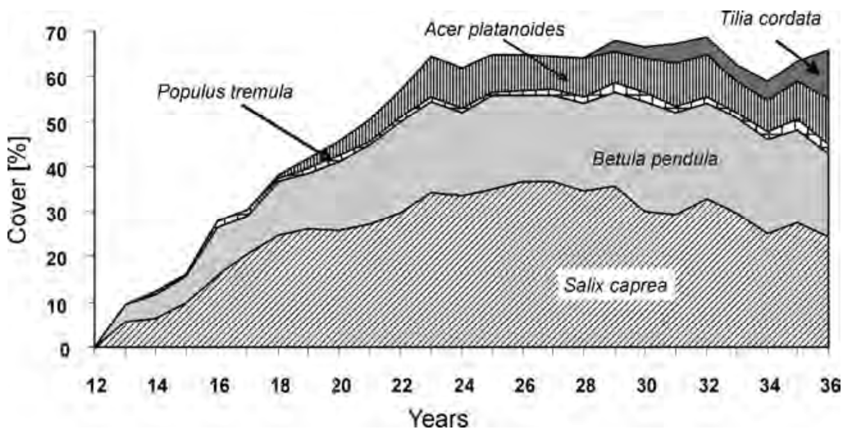

Fig. 9. Composition of the treestand in the course of secondary succession (after BOMANOWSKA, ADAMOWSKI 2009, supplemented).

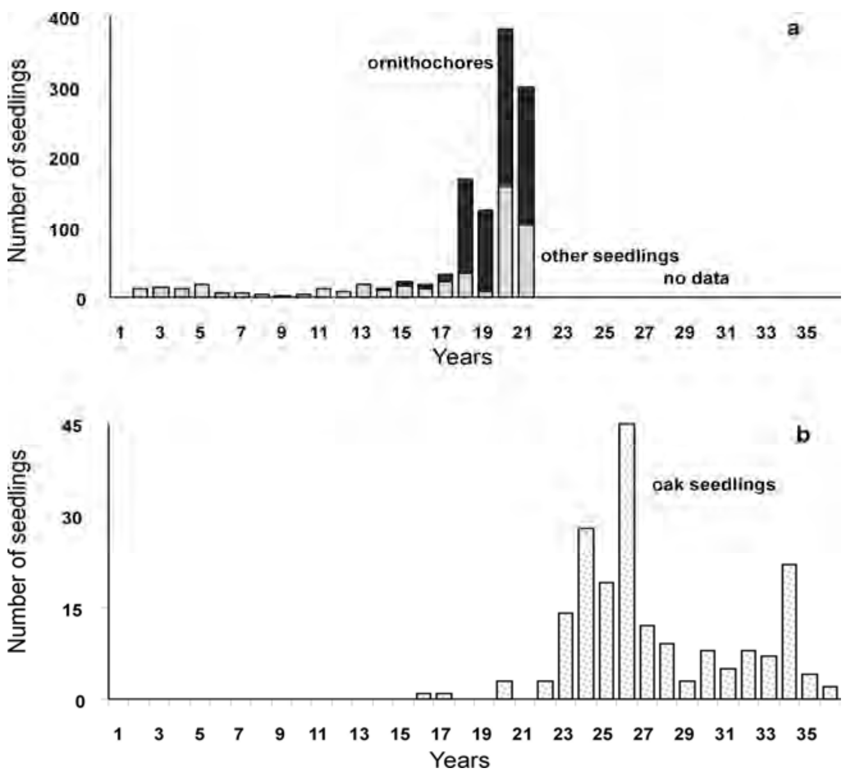

Fig. 10. Number of seedlings found in the course of secondary succession: (a) number of all seedlings and share of ornithochores; (b) number of oak seedlings (after BOMANOWSKA, ADAMOWSKI 2009, supplemented).

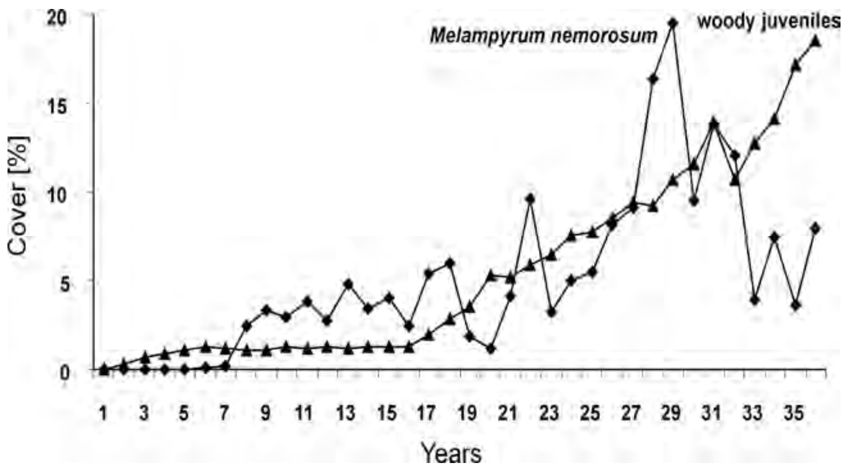

Fig. 11. Percentage cover of pre-forest species and woody juveniles in ground layer vegetation in the course of secondary succession.

species, most frequently *Frangula alnus* and *Sorbus aucuparia*, while in our study over a dozen species per 170 m^2 were found,

2) a very limited influence of herbivorous animals (European bison, red deer, wild boar, roe-deer, hare; only hares and the effects of their activity were already seen), caused by fencing in and the proximity of human dwellings; these animals can naturally significantly affect the succession process, eating part of the biomass produced, mechanically destroying, browsing and debarking young trees, displacing and treading seeds into the soil, manuring the soil with faeces, creating favourable conditions for germination (by damaging the vegetation and uncovering the inorganic soil horizons), limiting the competitive influence of grassy vegetation and so forth. The limited influence of large herbivores seems to be a serious shortcoming in our study, particularly in view of recent research on the role of these animals in seed dispersal (COUVREUR *et al.* 2005; WILLIAMS *et al.* 2007; JAROSZEWICZ *et al.* 2009),

3) yearly, and concentrated within the short observation period, damaging of plants (treading paths, combing the ground-cover vegetation for seedlings, unwittingly breaking branches), which may significantly affect the emergence and survival rate of the seedlings (seedlings developed in heavily shaded places often fail to survive if uncovered suddenly, especially when the weather is hot and dry),

4) inclusion in the succession process of trees and shrubs that are not native to the the Białowieża Forest (*Acer pseudoplatanus, Tilia platyphyllos, Pinus strobus, Cotoneaster sp.*, and suchlike; ADAMOWSKI, BOMANOWSKA 2007b, 2008) and whose role in the community that is forming is for the time being difficult to predict.

In addition, the succession process is largely affected by factors resulting from the small size of the research site, for example strong sideways light penetration, litter drifting, decreased air humidity in comparison to the interior of the forest community, etc. BARKMAN (1989) in his analysis of mixed forest in Northern America, evaluated the area of phytocoenosis required for its typical formation per 3 ha. Transitional zones may be 10-15, and even 30 m wide. For comparison, the surface of all of section C is as low as 400 m^2, while its breadth is 15 m. Study plots in our series are rather small but this is a compromise between requirements and capabilities developed during project design. Each year observations in sector C alone require approximately 20 hours, and the labour intensity increases with the development of the vertical community structure and the occurrence of first spring geophytes.

The fragment of the succession process analysed so far is only 1/10 of its predicted duration. Assuming that a researcher is able to actively participate in observations for 25-30 years, there will be at least another 10 generations of researchers required to complete these observations, and to fully analyse and publish the results.

Owing to the fact that the course of succession is influenced by accidental factors, such as extreme weather conditions, mass occurrence of insects and other animals, and natural disasters (TURNER *et al*. 1998; VON OHEIMB, BRUNET 2007), making projections far into the future is very difficult. Small size study plots, where one tree falling can significantly influence results, are particularly prone to such effects. Therefore, our predictions, especially concerning the terminal succession stage (Fig. 12), are highly hypothetical.

4. 2. Patterns

In view of the past observations conducted on experimental plots in the Białowieża Clearing, forest return to the abandoned field is a process similar to that predicted by the theoretical succession model (Fig. 2, 7, 12). Short-lived plants were eliminated by perennials associated with grass communities, which were later replaced by tree species. Despite the fact that only 1/10 of the time required for the restoration of mature oak-hornbeam forest elapsed (360 years; FALIŃSKI 2001), the first forest plants already occurred. In a considerably shorter time (in year 6 of observation), plants from this group were observed in the Wielkopolski National Park, but the study site there is directly surrounded by patches of oak-hornbeam forest communities (BALCERKIEWICZ, PAWLAK 2006), while sector C is located 115-140 m from the Palace Park border, the most significant source of seed fall (see ADAMOWSKI, KNOPIK 1996).

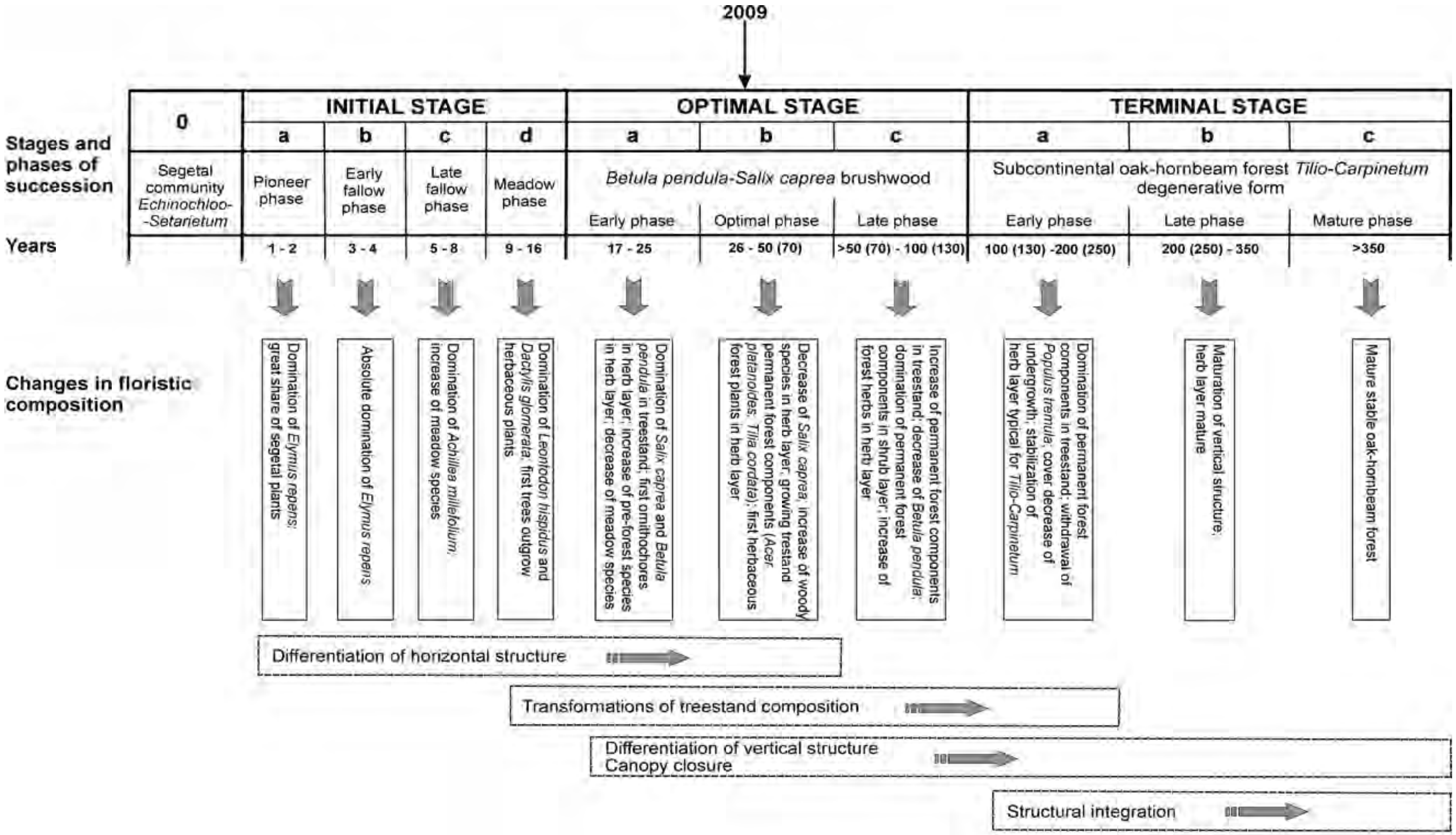

Fig. 12. Pattern of secondary succession in an abandoned field in oak-hornbeam forest habitat in the Experimental Garden of Białowieża Geobotanical Station (after Bomanowska, Adamowski 2007, modified and supplemented)

As in many other succession series, fast withdrawal of short-lived species has also been observed on the studied plots (OSBORNOVÁ *et al.* 1990; FALIŃSKI 1986; DEBUSSCHE *et al.* 1991; DÖLLE *et al.* 2008), except for three *Vicia* species, i.e. *Vicia angustifolia*, *V. tetrasperma* and *V. hirsuta*, which had their maximum cover rate when other terophytes almost completely withdrew (ADAMOWSKI, BOMANOWSKA 2007c; Fig. 3). The survival of *Vicia* spp. is possibly associated with the formation of a persistent seed bank by them and strong sideways light penetration of the study plot. The presence of such early-succession species, albeit most often in a sterile form, has also been observed at considerably advanced succession stages in other study series (DÖLLE *et al.* 2008).

Up to the present time, in the course of the experiment covering approximately 1/10 of the duration of the entire oak-hornbeam succession series, 224 species are involved, which is 70% of the species pool predicted by FALIŃSKI (2001). It cannot be excluded that their number will exceed 320, owing to the close proximity of study plots to the Palace Park and private gardens with numerous alien tree species. A similar number of species was observed in a corresponding study series (BALCERKIEWICZ, PAWLAK 2006; DÖLLE *et al.* 2008). However, this similarity largely results from the comparable diversity of local floras and the size of study plots.

Carried out observations (Fig. 2) do not confirm the directional changes in species diversity in the course of succession observed by some authors (DEBUSSCHE *et al.* 1991; BLATT *et al.* 2005). Moreover, it will be difficult to find them in the future if predictions by FALIŃSKI (2001) on the number of species involved in the formation of the final forest community (90 species) are confirmed. Similar patterns of fluctuating species diversity as observed were found in successional studies conducted in Germany (DÖLLE *et al.* 2008).

Strictly separated successional stages are difficult to distinguish in our series of observations. Neither the relay of species theory, nor the initial species composition theory have any practical confirmation here. Therefore, we can assume, following FALIŃSKA (2003), that in our case succession results more from various species replacement mechanisms than from being the consequence of predictable species compositions. Otherwise, it would be difficult to explain the above-described behaviour of *Vicia* spp. or the surprising phenomenon of the constant increase in coverage for typical grassland species, i.e. *Arrhenatherum elatius* and *Poa palustris* after the terrain was already occupied by trees (Fig 6; BOMANOWSKA, ADAMOWSKI 2007a).

Interestingly, invasive herbaceous species were almost entirely absent in our series of observations. Results of previous studies conducted by the authors on the same physiographical area (the Białowieża Clearing) demonstrated that many geographically alien plants, including herbaceous plants (*Solidago gigantea*, *Erigeron annuus*, *E. ramosus*) are involved in spontaneous secondary succession on abandoned farming land (ADAMOWSKI, BOMANOWSKA 2008), while a high number of non-native tree species were found in the described series. However, so far it is difficult to establish which species will permanently form the restoring forest community. The presence of invasive species, such as *Solidago gigantea*, sometimes demonstrating a high cover rate, has also been observed in other succession series (DÖLLE *et al*. 2008).

The crucial role in the course of the analysed succession is played by two species groups which, according to FALIŃSKA (1989) were defined as succession promoters and inhibitors. Succession promoters are pioneer tree species: *Salix caprea*, *Betula pendula*, *Populus tremula*, whose shading of the soil and production of litter contributed to the withdrawal of meadow species (Fig. 7, 9, 12), and also provided rest sites for birds dispersing numerous tree and shrub seeds (Fig. 10a; BOMANOWSKA, ADAMOWSKI 2007b). The first seedlings of ornithochores occurred on experimental plots when the tree layer cover reached approximately 30%, and their number rapidly increased during the subsequent years (Fig. 10a; ADAMOWSKI, KNOPIK 1996). Numerous *Quercus robur* seedlings occurred even later (Fig. 10b). The succession also seems to be promoted by *Melampyrum nemorosum* (Fig. 11), which dies back quite early in the summer, forming in consequence gaps for the germination of forest species. The role of persistent forest components (*Acer platanoides*, *Carpinus betulus*, *Tilia cordata*) accelerating succession has been pronounced in recent years. A similar role of succession promoters in the region of the Białowieża Primeval Forest is played by woody species (*Juniperus communis*, *Populus tremula*) in the secondary succession of the coniferous forest series (FALIŃSKI 1986, 1998), as well as *Alnus glutinosa* and *Salix cinerea* in the riparian forest series (FALIŃSKA 1989, 2003).

Elymus repens, a clonal species, and *Leontodon hispidus*, inhibiting the emergence of tree seedlings owing to its rosette structure, can be considered succession inhibitors (BOMANOWSKA, ADAMOWSKI 2007b). Both species reached very high cover rates in different phases of the initial stage of the secondary succession (Fig. 4, 5): 70% for *Elymus repens*, and 80% for *Leontodon hispidus* on single plots. The inhibiting effect of these species on the germination of tree seeds is confirmed by the very low number (23 specimens) of pioneer tree species in the first years of observation, as well as the increase in the number of tree and shrub seedlings after the formation of a tree stand and the withdrawal of inhibitors (BOMANOWSKA, ADAMOWSKI 2007b). *Elymus repens* also occurred as a dominant in other succession series (OSBORNOVÁ *et al.* 1990; BLATT *et al.* 2005), although not always during a similar period.

4.3. Prognosis

In forthcoming years we expect an increase in shrub layer cover associated with the growth of numerous lime, hornbeam and oak individuals, as well as vegetative colonisation of aspen. Increasing shading and deposition of litter demonstrating more forest features should accelerate the withdrawal of the remaining meadow plants, as well as *Melampyrum nemorosum,* and form a gap to be colonized by forest species. We expect the occurrence of other forest species in the herb layer and the increase of those already present (see Results).

During the coming decades the treestand cover will probably increase, as other lime specimens grow higher and hornbeams reach this layer. The features of the litter will then be changed (compare FALIŃSKI *et al.* 1988) from that composed mainly by the leaves of *Betula pendula*, *Salix caprea* and *Populus tremula,* promoting meso-xerophilous species, into more easily-degradable litter containing more *Tilia cordata* and *Carpinus betulus* leaves, promoting meso-hygrophilous species.

Salix caprea should be the first pioneer tree species to withdraw. This tree rarely exceeds ages of 50-60 years (FALIŃSKI 1997), and already, in year 36 of observation, it is demonstrating reduced growth speed and vitality (Fig. 9). *Betula pendula* and *Populus tremula* in forest communities reach ages of 80-100 years (ZARZYCKI 1979; FALIŃSKI 1998). Mature individuals of these species have not demonstrated reduced vitality on the study plot so far, although they have started losing lower branches, and their canopies grow outwards from the plot. Inhibited recruitment of *Betula pendula* has already been observed. *Populus tremula* 'crowds in' vegetatively in small-size gaps between the canopies of other trees. Therefore, we assume that this species will be the last pioneer tree to withdraw, or it may even survive as a component of the final treestand. A similar sequence of self-thinning of pioneer tree species was observed by FALIŃSKI *et al.* (1988) in the restoration of oak-hornbeam forest on strip clearcuts in the Białowieża National Park.

The role of oak, insignificant so far, in the shrub layer and its absence in the treestand (Fig. 8, 9) results from the dispersal strategy of this tree and the slow growth in the juvenile period (DANIELEWICZ, PAWLACZYK 2006). This species is characterised by a relatively high survival rate of juvenile specimens under experimental conditions. However, the potential incorporation of *Quercus robur* to the treestand will probably be observed later, by future generations of researchers. This incorporation may be inhibited by more shade-tolerant species like hornbeam (FALIŃSKI, PAWLACZYK 1993) and lime (FALIŃSKI, PAWLACZYK 1991).

We expect that the longest time will be required for the restoration of the mature vertical community structure. The tallest birch specimens already exceed 20 m, which is nearly a half of the height attained by the tallest oaks, limes and maples in Białowieża Primeval Forest (FALIŃSKI 1986). The trees that will form the future treestand are considerably smaller: maples grow 10-12 m high, and limes to 8-9 m.

The achievement of species combination typical for a mature oak-hornbeam forest is rather improbable in these experimental conditions because of the small size of the study plot (see "Limitations"). The expected result is rather the development of degenerative forms of oak-hornbeam forest similar to the one described by BALCERKIEWICZ and co-workers (BALCERKIEWICZ *et al.* 1992) – a facies with *Poa nemoralis,* connected with forest edges. The presence of more light-demanding non-forest species under these conditions is not excluded, especially on the edge of the plot.

Results presented in our paper add to the intense debate on the ideal succession model. Even if we assume that the process we describe has a local nature, it may still contribute to the explanation of succession causes and mechanisms. Individual studies conducted in different geographical regions and habitat conditions can establish a useful theoretical background for the design of a new model, and even, considering the variety of succession pathways in one area, of several succession models.

5. CONCLUSIONS

- Our study supports the view that succession is a process which is largely dependent on the initial conditions and surrounding vegetation.
- Result obtained up to this moment confirm that undisturbed secondary succession on an abandoned field leads from a typical segetal community to the formation of a juvenile treestand and allows for the assumption that the forest will return to the abandoned field.
- Forest return to the abandoned field is a process similar to that predicted by the theoretical succession model: short-lived plants were eliminated by perennials associated with grass communities, which were later replaced by woody species.
- However, our observations do not confirm the directional changes in species diversity in the course of succession. Neither the relay of species theory, nor the initial species composition theory have any practical confirmation here.
- Pioneer tree species are succession promoters by shading of the soil and production of litter which contributed to the withdrawal of meadow species, and also by providing rest sites for birds dispersing numerous tree and shrub seeds.

Role of pre-forest *Melampyrum nemorosum* and persistent forest components accelerating succession has been pronounced in recent years.

- Clonal grass *Elymus repens* and rosette-forming *Leontodon hispidus* can be considered succession inhibitors.
- Role of non-native species, especially trees and shrubs, in the community that is forming is for the time being difficult to predict.

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VEGETATION TRANSFORMATIONS OF KUJAWY-POMERANIA REGION IN THE LAST TWENTY YEARS PERIOD

Abstract: This paper contents dynamic tendencies analysis results of Kujawy-Pomerania region (N Poland) for a 20-year time period. Acreage changes as well as structure and species composition transformations of forest and shrub vegetation (associations) and non-forest vegetation (alliances) were evaluated. Main factors influencing on regressive and progressive changes were set out. Analysis was relied on results of geobotanical research and observations of selected objects. Regressive changes were noted for i.a. thermophilous oak forests, dry and fresh coniferous forests, aquatic, halophytic, pasture vegetation, vegetation of *Molinion* and *Cnidion* meadows, heaths and xerothermic grasslands. Whereas progressive were observed in case of mixed coniferous forests, mesophytic shrubs, rush and tall herbs vegetation, fresh meadows and some ruderal communities.

Key words: causes of transformations, ecological processes, plant communities, vegetation dynamics

1. INTRODUCTION

Existence of plant cover dynamic tendencies is well-known. Plant species and plant communities reveal dynamics under the influence of various natural factors and diverse, variables in space and time, anthropogenic factors (MICHALIK 1974; OLACZEK 1976, SENDEK 1981; KUCHARSKI 1999; JUTRZENKA-TRZEBIATOWSKI

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1999; FALIŃSKA 2004). Researchers' interests in this matter focus both on species population dynamics (taxons' threats) as well as on transformations of ecosystems and plant communities in a broad sense.

Concluding basis about all vegetation changes constitutes among others a possibility of comparison of current state with the past state. Since in the last few decades in Poland intense phytosociological research were carried out, analyses of vegetation transformations are currently undertaken more often. It concerns both different types of plant communities as well as different regions of our country (KORNAŚ 1987; MICHALIK 1990a, b; KORNAŚ, DUBIEL 1991; ZARZYCKI, KORZENIAK 1992; JAKUBOWSKA-GABARA 1993; KUROWSKI 1993; BARABASZ 1997; ZAŁUSKI 2002; SUGIER, CZARNECKA 2004; BODZIARCZYK, DRAJEWICZ 2007; KAŹMIERCZAKOWA, GRODZIŃSKA 2007; KUROWSKI, MICHALSKA-HEJDUK 2007; MICHALSKA-HEJDUK 2007; WRÓBEL 2007; ZARZYCKI, KAŹMIERCZAKOWA 2007; MATUSZKIEWICZ 2007a, DURAK 2009; GRYNIA *et al.* 2009).

This paper is an attempt of knowledge balancing on the subject of natural and anthropogenic transformations of different vegetation types in Kujawy-Pomerania region. It is an original point of view on plant cover of this region because evaluations thereof dynamic tendencies rely not only on documentation but also on different objects' observations. For a clearer image of vegetation changes a relatively short period of time was adopted – a period of the last 20 years. At the same time, it is a period of other than previously performed forms of nature use resulting from different economic reality.

2. MATERIAL AND METHODS

An analysis of dynamic tendencies of vegetation was carried our for Kujawy-Pomerania province (N Poland) including some of its adjacent areas. It is a non-homogenous area in physicogeographical terms, constituting a part of few macroregions – South Pomeranian Lakeland, Wielkopolska Lakeland, Toruń-Eberswalde Glacial Valley, Lower Vistula Valley and Chełmno-Dobrzyń Lakeland (KONDRACKI 2000). Vegetation transformations analyses were performed for the last twenty years period.

Both, acreage changes and degree of structure species composition transformation of respected vegetation types were evaluated. Main factors influencing on regressive and progressive changes were set out. As a basic unit of forest and shrub vegetation unit an association was adopted, whereas of non-forest vegetation – an alliance. A setout of values and causes of changes was presented in tables.

Syntaxonomical classification of forest, meadow and partially ruderal vegetation was adopted according to MATUSZKIEWICZ (2005), spring vegetation according to HINTERLANG (1992), whereas other non-forest plant communities – according to BRZEG and WOJTERSKA (2001).

The analysis was relied on results of author's research and other authors' research and also on observations of selected, previously geobotanically identified objects. Numerous published and unpublished papers concerning both forest (i.a. KĘPCZYŃSKI, ZIELSKI 1976; ZIELSKI 1978; BERNDT, CEYNOWA-GIEŁDON 1988; ZIELONY 1988; KĘPCZYŃSKI, ZAŁUSKI 1991; CYZMAN, REJEWSKI 1992; BIAŁY, ZAŁUSKI 1994; ZAŁUSKI, GAWENDA 1999; JAGODZIŃSKI, MACIEJEWSKA-RUTKOWSKA 2005, 2008; PASZEK 2005; MATUSZKIEWICZ 2007b; CYZMAN, KANNENBERG 2008; CYZMAN 2009) and non-forest (i.a. WILKOŃ-MICHALSKA 1970; KĘPCZYŃSKI, ZAŁUSKI 1977, 1988; NORYŚKIEWICZ 1978; SAMOSIEJ 1987; KĘPCZYŃSKI, CEYNOWA-GIEŁDON 1988; KRASICKA-KORCZYŃSKA 1996; MARCYSIAK 1999; ZAŁUSKI *et al.* 2005, 2008; EJANKOWSKI, KUNZ 2006; KRASICKA-KORCZYŃSKA *et al.* 2008; RATYŃSKA 2008; WALDON, RAPACKA-GACKOWSKA 2010; KUNZ, NIENARTOWICZ 2010; NIENARTOWICZ *et al.* 2010) vegetation changes were used. For each analyzed syntaxonomical unit documented and observed changes in at least 5 objects were taken into account. A detailed documentation of performed analyses and evaluations is located in Department of Biology and Pharmaceutical Botany, Ludwik Rydygier Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University in Toruń.

3. RESULTS AND DISCUSSION

Dynamic tendencies analysis of deciduous forests (Tab. 1) revealed that few plant communities from different phytosociological classes undergo distinct transformations.

Forest plant communities revealing regressive tendencies comprise eutrophic swamp forests *Ribeso nigri-Alnetum*, riparian poplar forests *Populetum albae*, higrophilous elm forests (*Ficario-Ulmetum minoris*, *Violo odoratae-Ulmetum*), oak-linden-hornbeam forests (*Tilio-Carpinetum*, *Galio-Carpinetum*) and thermophilous oak forests *Potentillo albae-Quercetum* (Tab. 1). About regressive tendencies of *Ribeso nigri-Alnetum*, including transformations of this plant community towards wet alder riparian forests *Fraxino-Alnetum*, decides mainly lowering from many years ground water level (cf. CYZMAN 2009). Riparian poplar forests *Populetum albae* have larger share of geographically alien species (i.a. *Acer negundo*, *Solidago gigantea*) and reveal transformations towards higrophilous elm forests *Ficario-Ulmetum minoris*. Higrophilous elm forests (*Ficario-Ulmetum minoris*, *Violo odoratae-Ulmetum*) reveal regression as a result of inundations which leads to changes towards oak-linden-hornbeam forest (cf. JAGODZIŃSKI, MACIEJEWSKA-RUTKOWSKA 2005, 2008; CYZMAN, KANNENBERG 2008). Oak-linden-hornbeam forests (*Tilio-Carpinetum*, *Galio-Carpinetum*) undergo degeneration (pinetization) as a result of coniferous trees introduction, which is a well-known process (OLACZEK 1974; ZIELSKI 1978; ZIELONY 1988; CYZMAN 1991). They also reveal gradual transformations as a result of abundant development of different deciduous trees or shrubs, which is a cause of strong shadowing of herb layer. Furthermore, they are exposed to danger of kenophytes' penetration (e.g. *Impatiens parviflora*). Heliophilous and thermophilous oak forests *Potentillo albae-Quercetum*, which can be acknowledged as the most endangered forest community (cf. JAKUBOWSKA-GABARA 1993), undergo analogical transformations. Changes occurring in their phytocoenoses are very clear and follow generally in a quick pace.

Table 1. Transformations of deciduous forest vegetation. Changes of area: –1 - small decrease; –2 - distinct decrease; 0 - lack of changes or small changes; +1 - small increase; +2 - distinct increase; ? – disputable assessment. Changes of structure and species composition: ↓ - small changes due to regression/degeneration; ↓↓ - distinct changes due to regression/degeneration; ↔ - lack of changes or small changes; ↑ - small changes due to succession/regeneration; ↑↑ - distinct changes due to succession/regeneration; ? - disputable assessment. Main causes: aff - afforestation; asexp - alien species expansion; asint - alien species introduction; bua - built-up areas; csint - coniferous species introduction; eh - eutrophication of habitats; fe - fishpond establishment; ff - forest felling; fl - floods; freg - forest regeneration; gwld - ground water level decrease; nrp - natural regression processes; nsp - natural succession processes; saf - shadowing by adjacent forests; ssuccu - secondary succession due to cessation of use; ssw - secondary swamping; tbulb - technical building up of lake banks; tburb - technical building up of river banks; tm - treestand monotypization; tr - trampling; tru - tourist and recreation use.

Syntaxonomic units	Changes of area	Changes of structure and species composition	Main causes of regressive changes	Main causes of progressive changes
Alnetea glutinosae Br.-Bl. et R. Tx. 1943; *Alnion glutinosae* (Malc. 1929) Meij. Drees. 1936				
Ribeso nigri-Alnetum Sol.-Górn. (1975) 1987	–2, 0, +1	↓↓↔↑	bua, fe, ff, gwld, nrp	freg, nsp, ssuccu, ssw
Sphagno squarrosi-Alnetum Sol-Górn. (1975) 1987	–1, 0, +1	↓↔↑	eh, gwld	freg, nsp
Cardamino-Alnetum (Meij. Drees. 1936) Pass. 1968	–1, 0	↔	fe	
Thelypterido-Betuletum pubescentis Czerw. 1972	–1, 0, +1	↓↔↑	eh, fe, gwld	freg, nsp, ssuccu, ssw
Salicetea purpureae Moor 1958; *Salicion albae* R. Tx. 1955				
Salicetum albo-fragilis R. Tx. 1955	–1, 0, +1	↓↔↑ ?	asexp, gwld, nrp, tburb	fl, nsp, ssuccu, ssw
Populetum albae Br.-Bl. 1931	–1, 0, +1	↓↓↔↑	asexp, asint, gwld, nrp, tm	fl, freg, nsp
Querco-Fagetea Br.-Bl. et Vlieg. 1937 ; *Alno-Ulmion* Br.-Bl. et R. Tx. 1943				
Fraxino-Alnetum W. Mat. 1952	–1, 0, +2	↓↔↑↑	asexp, bua, fe, ff, gwld, ssw, tbulb, tm, tru	aff, freg, nsp, ssuccu
Carici remotae-Fraxinetum W. Koch 1926 ex Faber 1936	–1, 0	↔	fe	
Astrantio-Fraxinetum Oberd. 1953	0 ?	↔ ?		

Table 1. *(Continued)*

Ficario-Ulmetum minoris Knapp 1942 em. J. Mat. 1976	–1, 0, +1	↓↓↔↑	csint, nrp, tm	aff, freg, nsp
Violo odoratae-Ulmetum minoris (Weevers 1940) Doing 1962	–1, 0, +1	↓↓↔↑	asint, csint, nrp, tm	freg, nsp
Carpinion betuli Issler 1931 em. Oberd. 1953				
Tilio cordatae-Carpinetum betuli Tracz. 1962	–1, 0, +1	↓↓↔↑	asexp, asint, csint, nrp, tru	aff, freg, nsp
Galio sylvatici-Carpinetum betuli Oberd. 1957	–1, 0, +1	↓↓↔↑	asexp, asint, csint, nrp, tru	aff, freg, nsp
Acer platanoides-Tilia cordata Jutrz.-Trzeb. 1995	0	↓↔	asexp, tr	
Fagion sylvaticae R. Tx. et Diem. 1936				
Luzulo pilosae-Fagetum W. Mat. et A. Mat. 1973	0, +1	↓↔↑	csint, saf, tru	freg, nsp
Galio odorati-Fagetum Rübel 1930 ex Sougnez et Thill 1959	0, +1	↔↑	csint, tru	freg, nsp
Potentillo albae-Quercion petraeae Zól. et Jakucs n.nov. Jakucs 1967				
Potentillo albae-Quercetum petraeae Libb. 1933 n.inv.	–2, 0	↓↓↔↑	asexp, asint, csint, nrp, saf, tm	ff, freg, nsp

Whereas into group of forest plant communities which reveal progressive tendencies alder riparian forests *Fraxino-Alnetum* and beech forests can be reckoned (Tab. 1). Communities of a wet alder riparian forests *Fraxino-Alnetum* character develop in areas of drained swamp forests *Ribeso nigri-Alnetum* and as a consequence of spontaneous or conscious afforestation of wet meadows. Whereas gradual yet more distinct share increase of beech forests (*Luzulo pilosae-Fagetum*, *Galio odorati-Fagetum*) in some forest complexes results from natural and anthropogenic share increase of beech *Fagus sylvatica* in deciduous and mixed coniferous forests' treestands.

Other deciduous forest associations (Tab. 1) are relatively stable on account of occupied area as well as structure and species composition, while undergoing changes in many observed phytocoenoses are not distinct. Particularly stable vegetation units are some plant communities of wet forests, mainly spring forests (*Cardamino-Alnetum*, *Carici remotae-Fraxinetum*, *Astrantio-Fraxinetum*) and slope maple-linden forest *Acer platanoides-Tilia cordata*. About stable character of this communities decide both natural stability of habitats and low availability for human management.

A setout of dynamic tendencies of coniferous and mixed coniferous forests vegetation (Tab. 2) depicts a specific regularity. It is and area shrinking and disappearing of individual features of phytocoenoses of oligotrophic dry and fresh pine coniferous forests (*Cladonio-Pinetum, Peucedano-Pinetum, Leucobryo-Pinetum*), while progressive tendencies for mixed coniferous forests (*Querco roboris-Pinetum, Serratulo-Pinetum*), typical for mesotrophic habitats. This direction of changes was documented in examined area (KĘPCZYŃSKI, ZAŁUSKI 1991; PASZEK 2005) and in other regions of Poland (MATUSZKIEWICZ 2007c). Changes mentioned above are generated both by natural factors, i.e. regeneration and succession processes on mesotrophic habitats, as well as supported by anthropogenic actions, mainly by preferring deciduous trees (*Quercus* spp.) in accordance with principles of contemporary forest management. Very clear disappearing tendencies of acid oak forests (*Calamagrostio arundinaceae-Quercetum petraeae*), barely noted in examined region should be underlined.

Analysis of changes of shrub and clearing vegetation (Tab. 3) revealed generally high variability of dynamic tendencies of respective phytocoenoses. Few plant associations reveal progressive tendencies (*Salicetum pentandro-cinereae, Euonymo-Prunetum spinosae, Aegopodio-Sambucetum nigrae, Agrostio-Populetum tremulae, Rubo plicati-Sarothamnetum*), which is an effect of extensive forms of use and lack of use of meadows and grasslands. Disappearing communities – *Betuletum humilis* and *Prunetum fruticosae*, of which dominants are strongly endangered species were also noted (cf. ZARZYCKI, SZELĄG 2006).

Regressive tendencies of many groups of aquatic vegetations were demonstrated (Tab. 4), which is conditioned by gradual natural or anthropogenic eutrophication of water bodies and thereby a water transparency decrease (cf. REJEWSKI 1981). Disappearing are also silt-covered ground communities of *Isoëto-Juncetea bufonii* class, which is mostly connected with developing and edge regulation of small, mid-field water bodies and lakes.

Table 2. Transformations of coniferous and mixed forest vegetation. Changes of area: explanations in Table 1. Changes of structure and species composition: explanations in Table 1. Main causes: aff - afforestation; asexp - alien species expansion; asint - alien species introduction; csint - coniferous species introduction; eh - eutrophication of habitats; ff - forest felling; freg - forest regeneration; gwld - ground water level decrease; nrp - natural regression processes; nsp - natural succession processes; saf - shadowing by adjacent forests; tm - treestand monotypization; tru - tourist and recreation use; tu – turfing.

Syntaxonomic units	Changes of area	Changes of structure and species composition	Main causes of regressive changes	Main causes of progressive changes
Quercetea robori-petraeae Br.-Bl. et R. Tx. 1943 ; *Quercion robori-petraeae* Br.-Bl. 1932				
Calamagrostio arundinaceae-Quercetum petraeae (Hartm. 1934) Scam. et Pass. 1959	–2	↓↓ ?	csint, nrp, tm	
Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939; *Dicrano-Pinion* (Libb. 1933) W. Mat. 1962				
Cladonio-Pinetum Juraszek 1927	–2, 0, +1	↓↓↔↑	asint, eh, nrp, saf	aff, ff, freg, nsp
Peucedano-Pinetum (W. Mat. 1962) W. Mat. et J. Mat. 1973	–2, 0, +1	↓↓↔↑	asexp, asint, eh, ff, nrp, saf, tru, tu	aff, freg, nsp
Leucobryo-Pinetum (W. Mat. 1962) W. Mat. et J. Mat. 1973	–2, 0, +1	↓↓↔↑	asexp, asint, eh, ff, nrp, tru, tu	aff, freg, nsp
Molinio (caeruleae)-Pinetum W. Mat et J. Mat. 1973	0 ?	↓↔ ?	asexp, asint, tu	
Querco roboris-Pinetum (W. Mat 1981) J. Mat. 1988	–1, 0, +2	↓↔↑↑	asexp, asint, csint, nrp, tm, tru, tu	aff, freg, nsp
Serratulo-Pinetum (W. Mat 1981) J. Mat. 1988	–1, 0, +2	↓↔↑	asexp, asint, csint, nrp, tm, tru	freg, nsp
Vaccinio uliginosi-Betuletum pubescentis Libb.1933	–1, 0, +1	↓↔↑	asexp, csint, gwld, nrp	freg, nsp
Vaccinio uliginosi-Pinetum Kleist 1929	0, +1	↓↔↑	eh, gwld	nsp
Vaccinio-Piceenion Oberd. 1957				
Querco-Piceetum (W. Mat. 1952) W. Mat. et Pol. 1955	0 ?	↓↔↑	csint, nrp	aff, nsp

Table 3. Transformations of shrub and clearing vegetation. Changes of area: see explanations in Table 1. Changes of structure and species composition: see explanations in Table 1. Main causes: asexp - alien species expansion; bua - built-up areas; cfag - conversion into farmlands or allotment gardens; eg - establishment of greenway; eh - eutrophication of habitats; fe - fishpond establishment; ff - forest felling; fl - floods; freg - forest regeneration; gwld - ground water level decrease; le - lawn establishment; lr - levelling of roadsides; nrp - natural regression processes; nsp - natural succession processes; p - plantings; saf - shadowing by adjacent forests; ssuccu - secondary succession due to cessation of use; ssw - secondary swamping; tburb - technical building up of river banks; we - wastelands elimination.

Syntaxonomic units	Changes of area	Changes of structure and species composition	Main causes of regressive changes	Main causes of progressive changes
Alnetea glutinosae Br.-Bl. et R. Tx. 1943; *Salicion cinereae* (Malc. 1929) Meij. Drees. 1936				
Salicetum pentandro-cinereae (Almq. 1929) Pass. 1961	–1, 0, +2	↓↔↑	asexp, fe, gwld, nrp, ssw, we	nsp, ssuccu
Salicetum auritae Jonas 1935 em. Oberd. 1964	–1, 0, +1	↓↔↑	eh, gwld, nrp	nsp
Betuletum humilis Steffen 1931	–2, 0	↓↓↔	gwld, nrp	
Salicetea purpureae Moor 1958; *Salicion albae* R. Tx. 1955				
Salicetum triandro-viminalis Lohm. 1952	–1, 0, +2	↓↔↑	asexp, nrp, tburb	fl, nsp
Rhamno-Prunetea Rivas-Goday et Carb. 1961 ex R. Tx. 1962; *Carpino-Prunion spinosae* R. Tx. 1952 em. Weber 1974				
Euonymo-Prunetum spinosae (Hueck 1931) Pass. in Pass. et Hofm. 1968	–1, 0, +2	↓↔↑	lr, nrp, we	nsp, ssuccu
Euonymo-Coryletum Pass. in Pass. et Hofm. 1968	–1, +1	↓↔↑	lr, nrp	nsp, ssuccu
Berberidion Br.-Bl. 1950 ex R. Tx. 1952				
Pruno-Ligustretum R. Tx. 1952 nom.inv.	–1, 0, +1	↓↔↑	nrp, we	nsp, ssuccu
Prunion fruticosae R. Tx. 1952				
Prunetum fruticosae Dziubałtowski 1926	–1	↓↓↔	nrp	
Arctio-Sambucion nigrae Doing 1962				
Aegopodio-Sambucetum nigrae Doing 1962 em. M. Wojt. 1990	–1, 0, +2	↓↔↑	asexp, bua, cfag, lr, we	eh, nsp, ssuccu
Chelidonio-Robinietum Jurko 1963	–1, 0, +1	↓↔↑	bua, eg, le, lr, we	p, asexp
Agrostio capillaris-Frangulion Pass. in Pass. et Hofm. 1968 em. Brzeg et M. Wojt. 2001				
Molinio-Franguletum Pass. in Pass. et Hofm. 1968 em. Brzeg et M. Wojt. 2001	–1, 0, +1	↔↑ ?	nrp, we	nsp, ssuccu
Agrostio-Populetum tremulae Pass. in Pass. et Hofm. 1968	–1, 0, +2	↓↔↑↑	bua, cfag, we	nsp, ssuccu
Rubo plicati-Sarothamnetum Weber 1977	–1, 0, +2	↓↔↑	cfag, freg, lr, nrp, saf, we	ff, nsp, ssuccu

Table 3. *(Continued)*

ass. *Rubus plicatus*	–1, 0, +1	↓↔↑	freg, lr, nrp, saf, we	ff, nsp, ssuccu
Epilobietea angustifolii R. Tx. et Prsg 1950; *Sambuco-Salicion capreae* R. Tx. et Neum. in R. Tx. 1950 ex Oberd. 1957				
Salicetum capreae Schreier 1955	–1, 0, +1 ?	↓↔↑ ?	freg, lr, nrp, saf	ff, nsp
Rubetum idaei Malinowski et Dziubałtowski 1914 em. Oberd. 1973	–1, +1	↓↔↑	freg, lr, nrp, saf	ff, nsp
Sambucetum racemosae (Noirf. 1949) Oberd. 1973	–1, +1 ?	↓↔↑ ?	freg, lr, nrp, saf	ff, nsp
Carici piluliferae-Epilobion angustifolii R. Tx. 1950	–1, 0, +1	↓↔↑	freg, lr, nrp	ff, nsp

Distinct progressive tendencies are noted for different rush and tall sedge vegetation (all. *Phragmition, Magnocaricion, Phalaridion*; Tab. 4). On water bodies' edges it is usually an effect of shallowing and eutrophication, whereas in grasslands complexes – an effect of cessation of use and secondary swamping. Clearly spreading plant communities constitute i.a. *Phragmitetum australis* and *Phalaridetum arundinaceae*.

Relatively stable are spring communities (Tab. 4). Pioneer halophytic communities (all. *Salicornion ramosissimae*) and adjacent therophytes (all. *Bidention tripartitae, Chenopodion glauci*), in turn, reveal irregular appearance dependent on water level and soil humidity fluctuations.

Specific plant cover dynamics is observed on peatlands (Tab. 4). More or less boggy peat communities (*Rhynchosporion albae, Caricion lasiocarpae, Sphagnion magellanici*) are currently relatively stable or undergo gradual regression as a result of shrub and forest vegetation succession. The most vulnerable on unfavourable changes (eutrophication and then shrub and forest succession) is however typical to fen vegetation (*Caricion nigrae, C. davallianae*, partially *C. lasiocarpae*), especially moss sedge fen (cf. HERBICHOWA, WOŁEJKO 2004). The least vulnerable are then transformations of phytocoenoses of oligotrophic and strongly bogged habitats.

Table 4. Transformations of aquatic, spring, coastal and peat vegetation. Changes of area: explanations in Table 1. Changes of structure and species composition: explanations in Table 1. Main causes: aff - afforestation; asexp - alien species expansion; del - developing of edge lakes; eh - eutrophication of habitats; fe - fishpond establishment; fl - floods; gwld - ground water level decrease; lr - levelling of roadsides; lssw - limitation of supply with saline water; nrp - natural regression processes; nsp - natural succession processes; saf - shadowing by adjacent forests; ssuccu - secondary succession due to cessation of use; ssw - secondary swamping; swp - surface water pollution; tbulb - technical building up of lake banks; tburb - technical building up of river banks; tr - trampling; tru - tourist and recreation use; tu - turfing; we - wastelands elimination; wld - water level decrease.

Syntaxonomic units	Changes of area	Changes of structure and species composition	Main causes of regressive changes	Main causes of progressive changes
Charetea fragilis Fukarek 1961 ex Krausch 1964				
Nitellion flexilis (Corillion 1957) Dąmbska 1966	–1, 0 ?	↓↔	eh, swp, wld	
Charion fragilis (Sauer 1937) Krausch 1964 em. W. Krause 1969	–2, 0	↓↔	eh, swp, tru, wld	
Charion vulgaris Dąmbska 1966 ex W. Krause 1981	–1, 0 ?	↓↔	eh, swp, wld	
Fontinaletea antipyreticae Hb. 1957				
Fontinalion antipyreticae Koch 1936	–1, 0	↓↔	eh, swp	
Littorelletea uniflorae Br.-Bl. et R. Tx. 1943				
Lobelion (Van den Berghen 1944) R. Tx. et Dierss. ap. Dierss. 1972	–2, 0	↓↔	eh, swp, tru	
Eleocharition acicularis Pietsch 1966 em. Dierss. 1975	–1, 0 ?	↓↔	eh, swp	
Utricularietea intermedio-minoris Den Hartog et Segal 1964 em. Pietsch 1965				
Sphagno-Utricularion Müll. et Görs 1960	–1, 0, +1	↓↔↑	eh, nrp, wld	nsp
Lemnetea minoris (R. Tx. 1955) de Bolós et Masclans 1955				
Lemnion minoris (R. Tx. 1955) de Bolós et Masclans 1955	–1, 0, +1	↓↔↑	nrp, swp, wld	eh, nsp, ssw
Hydrocharition morsus-ranae Rübel 1933	–1, 0, +1	↓↔↑	nrp, swp, wld	nsp, ssw
Potametea R.Tx. et Prsg. 1942 ex Oberd. 1957				
Potamion pectinati (W. Koch 1926) Görs 1977	–2, 0, +1	↓↔↑	eh, fl, nrp, swp, wld	nsp
Nymphaeion Oberd. 1957	–1, 0, +1	↓↔↑	nrp, swp, wld	nsp
Ranunculion fluitantis Neuhäusl 1959	–1, 0, +1	↓↔↑	eh, swp	nsp
Montio-Cardaminetea Br.-Bl. et R. Tx. 1943				
Cardamino-Montion Br.-Bl. 1925	–1, 0	↓↔	fe, saf	
Cratoneurion commutati W. Koch 1928	0 ?	↔ ?		
Caricion remotae Kästner 1941	–1, 0	↓↔	fe, saf	

Table 4. *(Continued)*

Phragmitetea australis (Klika in Klika Novák 1941) R. Tx. et Prsg 1942				
Phragmition australis W. Koch 1926	–1, 0, +2	↓↔↑	del, fe, gwld, nrp, swp, tbulb, tru, we	eh, nsp, ssuccu, ssw
Magnocaricion elatae W. Koch 1926	–1, 0, +2	↓↔↑	fe, gwld, swp, trurb, tru, we	nsp, ssw
Oenanthion aquaticae Hejný ex Neuhäusl 1959	–1, 0, +1	↓↔↑	eh, gwld, swp	nsp, ssw
Sparganio-Glycerion fluitantis Br.-Bl. et Siss. ap. Boer 1942 n.inv.	–1, 0, +1	↓↔↑	swp, wld	nsp
Phalaridion Kopecký 1961	–1, 0, +2	↓↔↑	gwld, swp, tburb	eh, fl, nsp, ssuccu, ssw
Thero-Salicornietea Pign. 1953 em. R. Tx. 1954 in R. Tx. et Oberd. 1958				
Salicornion ramosissimae R. Tx. 1974	–1, 0, +1	↓↔↑	gwld, lssw	nsp
Isoëto durieui-Juncetea bufonii (Br.-Bl. et R. Tx. 1943 ex Westh. et al. 1946) Riv.-Mart. 1988				
Elatino-Eleocharition ovatae Pietsch et Müller-Stoll 1968	–2, +1	↓↑	gwld, del, tburb, tu	wld
Nanocyperion flavescentis W. Koch 1926 ex Aichinger 1933 em. Rivas Goday 1961	–1, +1	↓↑	gwld, del, tbulb, tu	wld
Radiolion linoidis (Rivas-Goday 1961) Pietsch 1973	–2, +1	↓↑	gwld, lr, tu, we	tr
Bidentetea tripartitae R. Tx., Lohm. et Prsg in R. Tx. 1950				
Bidention tripartitae Nordh. 1940 em. R. Tx. in Poli et J. Tx. 1960	–1, +1	↓↑	asexp, del, lr, tburb, tu, we	nsp, ssw, tr
Chenopodion glauci (R. Tx.1960 in Poli et J. Tx. 1960) Hejný 1974	–2, +2	↓↑	asexp, del, tburb, we	fl, nsp
Scheuchzerio-Caricetea nigrae (Nordh. 1936) R. Tx. 1937				
Rhynchosporion albae W. Koch 1926	–1, 0	↓↔	nrp	
Caricion lasiocarpae Vanden Bergh. in Lebrun et all. 1949	–1, 0, +1	↓↓↔↑	aff, eh, gwld, nrp	nsp, ssw
Caricion nigrae W. Koch 1926 em. Klika 1934	–1, 0, +1	↓↔↑	aff, eh, gwld, nrp	ssw
Caricion davallianae Klika 1934	–1, 0, +1	↓↔↑	aff, gwld, nrp	nsp, ssw
Oxycocco-Sphagnetea Br.-Bl. et R. Tx. 1943				
Sphagnion magellanici Kästner et Flössner 1933 em. Dierss. 1975	–1, 0, +1	↓↔↑	gwld, nrp	nsp

Semi-natural meadows, tall herbs, grasslands and forest edges vegetation (Tab. 5) is dependent both on natural and anthropogenic factors. Wet meadows (all. *Molinion*, *Cnidion*) undergo transformations as a result of use intensification or cessation thereof. Fresh pastures (all. *Cynosurion*), halophyte grasslands (all. *Puccinellion maritimae*, *Armerion maritimae*) and xerothermic grasslands (all. *Cirsio-Brachypodion*, *Festuco-Stipion*) are decreasing their share in consequence of grazing cessation. Poor grasslands and heaths (all. *Violion caninae, Calluno-Arctostaphylion*) are disappearing as a result of eutrophication, shadowing or building-up. Progressive tendencies, in turn, reveal tall herbs and nitrophilous edge communities (all. *Filipendulion, Calystegion sepium, Aegopodion podagrariae, Galio-Alliarion*) and fertile fresh meadows (all. *Alopecurion pratensis, Arrhenatherion elatioris*). Particularly significant for the last 20 years period is a secondary tall herbs succession in conditions of wet meadows' cessation of use (cf. KOCHANOWSKA 1997; KRASICKA-KORCZYŃSKA *et al.* 2008).

From group of ruderal and segetal vegetation (Tab. 6) regressive tendencies have very rare phytocoenoses of *Caucalidion lappulae* alliance, whereas progressive tendencies have meso- and thermophilic ruderal communities (all. *Convolvulo-Agropyrion repentis, Onopordion acanthii, Sisymbrion, Eragrostion*).

Table 5. Transformations of meadow, grassland and forest edge vegetation. Changes of area: see explanations in Table 1. Changes of structure and species composition: see explanations in Table 1. Main causes: aff - afforestation; asexp - alien species expansion; bua - built-up areas; cfag - conversion into farmlands or allotment gardens; cfu - cessation of farmlands use; eg - establishment of greenway; eh - eutrophication of habitats; ff - forest felling; fl - floods; gcp - green crops ploughing; ges - grass extra sowing; gi - grazing intensification; gl - grazing limitation; gwld - ground water level decrease; le - lawn establishment; lr - levelling of roadsides; lssw - limitation of supply with saline water; mi - mowing intensification; ml - mowing limitation; nrp - natural regression processes; nsp - natural succession processes; o - overfertilization; p - plantings; saf - shadowing by adjacent forests; sge - sand and gravel exploitation; ssuccu - secondary succession due to cessation of use; ssw - secondary swamping; tburb - technical building up of river banks; tr - trampling; tru - tourist and recreation use; we - wastelands elimination.

Syntaxonomic units	Changes of area	Changes of structure and species composition	Main causes of regressive changes	Main causes of progressive changes
Molinio-Arrhenatheretea R. Tx. 1937 em. 1970				
Lolio-Plantaginion majoris R. Tx. 1947	–1, 0, +1	↓↔↑	eg, le, lr, we	gi, tr, tru
Agropyro-Rumicion crispi Nordh. 1940 em. R. Tx. 1950	–1, 0, +1	↓↔↑	gwld, nrp, we	gi, ssw
Filipendulion ulmariae Segal 1966	–1, 0, +2	↓↔↑↑	aff, gcp, mi	ssuccu
Molinion caeruleae W. Koch 1926	–2, 0, +1	↓↓↔↑	aff, cfag, eh, gcp,	gwld, ml

Table 5. *(Continued)*

			ges, mi, o, ssuccu	
Calthion palustris R. Tx. 1936 em. Oberd. 1957	–1, 0, +1	↓↓↔↑	aff, gcp, ges, gwld, o, ssuccu	ssw, ml
Cnidion dubii Bal.-Tul. 1966	–1, 0	↓↓↔	gwld, mi, o, ssuccu, ssw	fl, ml
Alopecurion pratensis Pass. 1964	–1, 0, +2	↓↔↑	asexp, aff, bua, cfag, gcp, ges, ssuccu	eh, fl, mi
Arrhenatherion elatioris (Br.-Bl. 1925) Koch 1926	–1, 0, +2	↓↓↔↑	aff, bua, cfag, gcp, ges, gi, lr, o, ssuccu	gl, gwld, mi
Cynosurion R. Tx. 1947	–2, 0, +1	↓↓↔↑	bua, cfag, ges, gl, mi, ssuccu	gi
Asteretea tripolium Westh. at Beeft. ap. Beeft 1962				
Puccinellion maritimae (Christ. 1927) R. Tx. 1937	–2, 0, +1	↓↓↔↑	gl, gwld, lssw, ssuccu	gi, ssw
Armerion maritimae Br.-Bl. et De Leeuw 1936	–2, 0, +1	↓↓↔↑	gl, gwld, lssw, ssuccu	gi, ssw
Koelerio glaucae-Corynephoretea canescentis Klika in Klika et Novák 1941				
Corynephorion canescentis Klika 1934	–1, 0, +1	↓↔↑	aff, bua, nrp, saf, sge, we	cfu, nsp
Thero-Airion R. Tx. 1951 ex Oberd. 1957 em. Brzeg in Brzeg et M. Wojt. 1996	–1, 0, +1 ?	↓↔↑ ?	aff, bua, cfag, nrp, saf, sge, we	cfu, nsp
Koelerion glaucae (Volk 1931) Klika 1934	–1, 0, +1	↓↔↑	aff, bua, cfag, nrp, saf, sge, we	cfu, nsp
Festuco-Brometea Br.-Bl. et R. Tx. 1943				
Cirsio pannonici-Brachypodion pinnati Hadač et Klika in Klika et Hadač 1944 em. Krausch 1961	–2, 0, +1	↓↓↔↑	aff, bua, gi, npr, ssuccu, we	nsp
Festuco-Stipion (Klika 1931) Krausch 1961	–2, 0, +1	↓↓↔↑	aff, bua, gi, lr, npr, ssuccu, we	nsp
Phleion boehmeri Głowacki 1972 ex Celiński et Balcerkiewicz 1973	–1, 0, +1 ?	↓↔↑ ?	aff, bua, cfag, lr, saf, sge, we	cfu, nsp
Alysso alyssoidis-Sedion albi Oberd. et Th. Müll. in Th. Müll. 1961	–1, 0, +1 ?	↓↔↑ ?	lr, p, sge, we	nsp
Trifolio-Geranietea sanguinei Th. Müll. 1962				
Geranion sanguinei R. Tx. in Th. Müll. 1962	–1, 0, +1	↓↔↑	lr, nrp, p, saf	ff, nsp

Table 5. *(Continued)*

Trifolion medii Th. Müll. 1962	–1, 0, +1	↓↔↑	aff, bua, cfag, lr, nrp, p, saf, we	ff, nsp, ssuccu
Melampyrion pratensis Pass. 1967	–1, 0, +1	↓↔↑	lr, nrp, p, saf	ff, nsp
Nardo-Callunetea Prsg 1949				
Violion caninae Schwick. 1944	–2, 0	↓↓↔	aff, bua, eh, gi, o, ssuccu, we	
Calluno-Arctostaphylion R. Tx. et Prsg 1949 ex Faliński 1965	–2, 0	↓↓↔	aff, bua, cfag, eh, saf, we	
Pohlio nutantis-Callunion (Shimwell 1973) Brzeg 1982	–1, 0, +1	↓↔↑	aff, nrp, saf	ff, nsp
Asplenietea trichomanis (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. in Oberd. 1977				
Cymbalario-Asplenion Segal 1969 em. Mucina 1993	0	↔		
Hypno-Polypodion vulgaris Mucina 1993	–1, 0	↔ ?	lr	
Artemisietea vulgaris Lohm., Prsg et R. Tx. in R. Tx. 1950				
Calystegion sepium R. Tx. 1947 em. 1950 1947	–1, 0, +2	↓↔↑↑	asexp, lr, nrp, tburb, we	ml, nsp, ssuccu
Aegopodion podagrariae R. Tx. 1967	–1, 0, +2	↓↔↑	aff, asexp, lr, nrp, saf	ml, nsp, ssuccu
Galio-Alliarion (Oberd. 1962) Lohm. et Oberd. in Oberd. et al. 1967	–1, 0, +2	↓↔↑	asexp, lr, p, saf	ff

Table 6. Transformations of ruderal and segetal vegetation. Changes of area: explanations in Table 1. Changes of structure and species composition: explanations in Table 1. Main causes: acu - arable cultivation; aff - afforestation; asexp - alien species expansion; bua - built-up areas; cfu - cessation of farmlands use; eh - eutrophication of habitats; ha - herbicide application; le - lawn establishment; lr - levelling of roadsides; o - overfertilization; p - plantings; ssuccu - secondary succession due to cessation of use; tr - trampling; tru - tourist and recreation use; we - wastelands elimination; wf - wastelands formation.

Syntaxonomic units	Changes of area	Changes of structure and species composition	Main causes of regressive changes	Main causes of progressive changes
Polygono arenastri-Poëtea annuae Riv.-Mart. 1975 corr. Riv.-Mart. et al. 1991				
Matricario matricarioidis-Polygonion arenastri Riv.-Mart. 1975 corr. Riv.-Mart. et al. 1991	–1, 0, +1	↓↔↑	bua, eg, le, lr, we	tr, tru
Saginion procumbentis R. Tx. et Ohba 1972 in Géhu et al. 1972	–1, 0, +1	↓↔↑	bua, eg, le, lr, we	tr, tru
Agropyretea intermedio-repentis (Oberd. et all. 1967) Th. Müll. et Görs 1969				
Convolvulo arvensis-Agropyrion repentis Görs 1966	–1, 0, +2	↓↔↑	asexp, aff, bua, eg, le, lr, p, we	eh, cfu, ssuccu
Artemisietea vulgaris Lohm., Prsg et R. Tx. in R. Tx. 1950				
Onopordion acanthii Br.-Bl. 1926 ex Br.-Bl. et al. 1936	–1, 0, +2	↓↔↑	asexp, aff, bua, eg, le, lr, p, we	cfu, eh, wf
Arction lappae R. Tx. 1937 em. Siss. in Westh. et al. 1946	–1, 0, +1	↓↔↑	bua, eg, le, lr, p, we	eh, wf
Stellarietea mediae R. Tx., Lohm. et Prsg in R. Tx. 1950				
Panico-Setarion Siss. in Westh. et al. 1946	–1, 0, +1	↓↔↑	ha, o	acu
Scleranthion annui (Kruseman et Vlieger 1939) Siss. in Westh. et al. 1946	–1, 0, +1	↓↓↔↑	asexp, ha, o	acu
Veronico-Euphorbion Siss. 1942 ex Pass. 1964	–1, 0, +1	↓↔↑	asexp, ha, o	acu
Caucalidion lappulae R. Tx.1950	–1, 0	↓↔	ha, o	acu
Sisymbrion R. Tx., Lohm. et Prsg in R. Tx. 1950	–1, 0, +2	↓↔↑	asexp, eg, le, lr, we	eh, wf
Malvion neglectae (Gutte 1966) Hejný 1978	–1, 0, +1	↓↔↑	eg, le, lr, we	eh, wf
Eragrostion R. Tx. in Slavnić 1944	–1, 0, +2	↓↔↑	asexp, lr, we	eh, wf

4. CONCLUSIONS

- Acreage changes and transformations of different vegetation types of examined region in a period of the last 20 years are both effects of factors existing mainly only in analyzed time period. Into first group regressive changes of wet riparian poplar and elm forests (*Populetum albae, Ficario-Ulmetum minoris*) and gradual overgrowing of xerothermic grasslands of *Festuco-Brometea* class can be reckoned. Whereas to the second group belong i.a. changes resulting from cessation of use of meadows and pastures and frequent mixed coniferous forests regeneration on account of proecological forest management.
- Frequent and drastic plant cover changes of swamp ecosystems as a result of anthropogenic ground water level lowering, which occurred in the middle of the 20th century, are not observed currently. Nowadays even often an overgrowing of drainage ditches and secondary swamping takes place, which is confirmed by progressive dynamic tendencies of rush vegetation. Preserved natural moss bogs undergo gradual overgrowing so they do not belong to strongly endangered plant cover elements of examined area. Also less often an intensive meadow management in grasslands and farmlands is applied. Moreover, greater preferences in forest management have deciduous species than introduced until recently on a large scale pine *Pinus sylvestris*.
- Shown regressive and progressive changes of different vegetation types are, to a larger degree (than in the middle of the 20^{th} century) generated by natural factors rather than anthropogenic factors. Disappearing and transformation of thermophilous oak forests, dry and fresh coniferous forests, halophytic, pasture, meadow, heathery and grassland vegetations result currently most of all from natural
- regeneration processes and secondary succession. At the same time, these factors create progressive changes in case of mixed coniferous forests, mesophytic shrubs, rush and tall herbs vegetation as well as fresh meadows vegetation.

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THE ANALYSIS OF THE FOREST FLORA OF THE STRZYŻOWSKIE FOOTHILLS FROM THE PERSPECTIVE OF PRESENCE OF ANTHROPOGENIC SPECIES

Abstract: The anthropogenic pressure of the forest communities of the Strzyżowskie Foothills (the Western Carpathians) was estimated on the basis of phytosociological materials. Carr communities are among the most threatened by invasive and alien species of the forest flora. The phenomenon of invasiveness of native species such as *Calamagrostis epigejos* or *Carex brizoides* was described. The highest number of ancient woodland indicator species was noted in the beech forest.

Key words: kenophytes, archaeophytes, invasive species, forest communities, the Strzyżowskie Foothills

1. INTRODUCTION

For centuries, the area of the Carpathian Foothills has experienced strong anthropogenic pressure, resulting in forest vegetation covering usually only small patches, often limited to pockets in the agricultural landscape (e.g. LOSTER 1991; PRZYBOŚ 1995; STACHURSKA 1998). The importance of these patches of forest vegetation as refugia for a number of plant and animal species is indisputable, and therefore they have remained a principal focus of research, particularly given the ever-changing landscape in areas with human settlements (e.g. DZWONKO, LOSTER 1988; DZWONKO 1993; BANASZAK 2000). The fragmentation of natural plant

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communities increases the exposure to either direct or indirect effects of anthropogenic impacts observable, like changes in the structure and function of these communities (e.g. KORNAŚ 1972; OLACZEK 1972; TRZCIŃSKA-TACIK, STACHURSKA-SWAKOŃ 2002; DYGUŚ 2003; JAKUBOWSKA-GABARA, ZIELIŃSKA 2003).

At present, the vegetation cover of the Strzyżowskie Foothills, situated in the eastern part of the Western Carpathians, is dominated by cultivated fields that occupy ca. 70% of the area (TOWPASZ 1990). Woodlands have survived only in those places less attractive to agriculture; namely, steep slopes, deep valleys, narrow gorges and ravines. Such places constitute ca. 15% of the area and create peculiar habitat islands. On the one hand, small forest patches separated from one another provide refugia for many forest plants and animals, and, on the other hand, they are often subject to strong anthropogenic pressure. Observations of their destruction or degradation can be made (TOWPASZ, STACHURSKA-SWAKOŃ 2008), as well as of their neophytism, occurring via penetration by newcomers (STACHURSKA-SWAKOŃ, TOWPASZ 2008).

The studies pursued in the Strzyżowskie Foothills for more then thirty years, have revealed a relatively high number of forest communities associated with diverse habitat conditions (TOWPASZ 1990; TOWPASZ, STACHURSKA-SWAKOŃ 2008, 2010). The location of the Strzyżowskie Foothills on the border with the Sandomierz Basin reflects in the occurrence of various syntaxonomical units characteristic of both foothill and lowland areas. Among the lowland syntaxa is *Luzulo pilosae-Fagetum*, rarely found in the Carpathian Foothills, and *Calamagrostio arundinaceae-Quercetum,* recorded in the Carpathians for the first time (TOWPASZ, STACHURSKA-SWAKOŃ, unpbl.). An important feature of the forest communities of the Strzyżowskie Foothills, which make the area stand out, is the presence of the East-Carpathian species, such as *Aposeris foetida* or *Cerastium sylvaticum*.

The presented study makes an approach to the problem of anthropogenic pressure to forest communities. The plant taxa alien to forest flora are known to exert degenerating effects on forest communities. This group includes both kenophytes and species from other communities, often introduced accidentally into the forest flora, or even forest species showing expansive properties and resulting from changing habitat conditions.

The description of the study area was presented in the studies by TOWPASZ (1990) and TOWPASZ and STACHURSKA-SWAKOŃ (2008). The location of the area is shown in Fig. 1.

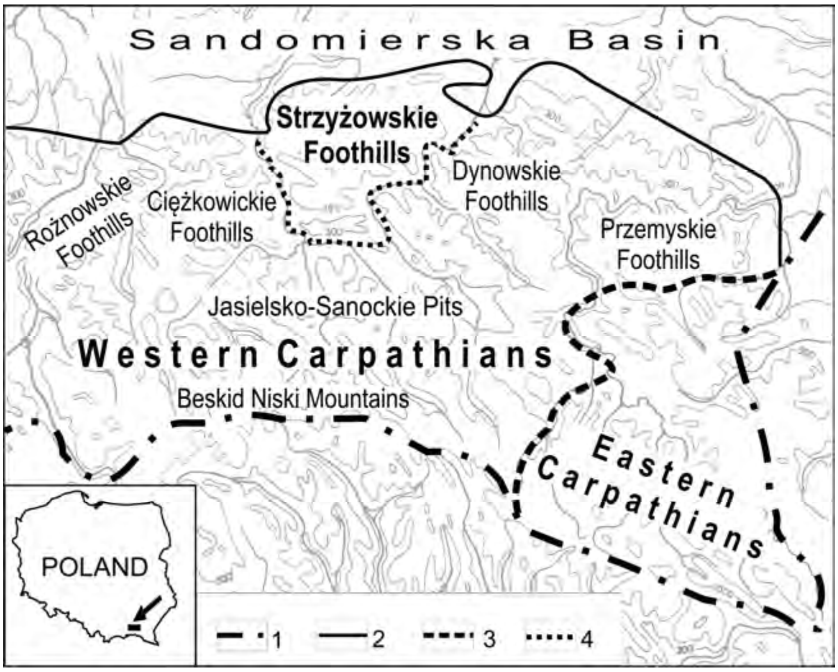

Fig. 1. Location of the Strzyżowskie Foothills against the regional division of the eastern part of the Polish Carpathians (after KONDRACKI 1978): 1 – state boundary, 2 – the northern limits of the Carpathians, 3 – boundary between the Western and Eastern Carpathians, 4 – the area investigated.

2. MATERIAL AND METHODS

The basic material used in this study is the relevés recorded during the years 1978-2009. Most of the material was published in studies conducted by TOWPASZ and STACHURSKA-SWAKOŃ 2008, 2010, STACHURSKA-SWAKOŃ and TOWPASZ 2008 and TOWPASZ *et al*. 2011. This paper also includes materials not yet published, that were obtained mainly in the period 2008-2009. Floristic lists and phytosociological tables were analysed with special attention given to the presence of species alien to forest flora. The long period covered by the studies allowed conclusions to be drawn, on the changes occurring in forest communities of the Strzyżowskie Foothills. The basis for the classification of kenophytes followed the studies undertaken by ZAJĄC *et al*. 1998 and TOKARSKA-GUZIK 2005. The species regarded as ancient woodland indicator species were also used (following the study of DZWONKO, LOSTER 2001). The methods applied, allowed for identification of forest communities in the Strzyżowskie Foothills, the ones most threatened by alterations in their floristic composition, as well as those whose composition was not disturbed by the participation of invasive species.

3. RESULTS

The naturalized kenophytes, i.e. observed for more than 30 years and showing high constancy in the forests of the Strzyżowskie Foothills, include *Helianthus tuberosus, Impatiens parviflora, Impatiens glandulifera, Reynoutria japonica* and *Solidago gigantea* (Tab. 1). Apart from these, *Echinocystis lobata, Rudbeckia laciniata, Heracleum sosnowskyi, Oxalis stricta* and *Telekia speciosa,* are also found in the area. The majority of these species are found in riparian carr communities, especially in the riparian carrs upon major rivers such as the Wisłok and Wisłoka. The species particularly threatening the local flora of the carrs, include: *Reynoutria japonica, Helianthus tuberosus* and *Solidago gigantea.*

In deciduous woods, *Impatiens parviflora* occurs, locally with considerable cover. This species was recorded in *Tilio-Carpinetum typicum* as well as in beech forests. It is likely that its presence has resulted from a local disturbance associated with a thinning of the forest stand.

Tree and shrub species constitute a large group among the kenophytes recorded in the forests of the Strzyżowskie Foothills, and those used in planting schemes include: *Pinus strobus, Prunus serotina, Robinia pseudoacacia* and *Quercus rubra.* However, the shrub *Ligustrum vulgare,* which also occurs on natural localities in the Strzyżowskie Foothills (primarily in brushwoods with *Prunetalia*), has been accidentally planted to create hedges, was also introduced and observed to establish itself in the community with *Alnus incana.*

Table 1. Alien plant species in the forest communities of the Strzyżowskie Foothills. Abbreviations of the forest communities: A – *Carici remotae-Fraxinetum,* B – *Alnus incana* community, C – *Salicetum triandro-viminalis,* D – *Salicetum albo-fragilis,* E – *Calamagrostio arundinaceae-Quercetum,* F – *Tilio-Carpinetum stachyetosum sylvaticae,* G – *T.-C. stachyetosum* with *Arum orientale,* H – *T.-C. melittetosum,* I – *T.-C. typicum,* J – *T.-C. caricetosum pilosae,* K – *Dentario glandulosae-Fagetum lunarietosum redivivae,* L – *D.-F. typicum,* M – *D.-F.* with *Rubus hirtus,* N – *Luzulo pilosae-Fagetum,* O – *Abies alba-Oxalis acetosella*. In case the constancy of species was higher then I, the occurrence of species is done in brackets.

Forest community	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**Number of forest communities with the species**
Number of releves	**35**	**10**	**5**	**3**	**11**	**14**	**9**	**3**	**39**	**24**	**3**	**20**	**13**	**9**	**12**	
Kenophytes:																
Impatiens parviflora	I		I	I			IV (+-1)		I (+-5)			I	I			7
Solidago gigantea	I		IV (1-4)	V (+-2)					I							4
Helianthus tuberosus			III (+-3)	I												2
Aesculus hippocastanum (a)	I															1
Echinocystis lobata			I													1
Heracleum sosnowskyi			I													1
Impatiens glandulifera			I													1
Ligustrum vulgare (b)		I														1
Oxalis stricta									I							1
Pinus strobus (a)														I		1
Prunus serotina (b)					I											1
Quercus rubra (a)					I											1
Reynoutria japonica			I													1
Telekia speciosa		I														1
Archaeophytes:																
Matricaria maritima subsp. *inodora*			I						I							2
Anthemis arvensis	I															1
Apophytes:																
Equisetum arvense	I	I	I						I	I			I			6
Arctium tomentosum			I	I		I				I						4
Cerastium arvense	I					I			I			I				4
Chelidonium majus							II (+)	I	I							3
Viola canina								I					I	I		3
Arctium lappa			I	I												2
Arctium minus	I	I														2
Cirsium arvense			I	I												2
Rumex conglomeratus			I	I												2
Artemisia vulgaris				I												1
Elymus caninus	I															1
Elymus repens				I												1
Plantago major	I															1
Poa annua	I															1
Poa pratensis					I											1
Potentilla anserina			I													1
Apophytes regarded as expansive:																
Carex brizoides	I								I	I			I		I	5
Calamagrostis epigejos			I													1

A more numerous group of species alien to forest flora, consists of apophytes whose presence is most often associated with gaps in forest canopies, as well in the close vicinity of buildings. This group includes 16 species, including amongst others *Arctium lappa, Cerastium arvense* and *Chelidonium majus* (Tab. 1). Archaeophytes, however, were only rarely recorded. The last group includes only two sporadically found species: *Anthemis arvensis* and *Matricaria maritima* subsp. *inodora*.

The expansion of native species is another interesting phenomenon. The occurrence of a forest species, *Carex brizoides,* in the form of large dense stands, was observed as an effect of habitat alterations, resulting mainly from changing economic activities. In recent years, expansive invasions of *Calamagrostis epigejos*, a species associated with non-forest habitats, have been noted. Because of its development potential, this species alters the character of forest communities.

The highest combined number of species alien to forest flora was noted in riparian willow communities *Salicetum albo-fragilis* (Tab. 2). Their share constituted ca. 4% of this flora. A similar situation was observed in *Salicetum triandro-viminalis*. It is worth noting that despite similar percentage shares in both riparian communities, there were differences in the numbers of kenophytes and apophytes. More kenophytes were observed in the brushwood community *Salicetum triandro-viminalis.* At the same time, these communities had the lowest share of ancient woodland indicator species. The forest communities in whose patches no alien species were found include beech forests, particularly *Dentario glandulosae-Fagetum lunarietosum redivivae*. Also in oak-hornbeam forests; namely: *Tilio-Carpinetum stachyetosum*, *T.-C. caricetosum pilosae* and *T.-C. melittetosum*, no kenophytes and only a few apophytes were observed. The proportion of ancient woodland indicator species is relatively high there, with the highest numbers noted in the warm subassociation of the *T.-C. melittetosum.*

4. DISCUSSION

The list of kenophytes occurring in the forest communities of the Strzyżowskie Foothills is relatively short, although one should note that it is definitely not complete. This fact is implied from the methodology used in this study, which derives the presence of species from relevés rather than complete accounts of forest floras. The spots where alien species can penetrate are mostly roads cutting through forest communities, paths, clearings or forest glades (PASZEK, ZAŁUSKI 2000; ZIARNEK 2000). Such places are not usually covered by phytosociological studies or if so, only to a limited extend.

Table 2. Ancient woodland indicator species and alien species in the forest communities of the Strzyżowskie Foothills.

Forest community	**Number of relevés**	**Total number of species**	**Average number of species per relevé**	**Total ancient woodland indicator species**	**% of ancient woodland indicator species**	**Number of alien species**	**% of alien species**
Carici remotae-Fraxinetum	35	197	30	60	30.5	11	5.6
Alnus incana community	10	136	37	48	35.3	6	4.4
Salicetum triandro-viminalis	5	80	19	28	35.0	15	16.3
Salicetum albo-fragilis	3	55	28	10	18.2	9	16.4
Calamagrostio arundinaceae-Quercetum	11	121	29	26	21.5	3	2.5
Tilio-Carpinetum							
T.-C. stachyetosum sylvaticae	14	119	34	49	41.2	2	1.7
T.-C. stachyetosum with *Arum orientale*	9	75	29	35	46.7	2	2.7
T.-C. melittetosum	3	78	41	37	47.4	2	2.6
T.-C. typicum	39	180	27	54	30.0	7	3.9
T.-C. caricetosum pilosae	24	122	29	53	43.4	4	3.3
Dentario glandulosae-Fagetum							
D.-F. lunarietosum redivivae	3	40	25	17	42.5	-	-
D.-F. typicum	20	102	24	43	42.2	2	3.9
D.-F. with *Rubus hirtus*	13	95	21	43	45.3	2	6.3
Luzulo pilosae-Fagetum	9	69	19	25	36.2	1	4.3
Abies alba-Oxalis acetosella	12	78	22	29	37.2	1	2.6

Riparian forest communities are the most vulnerable to alien plant invasion. This is reflected in a relatively high number (compared with other forest communities) of alien species, as well as in the proportion of ancient woodland indicator species. The phenomenon involving kenophyte invasions of riparian communities is observed in many places in Poland and elsewhere in the world. Quite often, the newcomers appear just in the riparian woodlands. This holds, e.g. for the very expansive *Reynoutria japonica* (TOKARSKA-GUZIK 2005) or *Impatiens glandulifera* (JASNOWSKI 1961), whose first appearance in Poland was recorded in riparian woodlands. The biology of these species, as well as other kenophytes associated with moist habitats, contributes most often to the sudden alterations in the floristic structures of these associations (DRESCHER, PROTS 2003; TOKARSKA-GUZIK 2005; STACHURSKA-SWAKOŃ, TOWPASZ 2008).

Impatiens parviflora, an Asian species which appeared in Europe in 1837 (HEGI 1966), is now treated as a naturalized component of deciduous and mixed forests (FALIŃSKI 1966; KUJAWA-PAWLACZYK 1991). In the first stage, however, it colonizes empty ecological niches and places which are continually destroyed and hence, it is found in oak-hornbeam forests where light penetrates easily through gaps made by logging (e.g. STACHURSKA 1998), in places disturbed by wild boars or on fallen trees or dead tree logs (PISKORZ, KLIMKO 2001). In the studied oak-hornbeam of the Strzyżowskie Foothills, the presence of *Impatiens parviflora* is undoubtedly associated with human economic activity and with the close vicinity of cultivated fields or meadow communities.

The most resistant to the penetration by alien species, are ancient beech forests and ancient oak-hornbeam forests. The patches of these associations in the Strzyżowskie Foothills are situated in large forest complexes, far away from potential sources of diaspores of species of foreign origin. It is where the importance of the forest islands' size for the preservation of their natural properties, as emphasized by many researchers (e.g. MCARTHUR, WILSON 1967; MAY 1975), is manifested.

The lists of ancient woodland indicator species were prepared, in order to determine the approximate dates of the emergence of forest islands for the purpose of assessing the natural quality and value of a given forest – which is of significance to nature conservation (e.g. HERMY *et al.* 1999; HONNAY *et al.* 1999; DZWONKO, LOSTER 2001; ENDELS *et al.* 2007). Applying such distinct lists in this study, indicates not only which forest communities are the most ancient in the study area, but also highlights the 'resistance' of these associations to the pressure from kenophytes.

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ANCIENT WOODLANDS' AND SYNANTHROPIC PLANTS AS INDICATORS OF MAINTENANCE OF THE FOREST COMMUNITIES IN THE NATURE RESERVES OF THE OŚWIĘCIM BASIN

Abstract: The landscape of the Oświęcim Basin, naturally dominated by forest communities, has been strongly transformed due to the long-term activities of man. Across time and space, it has been stamped by pond management and agriculture to the highest degree. Despite such a strong transformation of the natural environment fragments of forests which reflect the peculiarities of forest vegetation of the macroregion still occur. These are the Żaki and the Przeciszów nature reserves. The goal of the phytosociological studies done within their borders was the assessment of the *Tilio-Carpinetum* phytocoenoses which dominate in the reserves, regarding their: maintenance, naturalness, anthropological changes and compliance to anthropopressure, as well as natural values. Therefore, analyses related to the share of: character species, ancient woodland indicators and synanthropes were performed for purposes of the study. It has been proposed that transformations of the forest communities be assessed using the new formula of floristic naturalness coefficient (W_{NF}), based on the share of ancient woodland and synanthropic species.

Key words: *Tilio-Carpinetum,* reserves, ancient woodlands, coefficient of floristic naturalness

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1. INTRODUCTION

The natural environment of the Oświęcim Basin has been strongly transformed as a result of the long-term activities of man. Anthropopressure increased due to the development of colonization activities and associated with it – agriculture. As has been assessed, larger aggregations of inhabitants colonized river valleys – especially the Vistula River valley – in the second half of the 13th century, and the end of that century was characterized by intensive creation of villages and towns within the area being discussed (KOŹBIAŁ 2000). The main role in the transformation of the environment was played by breeding-pond management. This activity started at the turn of the 12th and 13th century, but the highest development took place in the 16th and partly the 17th century. As has been supposed, by then the managed ponds covered 25-35% of the area of the Upper Vistula Valley – the middle part of the larger unit (the Oświęcim Basin) which ranges along the Vistula River from Skoczów to the SW to Zator to the NE (WŁODEK 1957). After periods of flourishing and regression, the area of the ponds has significantly decreased and today it is not so large. However, across time, it has influenced the transformations of the natural environment because it gradually limited the area covered by forests. Actually, forests only grow in an area of approximately 8% of the Upper Vistula Valley (LEDWOŃ *et al.* 2004). The rest of the area is taken up by agricultural fields, buildings and industrial infrastructure. However, a cartographic analysis indicates that existing forests cover the same areas (locations) to a significant degree as they did before. This is clearly shown in one of the oldest cartographic works about the Oświęcim-Zator Dutchy – „DVCATVS OSWIECZIMIENSIS ET ZATORIENSIS DESCRIPTIO”. It reflects the 16th century hydrographic network and forests of the described area precisely (Fig. 1). This raises an interesting question: to what degree have these forests maintained their natural – or similar to natural – character and, on the other hand, how deeply have they been transformed due to strong long-term anthropopressure.

2. MATERIALS AND METHODS

Studies have been done in the remnants of the natural landscape of the Oświęcim Basin – specifically in the middle part called the Upper Vistula Valley (KONDRACKI 2001). These remnants are protected in nature reserves: the Żaki and the Przeciszów, which are examples of more interesting forest refuges within the discussed mesoregion. They are located in the Oświęcim commune, in the villages of Żaki and Przeciszów, on the right river bank of the Vistula River. Both places directly neighbour with the navigation channel called the Nawiga, which was built in the Seventies of the 20th century (Fig. 2). The investment caused the area of the Żaki reserve to decrease more than 25%, despite the fact that it had the status of a reserve (established in 1959). The Przeciszów reserve received its legal status only in 1996. Both reserves are of a small or medium size (the first consists of 11.84 ha and the second – 85.13 ha). Independent of their legal protection that feature increases their susceptibility to anthropogenic influences. These forest islands are surrounded by areas used for agriculture or fish-breeding ponds. The sub-continental oak-hornbeam-linden forest – the *Tilio-Carpinetum* association – is a dominant community in both reserves (WILCZEK 1998).

Phytosociological relevés (35) were made within the reserves, following the BRAUN-BLANQUET (1964) method. They were then compiled into a phytosociological table (FUKAREK 1967, SCAMONI 1967). In both reserves data is completed from two periods: in the Przeciszów from May (11 relevés) and July 2008 (8 relevés), for the Żaki from May (11 relevés) and August 2009 (5 relevés). Relevés from particular reserves are in separate columns, so they can be treated independently. Owing to that fact, the comparison of phytocoenoses at areas with such different histories was possible. In the analysis of relevés (made in two groups) the following aspects were taken into consideration: the share of diagnostic species, the share of ancient woodland indicators (DZWONKO, LOSTER 2001; DZWONKO 2007), the share of synanthropes (ZAJĄC *et al.* 1975; ZAJĄC *et al.* 1998; TOKARSKA-GUZIK 2005) together with the collective share of these groups – „G" category (PAWŁOWSKI 1977). An original coefficient of floristic naturalness (W_{NF}) was published in this paper for the first time and used for the assessment the the degree of phytocoenoses maintenance in relation to forest communities of the Żaki and

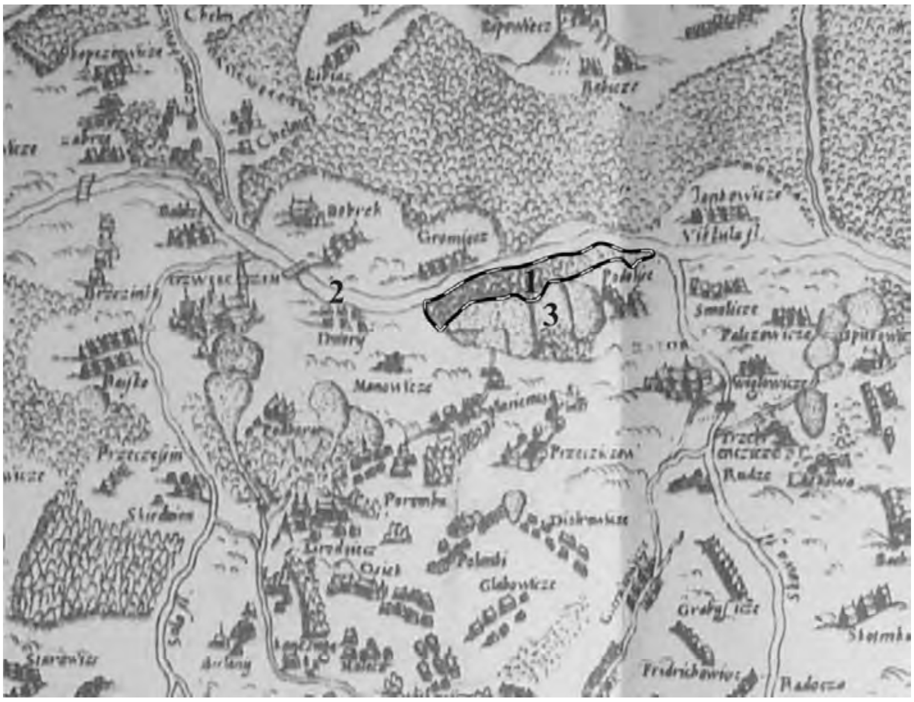

Fig. 1. Fragment of the Upper Vistula River Valley in the 16th century (after Krassowski *et al.* 1977). 1 – forest complex including future reserves; 2 – the Vistula River; 3 – breeding ponds

the Przeciszów nature reserves. The coefficient (W_{NF}) is the quotient of the roots from the sum of cover coefficients: the ancient woodland species and synanthropic species. However, the BRAUN-BLANQUET'S (1964) quantitative-cover scale should be transformed following the proposal by COETZEE and WERGER (DZWONKO 2007). The transformation of the scale makes it possible to promote species occurring in phytocoenoses numerously („r" to „5" amounts like 1:50), while at the same time, species present at low numbers will have a direct influence on the final result (this is important e.g. to synanthropic species at early stages of habitat colonisation).

$$W_{NF} = \begin{cases} \sqrt{\dfrac{\overline{P}_{las}}{\overline{P}_{syn}}} & \overline{P}_{las} > 0,\ \overline{P}_{syn} > 0 \\ \sqrt{\overline{P}_{las}} \quad dla & \overline{P}_{las} > 0,\ \overline{P}_{syn} = 0 \\ \sqrt{\dfrac{1}{\overline{P}_{syn}}} & \overline{P}_{las} = 0,\ \overline{P}_{syn} > 0 \end{cases} \qquad \overline{P} = \sum_{i=1}^{i=N} P_i/N$$

$$G\ (w\%) = \frac{g}{t}\ 100$$

W_{NF} – coefficient of the floristic naturalness

$\overline{P}_{las}$ – mean cover of ancient woodland species within the given area

$\overline{P}_{syn}$ – mean cover of synanthropic species within the given area

$\overline{P}$ – mean cover of the group of species within the given area

P_i – sum of cover coefficients of the group of species in the relevé

N – number of relevés made within the study area

G – collective share of the group (in %)

g – sum of occurrences in the table of species from the given group

t – sum of occurrences of all species in the table, in total

The goal of the phytosociological studies in the reserves mentioned was the assessment of forest phytocoenoses in relation to the maintenance of their floristic composition. It should be stressed that the difference in the time of the conservation between the Żaki and the Przeciszów reserves amounts to 30 years.

The names of vascular plants follow MIREK *et al.* (2002), mosses – follow OCHYRA *et al.* (2003), and syntaxonomic units – MATUSZKIEWICZ (2002).

3. RESULTS

Results of the studies have been compiled in a phytosociological table (Tab. 1). A significant naturalness of the phytocoenoses studied is indicated there. First, in patches of oak-hornbeam-linden wood in both reserves character taxa that are quite numerous for the upper syntaxonomic units (alliance, order and class) are present, despite a complete lack of character taxa for the *Tilio-Carpinetum* association.

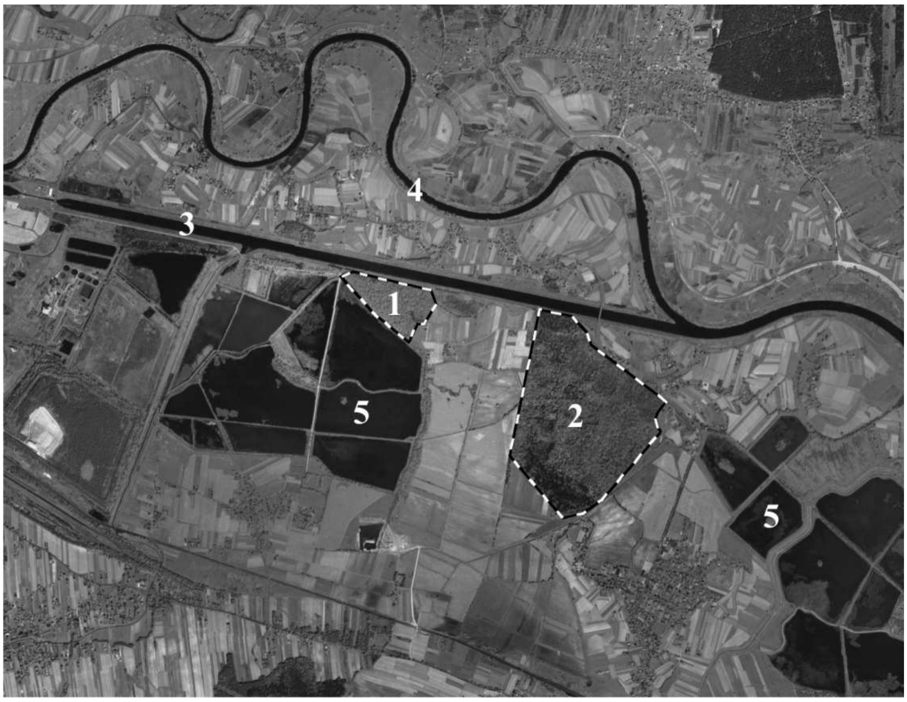

Fig. 2. Location of the nature reserves studied (source – Google Maps, changed). 1 – the Żaki reserve; 2 – the Przeciszów reserve; 3 – the Nawiga channel; 4 – the Vistula River; 5 – breeding ponds. Borders of the reserves are marked with white-black line

Secondly, good maintenance of the complexes analysed is proved by the significant share among vascular plants of the ancient woodland indicatory species (DZWONKO, LOSTER 2001; DZWONKO 2007). The collective share of that group (G) for the Żaki reserve amounts to 50.78%, and for the Przeciszów reserve – 47.31%. The limited abilities for spread and colonization of new areas in the case of ancient woodland indicators confirms the long-lasting presence of the woodlands in these areas. Therefore, the hypothesis based on an analysis of historical maps and stating that forests actually cover a small acreage within a strongly transformed Oświęcim Basin, but persist in their contemporary localities for hundreds of years, is true. Also the occurrence of anthropophytes (species diversity and quantity) indicates that vegetation cover is transformed to a low degree. The collective share of that group (G), represented exclusively in the material collected in the Przeciszów reserve amounts only 1.08%. A low degree of synanthropisation is also

Table 1. Phytosociological differentiation of vegetation in the Przeciszów and the Żaki nature reserves

Successive No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Constancy
Date		03 V	07 VII	03 V	03 V	03 V	03 V	03 V	03 V	03 V	03 V	07 VII	03 V	03 V	07 VII	07 VII	07 VII	07 VII	07 VII	07 VII	06 V	08 V	08 V	08 V	08 V	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	16 VIII	
Density of tree layer a [%]		95	90	90	90	85	80	95	80	85	90	90	90	65	90	90	80	90	100	100	100	90	95	85	75	90	90	80	70	90	90	90	80	70	100	90	
Density of shrub layer b [%]		20	–	–	5	5	5	–	5	10	–	20	5	60	zn	–	70	10	30	10	zn	15	5	5	20	30	30	20	30	zn	10	20	70	30	10	40	
Cover of herb layer c [%]		100	90	90	85	95	95	80	85	80	85	50	70	60	50	90	30	70	90	100	90	95	75	80	95	80	100	90	90	70	70	80	50	100	90	70	
Cover of moss layer d [%]		–	5	–	5	30	20	–	–	zn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	zn	–	–	–	–	–	–	–	–	–	–	
Area of relevé [m²]		150	100	150	100	150	150	150	100	100	100	100	150	100	100	100	100	100	100	100	120	120	150	120	120	200	200	200	200	200	200	200	200	200	200	200	
No. of species in the relevé		18	19	27	22	28	30	21	23	20	18	16	18	15	12	14	13	21	21	16	14	15	22	19	20	23	12	13	17	12	14	14	16	10	19	18	
No. of ancient woodland species		7	11	16	12	13	14	13	12	12	10	5	6	5	3	4	5	11	10	7	10	9	13	11	14	9	5	5	6	6	8	6	6	6	8	9	
No. of synanthropic species		0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Location of relevé		Przeciszów nature reserve																			Żaki nature reserve																
Ch. *Carpinion betuli*																																					
Tilia cordata	a	2.1	.	.	1.1	3.4	2.3	.	3.4	2.2	2.2	.	.	2.3	1.2	.	2.2	1.1	3.3	3.3	4.4	5.5	3.3	4.5	3.4	5.5	3.3	4.4	.	3.3	3.3	4.4	3.3	4.4	5.5	3.3	
Tilia cordata	b	+	.	.	.	1.1	.	.	1.1	.	.	.	.	.	.	.	.	.	.	.	+	2.2	.	1.1	1.2	2.2	2.3	2.3	2.3	.	+.2	1.2	1.2	2.3	1.2	2.2	V
Tilia cordata	c	.	.	.	+	+	+	.	r	.	.	.	.	.	.	.	.	.	.	.	+.2	.	+	.	.	.	.	.	.	.	.	.	+	.	.	+	
Carpinus betulus	a	4.4	3.3	4.4	3.4	2.2	2.1	4.5	.	3.3	2.2	4.4	3.4	.	3.3	4.4	2.2	3.3	2.2	2.2	4.5	.	3.3	.	.	.	.	.	.	4.4	2.3	.	1.2	.	1.2	2.2	
Carpinus betulus	b	.	.	.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.1	.	.	.	.	.	2.2	.	+.2	1.2	+.2	1.2	.	1.2	IV
Carpinus betulus	c	.	.	r	.	.	.	.	.	1.1	1.1	+	2.3	r	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	
Stellaria holostea		.	.	.	.	.	.	.	.	3.3	2.3	1.2	1.1	.	.	.	.	.	.	.	.	.	.	.	.	3.3	3.3	3.3	.	.	.	.	.	.	.	.	I
Ch. *Fagetalia + Querco-Fagetea*																																					
Acer platanoides	a	.	.	1.1	1.2	1.1	2.2	2.2	.	.	3.3	.	.	.	2.2	2.2	.	.	2.2	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Acer platanoides	b/c	2.2	.	1.1	2.2	1.2	1.2	+	1.1	.	1.1	+	+	+	.	+	+	.	3.3	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Fraxinus excelsior	a	2.3	3.3	2.3	2.2	3.4	3.4	.	3.4	.	.	.	1.1	1.1	.	.	.	.	2.2	2.2	.	.	.	.	.	.	.	.	4.4	.	.	.	.	.	.	.	II
Padus avium	b	2.3	.	.	.	.	.	.	.	2.3	.	.	3.3	4.4	.	.	4.4	.	1.2	.	.	1.2	.	+.2	.	2.3	.	.	.	.	.	2.3	4.4	1.2	1.2	1.2	III
Padus avium	c	+.2	.	.	.	.	.	.	.	1.3	.	.	2.2	2.2	.	.	.	.	.	.	.	.	+	1.3	.	.	.	.	.	.	.	.	.	.	.	.	
Milium effusum		+.2	1.2	.	1.2	1.2	2.2	+	1.2	+	+	2.3	+	.	2.3	.	1.2	3.3	2.2	+.2	+.2	+.2	+.2	+	2.2	3.3	2.3	2.3	3.3	4.4	4.4	3.3	3.3	3.3	4.4	3.3	V
Aegopodium podagraria		+	2.3	2.3	2.2	1.3	+.2	2.2	2.2	1.2	.	.	.	.	.	3.3	.	+	3.3	+	+	+	1.2	1.2	.	1.1	+	1.3	.	1.2	1.2	.	+	3.3	2.3	.	IV
Polygonatum multiflorum		+	1.3	+	2.3	1.3	1.2	1.1	.	+.2	+.2	1.2	1.2	+.2	.	.	+	+	.	.	+.2	+.2	1.2	1.2	2.2	1.1	.	.	.	.	+	+	+	.	.	+	IV
Pulmonaria obscura		.	2.3	1.2	2.2	2.2	2.3	1.2	2.2	+.2	1.2	.	.	.	.	1.2	.	1.2	+.2	3.3	.	.	1.2	+.2	+	+.2	.	.	+.2	.	.	+.2	.	+.2	+.2	+	IV
Galeobdolon luteum		.	.	+.2	1.2	2.2	1.2	1.3	1.2	2.2	1.1	.	.	.	.	3.3	2.2	1.2	1.2	.	1.1	2.2	2.3	1.2	3.4	+	.	.	+	1.1	.	.	.	.	.	1.1	III
Mercurialis perennis		.	3.3	1.2	2.3	+	1.3	+	2.2	.	.	.	.	.	2.3	.	.	.	+.3	3.3	+.2	.	1.2	1.2	2.3	.	.	.	.	.	+.2	.	+	+.3	+.2	1.1	III
Impatiens noli-tangere		.	.	.	.	.	.	.	3.4	+.2	.	.	+	.	.	.	1.2	1.2	1.2	2.3	.	.	.	.	+	.	+.2	+.2	+	.	+	1.1	+	1.1	1.1	1.1	III
Anemone nemorosa		3.3	.	1.2	3.3	2.3	2.3	4.5	+	2.3	3.4	.	2.3	3.3	.	.	.	.	.	.	2.3	2.3	4.4	3.4	3.3	.	.	.	.	.	.	.	.	.	.	.	III
Ficaria verna		.	.	+.2	1.2	4.5	5.5	3.3	2.3	2.2	2.3	.	.	.	.	.	.	.	.	.	2.3	1.2	2.2	2.3	2.3	.	.	.	.	.	.	.	.	.	.	.	II
Allium ursinum		5.5	3.3	5.5	4.4	1.2	+.2	+	.	.	.	.	.	.	.	.	.	.	.	.	5.5	5.5	1.2	1.2	+	.	.	.	.	.	.	.	.	.	.	.	II
Sporadic species:		*Acer pseudoplatanus* 1a(1.1),6(r),8(r),11,13a(2.2),13(r),14; *Anemone ranunculoides* 6(1.2); *Atrichum undulatum* 4d(1.2),6d(1.2),12d,25d; *Carex sylvatica* 24; *Circaea lutetiana* 2,3(1.2),18(1.2),19,28; *Dryopteris filix-mas* 3,5,8,18,34; *Epipactis latifolia* 19; *Euonymus verrucosa* 26; *Eurhynchium* sp.2d; *Festuca gigantea* 35; *Gagea lutea* 7; *Galium odoratum* 7,10(3.3),14(2.3); *Hedera helix* 29(1.1),34; *Isopyrum thalictroides* 24(1.2); *Melica nutans* 10,11,15; *Paris quadrifolia* 22(1,2),29,30; *Plagiomnium undulatum* 2d(1.2),5d(2.3),6d(2.2); *Poa nemoralis* 17; *Primula elatior* 2; *Rubus hirtus* 5,10(r),19,27,35; *Stachys sylvatica* 28; *Stellaria nemorum* 5(1.3); *Ulmus scabra* 7a(3.3),8a(2.2),14b; *Veronica montana* 3; *Viola reichenbachiana* 4(r),9,25.																																			
Accompanying species																																					
Quercus robur	a	2.2	.	2.2	2.2	.	.	1.1	.	2.2	2.3	3.3	2.3	3.3	2.2	.	3.3	3.3	1.1	.	.	.	2.2	2.1	2.1	.	3.3	2.3	.	.	2.3	2.2	3.3	.	1.1	2.2	IV
Quercus robur	c	r	.	r	.	+.2	.	.	.	+	.	+	+	2.1	.	.	+	+	.	.	.	.	+	+	+	+	.	+	.	+	+	+	+	.	.	+	
Sambucus nigra	b	.	.	.	.	1.1	2.2	.	1.1	.	1.1	2.2	.	.	.	.	.	2.2	3.3	2.2	.	+	.	+	2.2	2.3	2.3	2.3	1.2	+.2	2.3	+.2	1.2	.	.	+.2	V
Sambucus nigra	c	+	.	+.2	1.2	+	2.2	+	1.1	+	r	.	r	.	.	.	+	+	.	+	+	.	1.2	1.2	1.2	.	.	.	.	+	.	.	.	.	+	+	
Euonymus europaea	b/c	.	.	.	.	.	+	.	.	.	.	.	.	.	+	+	.	+	.	.	.	+	.	.	.	+	.	.	+.2	.	.	.	.	.	+	.	II
Carex brizoides	c	+	+.2	.	.	1.2	1.2	+.2	1.2	2.2	.	+	3.4	3.3	+.2	+.2	+	1.2	1.2	+.2	.	.	+.2	2.3	+.2	.	2.3	3.3	+.2	+.2	.	4.4	1.3	.	1.3	+.3	IV
Oxalis acetosella		2.3	.	+.2	.	+.2	1.2	.	1.3	2.2	.	.	.	+	.	.	2.3	.	.	.	1.2	+.2	2.3	1.3	2.2	.	.	+.2	.	+.2	+.2	+.2	.	.	.	+.2	III
Anthriscus nitida		+.2	.	+	+.2	2.2	+	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+.2	+	+	.	.	.	+	+	+.2	+.2	2.3	2.3	III
Galium aparine		1.2	.	1.2	+	+	+.2	1.2	1.2	1.2	+.2	.	+.2	.	.	r	.	.	.	.	1.2	2.2	+	1.2	1.2	.	.	.	2.3	.	.	.	.	.	.	.	III
Glechoma hederacea		+	+.2	+.2	.	2.3	.	.	.	1.2	.	.	.	.	.	.	.	+.2	+.2	.	.	.	1.2	2.2	2.2	+	.	+	.	.	2.3	+	+	1.1	+	.	III
Sporadic species:		*Abies alba* 3a,12a(1.1),15a(1.1); *Ajuga reptans* 2,4,6,8,9,17; *Alliaria officinalis* 15,17; *Alliaria petiolata* 4,6,7,25,28,35; *Alnus glutinosa* 12a(1.1),18a(1.1); *Athyrium filix-femina* 3(1.2),13,17,18(1.2),19; *Betula pendula* 19a(1.1); *Brachythecium rutabulum* 4d(1.2),5d(1.2); *Cardamine pratensis* 6,8; *Ceratodon purpurescens* 25d; *Chaerophyllum temulum* 2,11(1.2),15,18(1.2); *Chelidonium majus* 12; *Crataegus monogyna* 23b,32,34,35b(2.2); *Convallaria majalis* 10,17(2.3); *Deschampsia caespitosa* 26; *Dryopteris carhtusiana* 2,8,12,18(1.2); *Dryopteris dilatata* 13; *Euonymus europaea* 6,14,15,17,25,26,34; *Fissidens taxifolius* 2d; *Frangula alnus* 5b (1.1); *Galeopsis pubescens* 21,27,30,32,34; *Galeopsis speciosa* 26,27,29,31,32; *Geranium palustre* 25,28; *Geum urbanum* 2,6,11,25; *Impatiens parviflora* 16(1.3); *Juncus* sp. 13; *Lamium maculatum* 3; *Larix europaea* 8a(r),10a(1.1); *Maianthemum bifolium* 3,7(1.2); *Mycelis muralis* 17; *Picea abies* 28a(1.1);*Plagiomnium cuspidatum* 5d(1.2),6d(1.2),25; *Plagiomnium rostratum* 25d; *Ribes rubrum* 3,5,6; *Rubus caesius* 25; *Rubus idaeus* 13; *Symphytum tuberosum* 3,20(1.2),21,22(1.2),24(1.2); *Urtica dioica* 8(1.2),17,28(2.3); *Valeriana sambucifolia* 3.																																			

evidenced by the value of the floristic naturalness coefficient (W_{NF}) – in the Żaki reserve it achieves a value of 10.12 and in the Przeciszów – 9.56.

The areas studied are the forest islands among rural areas. Both are of different acreages and have a different protection history. The protection has however meant that they have been excluded from management and this has decreased threats of vegetation cover caused by anthropopressure. In particular, it reveals certain changes in habitat conditions. Unfortunately, changes occurring (e.g. at hydrological systems) have not retreated. In spite of this, the vegetation in both reserves still remains significantly natural and it is anthropogenically transformed only to a low degree. Between the Żaki and the Przeciszów nature reserves there are no distinct varieties. Anthropogenic transformations are insignificant and do not reveal the entire area of the areas studied, only fragments (e.g. *Pinus strobus* plantation in the Żaki reserve). Therefore, it can be expected that the oak-hornbeam-linden phytocoenoses will also maintain their naturalness in the future.

4. DISCUSSION

Nature reserves play an important role in the Polish system of nature protection. Together with national parks and Nature 2000 they maintain the most valuable fragments of the natural environment. They play a significant role in the protection of forest communities, especially within areas significantly transformed by man, where the area of patches maintained is small, and therefore the other mentioned forms of protection cannot be applied. Despite their important functions many nature reserves in Poland cannot fulfill their tasks in an appropriate way and therefore, the degree of maintenance of the plant cover there is not good.

The original coefficient of floristic naturalness (W_{NF}) was used for the assessment of the degree of maintenance in relation to forest communities. It also seems to be useful for the comparison of forest vegetation transformations, even without detailed floristic field studies. Because of the presented method, it is possible to plan for the future e.g. using materials compiled at assessments of nature (valorisations) or management plans for protected forest areas – as it was before. On the one hand, these are valuable as a historic data, because they are often the only source of knowledge about the vegetation at that time and they allow for conclusions regarding its transformations to be made. On the other hand, the validity and accuracy of some elaborations of that type is doubtful (HOLEKSA *et al.* 2008). Nevertheless, an instrument using two quite easily recognised groups of plants: ancient woodland species and synanthropic species seems to be very practical.

The degree of flora and vegetation transformations depends on many factors. The date of the establishment of the protection form is important, as well as conservation activities (not always appropriately selected). Many unfavourable transformations made by man before the establishment of the reserves have a long-lasting effect on their plant cover. For instance: changes in the water regime and the introduction of alien species (*Pinus strobus*) influenced the plant cover of the Żaki reserve in the direct vicinity of these places (WILCZEK *et al.* 2008). Moreover, the acreage and the shape of protected area play a crucial role in the maintenance of forest communities. BABCZYŃSKA-SENDEK *et al.* (1993) proved the distinct influence of reserves' acreage to the threat of their flora by the synanthropisation process. In the case of the areas they have studied an area of 10 ha provided the minimum resistance of ecosystems to some types of unfavourable changes. This problem was also studied and recognized by HOLEKSA (1993, 1997). He stressed the crucial role of acreage for effective maintenance of a forest during the entire natural life cycle, from regeneration, through development, and old age, and on to the natural death. As an area, which guarantees the functioning of these processes that shape the dynamics and structure of mixed fir-spruce-beech forests in the West Carpathians' lower belt, he suggests 42 to 100 plus ha (for the central zone to have the appropriate protection). The shape is closely connected with the dimensions of protected areas. A long border increases the probability of unfavourable influences from neighbouring areas. The more the shape of the reserve differs from a circle, the higher the relation of the periphery to acreage and the „edge effect" is more distinctive (PULLIN 2004). However, small nature reserves and those with an excessively developed borderline are supported by transition zones, which surround them and create an additional barrier against the influence of external factors.

The way areas adjacent to nature reserves are used is another factor which influences the naturalness of their plant cover. Studies of ADAMOWSKI *et al.* (1998)

indicate that the number of alien to forest species correlates with the degree of habitat degradation and plant community transformation. The deposit of rubbish at forest edges, herb layer trampling or grazing – strongly influence the process of the penetration and dispersion of alien taxa in forest complexes. Also phytocoenoses of protected areas neighbouring settlements and transportation routes are characterized by a significant degree of degeneration (GORCZYCA 2008). Transportation routes (represented by: asphalt routes and cart-roads, paths or river valleys) make the appearance of anthropophytes quite easy. The important role of transportation routes in the synanthropisation process of forest phytocoenoses was stressed by PAWLACZYK (1993). Among other factors causing forest transformations he also mentioned: the use and cultivation of forest (especially cuttings), the conscious introduction and unconscious bringing of alien species (that became a fact in the Żaki reserve), trampling and grazing and – what seems to be particularly important regarding this study – the fragmentation of forest complexes and the creation of long borderlines between forests and land used for agriculture or non-forest areas used in other ways. Plant communities (representing the *Rhamno-Prunetea* class and the *Trifolio-Geranietea sanguinei* class) on the edges of forests play a particular role in the synanthropisation process of forest phytocoenoses – as PAWLACZYK (1993) notes after BALCERKIEWICZ, KASPROWICZ (1989). They can speed up the synanthropisation process (as a „starting points" for invasive neophytes) or stop it (making the appearance and colonization of neophytes more difficult). SIERKA and CHMURA (2007) studied problems related to invasive and expansive species in the forest reserves of the Silesian-Cracow Upland. Among the factors which increase the frequency of the occurrence of invasive and expansive species in forest communities they noted: location of protected areas in the vicinity of settlements, intensive penetration by tourists and local people, fragmentation of phytocoenoses and habitat diversity. These elements influenced both: the encroachment and colonization of forest reserves by these taxa.

5. CONCLUSIONS

- The share of ancient woodland indicators and synanthropic species in phytocoenoses allows for the coefficient of floristic naturalness to be counted, which makes the assessment of anthropogenic transformations of forest vegetation possible.
- Strong and long-lasting anthropopressure has not caused significant changes in the species composition and vertical structure of the phytocoenoses studied.
- Shrubs surrounding the forest edge of the reserves studied influence the microclimatic conditions in the forest communities in a positive way and can form a natural barrier against the penetration and expansion of synanthropic species. The synanthropisation process of forest communities is probably also limited by neighbouring agricultural lands.

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IMPACT OF LAND USE CHANGES AND DYNAMIC VEGETATION CHANGES ON VASCULAR FLORA DIVERSITY IN MAŁKÓW-BARTOCHÓW (THE WARTA RIVER VALLEY)

Abstract: The paper presents the changes of vascular plant flora in the Małków-Bartochów peatland area (the Warta River valley) which took place over a 40-year period. Vanishing, permanent and new components of the flora are presented with a special focus on valuable (protected by the law, threatened and locally rare) species. Changes in the share of ecological groups are estimated and discussed. Anthropogenic and natural factors, directly or indirectly influencing (in the past and at present) flora composition, are noted and analyzed.

Key words: flora, peatland, land use, degradation, Małków & Bartochów, Central Poland

1. INTRODUCTION

Wetland ecosystems are one of the most endangered in Poland. They have been under multidirectional human influences through the centuries. Changes of land use and transformation of river valley landscapes are the main causes of the extinction of lowmoors (rich fens). Specialized flora associated with these habitats is strongly endangered.

The hydrological conditions of the Warta River valley (Central Poland) have been changed significantly as a result of long-term (over 200 years) hydro-technical activities, such as river regulation, floodbank building, drainage and water reservoir

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construction. These hydro-technical operations have also influenced wetlands situated near the “Jeziorsko” water reservoir. One of them is located upstream the reservoir, near the villages of Małków and Bartochów (Fig. 1).

The Małków-Bartochów peatland is located in the physical geographical mesoregion of the Sieradzka Basin (KONDRACKI 2002). Its geographical position is marked by the co-ordinates: 51°40′25″-51°40′57″ N and 18°38′11″-18°38′34″ E. It fills the bottom of an elongated part of the Warta River valley, 1200 metres in length and about 500 metres in width. It covers an area of 40 hectares.

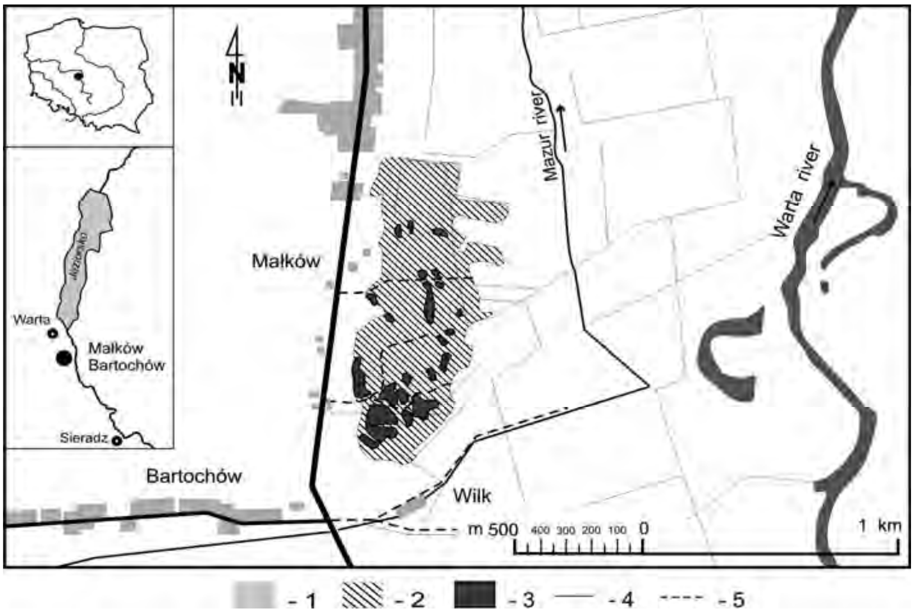

Fig. 1. Location of the study area. Explanation: 1 – buildings; 2 – forests and thick brushwoods on the peatland area; 3 – peat pits filled with water; 4 – permanent flow and drainage ditches; 5 – main tracks leading to the meadows and pastures.

This area has been strongly transformed due to long-lasting anthropogenic influences (Fig. 2). The peat deposits were extracted in the past for local demand. The largest peat pits were then changed into fishing ponds. They have slowly overgrown with rush communities as a result of the natural development of vegetation. This degraded peatland with partially saved peat seams was classified as

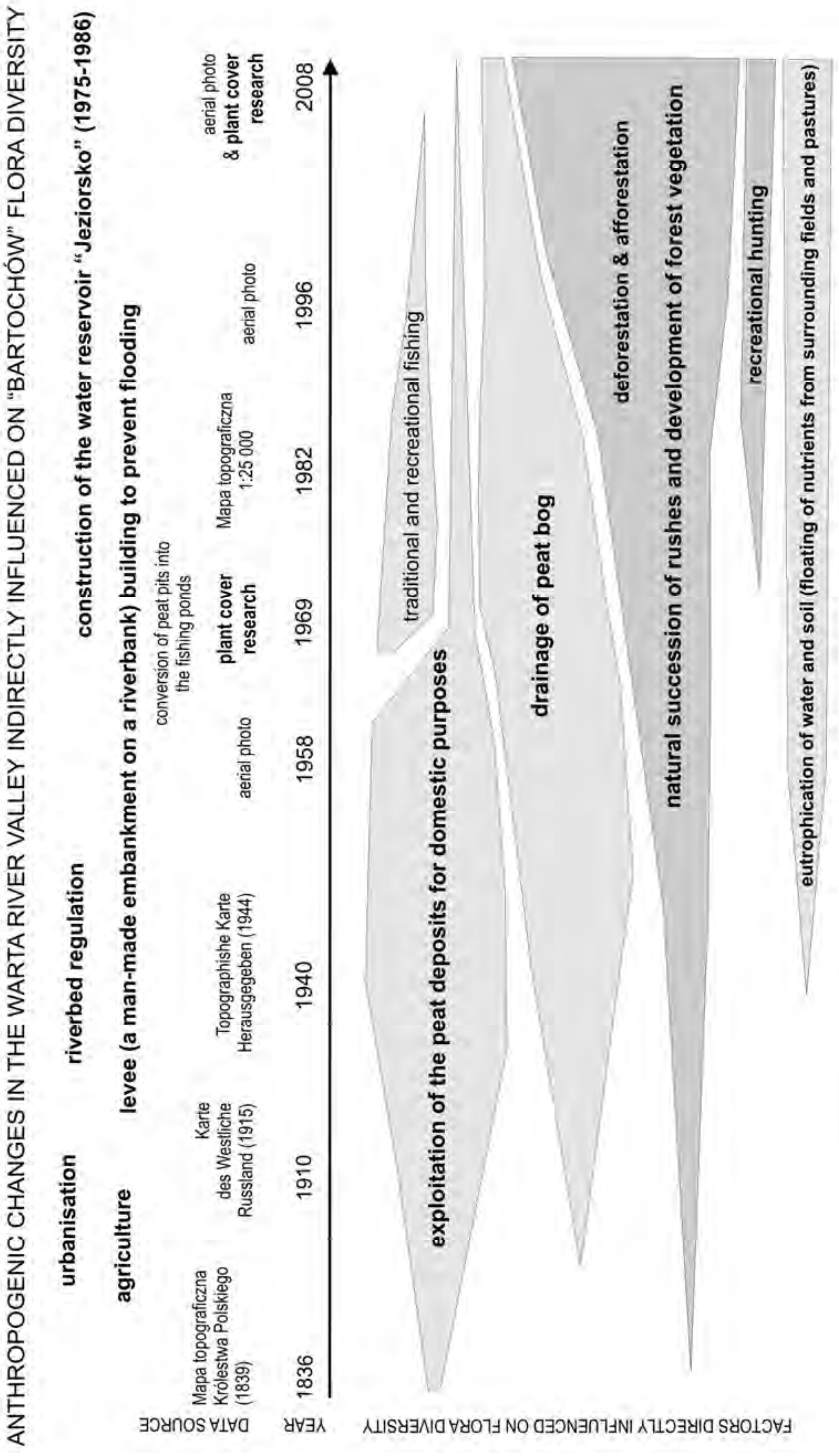

Fig. 2. Natural and anthropogenic factors influencing Małków-Bartochów flora diversity.

wasteland. Significant drainage of the whole area in the 1970's enabled its afforestation with alder trees. At present forest communities occupy almost all of the area. As a result of the changes in the water regime, the riparian forest was replaced by alder forest typical of swampy habitat.

The Małków-Bartochów peatland was researched by botanists in the 1960's. A description of this site, including the characteristics of its flora and vegetation can be found in the works of KRZYWAŃSKA (1970, 1974) and KRZYWAŃSKA & KRZYWAŃSKI (1972, 1974). For the purposes of this study, the plant cover research was repeated by the Authors in 2007 and 2008, and further supplemented in 2009.

The main subject of this article is the analysis of the changes of vascular flora diversity in the Małków-Bartochów peatland area after 40 years.

2. MATERIALS AND METHODS

The floristic data from the year 1969 (KRZYWAŃSKA 1970) and 2009 (own studies) have been compared. Vanishing, permanent and new components of vascular plant flora in this area were noted. Changes in the share of particular ecological groups were estimated using indicator values of vascular plants (ELLENBERG *et al.* 1991). Four indicators were taken into account: the light figure (L) whose value ranges from 1 (full shadow) up to 9 (full light); the moisture figure (F) which has a value from 1 (extremely dry soil) up to 12 (underwater plants); the reaction figure (R) from 1 (very acid soil) up to 9 (basic soil) and the nitrogen figure (N) from 1 (soil very poor in mineral nitrogen) up to 9 (soil very rich in mineral nitrogen). The frequency of species occurrence was considered. The following quantitative scale was applied for calculation: species very frequent (common in the majority of plant communities) – 20; common species (common but only in habitats typical of them) – 10; rare (occurrence between 6 and 20) – 3; very rare (occurrence between 1 and 5) – 1.

Changes in the share of ecological groups (the share of species characteristic of different plant communities and vegetation types) were also analyzed. The classification of species follows MATUSZKIEWICZ (2001). Special attention was paid to valuable plant species such as those protected by the law, endangered and rare.

In the alphabetic list of vascular plants given below all species noted in the investigated area are enumerated. The nomenclature of plants follows MIREK *et al.* (2002), synonymous names used by KRZYWAŃSKA (1969) are given in parentheses. Moreover, the following marks are used: (+) – species noted nowadays, not observed in the 1960's; (-) – species noted in the 1960's, not found in 2007-2009.

3. RESULTS

In the Bartochów-Małków peat-land complex, 207 species of vascular plants were found in the years 2007-2008. In the same area, 234 species were noted in the 1960's. 86 species which were noticed 40 years ago were not observed at present, but at the same time 59 new species were noticed. The majority of them were classified as sporadic or very rare.

List of vascular plant species noted in Małków-Bartochów peatland:

Achillea millefolium, *Acorus calamus*, *Actaea spicata*, *Aegopodium podagraria*, *Agrostis sp.* (+), *Alisma plantago-aquatica*, *Alliaria petiolata* (+), *Alnus glutinosa*, *Alnus incana* (-), *Alopecurus geniculatus*, *Alopecurus pratensis*, *Anagallis arvensis* (-), *Anchusa arvensis* (*Lycopsis arvensis*), *Anchusa officinalis*, *Angelica sylvestris*, *Anthemis arvensis*, *Anthoxanthum odoratum* (-), *Antriscus nitida* (+), *Antriscus sylvestris* (+), *Arctium lappa*, *Arrhenatherum elatius* (+), *Artemisia absinthium*, *Artemisia vulgaris*, *Asperugo procumbens* (-), *Athyrium filix-femina*, *Atriplex patula*, *Ballota nigra* (+), *Batrachium aquatile* (-), *Batrachium circinatum* (-), *Batrachium trichophyllum* (-), *Bellis perennis*, *Betula pendula*, *Betula pubescens*, *Bidens cernua* (+), *Bidens tripartita* (+), *Briza media* (-), *Butomus umbellatus* (-), *Caltha palustris*, *Calystegia sepium*, *Cannabis sativa* (-), *Capsella bursa-pastoris* (+), *Cardamine amara*, *Cardamine pratensis* (+), *Carduus acanthoides* (-), *Carduus crispus* (+), *Carex acutiformis*, *Carex appropinquata* (*C. paradoxa*), *Carex flava* (-), *Carex gracilis*, *Carex hirta*, *Carex nigra* (*C. fusca*) (-), *Carex ovalis* (*C. leporina*) (-), *Carex panicea* (-), *Carex paniculata*, *Carex pseudocyperus*, *Carex riparia* (+), *Carex rostrata* (-), *Carex vesicaria* (-), *Carex vulpina* (-), *Centaurea jacea*, *Cerastium arvense*, *Cerastium holosteoides* (*C. vulgatum*), *Ceratophyllum demersum*, *Chamomila suaveolens* (+), *Chara sp.* (+), *Chelidonium majus* (+), *Chenopodium album*, *Chrysosplenium alternifolium* (+), *Cicuta vilosa* (-), *Circaea intermedia* (+), *Cirsium arvense*, *Cirsium oleraceum*, *Cirsium palustre*, *Conium maculatum* (+), *Cornus sanguinea*, *Corylus avellana*, *Crepis paludosa*, *Cuscuta europaea*, *Cyperus fuscus* (-), *Dactylis glomerata*, *Dactylorhiza maculata* (*Orchis maculata*) (-), *Dactylorhiza majalis* (*Orchis latifolia*) (-), *Daucus carota* (+), *Deschampsia caespitosa*, *Dryopteris austriaca* (+), *Dryopteris carthusiana* (*D. spinulosa*), *Dryopteris cristata*, *Dryopteris filix-mas*, *Echinochloa crus-galli* (-), *Eleocharis palustris* (*Heleocharis palustris*) (-), *Elodea canadensis* (-), *Elymus caninus* (*Agropyron caninum*), *Elymus repens* (*Agropyron repens*) (+), *Epilobium hirsutum*, *Epilobium palustre*, *Epipactis palustris* (-), *Equisetum arvense* (-), *Equisetum fluviatile* (*E. limosum*), *Equisetum palustre*, *Equisetum pretense* (+), *Eriophorum angustifolium* (-), *Euonymus europaea*, *Eupatorium cannabinum*, *Euphrasia rostkoviana* (-), *Fallopia dumetorum* (*Polygonum dumetorum*) (+), *Festuca gigantea*, *Festuca pratensis*, *Festuca rubra* (-), *Ficaria verna* (-), *Filipendula ulmaria*, *Filipendula vulgaris* (*F. hexapetala*) (-), *Frangula alnus* (+), *Fraxinus excelsior* (-), *Galeopsis speciosa*, *Galeopsis tetrahit*, *Galium aparine*, *Galium mollugo* (+), *Galium palustre*, *Galium uliginosum*, *Galium verum* (-), *Geranium palustre*, *Geranium pratense*, *Geranium robertianum*, *Geranium sanguineum* (-), *Geum rivale* (+), *Geum urbanum* (+), *Glechoma hederacea*, *Glyceria fluitans*, *Glyceria maxima* (*G. aquatica*), *Gnaphalium uliginosum*, *Heracleum sphondylium* (+), *Holcus lanatus*, *Hottonia palustris*, *Humulus lupulus*, *Hydrocharis morsus-ranae*, *Hypericum maculatum* (-), *Hypericum perforatum* (-), *Hypericum tetrapterum* (*H. acutum*) (+), *Impatiens glandulifera* (*I. roylei*) (-), *Impatiens noli-tangere*, *Iris pseudacorus*, *Juncus articulatus*, *Juncus bufonius*, *Juncus effusus* (+), *Lactuca serriola* (+), *Lamium maculatum*, *Lathyrus pratensis* (+), *Lemna gibba* (-), *Lemna minor*, *Lemna trisulca*, *Ligustrum vulgare* (-), *Lotus corniculatus*, *Lotus uliginosus*, *Lychnis flos-cuculi*, *Lycopus europaeus*, *Lysimachia nummularia* (-), *Lysimachia thyrsiflora* (+), *Lysimachia vulgaris*, *Lythrum salicaria*, *Malva neglecta* (-), *Medicago falcata* (+), *Medicago lupulina* (+), *Melandrium album*, *Mentha aquatica* (-), *Mentha arvensis*, *Mentha longifolia* (-), *Mentha* x *verticillata* (-), *Menyanthes trifoliata* (-), *Moehringia trinervia*, *Molinia caerulea*

(-), *Myosotis palustris* (+), *Myosotis sparsiflora*, *Myosoton aquaticum* (*Malachium aquaticum*), *Myriophyllum spicatum* (-), *Myriophyllum verticillatum* (-), *Nuphar lutea* (-), *Odontites serotina* (*O. rubra*) (-), *Oenanthe aquatica*, *Ophioglossum vulgatum* (-), *Padus avium* (+), *Papaver rhoeas*, *Paris quadrifolia*, *Parnassia palustris* (-), *Parthenocissus quinquefolia* (+), *Peplis portula* (-), *Peucedanum palustre* (-), *Phalaris arundinacea*, *Phleum pratense*, *Phragmites australis* (*P. communis*), *Pimpinella major* (-), *Plantago intermedia* (*P. pauciflora*) (-), *Plantago lanceolata*, *Plantago maior*, *Plantago media* (+), *Poa annua*, *Poa palustris*, *Poa pratensis*, *Poa trivialis*, *Polygonum amphibium* (-), *Polygonum aviculare*, *Polygonum bistorta*, *Polygonum hydropiper* (-), *Polygonum lapathifolium subsp. lapathifolium* (*P. nodosum*) (-), *Polygonum lapathifolium subsp. pallidum* (*P. tomentosum*) (-), *Polygonum persicaria*, *Populus alba* (-), *Populus nigra* (+), *Populus tremula*, *Potamogeton perfoliatus* (-), *Potentilla reptans* (+), *Prunella vulgaris*, *Prunus spinosa* (+), *Quercus robur* (+), *Ranunculus acris* (*R. acer*), *Ranunculus flammula*, *Ranunculus lanunginosus* (-), *Ranunculus lingua*, *Ranunculus repens*, *Ranunculus sceleratus*, *Rhinanthus minor* (*Alectorolophus minor*) (-), *Rhinanthus serotinus* (*Alectorolophus glaber*) (-), *Ribes nigrum*, *Ribes spicatum* (*R. schlechtendalii*), *Rorippa amphibia* (-), *Rorippa palustris*, *Rorippa sylvestris* (-), *Rosa canina*, *Rubus caesius*, *Rubus idaeus* (+), *Rumex acetosa* (+), *Rumex crispus*, *Rumex hydrolapathum*, *Rumex maritimus*, *Rumex obtusifolius*, *Rumex palustris* (-), *Sagina nodosa* (-), *Sagina procumbens* (-), *Salix alba* (+), *Salix aurita* (+), *Salix cinerea*, *Salix fragilis* (+), *Salix purpurea* (+), *Salix triandra* (-), *Sambucus nigra*, *Schoenoplectus lacustris*, *Scirpus sylvaticus*, *Scrophularia nodosa*, *Scrophularia umbrosa* (*S. alata*), *Scutellaria galericulata*, *Secale cereale* (+), *Sedum maximum* (-), *Senecio congestus* (*S. paluster*), *Senecio jacobaea* (-), *Sium latifolium* (-), *Solanum dulcamara*, *Sorbus aucuparia*, *Sparganium erectum* (*S. ramosum*), *Spirodela polyrhiza*, *Stachys palustris*, *Stachys sylvatica* (+), *Stellaria graminea* (+), *Stellaria media*, *Stellaria nemorum*, *Stellaria palustris*, *Stellaria uliginosa* (-), *Stratiotes aloides* (-), *Symphytum officinale*, *Taraxacum officinale*, *Teucrium scordium* (-), *Thalictrum aquilegiifolium* (+), *Thalictrum flavum* (+), *Thelypteris palustris* (*Dryopteris thelypteris*), *Torilis japonica*, *Trifolium campestre*

(+), *Trifolium repens* (+), *Triglochin palustre* (-), *Tussilago farfara*, *Typha angustifolia*, *Typha latifolia*, *Ulmus laevis* (+), *Urtica dioica*, *Urtica urens* (-), *Utricularia vulgaris*, *Valeriana dioica* (-), *Valeriana officinalis* (-), *Verbena officinalis* (-), *Veronica anagallis-aquatica* (*V. anagallis*) (-), *Veronica beccabunga* (-) *Veronica chamaedrys*, *Veronica scutellata* (-), *Viburnum opulus*, *Vicia cracca* (+), *Viola reichenbachiana* (*V. silvestris*) (+), *Wolffia arrhiza* (-).

Table 1 shows the most valuable vanishing species. Some hydro- and hygrophilous plants were not found, for example *Stratiotes aloides*, *Triglochin palustre*. It is interesting to notice that many species which are still present in the described peat-land are significantly lower in numbers (e.g. *Dryopteris cristata*, *Hottonia palustris*). The proportion of hygrophilous species associated with water plant and rush communities has also decreased.

In the investigated flora, nine alien species have disappeared. Seven new species of archeophytes and kenophytes have appeared but no invasive alien plants have been found.

Syntaxonomic analysis of the noted species indicates a decrease in the number of species characteristic of non-forest water plant and rush communities of the *Lemnetea*, *Potametea* and *Phragmitetea* classes (Fig. 3). The analysis of ecological indicator values, especially the humidity value (which changed from 7.7 to 7.2) confirms this tendency (Fig. 4). At the same time the number of forest community species (of the *Alnetea glutinosae* and *Querco-Fagetea* classes) remains stable. A slight decrease of the light indicator value (Fig. 4) shows that the penetration of light into the lowest layers of vegetation is smaller. It is connected with the overgrowing of peat pits and the development of thicket and forest communities.

4. DISCUSSION AND CONCLUSIONS

Significant changes of peatland plant cover have been observed in Poland for many years. Decreasing water level, eutrophication and bog exploitation are the main causes of these changes. All these anthropogenic influences conducing to the degradation of habitats cause deep irreversible changes in vegetation, i.e.

Table 1. Special care species in the Małków-Bartochów forest-pit-bog complex. Explanation: ch – species under strict protection; czch – partially protected species (ROZPORZĄDZENIE 2004); 1 – threatened in Poland (ZARZYCKI, SZELĄG 2006), 2 – threatened in Central Poland (JAKUBOWSKA-GABARA, KUCHARSKI 1999), 3 – threatened pit bog species (JASNOWSKA, JASNOWSKI 1977): III – threatened species; rare species (+), common species (++).

Special care species	Species protection	Categories of threat			Occurrence	
		1	2	3	1969	2009
			stable species			
Myosotis sparsiflora Pohl			CR		++	++
Ribes nigrum L.	czch				++	++
Senecio congestus (R. Br.) DC.			VU	III	+	+
Utricularia vulgaris L.	ch				+	+
			vanishing species			
Dryopteris cristata (L.) A. Gray		V	VU	III	++	+
Hottonia palustris L.				III	++	+
Butomus umbellatus L.				III	+	
Carex flava L.				III	+	
Dactylorhiza maculata (L.) SOÓ	ch	V	EN		+	
Dactylorhiza majalis (Rchb.) P.F. Hunt & Summerh.	ch		LRnt		+	
Lemna gibba L.			LRnt		+	
Parnassia palustris L.				III	+	
Teucrium scordium L.		V	VU	III	+	
Nuphar lutea (L.) Sibth.& Sm.	czch				++	
Ophioglossum vulgatum L.	ch	V	VU	III	++	
Stellaria uliginosa Murray			LRnt	III	++	
Wolffia arrhiza (L.) Wimm			LRnt		++	
			new species			
Frangula alnus Mill.	czch					+
Lysimachia thyrsiflora L.				III		+

the degeneration of peat-bog communities and succession of non-forest communities into forest ones (JASNOWSKI 1972, 1977; OLACZEK *et al*. 1990; HERBICH 2001; KUCHARSKI, MICHALSKA-HEJDUK 2000; KUCHARSKI *et al*. 2004 a, b).

The changes of flora and vegetation in Małków-Bartochów do not differ from those observed in other peat-bogs in Poland (JASNOWSKI 1972; HERBICH 2001; PISAREK, POLAKOWSKI 2001).

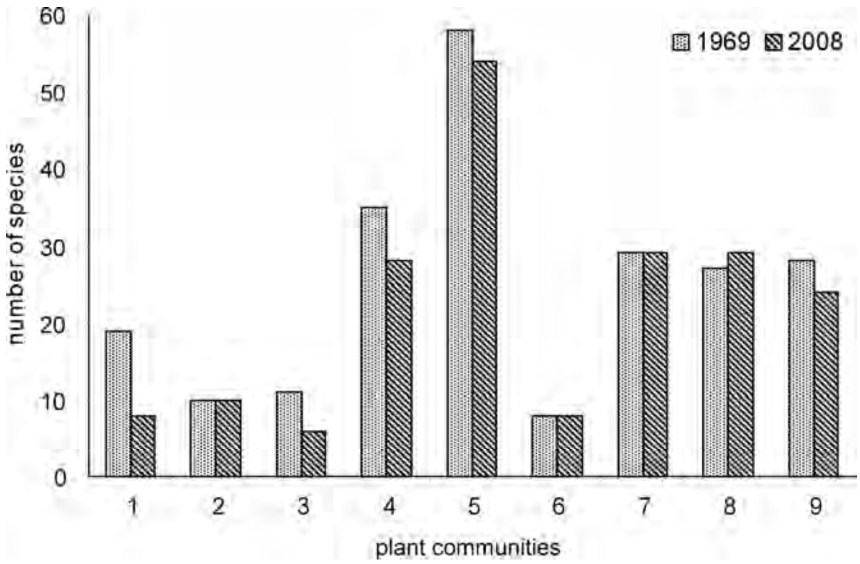

Fig. 3. Changes in the share of species characteristic of different types of vegetation. Explanation: 1 – water plant communities (*Potametea, Lemnetea, Charetea*); 2 – communities of summer terrophytes (*Isoëto-Nanojuncetea, Bidentetea*); 3 – lowmoors and transitional moors, boggy meadows (*Scheuchzerio-Caricetea*); 4 – rushes (*Phragmitetea*); 5 – meadows and pastures (*Molinio-Arrhenatheretea*); 6 – alder forests (*Alnetea glutinosae*); 7 – mezo- and eutrophic thickets and forests (*Rhamno-Prunetea, Salicetea purpureae, Querco-Fagetea*); 8 – nitrophilous ruderal communities (*Artemisietea*); 9 – others (*Agropyretea, Betulo-Adenostyletea, Epilobietea, Festuco-Brometea, Koelerio-Corynephoretea, Stellarietea, Trifolio-Geranietea, Vaccinio-Piceetea*).

The land-use changes are the main reason for the changes in the flora of this area. The end of peat deposit exploitation, the abandonment of fishing ponds and the limitation of land reclamation have all created favourable conditions for dynamic development of stable communities. Small-scale disturbances caused by human management, such as the deepening of artificial water reservoirs or mowing of the sedges and reed rushes, are important mechanisms for maintaining species richness in space-limited communities by producing a mosaic of patches that vary species composition.

The handing over of this area to forestry use in the second half of the 20th century and its afforestation with *Alnus glutinosa* sped up the development of alder swamp forest. The water plant, sedge and rush communities have been successively replaced by shrub and forest communities. The loss of a water reservoir with open water surface and the vanishing of open, wet habitats are the main causes of the decrease in hygrophilous species abundance.

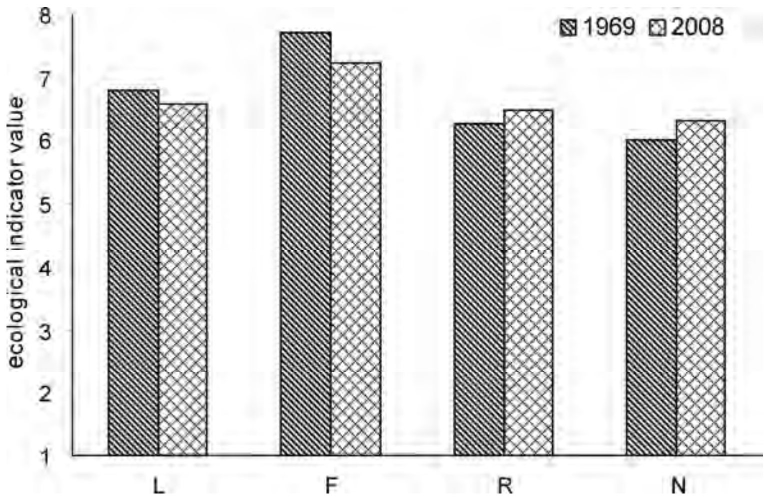

Fig. 4. Changes in ecological indicator values: L - light figure; F - moisture figure; R - reaction figure (soil acidity); N - nitrogen figure.

It is noteworthy that the degree of anthropogenic flora transformation in Małków-Bartochów is lower than in other sites with similar habitats. The share of alien species (including archeophytes, kenophytes and efemerophytes) is lower than 6%, whereas it reaches almost 8% in the other parts of the Warta River valley (RAKOWSKI, STACHNOWICZ 1999 a, b). Alien invasive plants such as *Epilobium* *ciliatum* or alien species of the *Solidago* and *Bidens* genera (TOKARSKA-GUZIK 2005), which commonly invade wetland communities (RAKOWSKI, STACHNOWICZ 1999a; DAJDOK, TOKARSKA-GUZIK 2009; URBISZ *et al.* 2009; MICHALSKA-HEJDUK, KOPEĆ 2010), do not occur in Małków-Bartochów. Furthermore, two invasive species noted in the 1960's: *Elodea canadensis* and *Impatiens glandulifera*, were not found during recent field investigations. This situation can be linked to a high stability of plant communities in the described area.

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ANTHROPOGENIC CAUSES OF PEATLAND SPECIES VANISHING IN THE GLINNO ŁUGI AREA

Abstract: The paper presents information about the occurrence and state of preservation of valuable peat-bog species as well as about the threats facing them. The anthropopressure-related changes which occurred in the habitat of the Glinno Ługi peatland and their influence on the flora are presented and discussed.

Key words: flora, wetlands, peat bog, human impacts, nature protection, Central Poland

1. INTRODUCTION

Wetland habitats such as fen meadows or peat bogs are characterised by unique flora that includes numerous vulnerable species. Peatland plants are among the most endangered in Poland (PAWLACZYK *et al.* 2002; HERBICHOWA *et al.* 2004; ZARZYCKI, SZELĄG 2006). There are 36 "red list" species in Central Poland which are strictly connected with raised bogs of the *Oxycocco-Sphagnetea* class and with rheotropic and transitional peatlands of *Sheuchzerio-Caricetea nigrae* (JAKUBOWSKA-GABARA, KUCHARSKI 1999). Among them six species are already extinct (one preserved *ex situ*), thirteen are on the border of extinction and six are threatened with extinction. The preservation and conservation of peatlands and peatland species are one of the main aims of nature protection (HERBICHOWA *et al.* 2004; KUCHARSKI 2004).

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The paper presents valuable plant species which occur in the Glinno Ługi peatland, their distribution, state of preservation, current and potential threats and suggestions for effective conservation.

2. STUDY AREA

Glinno Ługi is situated about 3 km east of the “Jeziorsko” water reservoir, in the River Jadwichna valley (the part within the old system of the Warta River valley; Fig. 1). It is located in the eastern part of the Sieradzka Basin mesoregion (KONDRACKI 2002). Its geographical position is marked by the co-ordinates: 51°43′40″-51°44′20″ N and 18°42′40″-18°43′34″ E. The area encompasses about 100 ha of degraded peatland, surrounded from the south, west and north-west by mostly forested sandy dunes. The peat deposit filled the plain basin of the Holocene valley of the Warta River (KLATKOWA, ZAŁOBA 1992; FORYSIAK 2005). The larger part of the area has been degraded due to long-lasting anthropogenic influences.

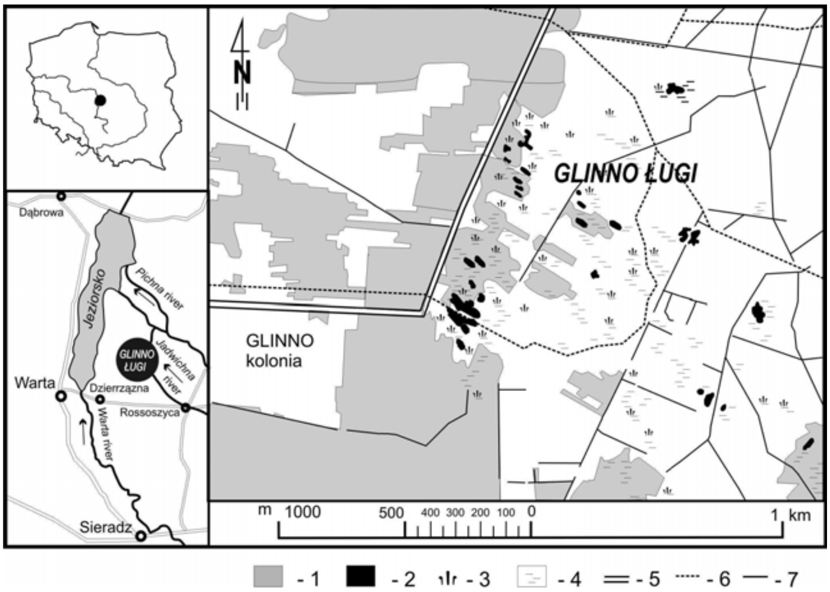

Fig. 1. Location of the study area. Explanation: 1 – forests and thick brush woods; 2 – peat pits filled with water; 3 – reed rushes and sedges; 4 – wet and fresh meadows and pastures; 5 – road from Glinno to Ferdynandów village; 6 – main tracks; 7 – permanent flow and drainage ditches.

The spatial mosaic of current vegetation is formed by water, rush, sedge, shrub and forest plant communities, such as: an unattached floating aquatics community with duckweeds *Lemnetum trisulcae* and with frogbit *Hydrocharitetum morsus-ranae*, a community of rooted aquatics with floating leaves *Hottonietum palustris*, a rush community with common reed *Phragmitetum australis*, also with ferns *Thelypteridi-Phragmitetum*, brushwoods with willows *Salicetum pentandro-cinereae*, natural forest communities: bog pine forest *Vaccinio uliginosi-Pinetum*, wet pine forest *Molinio-Pinetum*, swampy alder forest *Ribeso nigri-Alnetum, Betula-Phragmites* and *Betula-Salix* communities as well as anthropogenic forest communities: *Pinus-Phragmites* and *Alnus glutinosa-Carex acutiformis*.

At present the flora of Glinno Ługi encompasses 316 vascular plant species, 78 mosses and 12 liverworts.

3. MATERIAL AND METHODS

The data concerning the occurrence, distribution and state of preservation of valuable species in the Glinno Ługi peatland have been collected during own field investigation in the years 2007-2009. Valuable species include species protected by the law (ROZPORZĄDZENIE 2004), endangered and threatened vascular plant species on a national (ZARZYCKI, SZELĄG 2006) and regional scale (JAKUBOWSKA-GABARA, KUCHARSKI 1999) and locally rare wetland species.

The history of human impact on peat bog vegetation and peatland habitat has been described on the basis of historical sources (maps, aerial photos and available printed data).

4. RESULTS

4.1.Valuable species in the Glinno Ługi peatland

Peatmosses: ***Sphagnum palustre, S. fimbriatum, S. teres, S. fallax, S. squarossum***, ***S. capillifolium, S. girgensohnii*** and ***S. russowii*** (*Sphagnaceae*).

Sphagnum mosses are the most characteristic components forming the ground cover of bogs and the most important peat-building plants. They form a dense “carpet” with hummocks 30 to 40 cm high only in the southern part of the Ługi peatland. Small patches of peatmosses occur quite often in the degraded part of the peatland, mostly on the peat pit shores. In the driest places the moss hummocks are also built by *Polytrichum commune* and *Aulacomnium palustre* (mosses characteristic of the *Oxycocco-Sphagnetea* class).

Sphagnum palustre, *S. fimbriatum*, *S. teres* are strictly protected by the law and *Sphagnum fallax*, *S. squarossum* are partially protected in Poland.

Drosera rotundifolia (*Droseraceae*) – common sundew – grows in an open, partly sunny place with a high water table, around a shallow depression. The dominance of *Sphagnum* in the moss layer indicates an acidic habitat poor in nutrients. *D. rotundifolia* tolerates flooding for several weeks but dry periods only for a very short time. Sundews can naturally invade disturbed bog sites where other vegetation has been removed.

Oxycoccus palustris (*Ericaceae*) – cranberry – The slender, slight stems with small evergreen leaves densely cover the peatmoss „carpet" and hummocks. The berries are edible, but no instances of cranberry fruit picking have been noted in Ługi.

Ledum palustre (*Ericaceae*) – A few marsh tea (Labrador tea) shrubs grow only in the patches of the *Vaccinio uliginosi-Pinetum* bog pine forest in the south-eastern part of Ługi.

Andromeda polifolia (*Ericaceae*) – The only one (!) small cluster of bog rosemary exists in the bog pine forest.

Vaccinium uliginosum (*Ericaceae*) – bog blueberry – A few low shrubs grow on the less waterlogged hummocks in the bog pine forest. Bog blueberry has low tolerance to drought and restricted water conditions.

The low-growing woody plants with small leathery leaves of the *Ericaceae* family are an important part of bog communities on acid peat. Ericoids are vulnerable to fire, grazing and competing sedges and grasses, e.g. *Eriophorum vaginatum* or *Molinia caerulea.*

Eriophorum vaginatum (*Cyperaceae*) – common tussock cottongrass – In drained peatlands it can become dominant with the disappearance of the *Sphagnum* mosses.

Eriophorum angustifolium (*Cyperaceae*) – common cottongrass – It grows up to about 60cm and inhabits shallow, standing water or wet, peaty ground.

Dryopteris cristata (*Aspidiaceae*) – gray crested shield fern, ***Carex diandra*** (*Cyperaceae*) – lesser panicled sedge, ***C. flacca*** (*Cyperaceae*) – glaucous sedge, ***Ranunculus lingua*** (*Ranunculaceae*) – water buttercup, ***Menyanthes trifoliata*** (*Menyanthaceae*) – bogbean and ***Comarum palustre*** – marsh cinquefoil (*Rosaceae*) are other valuable wetland species, worthy of note (Tab. 1).

Table 1. Valuable vascular plant species occurring in the Glinno Ługi peatland.

Species	Strictly protected by low	Partially protected by low	Threate-ned in Poland	Threate-ned in Central Poland	Locally rare
Drosera rotundifolia	●		●	●	●
Ledum palustre	●			●	●
Menyanthes trifoliata		●			●
Ranunculus lingua			●		●
Dryopteris cristata			●	●	●
Andromeda polifolia				●	●
Carex diandra				●	●
Carex flacca				●	●
Oxycoccus palustris				●	●
Comarum palustre					●
Equisetum fluviatile					●
Eleocharis palustris					●
Eriophorum vaginatum					●
Eriophorum angustifolium					●
Vaccinium uliginosum					●

4.2. The impact of human land use and natural vegetation changes on peatland species in the Glinno Ługi – the past and present of peatland plants

In the 19th and 20th centuries drastic and usually irreversible anthropopressure-related changes occurred in the habitat of the Glinno Ługi peatland (Fig. 2). The degeneration of the habitat caused the degradation of numerous precious species and changes in vegetation.

4.2.1. Peat extraction

Peat extraction is the main cause of bog habitats and peat-bog species loss in Glinno Ługi. The most intensive peat extraction took place in the nineteenth century and it ceased completely at the beginning of the twentieth century. Peat deposits were extracted as a raw material for a domestic use, mainly as a source of energy. The plain surface of the peatland was changed into a system of parallel lines of pit peats and causeways (they determine the borders of private properties). The habitat of bog communities was almost completely destroyed. The larger part of the degraded peatland with partially saved peat seams was classified as wasteland, abandoned and excluded from any management. The peat pits have slowly overgrown with rush and sedge communities as a result of the natural development of vegetation. The causeways have changed into dense willow brushwoods or birch "forest lines".

4.2.2. Peatland drainage and agriculture

Drainage of the peatland to win area for agriculture in the twentieth century caused a significant decrease of the groundwater layer. The eastern, less wet parts of Glinno Ługi have gradually been converted into meadows and pastures, and nowadays they are used extensively or intensively by local farmers. The grassland soils are enriched with chemical and organic fertilizers. Consequently the whole wetland area receives increased nutrient inputs. Plant communities connected with oligotrophic habitats are substituted by meso- and euthrophic vegetation.

Some of the drainage ditches have little by little overgrown with reed rushes and sedges, and the flow of water into the River Jadwichna is limited. It creates favorable conditions for peat accumulation and regeneration of peatland vegetation. The areas too wet for agriculture are gradually invaded by willows or trees.

4.2.3. Afforestation

Trees such as pines, birches, and spruces naturally occur in peatland areas, but they are stunted in growth because of the intensive moss growth and poor substance of peat soils.

The significant land reclamation of the Glinno Ługi wetland enabled its afforestation. The western and south-western areas were partly used for forestry. The afforestation with the Scots pine *Pinus sylvestris* and with the alder tree *Alnus glutinosa* has been more intensive since the 1950s. The development of the tree stand has caused changes of habitat conditions and has indirectly reduced the occurrence of bog species which prefer open and sunny places.

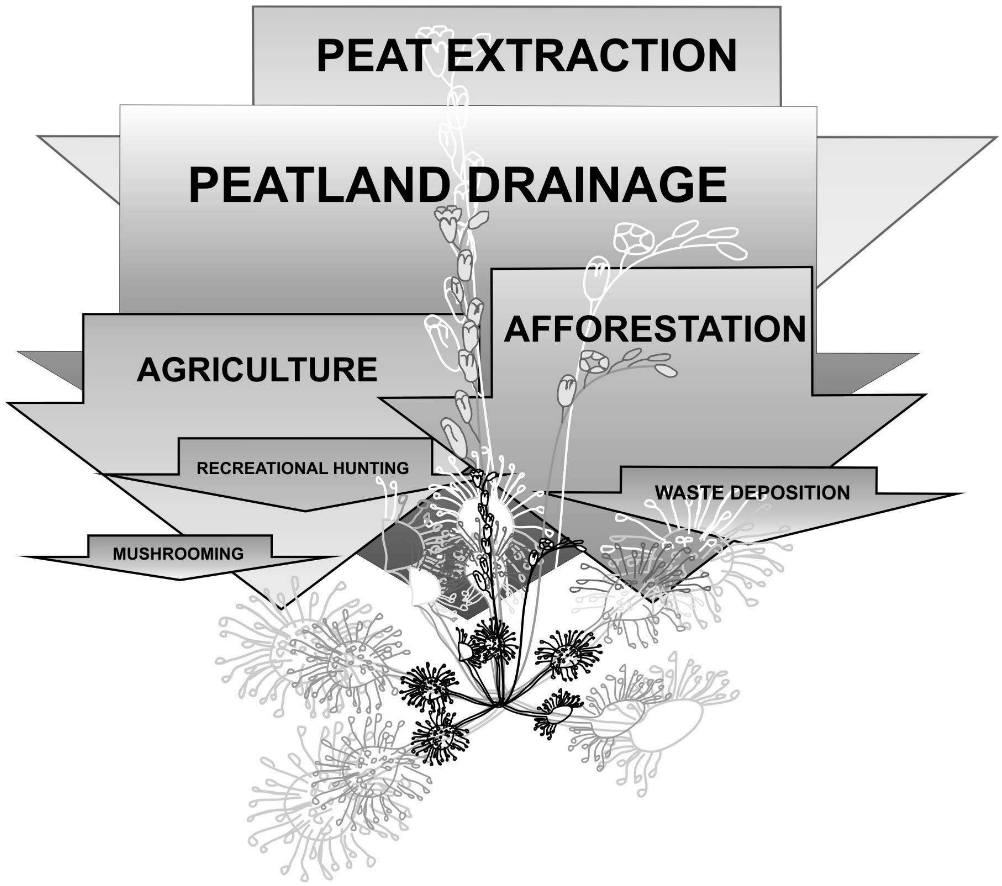

Fig. 2. Forms of human land use threatening peat-bog plant species in the Glinno Ługi peatland.

4.2.4. Recreational hunting and mushrooming

A number of wild animals – invertebrates, amphibians, reptiles, birds and mammals inhabit the Glinno Ługi peatland. The biggest herbivores and omnivores such as roe deer *Capreolus capreolus* and wild boars *Sus scrofa* occur permanently or periodically due to food richness and the diversity of habitats for resting. They destroy the surface of the peat deposit but, on the other hand, they create new open microhabitats for bog plant seeds. The boars usually rest in swampy places in shallow peat pits. The common sundew *Drosera rotundifolia* grows around this kind of boar “bathing place”. This plant may be destroyed by big animals, but its survival may also depend on boars' “activity” – they locally remove the vegetation cover and form open spaces for vegetative and generative reproduction of sundews.

The deer and boars are objects of recreational hunting. The hunting, as well as mushrooming, may pose a threat to the survival of the sensitive bog habitat and bog plants. Those activities are usually connected with intensive walking, which may cause the destruction of the bog surface.

4.2.5. Unlawful waste dumps

The abandoned degraded peatlands, classified as wastelands, are often the site of unlawful waste dumps. A number of small waste deposits are located in the vicinity of the Ługi peatland or within it. The domestic rubbish litter the landscape. They are also the source of seeds of geographically or ecologically alien plants such as *Galinsoga ciliata, G. parviflora, Bidens frondosa, Conyza canadensis* and many other synanthropic (segetal and ruderal) plants, which may threaten the peatland flora.

5. DISCUSSION AND CONCLUSIONS

The main factor causing peat bog plants extinction is the drainage of wetland area and the decrease of water level.

Variable water level with a lowering tendency stimulates the encroachment, and then mass appearance of purple moor grass *Molinia caerulea* (HERBICHOWA *et al.* 2004, 2007). This grass forms high, compact tussocks, strongly reducing the occurrence of true peatland species. The encroachment of individual specimens of *Molinia caerulea* in the Ługi peatland habitat can already be observed. Mass occurrence of purple moor grass is also a sign that the mineralisation process of the upper peat layer has advanced and that phosphorus in a form available to plants has been released (HERBICHOWA *et al.* 2004, 2007). Decrease in water level has led to an invasion of woody species from the surrounding forest such as the Scots pine *Pinus sylvestris* or the silver birch *Betula pendula* – the succession process towards brushwood and forest communities is accelerated.

Where woody vegetation is dense, it has lowered the water table and may result in subsequent alterations of the composition of the vegetation (HERBICH 2001;

PISAREK, POLAKOWSKI 2001; HERBICHOWA *et al.* 2004; KUCHARSKI *et al.* 2004). As a result of the progressive decrease of groundwater surface, the preserved fragment of the *Vaccinio uliginosi-Pinetum* bog pine forest in Ługi will change into wet pine forest *Molinio-Pinetum* and then into mixed forest *Querco roboris-Pinetum*. The most valuable plants such as peatmosses, common sundew, marsh tea, cranberry, and cotton grasses will die and disappear gradually.

One of the most important concerns in the conservation of species richness is the conservation of the habitats in which these more specialised species can survive. A stable hydrological regime is a prerequisite for the maintenance of wetland flora biodiversity of the Glinno Ługi peat bog. Moreover, we ought to control and actively reduce the spread of reeds *Phragmites australis* and willows *Salix* to limit the succession of rush and brushwood vegetation into open areas of the bog pine forest.

This valuable natural site with unique peatland flora is worthy of preservation and the establishment of the Warciańskie Ługi nature protected area is suggested. The maintenance and active restoration of less eutrophicated habitat in wetlands is a necessity for maintaining overall species diversity.

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DIVERSITY OF FOREST AND SHRUB COMMUNITIES AS A RESULT OF SITE HISTORY AND OF EXTENSIVE AND INTENSIVE FOREST MANAGEMENT (GLINNO ŁUGI CASE STUDY)

Abstract: The paper presents the diversity of natural and anthropogenic forest communities occurring in post-cultivated fields in Glinno Ługi. An impoverished fresh pine forest association (*Leucobryo-Pinetum*) and nine secondary forest communities have been distinguished in the transect line (1.16 km in length). Factors influencing the structure and species composition of recent forest communities, such as habitat properties, previous land use forms and the intensity of forest management, are described.

Key words: land use, abandoned arable fields, afforestation, succession of vegetation, Scots pine, Central Poland

1. INTRODUCTION

Abandonment of farmlands on the poorest soils is one of the symptoms of socio-ecological changes taking place in the Polish countryside at present. Formerly cultivated fields have usually been artificially afforested with Scots pine (GORZELAK 1999). Land use history, as well as habitat conditions and the intensity of forest management can have a large effect on the species composition of secondary forest communities (GRASHOF-BOKDAM, GEERTSEMA 1998; DZWONKO, LOSTER 2001; ZERBE *et al*. 2007). The conversion of anthropogenic forests into natural ones has

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become a major task of European forestry (ZERBE 2002). The recognition as well as maintenance and enhancement of biological diversity in anthropogenic forests are one of the prerequisites for sustainable forest management.

In this study we investigated the floristic composition and structure of plantations and natural forests occurring in abandoned arable fields in Glinno Ługi near the Warta River.

2. MATERIAL, METHODS AND STUDY AREA DESCRIPTION

Phytosociological studies of forest vegetation were conducted in 2008 in the Glinno Ługi area. The study area is situated about 3 km east of the “Jeziorsko” water reservoir (Fig. 1). It is located in the eastern part of the Sieradzka Basin mesoregion (Kondracki 2002).

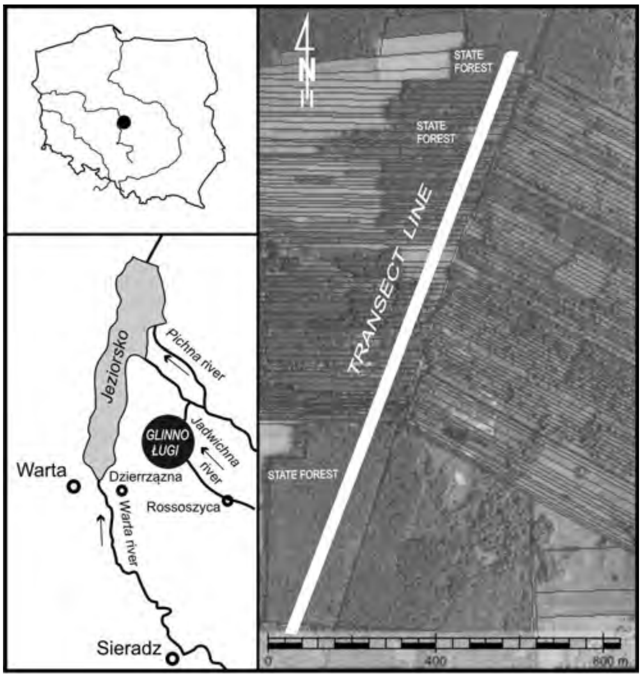

Fig. 1. Location of the study area and of the transect line.

The analysis of 32 phytosociological relevés was made according to the Braun-Blanquet approach. The sequence of forest communities was studied with the transect method. The transect line was 1160 m in length and 20 m in width, and it ran through sandy dunes and a local topographic depression, in the direction from the south-west (51°43′38″N and 18°42′25″ E) to the north-east (51°44′21″ N and 18°42′52″ E; Fig. 1). It cut through forest patches differing in terms of tree stand age and composition. The larger part of this area had been artificially afforested. Some abandoned arable fields have successively overgrown with shrubs and trees. Most of the narrow (10 or 20 metres wide) plots are private properties. The southern segment of the transect line and a few patches in the north are located in state-owned woodlands. The borders of properties are determined by forest roads and field tracks.

The nomenclature adopted for vascular plants follows MIREK *et al.* (2002), for bryophytes – OCHYRA *et al.* (2003) and SZWEYKOWSKI (2006).

3. RESULTS

The results of the phytosociological studies are presented in Table 1. Figure no. 2 shows the sequence of the forest communities distinguished.

3.1. Description of forest communities

A fresh pine forest (*Leucobryo-Pinetum*) association and a Scots pine community closely resembling sub-Atlantic mesic pine forest (Tab. 1, columns: 1-11). The areas with the habitat of oligotrophic coniferous forests are forested mostly by Scots pine *Pinus sylvestris*. The currently mature, single-species tree stand was planted 70-90 years ago in what was then a clearing. Separate patches of this fresh pine forest community display a large diversity as regards the species composition of the undergrowth and herb layer.

The physiognomy, vertical structure and species composition of the patches with the oldest pine tree stand (over 80 years old) are close to those of natural fresh pine forest. These patches are described as an impoverished regeneration form of a *Leucobryo-Pinetum* association. They are characterized by the presence of acidophilous species associated with coniferous forests, such as *Vaccinium myrtillus, Calluna vulgaris, Festuca ovina*. The layer of cryptogams is conspicuous and forms a carpet covering of up to 100% of the patch. It is dominated by species characteristic of the *Vaccinio-Piceetea* class such as *Dicranum scoparium, D. polysetum* and *Pleurozium schreberi*.

The other patches have better developed undergrowth. The shrub layer is built mainly by *Frangula alnus* and *Sorbus aucuparia*. *Padus serotina*, which is an alien species, occurs almost everywhere (both in the undergrowth, and in the herb layer). Another foreign species, *Quercus rubra,* grows only in the southern part of the transect. The herb layer is usually less diverse than the moss layer. *Agrostis stolonifera* and *Dryopteris carthusiana* are frequently noticed in the relevés. In some patches, the ground cover is dominated by *Calamagrostis epigejos*, which occupies up to 3/4 of the area. Different species of bryophytes cover from 5% to 95% of the patch area. *Pleurozium schreberi* and *Pohlia nutans* appear commonly.

Young monocultures of *Pinus sylvestris* (Tab. 1, columns: 12-19). In the analyzed phytocoenoses, the tree stand is highly well-stocked (70-90%). The Scots pine grows on poor sandy arable fields excluded from agriculture. Most of the patches lack developed undergrowth and the herb layer is very sparse or there are no herb species altogether. However, young individuals of *Quercus robur, Frangula alnus* and the invasive *Padus serotina* occur on almost every patch. Bryophyte coverage is diverse and extends from 3% to 50%. Only *Sciuro-hypnum oedipodium* is noted everywhere. It is interesting to note the occurrence of mosses associated with natural coniferous forests (*Vaccinio-Piceetea*) such as *Pleurozium schreberi* and *Dicranum scoparium.*

Young plantations of *Pinus sylvestris* and *Betula pendula* (Tab. 1, columns: 20-23). Patches of this community are located on the top of a sandy dune. Scots pines and silver birches were planted together, but the *Betula pendula* trees are dying because of a water shortage. The herb layer is poorly developed. Vascular plants occur mainly in the microhabitats in the shade of trees. Species characteristic of seminatural and anthropogenic communities, such as *Rumex acetosa*, *R. acetosella*, *Agrostis stolonifera*, *Convolvulus arvensis* and *Knautia arvensis*, are more widespread. The moss layer covers from 15% to 60% and it is built both by mesophilous (*Pleurozium schreberi*) and thermo- and xerophilous species (*Polytrichum juniperinum, P. piliferum*).

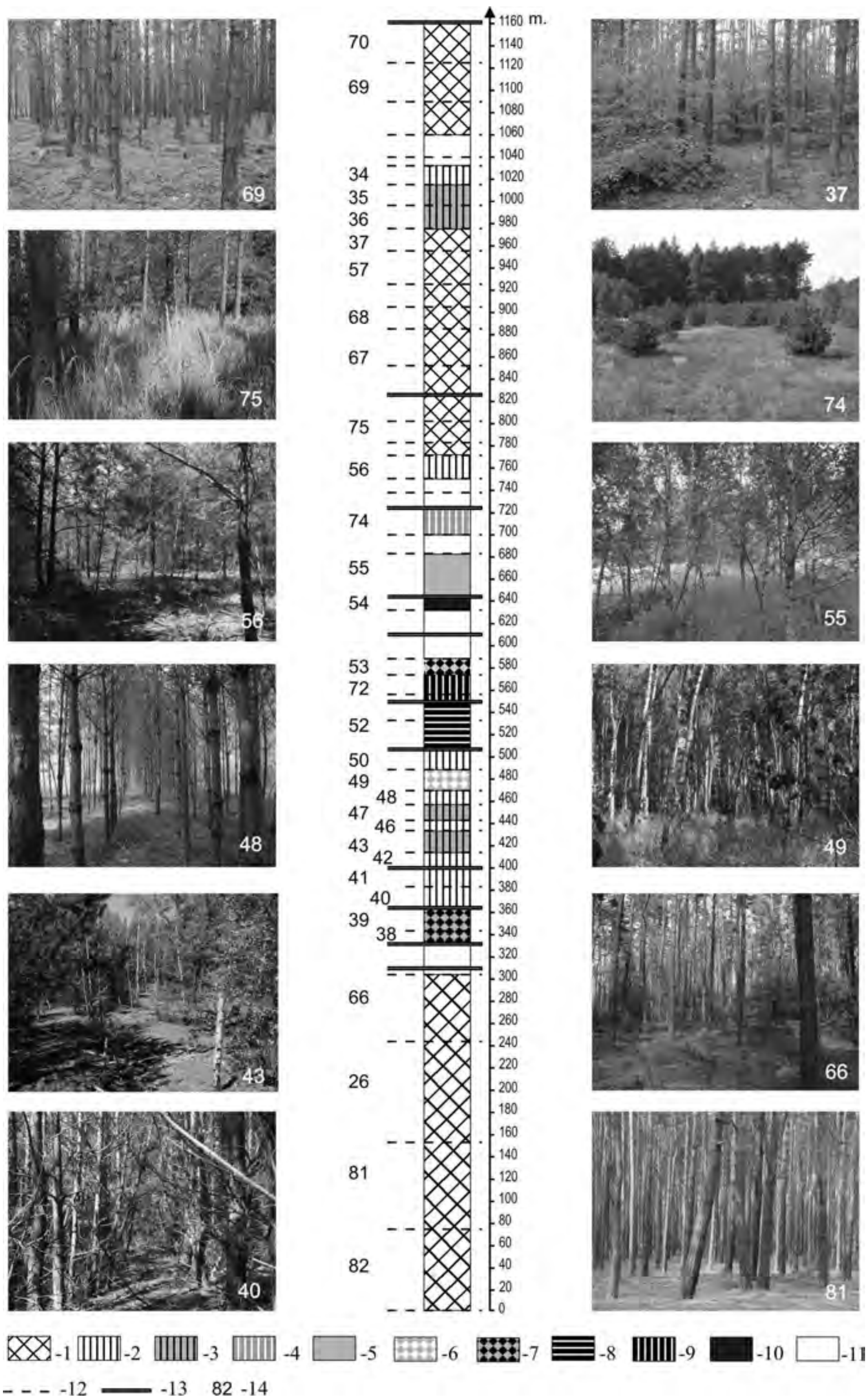

Fig. 2. Sequence of diverse plant communities along the transect line in Glinno Ługi. Explanation: 1 – fresh pine forest (*Leucobryo-Pinetum*) and Scots pine community close to the fresh pine forest, 2 – young monocultures of *Pinus sylvestris*, 3 – young plantations of *Pinus sylvestris* and *Betula pendula*, 4 – thickets of *Pinus sylvestris*, 5 – thicket of *Betula pendula*, 6 – *Betula pendula-Holcus mollis* community, 7 – mixed tree stand of *Betula pendula* and *Populus tremula*, 8 – *Alnus glutinosa-Rubus sp.* community, 9 – willow brushwood, 10 – plantation of *Alnus glutinosa* and *Picea abies*, 11 – ecotone zones, 12 – narrow tracks, 13 – forest & field tracks, 14 – relevé number.

Thickets of *Pinus sylvestris* (Tab. 1, column 24) developed naturally in a succession process on acid, sandy soils. It is a typical habitat of xerophilous and thermophilous grassland communities of the *Koelerio-Corynephoretea* class, occasionally and extensively used as a pasture for cattle. The young, widely-spaced pine individuals spread into the area from the adjacent 80-year-old Scots pine plantation. The further from the border of the mature tree stand, the lower the shrub density. The herb layer is floristically rich, built by species characteristic of the *Koelerio-Corynephoretea* class such as *Corynephorus canescens, Jasione montana* and *Helichrysum arenarium*, all of which grow plentifully. Species associated with arable fields (the *Stellarietea mediae* class) are also commonly noted, for example *Conyza canadensis*, *Atriplex patula*, *Fallopia convolvulus*, *Raphanus raphanistrum* and *Setaria viridis*. The sparse moss layer is built by only two species: *Brachythecium rutabulum* and *Ceratodon purpureus.*

A thicket of *Betula pendula* (Tab. 1, column 25). This forest community is situated in the immediate neighbourhood of a psammophilous grassland community of the *Koelerio-Corynephoretea* class. The tree stand is built by *Betula pendula*, planted in straight rows. The herb layer is dominated by species characteristic of *Molinio-Arrhenatheretea*, such as *Deschampsia caespitosa*, *Elymus repens* or *Holcus lanatus.* There also occur species characteristic of the *Koelerio-Corynephoretea* class, for example *Corynephorus canescens* and *Helichrysum arenarium.* The bryophyte layer is really poor.

A *Betula pendula-Holcus mollis* community (Tab. 1, column 26). The anthropogenic tree stand is built exclusively by silver birch *Betula pendula*, at a density of 70%. *Frangula alnus*, *Pinus sylvestris* and *Betula pendula* occur sporadically in the undergrowth. The main components of the dense herb layer are grasses such as: *Holcus mollis, Festuca ovina, Anthoxanthum odoratum* and *Agrostis stolonifera.* The moss layer covers 20% of the relevé area and it is made up mainly of *Sciuro-hypnum oedipodium* and *Brachythecium rutabulum*.

A mixed tree stand of *Betula pendula* and *Populus tremula* (Tab. 1, columns: 27-29). The silver birches and common aspens were planted on abandoned arable fields. At present they also build the undergrowth and spread spontaneously into the adjacent Scots pine monocultures. The herb layer is dominated by grass and sedge species characteristic of the *Molinio-Arrhenatheretea* class, such as *Juncus effusus*, *Carex hirta* and *Agrostis stolonifera*. Ruderal species of the *Artemisietea* class are also frequently noted. The coverage of moss layers, dominated by *Brachythecium rutabulum*, extends from 10% to 30%.

An *Alnus glutinosa-Rubus sp.* community (Tab. 1, column 30). This anthropogenic phytocoenosis occupies a local depression situated between sandy dunes. The tree stand is built by even-aged black alders. *Betula pendula* and *Betula pubescens* occur in admixture. The undergrowth contains among others *Sambucus nigra*, *Frangula alnus*, *Padus serotina* and *Salix cinerea.* A significant area – about 3/4 of the patch – is occupied by blackberries *Rubus sp.*. The species composition of the herb layer is quite diverse and it includes 25 vascular plant species. Clumps of *Urtica dioica* and tussocks of *Phragmites australis* dominate. The local wet shallows are partially overgrown with nitrophilous species associated with the *Bidentetea tripartiti* class such as *Rorippa palustris* and *Polygonum hydropiper*. The bryophyte layer is very weakly developed.

A willow brushwood (Tab. 1, column 31) is located on the edge of the local depression in the neighbourhood of the alder tree stand. The dense thickets are formed by large gray willow *Salix cinerea* with a little admixture of eared willow *Salix aurita* and single specimens of white birch *Betula pubescens*. The herb layer is built by hygrophilous species such as *Lycopus europaeus* and *Solanum dulcamara* (the *Alnetea glutinosae* class), *Deschampsia caespitosa*, *Lysimachia vulgaris*, *Myosotis palustris* (*Molinio-Arrhenatheretea*), *Galium palustre*, *Peucedanum palustre* and *Scutellaria galericulata* (*Phragmitetea*). The share of mosses in the species composition is small. Among the 6 noted bryophytes only *Calliergonella cuspidata* reaches higher coverage.

A plantation of *Alnus glutinosa* and *Picea abies* (Tab. 1, column 32). The Norway spruce *Picea abies* and black alder *Alnus glutinosa* build a dense tree stand and undergrowth. The herb layer is weakly developed due to the deep shade on the forest floor. Only *Holcus lanatus* and *Urtica dioica*, which occupy up to 10% of the investigated area, reach a significant coverage. There are 12 moss species noted

Table 1. Phytosociological diversity of shrub and forest communities in Glinno Ługi.

Successive No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Relevé No.		82	81	26	69	68	75	66	57	67	37	70	41	56	40	50	42	48	46	34	43	36	47	35	74	55	49	39	38	53	52	72	54
Density of higher tree layer a1 (%)		80	80	80	70	20	40	80	60	50	80	80	90	90	90	90	90	90	90	70	.	.	.	.	.	.	50	70	20	50	90	20	30
Density of lower tree layer a2 (%)		.	.	.	.	70	3	30	.	5	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	20	20	60	10	10	.	50
Density of shrub layer b (%)		5	10	5	60	80	30	60	70	80	10	3	5	.	.	.	.	.	5	20	60	70	30	90	20	70	5	15	40	60	30	80	40
Cover of herb layer c (%)		.	5	10	30	30	95	30	70	50	40	3	3	10	3	3	3	3	3	3	10	30	5	5	90	70	80	70	50	90	90	80	20
Cover of moss layer d (%)		100	100	100	95	5	80	70	60	60	40	80	50	20	3	3	3	3	3	20	60	60	15	20	5	3	20	30	20	10	5	10	20
Total number of species		**8**	**13**	**21**	**21**	**25**	**22**	**25**	**19**	**28**	**19**	**9**	**14**	**20**	**14**	**12**	**10**	**8**	**8**	**16**	**17**	**24**	**12**	**15**	**30**	**22**	**20**	**25**	**21**	**37**	**42**	**35**	**35**
Number of tree and shrub species		3	4	7	8	8	7	9	8	7	6	4	5	8	6	6	7	5	5	4	6	4	4	5	3	3	5	11	9	9	11	4	9
Number of herb species		.	3	7	6	3	8	10	6	10	9	1	3	7	3	3	.	.	.	5	3	12	3	5	25	16	7	7	9	22	25	25	14
Number of bryophytes		5	6	7	7	14	7	6	5	11	4	4	6	5	5	3	3	3	3	7	8	8	5	5	2	3	8	7	3	6	6	6	12
Trees & shrubs:																																	
Pinus sylvestris VP	a1	5	5	5	4	1	3	2	4	3	5	5	5	5	5	5	5	5	5	4	.	.	.	.	.	.	.	.	.	.	.	.	.
	a2	.	.	.	.	3	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	+	.	.	.	.	.
	b	.	.	.	.	+	.	.	.	.	+	+	+	.	.	.	.	.	+	2	3	3	2	5	2	.	+	.	+	.	.	.	.
	c	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	.	.	.	.	+	.	.
Betula pendula	a1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	4	4	2	3	+	.	1
	a2	.	.	.	.	2	.	2	.	.	.	.	+	.	.	.	.	.	+	.	.	.	1	.	.	.	2	1	2	+	.	+	.
	b	.	+	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	+	4	+	.	+	.	.	.	.
	c	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	+	.	.	.	.	.	.	.
Betula pubescens	a1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
	a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	1	+	2	.
	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	+	+	.
	c	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	+	+	.
Populus tremula	a1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.
	a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	.
	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	.	.
	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	+	1	.	.	.
Alnus glutinosa	a1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	2
	a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
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	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

Table 1. (*Continued*)

Successive No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Quercus robur	a1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	b	.	.	.	+	1	+	+	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.
	c	+	+	+	1	+	+	+	+	+	2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	+
Padus serotina	a2	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	b	.	.	.	2	1	1	+	2	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	1	.	+
	c	.	.	+	+	2	+	1	2	1	3	+	.	+	+	+	+	+	+	+	+	.	+	.	.	.	1	+	+	.	+	.	.
Picea abies	a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
	b	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	2
	c	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Frangula alnus	b	.	.	+	4	4	1	2	2	2	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	+	1	1	1	1	.	.
	c	.	.	1	2	1	+	1	+	1	.	+	+	+	+	+	+	+	+	+	+	.	.	.	.	.	+	2	1	+	+	.	+
Sorbus aucuparia	b	.	.	.	1	1	1	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
	c	.	.	+	+	+	+	+	1	1	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.
Salix cinerea (Ag)	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	.
Rubus sp.	c	.	.	+	+	1	2	1	2	3	+	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	2	1	1	4	.	1

Others: *Padus avium* **4** a2/+, **5** a2, c/+, **8** c/+, **9** a2/+, 11 – a2/+; *Quercus rubra* **7** a2/1, b/2; *Sambucus nigra* **30** a2/1, **32** a2/+; *Salix aurita* (Ag) **31** b, c/+, **27** c /+, **29** c/3; *Juniperus communis* **4** b/+; *Pyrus communis* **7** c/ +, **13** c/+, **23** c/+; *Ribes rubrum* **32** c/+.

Herbs		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Holcus lanatus	MA	.	.	.	.	.	.	.	1	.	+	.	+	+	+	.	.	.	.	+	+	+	.	.	.	1	+	.	.	3	+	+	1
Agrostis stolonifera	MA	.	.	1	+	+	+	+	1	1	+	.	+	.	.	.	.	.	.	+	.	2	+	+	.	+	2	2	1	2	.	1	.
Holcus mollis	Qrp	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	3	2	+	.	.	.	.
Deschampsia caespitosa	MA	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	+	.	.	1	+	2	+
Juncus effusus	MA	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	3	2	+	1	.
Urtica dioica	Art	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	1	1
Galium aparine	Art	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	.
Mentha arvense	Acc	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	2	.
Solanum dulcamara	Ag	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	+	+	2	.
Viola palustris	Sch	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.
Cirsium palustre	MA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.
Ranunculus repens	MA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.
Lysimachia vulgaris	MA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+
Lycopus europaeus	Ag	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.
Epilobium palustre	MA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.
Rorippa palustris	Bt	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.
Corynephorus canescens	KC	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	+	.	2	1	.	.	.	.	.	.	.
Rumex acetosa	MA	.	.	+	.	.	.	.	.	+	2	.	.	+	.	.	.	.	.	.	.	1	.	.	2	+	.	.	.	.	.	.	+
Convolvulus arvensis	Agr	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	+	.	+
Knautia arvensis	MA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.
Rumex acetosella	Ea	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	1	+	.	+	.	.	.	.	.

Table 1. (*Continued*)

Successive No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Anthoxanthum odoratum	.	.	.	.	.	+	+	.	+	+	.	.	+	.	.	.	.	.	.	.	+	+	.	+	+	1	.	+	.	.	.	.
Carex ovalis	.	.	.	.	.	.	1	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	+	+	.	.	.
Dryopteris carthusiana	.	+	+	+	+	1	1	+	1	+	.	.	+	+	+	.	.	.	.	.	+	.	.	.	.	.	+	+	.	1	+	.
Moehringia trinervia	.	.	.	.	.	.	.	.	+	+	.	.	+	.	+	.	.	.	.	.	+	.	.	.	.	.	+	.	1	1	2	+

Others: *Vaccinium myrtillus* (VP) **3**, **6**, **7**, /+, **4**/1; *Mycelis muralis*: **9, 25, 30**/+, **29**/1; *Dryopteris filix-mas* (QF) **6**/1, **8**, **9**, **21** /+; *Hypericum perforatum* **12**, **21**, **24**, **25** /+; *Carex hirta* **27**/1, **28**, **29**, **30**/+; *Dryopteris dilatata* **3**, **7**, **28**/+; *Carex nigra* (Sch) **3**/1, **7**, **28**/+; *Calamagrostis epigejos* (Ea) **6**/4, **8**/+, **9**/2; *Achillea millefolium* (MA) **24, 25, 29**/+; *Vicia cassubica* (QF): **25, 29, 30**/ +; *Melandrium album* (Art) **24, 25, 32**/ +; *Festuca ovina* **4**, **19**/+, **26**/2; *Calluna vulgaris* (NC) **2**, **3** /+; *Helichrysum arenarium* (KC) **24**/1, **25**/+; *Linaria vulgaris* (Art) **13, 24**/+; *Equisetum palustre* **29, 32** +, **30**/ 1; *Cirsium arvense* (Art) **29, 32** /+; *Epilobium tetragonum* **29, 31**/+; *Hypericum maculatum* **29, 31**/+; **Species occuring in one relevé only:** **4**: *Molinia caerulea* +; **7**: *Danthonia decumbens* (NC) +, *Carex pilulifera* (NC) +; **8**: *Equisetum arvense* (Agr) +; **9**: *Carex vulpina* (Ph) +; 10: *Sanguisorba officinalis* (MA) +, *Sedum maximum* +, *Viola riviniana* +; **21**: *Anthoxanthum aristatum* +; **24**: *Conyza canadensis* (Sm) 2, *Potentilla erecta* (NC) +; *Geranium robertianum* (Art) +, *Atriplex patula* (Sm) +, *Fallopia convolvulus* (Sm) +, *Raphanus raphanistrum* (Sm) +, *Setaria viridis* (Sm) +, *Gnaphalium sylvaticum* (Ea) +, *Jasione montana* (KC) +; **25**: *Elymus repens* (MA) 1, *Alopecurus pratensis* (MA) +, *Viola tricolor* +; **30**: *Phragmites australis* (Ph) 2, *Polygonum hydropiper* (Bt) +, *Carex acutiformis* (Ph) +, *Chamaenerion angustifolium* (Ea) +, *Prunella vulgaris* (MA) +; **31**: *Myosotis palustris* (MA) 1, *Peucedanum palustre* (Ph) 1, *Scutellaria galericulata* (Ph) 1, *Aegopodium podagraria* (QF) +, *Galium palustre* +, *Ranunculus flammula* (Sch) +; **32**: *Hieracium pilosella* (NC) +, *Galium mollugo* +.

Mosses

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Pleurozium schreberi	VP	4	4	5	5	+	3	.	.	.	2	4	.	+	+	+	+	.	+	2	2	3	.	.	.	.	+	.	.	.	.	.	.
Dicranum scoparium	VP	3	2	2	2	+	+	.	.	.	.	1	.	.	+	.	.	.	.	2	2	+	1	.	.	.	+	.	.	.	.	.	+
Dicranum polysetum	VP	3	3	3	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Pohlia nutans		+	+	+	+	+	+	+	1	.	.	+	.	.	.	.	.	+	+	+	+	+	+	.	.	.	+	.	+	.	.	.	+
Sciuro-hypnum oedipodium		.	.	.	.	+	+	+	+	4	1	.	+	2	+	+	+	+	+	+	+	3	+	2	.	+	2	.	2	.	.	.	2
Brachythecium rutabulum		.	.	.	.	+	.	+	3	+	.	.	1	+	.	.	.	.	.	.	.	.	.	1	+	+	1	3	2	1	+	+	+
Ceratodon purpureus	KC	.	.	.	.	+	+	.	.	.	.	.	.	+	.	.	.	.	.	+	+	+	.	.	1	+	+	+	.	.	.	.	+
Hypnum jutlandicum	NC	+	.	.	+	.	.	1	.	.	.	+	.	+	+	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Brachythecium albicans	KC	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	+	.	.	+	.	.	.	.	.	.
Hypnum cupressiforme	Qrp	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	+	+	+	+
Lophocolea heterophylla		.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	1
Plagiothecium curvifolium		.	.	+	+	+	.	.	.	+	.	.	.	.	.	+	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.

Others: *Polytrichastrum formosum* **2**, **3**, **4**, **5**, **19**/ +; *Pseudoscleropodium purum* **6**/2, **7**/4, **12**/+, **21**/1; *Brachythecium salebrosum* **9**, **27**, **29**, **32** /+, **30**/1; *Amblystegium serpens* **27**, **29**, **30**, **32** /+; *Herzogiella seligeri* **8**, **9**, **32**/+; *Polytrichum juniperinum* **22**/2, **23**, **26**/+; *Aulacomnium androgynum* **5**, **9** /+; *Plagiothecium denticulatum* **5**, **9** /+; *Plagiomnium affine* **9**, **10**/+; *Atrichum undulatum* **5**, **32**/+; *Brachythecium velutinum* **30**, **32**/+; **Species occuring in one relevé only:** **3**: *Orthodicranum lineare* + ; **8**: *Lophocolea bidentata* +; **9**: *Plagiothecium laetum* +; **20**: *Polytrichum piliferum* 3; **21**: *Rhytidiadelphus squarrosus* 1; **27**: *Hypnum cupressiforme var. filiforme* 2; **29**: *Amblystegium juratzkanum* 1, *Orthodicranum diaphanum* +; **31**: *Calliergonella cuspidata* 1, *Calliergon cordifolium* +, *Climacium dendroides* +

Explanation: Ag – *Alnetea glutinosae*, Agr – *Agropyretea*, Art – *Artemisietea*, Bt – *Bidentetea tripartiti*, Ea – *Epilobietea angustifolii*, KC – *Koelerio-Corynephoretea*, MA – *Molinio-Arrhenatheretea*, NC – *Nardo-Callunetea*, Ph – *Phragmitetea*, QF – *Querco-Fagetea*, Qrp – *Quercetea robori-petraeae*, Sch – *Scheuchzerio-Caricetea nigrae*, Sm – *Stellarietea mediae* VP – *Vaccinio-Piceetea*, **1**, **2** …**32** – relevé number.

on the ground, stumps and on the lowest parts of the trees' trunks. *Sciuro-hypnum oedipodium* dominates.

4. DISCUSSION AND CONCLUSIONS

One impoverished fresh pine forest association (*Leucobryo-Pinetum*) and nine secondary forest communities have been distinguished in the transect line in Glinno Ługi. The tree stands and thickets of Scots pine are dominant and they cover more than 70% of the transect line area. The silver birch forest patches, the young tree-stands of *Betula pendula* and the poplar forest cover about 10%. The anthropogenic monoculture of black alder and the spontaneous willow brushwood overgrow only the local wet depression (about 6% of the investigated patches) with thin peat deposit. The road lines, forest division lines and narrow ecotone zones (edges of plantations and tracks) are a significant part of the transect line – they constitute as much as 14%. It is the result of intensive fragmentation of this area among many owners and the ensuing necessity to clearly outline borders in the landscape.

The sequence, tree stand composition and area of the forest communities reflect the areas of private properties and their borders. Land use forms and their intensity are different and depend on the local needs of field owners. The tree stand composition is determined by forest management, extensive in the majority of private forests and intensive in state-owned forests. The species composition of the herb and moss layer is natural and determines the habitat properties better than the tree-stand or undergrowth. It also gives an account of previous land-use forms and indicates the tendencies of spontaneous vegetation development.

The species composition of secondary coniferous communities in the Glinno Ługi area, significantly differs from that typical of a natural forest (see MATUSZKIEWICZ 2001). These communities found on afforested post-cultivated sandy sites are characterized by a significant share of non-forest species in their flora. Besides numerous psammophilous plants they contain evident field weeds. True forest species (DZWONKO, LOSTER 2001; ZERBE *et al*. 2007) characteristic of forest communities are absent in the youngest plantations. They appear successively along with the ageing of the woodlands (DZWONKO 2001; GÓRAS, ORCZEWSKA 2009). Moreover, they are present in the patches with young pine tree stand, where the logging area was artificially re-afforested. The persistence of forest land use is one of the main factors determining the occurrence of forest indicator species (HONNAY *et al*. 1999; DZWONKO, LOSTER 2001; MAJCHROWSKA, WOZIWODA 2009). The rate of natural succession of coniferous forest vegetation on abandoned arable fields is indicated by the habitat properties as well as by the age of the trees in the neighbouring woodlands (availability of the seeds; GRASHOF-BOKDAM, GEERTSEMA 1998; GRINN-GOFROŃ 2004; KOPRYK *et al.* 2004).

The final species composition and structure of anthropogenic forest communities significantly depend on human activity and procedures related to forest management (ZERBE *et al*. 2007). Special attention should be paid to woodlands with a considerable participation of *Padus serotina* and *Quercus rubra*. These forest stands should be monitored to observe the development and spread of invasive alien species.

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ACTUAL STATE AND CHANGES OF FLORA AND VEGETATION IN THE BROCZÓWKA STEPPE RESERVE

Abstract: This paper presents floristic characterization of xerothermic plant associations and analysis of changes of flora within Broczówka steppe reserve. The floristic research was carried out in 2004-2009. Numerous species that were noted here almost 30 years ago were not found in the present study, the size of other populations decreased. Nevertheless, many plant species occurring in the reserve are rare, endangered or protected. Six major plant associations, impoverished form of two ones and one plant community are distinguished in the whole area of the reserve. Occurrence of two plant associations was not confirmed.
Key words: steppe reserve, rare and endangered species, succession

1. INTRODUCTION

Almost all sites of xerothermic vegetation in middle-east Poland were investigated in respect of flora and plant associations and communities. The researches were conducted in 1960s (e.g. FIJAŁKOWSKI 1959, 1964, 1972; FIJAŁKOWSKI, IZDEBSKI 1957; FIJAŁKOWSKI, ADAMCZYK 1980; FIJAŁKOWSKI *et al.* 1987). Conducted comparative researches show, that both flora and plant communities have been changed to a great extent. Preliminary information on this theme was published by FIJAŁKOWSKI *et al.* (1987) and KUCHARCZYK and WÓJCIAK (1995). This paper presents floral and ecological characterization of currently occurring xerothermic plant associations and analysis of changes of flora within

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Broczówka steppe reserve. Particular attention was paid to rare and endangered vascular plant species.

2. MATERIALS AND METHODS

Broczówka nature reserve located about 1.5 km north-east of Skierbieszów is a part of Skierbieszów Landscape Park. It is situated in the south-east part of the Lublin Upland, in the mesoregion of Działy Grabowieckie (CHAŁUBIŃSKA, WILGAT 1954; KONDRACKI 1994, 2000).

Broczówka nature reserve was established in 1989 for conservation of xerothermic plant associations with rare and protected plant species. It covers a part of a 40 m high hill's slope of about 50^o inclination and south-western exposition. In the north and north-east the reserve borders on arable fields. A small forest complex adjoins the south-eastern part of the reserve. At the foot of the reserve in its south-western part, there's a strip of hay-growing meadow (DUDA, PRÓCHNICKI 1998). The area of Broczówka reserve (about 6 ha) is geomorphologically diversified. There are many erosional forms both in the loess and Cretaceous rock formations. Chalky marls that are exposed in the lower and middle section of the slope are covered by a few meters thick loess layer in its upper part. Brown soils are developed on loess and rendzinas on chalky marls, respectively (FIJAŁKOWSKI, ADAMCZYK 1980; DUDA, PRÓCHNICKI 1998).

The floristic research in Broczówka reserve was carried out in 2004-2009. Every plant species occurring in the reserve area was recorded, but special attention was paid to rare, endangered and protected species. A list of rare species was prepared according to *Red list of plants and fungi in Poland* (MIREK *et al.* 2006), red list of vascular plants in the Lublin Region (KUCHARCZYK 2004), the order of the Minister of the Environment from July 9th 2004 and *Distribution Atlas of Vascular Plants in Poland* (ZAJĄC, ZAJĄC 2001). The botanical terminology was taken from MIREK *et al.* (2002). The categories of threat of species in Poland were given according to MIREK *et al.* (2006) and in the Lublin Region according to KUCHARCZYK (2004). A scale analogous to the one presented by FIJAŁKOWSKI and ADAMCZYK (1980) was used in determining the frequency of species.

Plant associations were examined according to the BRAUN-BLANQUET (1964) method. The phytosociological terminology and taxonomy of plant associations was taken from MATUSZKIEWICZ (2001). The affilation of particular species to plant associations was also determined according to MATUSZKIEWICZ (2001). To describe vegetations changes, the Shannon – Wiener index of diversity (H) and index of evenness ($J=H_{observed}/H_{max}$) were counted (SHANNON, WEAVER 1949).

3. RESULTS

Flora and its changes

257 species of vascular plants occur in the area of the reserve. Rare and endangered, in that listed by FIJAŁKOWSKI and ADAMCZYK (1980), are presented in Table 1.

In the area of the reserve, the most interesting are xerothermic plants e.g. *Asperula tinctoria*, *Carex praecox*, *Cerasus fruticosa*, *Elymus hispidus*, *Orobanche alsatica* – species included in the *Red list of plants and fungi in Poland*. Moreover, 19 species are protected (13 strictly, 6 partially), among them: *Aster amellus, Campanula sibirca*, *Cirsium pannonicum*, *Clematis recta*, *Primula veris*, *Daphne mezereum*, *Neottia nidus-avis, Frangula alnus, Viburnum opulus.* Other 12 species are endangered on Lublin region e.g: *Asperula cynanchica*, *Inula ensifolia*, *I. hirta*, *Carex humilis, Crepis praemorsa*, *Tanacetum corymbosum*, *Thesium linophyllon*. In the reserve area abundant are xerotherimc species: *Peucedanum cervaria*, *Teucrium chamaedrys*, *Scabiosa ochroleuca*, *Stachys recta*, *Anthericum ramosum*, *Salvia pratensis* and *S. verticillata.* But flora has changed for last 30 years (Tab 1.). The size of numerous xerothermic plants populations decreased, for example: *Cerasus fruticosa*, *Anemone sylvestris, Anthemis tinctoria, Elymus hispidus, Clematis recta* and *Inula hirta*. According to FIJAŁKOWSKI and ADAMCZYK (1980) the population of *Inula hirta* was almost as numerous as *Inula ensifolia*, and at present only a few flowering plants were found. Similarly, *Cerasus fruticosa* occupied a patch of 100 m^2 area, at present only few plants grow. The number of termophilous shrubs and forest species changed in less degree. Numerous species that were noted here 30 years ago were not found in the present study (Tab 1, Fig. 1.). Many of them (33 from 71) are rare xerothermic species belonging to *Festuco-Bromea* class,

Table 1. List of rare and endangered species noted in the Broczówka reserve. Explanations: * – strict protected species, ** – partial protected species; syntaxonomical group: Av – *Artemisietea vulgaris*, F-B – *Festuco-Brometea*, Cirs-Brach – *Cirsio-Brachypodion pinnati*, Fes val – *Festucetalia valesiaceae*, Fest-Stip – *Festuco-Stipion*, Q-F – *Querco-Fagetea*, Que pub – *Quercetalia pubescenti-petraeae*, Sm – *Stellarietea mediae*, Caucalid – *Caucaliodion lappulae*, K-C – *Koelerio glaucae-Corynephoretea*, M-A – *Molinio-Arrhenatheretea*, R-P – *Rhamno-Prunetea*, T-G – *Trifolio-Geranietea*, Th – *Thlaspietea rotundifolii*, V-P – *Vaccinio-Piceetea*; LR – the category of threat in the Lublin Region (Kucharczyk 2004): CR – critically endangered species, EN – endangered species, VU – vulnerable species, LR – species of lower risk; PL – the category of threat in Poland (Mirek *et al.* 2006): E – declining – critically endangered species, V – vulnerable species, R – rare – potentially endangered species; frequency on the area of reserve: 1 – single or a few specimens, 2 – 10-50 specimens; 3 – 50-100 specimens; 4 – species occurring in large number within 50-100 m^2; 5 – species forming patches 100-1000 m^2 ; 6 – species forming patches over 1000 m^2; + species listed in phytosociological tables.

	Name	Syntaxonomical group	LR	PL	Frequency	
					1980	2007
1	*Adonis vernalis**	F-B	VU	V	1	-
2	*Allium montanum*	F-B	EN		2	-
3	*Anemone sylvestris**	T-G			5	2
4	*Aquilegia vulgaris**	Q-F (Que pub)			2	-
5	*Asperula tinctoria*	F-B	VU	V	2	3
6	*Asarum europaeum***	Q-F			-	5
7	*Aster amellus**	F-B (Cirs-Brach)	LR		+	2
8	*A. danicus*	F-B	EN		1	-
9	*A. onobrychis*	F-B	VU		2	-
10	*Botrychium lunaria**	N-C		V	1	-
11	*Campanula bononiensis**	F-B (Cirs-Brach)			3	-
12	*C. sibirica**	F-B			4	3
13	*Carex humilis*	F-B	VU		6	5
14	*C. michelii*	F-B (Cirs-Brach)	LR		3	2
15	*C. supina**	F-B (Fest-Stip)	EN	R	1	-
16	*C. transsilvanica*	F-B	VU		3	-
17	*C. umbrosa*	Q-F	LR	R	1	-
18	*Centaurium erythraea**	M-A			2	1
19	*Cerasus fruticosa**	R-P	CR	V	4	1
20	*Cimcifuga europaea**	Q-F (Que pub)	VU		1	-
21	*Cirsium pannonicum**	F-B (Cirs-Brach)	EN		5	4
22	*Clematis recta**	T-G	VU		3	2
23	*Crepis praemorsa*	F-B	VU		2	1
24	*Cyperipedium calcelous**	Q-F (Que pub)	VU	V	1	-

Table 1. *(Continued)*

25	*Daphne mezereum**	Q-F			2	3
26	*Dianthus carthusianorum*	F-B			5	-
27	*Digitalis grandiflora**	Q-F (Que pub)			2	-
28	*Echium russicum**	F-B	CR	E	1	-
29	*Elymus hispidus*	F-B (Cirs-Brach)	LR	R	5	2
30	*Festuca rupicola*	F-B	EN		4	1
31	*Festuca valesiaca*	F-B (Fest-Stip)	EN	V	3	-
32	*Frangula alnus***	V-P			-	4
33	*Galium odoratum***	Q-F			-	3
34	*Gentiana cruciata**	F-B	VU		1	-
35	*Hedera helix***	Q-F			5	-
36	*Helianthemum nummularium* subsp. *obscurum*	F-B			5	-
37	*Hepatica nobilis**	Q-F			-	6
38	*Hieracium echioides*	K-C	VU	V	2	-
39	*Hierochloe australis***	V-P	VU	V	+	-
40	*Hypochoeris maculata*	F-B			1	-
41	*Inula ensifolia*	F-B (Cirs-Brach)	VU		6	6
42	*I. hirta*	T-G	VU		5	1
43	*Iris aphylla**	F-B (Cirs-Brach)	VU	V	1	-
44	*Koeleria macrantha*	F-B	VU		5	1
45	*Lilium martagon**	Q-F			2	-
46	*Linosyris vulgaris**	F-B	EN	R	2	-
47	*Linum flavum**	F-B (Cirs-Brach)	EN	R	1	-
48	*Melittis melissophyllum**	Q-F (Que pub)			4	2
49	*Neottia nidus-avis**	Q-F			-	2
50	*Ononis arvensis***	F-B			-	1
51	*Orchis militaris**	F-B (Cirs-Brach)	EN	V	1	-
52	*Orobanche alsatica**	F-B		E	-	2
53	*Potentilla recta*	F-B			2	-
54	*Primula veris***	Q-F (Que pub)			4	3
55	*Rosa gallica**	Q-F (Que pub)	CR	V	1	-
56	*R. majalis*	R-P	EN		1	-
57	*R. tomentosa*	R-P	VU		2	1
58	*Sanguisorba minor*	F-B			5	-
59	*Scorzonera purpurea**	F-B	EN	V	1	-
60	*Tanacetum corymbosum*	Q-F (Que pub)	VU		4	3
61	*Thalictrum minus*	T-G	VU		5	2
62	*Th. simplex*	F-B	VU		1	1
63	*Thesium linophyllon*	F-B	VU		4	4
64	*Thlapsi perfoliatum*	F-B	EN		1	-
65	*Trifolium rubens*	T-G	VU		1	-
66	*Veronica austriaca*	F-B	VU		4	-
67	*V. prostrata*	F-B	VU		1	-
68	*Viburnum opulus***	R-P			-	4
69	*Viola collina*	Q-F (Que pub)	VU		3	-
70	*V. rupestris*	F-B			4	-

e.g. *Adonis vernalis*, *Echium russicum*, *Linosyris vulgaris*, *Linum flavum*, *Rosa gallica*, *Scorzonera purpurea*, *Orchis militaris*, *Gentiana cruciata*, *Iris aphylla*. *Iris aphylla* extincted and it was reintroduced in 1995 (DĄBROWSKA *et al*. 2000). During the present study not even a single plant was found. Also some of rare forest species, e.g. *Aquilegia vulgaris*, *Cypripedium calceolus*, *Cimicifuga europaea* were not found at present. Also some termophilous plants that often occur on abandoned land, e.g. *Fumaria vallianti*, *Lathyrus tuberosus*, *Melampyrum arvense*, *Stachys annua*, *Euphorbia falcata*, *E. platyphyllos*, were not found.

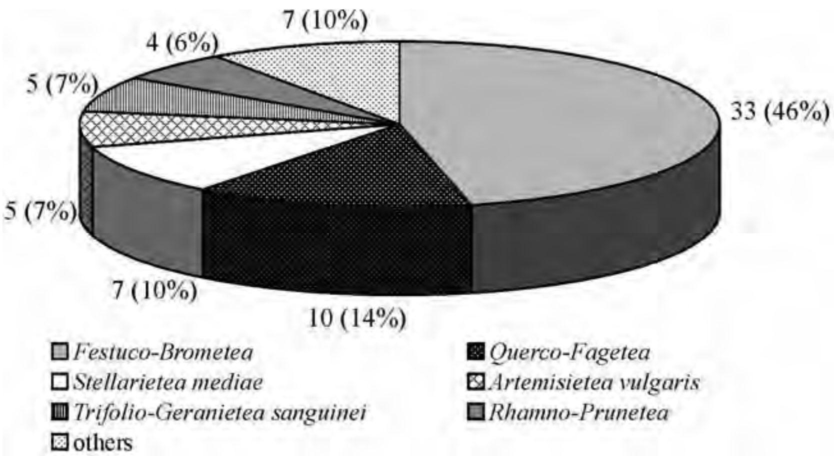

Fig. 1. Number of extinct species from particular syntaxonomical groups in the Broczówka reserve.

Vegetation cover and its changes

Six major plant associations are distinguished in the whole area of the reserve. Also two impoverished associations and one community were noted. Their syntaxonomic position can be presented as follows:

Class: *Festuco-Brometea* Br.Bl. er R.Tx. 1943

Order: *Festucetalia valesiacae* Br.Bl. er R.Tx. 1943

Alliance: *Cirsio-Brachypodion pinnati* Hadač et Klika 1944 em. Krausch 1961

Association: *Inuletum ensifoliae* Kozł. 1925

Impoverished form of *Thalictro-Salvietum pratensis* Medw.-Korn. 1959

Community with *Brachypodium pinnatum*

Class: *Trifolio-Geranietea sanguinei* Th. Müller 1962

Order: *Origanetali*a Th. Müller 1962

Alliance: *Geranion sanguinei* R. Tx. 1961

Association: *Geranio-Peucedanetum cervariae* (Kuhn 1937) Th. Müller 1961

Class: *Rhamno-Prunetea* Rivas Goday et Garb. 1962

Order: *Prunetalia spinosae* R. Tx. 1952

Alliance: *Pruno-Rubion fruticosi* R. Tx. 1952 corr. Doing 1962

Association: *Rubo fruticosi-Prunetum spinosae* Web. 1974 n.inv. Wittig 1976

Alliance: *Berberidion* Br.-Bl. (1947)1950

Association: *Rhamno-Cornetum sanguinei* (Kais. 1930) Pass. (1957)1962

Class: *Querco-Fagetea* Br.-Bl. et Vlieg 1937

Order: *Quercetalia pubescenti-petrae* Klika 1933 corr. Moravec in Beg. et Theurill 1984

Alliance: *Potentillo albae-Quercion petraeae* Zól et Jakucs n.nov. Jakucs 1967

Impoverished form of *Potentillo albae-Quercetum* Libb. 1933

Order: *Fagetalia sylvatica* Pawł., in Pawł., Sokoł. et. Wall 1928

Alliance: *Carpinion betuli* Issl. 1931 em. Oberd. 1953

Association: *Tilio cordate-Carpinetum betuli* Tracz. 1962

Association: *Ficario-Ulmetum minoris* Knapp 1942 em. J. Mat. 1976

Upper section of the slope and the top of the hill with a thick layer of loess cover is occupied by *Tilio-Carpinetum* forest. *Carpinus betulus* with *Fagus sylvatica*, *Populus tremula* and *Prunus avium* occur within the tree stand. In the southern part of the reserve *Pinus sylvestris* (planted here in the 1970’s) has large participation in the tree stand. In the shrub layer *Corylus avellana* predominates with *Euonymus verrucosus*, *Cornus sanguinea* and trees saplings. Undergrowth is mainly represented by: *Asarum europaeum*, *Hepatica nobilis*, *Pulmonaria obscura* and in spring *Anemone nemorosa*. Within lower, more sunlit parts of the slope *Quercus robur*, *Pinus sylvestris*, *Pyrus communis* and *Malus* sp. occur in the tree stand. In the shrub layer, *Euonymus verrucosus*, *Cornus sanguinea* and *Crataegus monogyna* are noted. *Daphne mezereum* grows (sometimes in abundance) in lower layers. In the undergrowth *Melampyrum nemorosum, Melica nutans* occur, and in more sunny places *Brachypodium pinnatum* and *B. sylvaticum* are found. Within one of loess prominences among shrubs grow singly *Potentilla alba*, *Inula hirta* and *Rubus saxatilis*. These species are connected with *Potentillo albae-Quercetum petrae* forests. However, in deep ravines, where an intensive surface flow occurs, species growing on moisture and rich soils are noted. In such places, fragments of humid dry-ground forest referring to *Ficario-Ulmetum* develop. In the tree stand of this area *Fraxinus excelsior* and *Alnus incana* occur and in undergrowth *Rubus caesius*, *Ficaria verna*, *Aegopodium podagraria* and *Urtica dioica* appear.

At the hill’s foot the stripe of shrubs from the *Rhamno-Prunetea* class occurs. In the vicinity of hay-growing meadow, the *Rubo fruticosi-Prunetum spinosae* association develops. It is mainly represented by *Prunus spinosa*, and in poor undergrowth by *Stellaria holostea* and *Poa nemoralis*. Within shrubs communities over the stripe of *Prunus spinosa* occur: *Rhamnus catharticus*, *Cornus sanguinea*, *Euonymus europaeus* and *E. verrucosus*, *Viburnum opulus, Frangula alnus* and *Crataegus monogyna*. The association *Rhamno-Cornetum sanguinei* is also present here. In one of the clearings *Corylus avellana* with *Carpinus betulus*, *Quercus robur* and *Rosa canina* form a low-density brushwood. In the undergrowth, *Brachypodium pinnatum* and *Peucedanum cervaria* are predominant and they occur with numerous species from the *Festuco-Brometea* class. In the previous studies such plant community was described as the *Peucedano cervaria-Coryletum* association, at present it was classified as *Geranio-Peucedanetum cervariae.*

The xerothermic grasslands are the most valuable in the reserve. They occupy a shallow-soil area in the central and lower parts of the slope. In places with the shallowest soil, mostly within central parts *Inuletum ensifoliae* association develops. In this association *Inula ensifola* is predominant with a large participation of: *Carex humilis*, *Cirsium pannonicum*, *Thesium linophyllon*, *Prunella grandiflora* and *Asperula tinctoria*. Less frequent is *Aster amellus*, which is characteristic for this association. Often in the *Inuletum ensifoliae* grasslands different species of shrubs appear: e.g. *Juniperus communis*, *Cornus sanguinea*, *Rhamnus catharticus* and *Quercus robur*. Within a small area, on a relatively deeper soil, impoverished form of the *Thalictro-Salvietum pratensis* association occurs. In this association characteristic for this association *Elymus hispidus* s.l., *Carex praecox*, *Potentilla arenaria* and *Thalictrum minus* are noted. Those grasslands are overgrown by shrubs, especially *Prunus spinosa*.

On the edge of clearings occupied by *Inuletun ensifoliae*, transitional, rich in species, plant communities form. In these communities, *Brachypodium pinnatum* or *Inula ensifolia* with *Peucedanum cervaria* predominates interchangeably. Aside from species of the *Festuco-Brometea* class, plants characteristic for *Trifolio-Geranietea sanguinei* grow here, e.g. *Clematis recta*, *Anemone sylvestris*, *Coronilla varia*, *Origanum vulgare*, but also species included to the ordo *Quercetalia pubescentis*, e.g. *Melittis melissophyllum*, *Tanacetum corymbosum*, *Vincetoxicum hirundinaria* or *Campanula persicifolia*. Abundant are: *Galium verum*, *Geranium sanguineum*, *Lembotropis nigricans*, *Chamaecytisus ruthenicus*. Fragments of such communities, the with domination of *Peucedanum cervaria* and other species from *Quercetalia pubescentis* abundance may be classified as the *Geranio-Peucedanetum cervariae* association. Fragments with the domination of *Brachypodium pinnatum* and other mesophilic species, e.g. *Salvia pratensis*, *Achillea pannonica* abundance, may be described as a community with *Brachypodium pinnatum*. This community develops in a place that was cultivated in the past so accompanying species have great share in it.

The vegetation units, especially area and structure, of grasslands have changed since the researches conducted by FIJAŁKOWSKI and ADAMCZYK (1980). The xerothermic grasslands associations have became poorer in species and more homogenous. Both the number of species forming individual communities and the index of diversity have decreased. The diminishing index of evenness indicates that some of species dominate in communities while others have fewer shares in plant cover (Tab. 2). Only very impoverished fragments of *Thalictro-Salvietum pratensis* left. Similarly, a few specimens of *Potentilla alba* may indicate past existence of *Potentillo albae-Quercetum*. Also occurrence of *Prunetum fruticoseae* was not confirmed at present study. In all xerothermic grasslands associations and communities number of species from *Festuco-Brometea* decreased, on the contrary, number of taxons from other group increased (Fig. 2). *Inuletum ensifoliae* reshapes in communities from the *Trifolio-Geranietea* class, however community with *Brachypodium pinnatum* overgrows by shrubs and trees from the *Rhamno-Prunete*a and *Querco-Fagetea* classes.

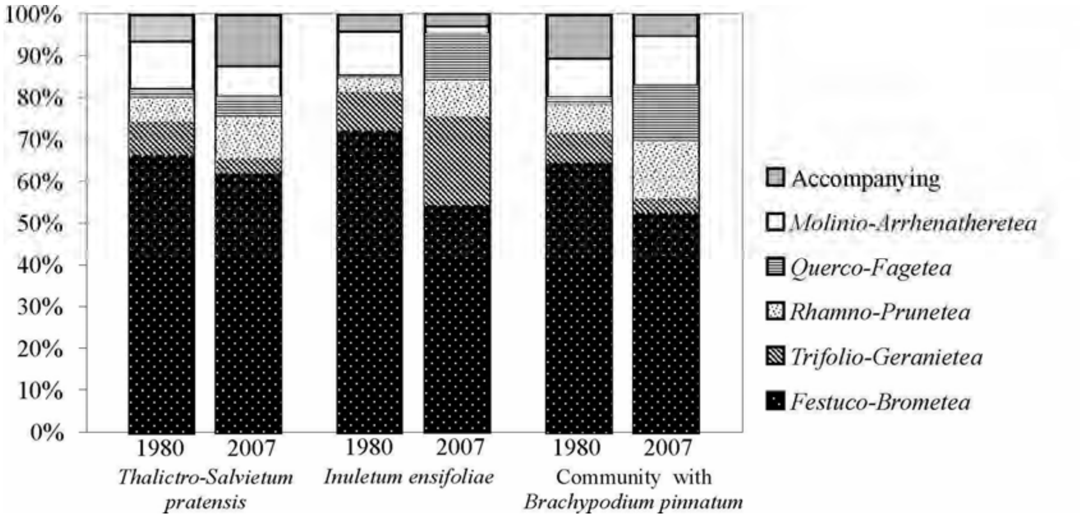

Fig. 2. Changes in share of syntaxonomical groups in xerothermic grasslands communities.

4. DISCUSSION AND CONCLUSIONS

There are several data on xerothermic flora of the Działy Grabowieckie and on the Lublin Upland (e.g. FIJAŁKOWSKI 1959, 1964, 1972; FIJAŁKOWSKI, IZDEBSKI 1957; FIJAŁKOWSKI, ADAMCZYK 1980; FIJAŁKOWSKI *et al.* 1987). So, it may be concluded that xerothermic species are endangered and their populations decrease. In the area of Broczówka reserve, numerous species that were noted here 27 years ago were not found in the present study, e.g. *Echium russicum*, *Adonis vernalis*, *Rosa gallica* and *Iris aphylla*. The size of others e.g. *Cerasus fruticosa* and *Inula hirta* populations decreased. Also composition and structure of plant communities have changed. Grasslands associations become poorer, and area of shrubs communities increases. Three of distinguished here by FIJAŁKOWSKI and ADAMCZYK (1980) plant communities were not identified in the present studies: *Potentillo albae-Quercetum*, *Ulmetum campestris suberosae, Prunetum fruticosae* and *Adonido-Brachypodietum pinnati* was recognized as community with *Brachypodium pinnatum*.

Table 2. Changes of floristic diversity in xerothermic grasslands in the Broczówka reserve.

	Thalictro-Salvietum pratensis		*Inuletum ensifoliae*		com. *Brachypodium pinnatum*	
	1980	2007	1980	2007	1980	2007
Average nuber of species in releve	50.0	49.0	53.0	28.5	51.0	29.5
Index of diversity (H)	1.70	1.58	1.68	1.37	1.65	1.33
Index of evennes (J)	0.99	0.98	0.99	0.95	0.97	0.96

The changes that have place in Broczówka reserve are analogous to those observed in other steppe reserves and generally in xerothermic grasslands (e.g. KAPUŚCIŃSKI 1990; MICHALIK 1990a, 1990b; SENDEK, BABCZYŃSKA-SENDEK 1990; ŚWIERCZYŃSKA 1990; DZWONKO, LOSTER 1992; MICHALIK, ZARZYCKI 1995; BĄBA 2003). The major therat for xerothermic plants is vegetation sucession. The trees and shrubs appearing in grasslands overshade photophilic species and inhibit their growth. Moreover, trees and shurbs decrease evaporation favoring the growth of mesophilic species. Cutting down the trees and shrubs from the central parts of clearings is done for protection of xerothermic flora in Broczówka reserve. Such treatment is favorable for xerothermic species, but seems to be insufficient. It only temporarily reduces shading and it is necessary to repeat it frequently. To improve the protection, the trees and shrubs should be cut down at least from two bigger clearings (not only from central but also from its peripheral parts). It would improve the microclimatic condition, decrease shading and increase evaporation. Another danger for xerothermic flora is destroying the plants by people digging them up and moving to gardens. It doesn't cause a big danger if it is limited to common species, but when the species is rare, it may lead to extintion. It is possible that it happened to *Iris aphylla* and *Adonis vernalis*, which disappeared from their natural sites in the reserve.

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INTRODUCTION OF ALIEN TREE SPECIES AND ITS INFLUENCE ON FLORISTICAL COMPOSITION AND VEGETATION STRUCTURE OF ACIDOPHILOUS OAK FORESTS: THE EXPERIMENTAL PLOTS IN THE ZIELONKA FOREST

Abstract: In 1879 Schwappach first established 54 experimental forest plots on habitat of acidophilous oak forest *Calamagrostio-Quercetum* in the Zielonka Forest near Poznań, on which 20 exotic tree species were cultivated. Until this day 32 of the mentioned forest sites have been preserved and today only 9 species are present there. The aim of the study was to determine actual condition of the experimental plots, a description of their flora and vegetation, as well as a comparison with other test plots situated in the direct neighbourhood. Basing on 63 phytosociological relevés, an influence of exotic species plantings on the structure of vegetation and local biodiversity was assessed. Floristic richness of both experimental plots (88 species), as well as their direct neighbourhood (68) was recognised, along with the geographical-historical groups spectrum and species affiliation to phytosociological classes.

Key words: experimental plots, alien tree species, flora, the Zielonka Forest

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1. INTRODUCTION

Since the end of the 19th century numerous exotic tree species, mainly coming from North America, have been cultivated in forests in various regions of Europe. In Poland, in areas formerly annexed by German Prussia, such experimental plantings were established by Schwappach and by his successor Wiedemann (BELLON *et al*. 1977). They wanted to obtain new species for cultivation, characterised by increased productivity comparing with those of native taxa.

Indeed, effects of an introduction of alien tree species may be assessed only after a relatively long time, but just in a dozen or so years since establishment of the experiment it turned out that many species and varieties were useless for forestry or they became exinct (e.g. REICHENAU 1911; HERMANN 1911). Moreover, not all experimental plots have survived until present times (BIAŁOBOK, CHYLARECKI 1965). Thus, the preserved forest stands dominated by anthropophytes seem to be even more precious for research and practical purposes. In many publications (e.g. BELLON *et al*. 1977) such features as: development, productivity, susceptibility to infections or potential adaptation to our climate, were analysed in relation to exotic tree species. The presented paper, focusing on phytocoenological analysis, differs from this trend and in this way it fills the gap in our knowledge about the influence of introduced alien tree species on local phytocoenoses.

In 1879, in the Zielonka Forest near Poznań, Schwappach established his first experimental plots within a homogeneous habitat of the acidophilous oak forest. In these sites 20 alien tree species have been cultivated. The state of preservation of these sites after ca. half a century since their establishment, was described by MIKLASZEWSKI (1928). A comparison of data obtained more than 100 years ago with results of other investigations carried out in the 1950s (KOSTURKIEWICZ, MEIXNER 1956) and our contemporary research enable us to make an assessment of changes which took place in forest communities as a result of alien species introduction, as well as to reveal that most of tree species originating from different climatic zones failed in cultivation.

The main aims of the study comprised: an assessment of a state of preservation of experimental plots in comparison with data collected in 1954

(KOSTURKIEWICZ, MEIXNER 1956), a description of flora and vegetation of the experimental and test plots, and on this basis – a determination of an effect of exotic species plantings on the vegetation structure and on the local biodiversity of experimental plots.

2. GENERAL DESCRIPTION OF THE INVESTIGATED AREA

According to the physical-geographical division of Poland (KONDRACKI 1998) the investigated area is situated in the Macro-region of the Wielkopolskie Lakeland (315) and comprises a part of the Gnieźnieńskie Lakeland Meso-region (315.54). The absolute altitude fluctuates between 107 and 121 m a.s.l. The matrix of soils was shaped by the last glaciation, during the so-called Frankfurt and the Vistulian period. They are classified as podsolic soils, poorly or moderately developed of slightly clayish sands, with ca. pH 6 in the humus layer. The groundwater level lays below 2 m under the soil surface (KOSTURKIEWICZ, MEIXNER 1956).

As far as the climate is concerned, according to WOŚ (1996), it is the Middle-Wielkopolska Region (XV) characterised by moderate features related to neighbouring regions: a low precipitation, late ground frosts observed sporadically even in May and early frosts appearing sometimes in the third decade of September. According to data obtained from a meteorological station in the Zielonka Arboretum, the mean annual temperature is 8.1°C, the mean temperature of January is –2.2°C, in July +18.1°C, the many years' minimum is –32.4°C, whereas the long-term maximum is +35.0°C. The mean annual precipitation is ca. 540 mm.

The experimental plots with alien species are situated in the Zielonka Experimental Forestry District belonging to the Poznań University of Life Sciences. They are located in a large forest complex, in the section No. 121a, and their total area is 27.93 ha. The potential natural vegetation is classified as representing the acidophilous oak forest *Calamagrostio arundinaceae-Quercetum*. Both compared test plots, as well as surrounding forest stands are quite well developed and preserved patches of the mentioned acidophilous oak forests.

In the classification of forest habitats it is the fresh mixed broadleaved forest (LMśw) with various-age stands of: Scots pine *Pinus sylvestris* – ca. 95 yrs old, oak

Quercus robur – 110 yrs old, and as an example of exotic species, the coast Douglas-fir *Pseudotsuga manziesii* reaching an age of up to 140 years. The mean diameter at breast height in case of Scots pines is 31 cm, while the tree's mean height is 26 m, whereas these measure for oaks are respectively: 36 cm d.b.h. and 27 m. Sanitation cuttings have often been made in forest plantations, whereas tending interventions had never been done, which have resulted in a relatively high density of the tree layer.

3. MATERIAL AND METHODS

We used data taken from a publication by KOSTURKIEWICZ and MEIXNER (1956) and the results of our own field investigations carried out in the vegetation season of 2008. Own observations show that only 32 of 54 plots established over 100 years ago have been preserved until now, including just 22 sites with closed tree stand. Initially there were 20 cultivated species but only 9 of them have survived (Table 1).

Table 1. A list of cultivated species and the number of occupied plots.

Species	Number of plots in 1956	Number of plots in 2008
Abies nordmanniana	5	5
Betula lenta	1	1
Carya cordiformis	3	3
Carya ovata	5	4
Chamaecyparis lawsoniana	2	2
Fraxinus Americana	11	3
Pinus strobus	2	1
Pseudotsuga menziesii	6	2
Thuja plicata	14	11

As far as the health condition of trees is considered, the only species with a good vitality were: *Pseudotsuga menziesii*, *Carya cordiformis* and *C. ovata*. It should be mentioned that old individuals of the two last species were cut off during the Second World War, so there was a next generation of shagbark hickory growing in the plots. *Chamaecyparis lawsoniana* and *Thuja plicata* were infected by brown root fungus *Fomes annosus*, which was reported even by KOSTURKIEWICZ and MEIXNER in 1956. *Pinus strobus* was infected by rust *Cronartium ribicola*. Individuals of *Fraxinus americana* and *Betula lenta* were characterised by a diminished vitality, which may be attributed to their age.

Species which have not survived (i.e. destroyed plots) comprise: *Abies alba*, *A. concolor*, *Acer negundo, Catalpa speciosa*, *Juniperus virginiana*, *Larix kaempferi*, *Picea engelmanni*, *P. pungens*, *P. sitchensis*, *Quercus rubra* and *Zelkova errata*.

The material comprises altogether 63 phytosociological relevés made (200 m^2, according to the well-known Braun-Blanquet's method) in the preserved experimental plots (32 of relevés) (0.05 – 0.42 ha) and in their direct vicinity (31 of relevés). On this basis we assessed an effect of exotic species plantings on the vegetation structure and biodiversity. Local floristic richness (vascular plant species and mosses) of experimental plots and their neighbourhood was determined. We also analysed a spectrum of geographical-historical groups and life forms of plants – in both cases using a classification of species according to JACKOWIAK (1990), and affiliation of taxa to phytosociological classes – according to BRZEG and WOJTERSKA (2001). Names of vascular plant species were used after RUTKOWSKI (2007).

The phytosociological relevés of gradient were analysed using the program MVSP (KOVACH 2002). The Braun-Blanquet scale was transformed to van der Mareel 9-degree scale (VAN DER MAREEL 1979). We used quantitative and qualitative data to compatibility analysis (DCA).

4. RESULTS

The monolayer or two-layer forest structure of experimental plots consist mainly with *Quercus petraea* with an admixture of *Pinus sylvestris*. A density of trees is fairly even and varies from 40 to 80% in the layer a1 and up to 70% in a2. The forest stand of alien trees species is most commonly monolayer. A density of trees is very different: from very high (85%) to gaps completely devoid of trees. A high density of trees is characteristic of stand with *Carya cordiformis*, *C. ovata*, *Chamaecyparis lawsoniana* and *Thuja plicata*. The lower tree layer, which consists mainly of species of the genus *Carya* and *Fraxinus pensilvanica* reaches 50%.

A brushwood is comparable and not very high (up to 20%), both in control and experimental plots. A distinct difference in the coverage of ground cover is emphasised: in the experimental plots, dominated by coniferous trees growing in a large density it is very minor, but increases, up to 80%, under the tree cover of deciduous trees. In the control plots the coverage of herb layer is more aligned, it hesitates from minimal to 75%, on average approximately 40%.

The moss layer in the control plots is less developed, occasionally reaches 25%. Whereas in the experimental plots, especially under the tree cover of *Abies normandiana*, *Pinus strobus* and *Pseudotsuga menziesii* the coverage reaches up to 80%.

A tendency to natural seedling and regeneration, that is also a potential expansion was shown mainly by *Carya cordiformis* and *Carya ovata*, also to a lower extent by *Pseudotsuga menziesii*. In case of *Abies nordmanniana*, *Chamaecyparis lawsoniana* and *Thuja plicata*, which germinated rather abundantly, the dying out of 3-4 years old seedlings was observed.

Total flora of the experimental plots and in the directly neighbouring with them control plots was composed of 98 species, 21 of which were mosses. Flora of the experimental plots (88 taxa, including 21 mosses) was richer than in their neighbourhood (only 68 species, including 8 mosses). More abundant in species, and at the same time more heterogeneous were the stands with coniferous plantings (70 species). In stands with loose tree layer we recorded 55 species, whereas in the plots with dense coniferous plantings – 51 taxa. In the sites with deciduous trees 63 species were observed. There were 44 common taxa (45%) which were present both in the experimental plots and their vicinity.

Eigenvalues of axis diagram obtained by indirect analysis (DCA) indicate that the gradient represented by the first axis differentiates significantly the occurrence of species and explains 6.5% of the variability of vegetation, and the other axis – 5.5%. Consulting diagram allowed to distinguish four groups of phytosociological relevés (indicated by ellipses in Fig. 1):

A – Records made on experimental plots with species of the genus *Carya* in the highest layers of the forest stands, the most different from the control plots;

B – Records made on experimental plots with *Betula lenta* and *Fraxinus americana*, which mostly relate to the control plots;

C – Records made on experimental plots with coniferous plantings; Records with the smallest density of trees and concurrently with larger coverage in ground cover and mosses are closer to the control plots. (e.g. records 14a-24a);

D – Records in the control plots, which are devoid of alien planting, creates the most homogenous group (Fig. 1).

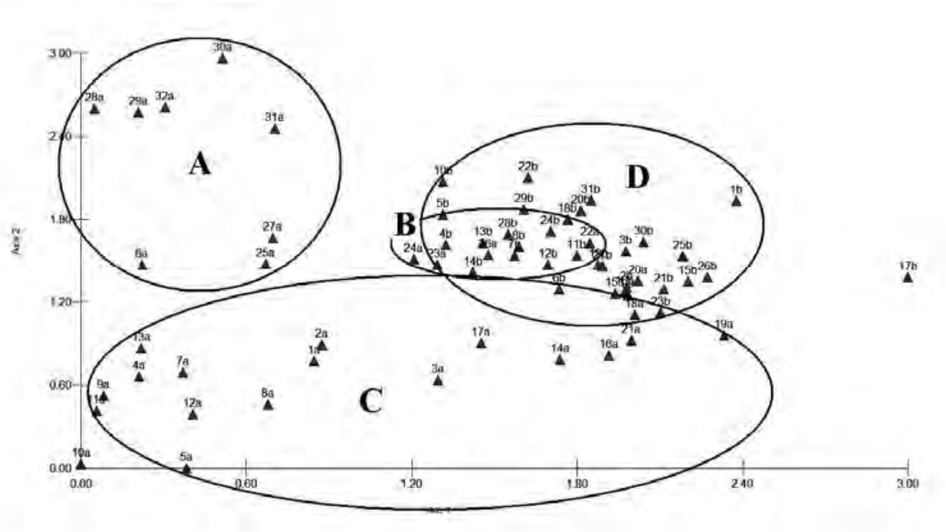

Fig. 1. Results of the indirect analysis DCA (MVSP) of records made in the experimental plots (a) and in the direct vicinity (b). A – patches with *Carya cordiformis and C. ovata*, B – patches with *Betula lenta* and *Fraxinus americana*, C – patches with coniferous plantings, D – control plots.

In all investigated plots native species were dominating, particularly the non-synanthropic spontaneophytes (Fig. 2). Alien taxa were slightly more represented in the experimental plots. Among the life form spectrum the most frequent were hemicryptophytes which were more numerous in the experimental plots (Fig. 3). The presence of phanerophytes was considerably high (21 species). Significantly numerous herbaceous chamaephytes were recorded in the experimental plots which may be explained by a relatively high share of mosses. In the experimental plots, particularly in those dominated by broadleaved tree stands, more species with short life cycles (therophytes) were noticed.

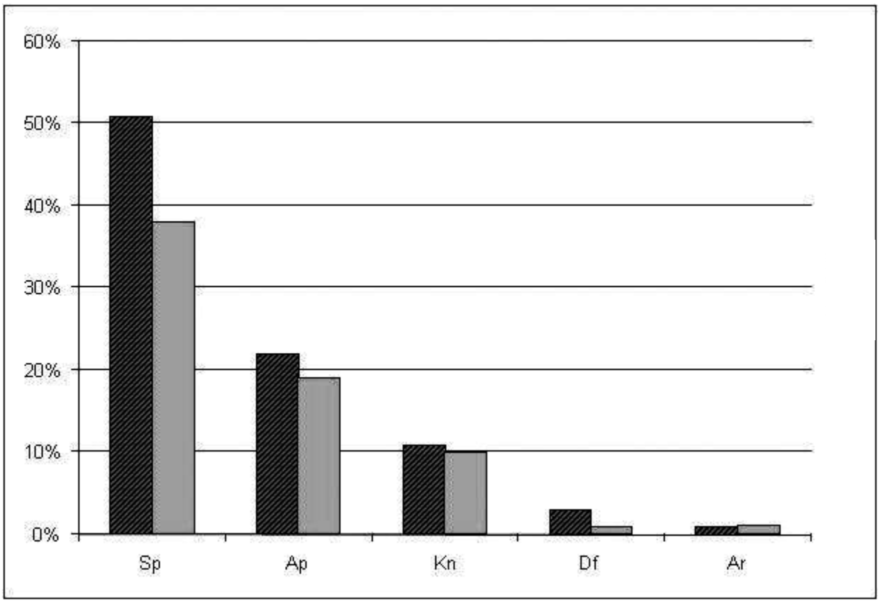

Fig. 2. Number of species representing historical-geographical groups in the flora of the experimental plots and in directly neighbouring. Sp – spontaneophytes, Ap – apophytes, Ar – archeophytes, Kn – kenophytes, Df – diaphytes, experimental plots (black bars), neighbouring control plots (grey bars).

Floristical composition of the investigated communities was dominated by acidophilous species representative of the *Quercetea robori-petraeae* and the *Vaccinio-Piceetea* classes (the most numerous in experimental plots, particularly in those with coniferous tree plantings). Some plants of relatively higher trophic requirements were also present, i.e. species diagnostic of the classes: *Querco-Fagetea* (which were slightly less frequent in the experimental plots with coniferous tree stands) and *Artemisietea* (Fig. 4). Taxa regarded as characteristic of other

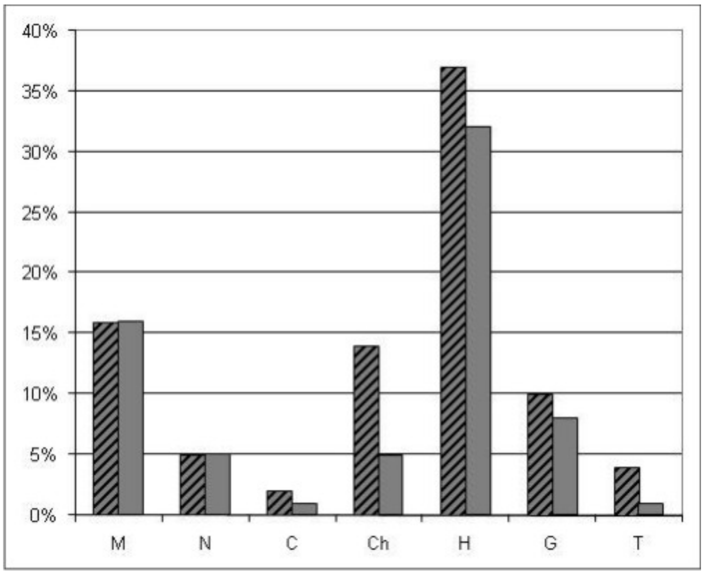

Fig. 3. Percentage of vascular plant life forms in the flora of the experimental and control plots in the Zielonka Forest. M – megaphanerophytes, N – nanophanerophytes, Ch – lignify chamaephytes, C – chamaephytes, G – geophytes, H – hemicryptophytes, Hy – hydrophytes, T – terophytes, experimental plots (dashed bars), control plots (grey bars).

classes appeared only exceptionally. It was noticeable that particularly in experimental plots, the number of companion taxa was significantly higher.

5. DISCUSSION

To this day ca. 59% of the former experimental plots have survived, many tree stands of which are in their terminal stages, whereas only 40% have more or less close stands. In the investigated area there are still the largest in Poland tree stands of *Thuja plicata* (BELLON *et al*. 1977).

A relatively poor habitat, with upper soil level in some places additionally acidified in consequence of an introduction of coniferous trees, is the main reason why the investigated plant communities are not rich in species. The relatively higher floristical richness of the experimental plots resulted not only from the presence of the introduced tree species, but may also be attributed to a spontaneous encroachment of other plants into stands with lower tree density and the herb layer in some places disturbed by wild boars, which is more often observed within experimental plots. More rich, and at the same time more heterogeneous as far as the floristical composition is considered, were the stands with coniferous plantings. On the other hand, patches with a high density of the tree layer, and consequently a poor sun exposure of the forest floor, were floristically the poorest ones (i.e. only 50 species). The number of common taxa for both the experimental plots and their vicinity was 44 (i.e. 45%), which may indicate a high heterogeneity of analysed sites, particularly the experimental plots. This is confirmed by the results of statistical analysis (Fig. 1), which indicate a relatively high homogeneity of the neighbourhood (patches of acidophilous oak forest – D) and high heterogeneity of the experimental area – A-C. The consulting diagram shows that the most important determinants of phytosociological relevés are species composition of planting and density of tree layers having an impact on the formation of the lower layers of phytocoenoses. An important factor can be also a change of the properties of the substrate, e.g. due to decomposition leaf processes of alien species. In patches with mature specimens *Carya* reported an increase in the proportion of species from richer habitats from *Artemisietea* class compared with the control areas.

A small contribution of anthropophytes in all investigated stands resulted from the situation of the plots within a large forest complex which caused a limited inflow of alien species diaspores, excepting the introduced trees.

In the biological spectrum, similarly as it was calculated for the whole Poland (cf. KORNAŚ, MEDWECKA-KORNAŚ 1986; MATUSZKIEWICZ 1990), the dominant life form were hemicryptophytes. A relatively high number of phanerophytes was a consequence of an introduction of alien trees and their self sowing not only within but also in the neighbourhood of the plots. A percentage share of trees would significantly diversify the experimental plots and their vicinity if their presence is analysed in particular vegetation layers. A higher presence of therophytes in the experimental plots, and particularly in those sites with broadleaved tree stands, may be attributed to available ecological niches provided by digging boars and also as a result of loosen tree stands.

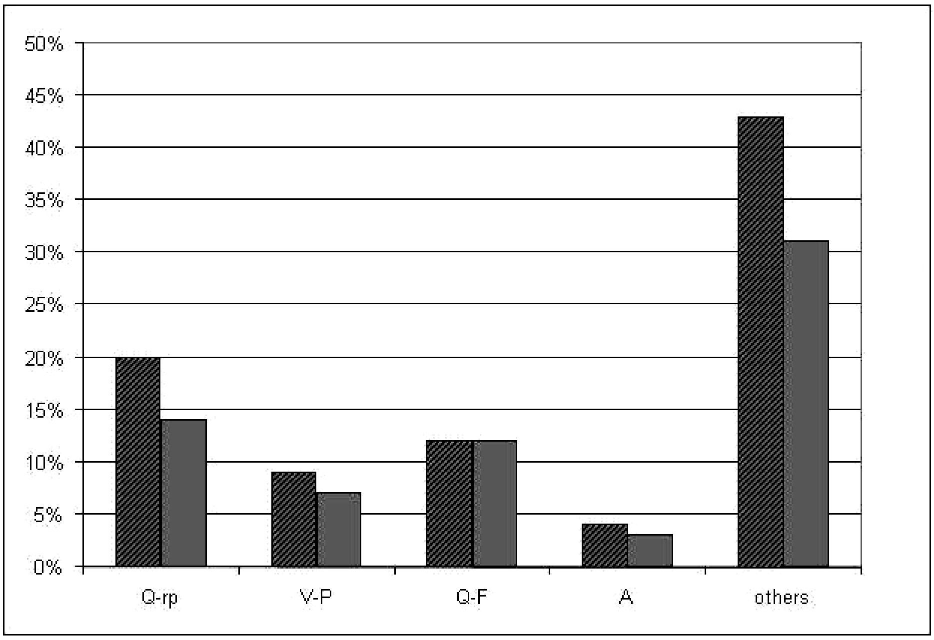

Fig. 4. Percentage of the phytosociological groups of the experimental and control plots in the Zielonka Forest. Q-rp – *Quercetea robori-petreae*, V-P – *Vaccinio-Piceetea*, Q-F – *Querco-Fagetea*, A – *Artemisietea*, experimental plots (black bars), neighbouring control plots (grey bars).

Analysis of the presence of diagnostic species of various phytosociological classes indicated that acidophilous taxa were dominant and particularly numerous in the experimental plots, mainly in those with conifer stands, the litter of which additionally acidified the soil, thus contributing to its degeneration. KUCABA (1980) demonstrated that western redcedar acidifies soils to a smaller extent than spruce, and that the litter of the former species decomposes faster, but at the same time the stands with *Thuja plicata* and *Chamaecyperis lavsoniana* are the most dense, and as such they have the most shaded and the poorest-in-species forest floor. The presence of the representatives of *Artemisietea*, although not high, is also an indicator of disturbances in forest vegetation. They were the most numerous in broadleaved tree stands which indicates the lowest acidity of their top soil levels.

In comparative test sites, situated in a direct vicinity of the experimental plots, the dominant vegetation type was the acidophilous oak forest. Some phytocoenoses demonstrated signs of degeneration processes, i.e. of the so-called ‘pinetisation’ (OLACZEK 1972, 1974). In such patches the seedlings of introduced trees were found. Vegetation of the experimental plots, with old tree stands composed of introduced species, should be treated as the so-called ‘substitute forest communities’. Apart from significant floristical differences in relation to the control plots, the vertical structure of such phytocoenoses was strongly modified: from highly dense stands, without underwood and shrubs and with a very poor forest floor, up to irregularly stocked open stands with scattered trees and a luxuriant herb layer.

Among patches with *Carya ovata* and in their vicinity we even observed an invasion of shagbark hickory. CHYLARECKI (1963) and BELLON *et al.* (1977) reported that in Poland and particularly in Silesia this species passes the complete life cycle and it regenerates through self sowing.

It is interesting that both KOSTURKIEWICZ and MEIXNER (1956), as well as authors of the presented article have never found brown root in the neighbouring pine stands. Introduced taxa were probably the only species infected by any fungus diseases.

6. CONCLUSIONS

- Only few species of the introduced alien trees were able to overcome the environmental resistance and to survive in the same places for over 100 years. Merely four of them formed close stands and three remained in a good health.
- Differences in the vegetation structure of the experimental plots manifested in: a degree of survival of the tree layer (from insignificantly present to very dense stands), the diversified coverage of the herb layer (i.e. insignificant under a canopy of dense tree stands and luxuriantly developed in patches with well-spaced stands).

- Flora of the experimental plots and their direct vicinity, due to the habitat potential, was not particularly rich-in-species. More taxa (by ca. 24%) were recorded in the experimental plots.
- The introduction of alien trees into a compact forest area has caused changes in floristical composition not only within the experimental plots, but also in their vicinity (self sowing of some species). More anthropophytes were found in the experimental plots than in the control plots.
- Higher changes in the floristical composition and structure of phytocoenoses were noticeable in coniferous stands, particularly in those with a high canopy density. The decisive factor for floristic richness in patches was rather an access to sunlight (the shade in the herb layer) than the appearance of cultivated tree species. Changes of the properties of the soil caused by planting alien taxa may also be significant. A continuous local extinction of alien species should be predicted, mainly in consequence of a natural ageing process. The only species showing a high dynamics of natural regeneration is *Carya ovata*, which becomes a permanent component of the flora of the Zielonka Forest.

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AN ATTEMPT AT ASSESSMENT OF *ALNETUM INCANAE* LÜDI 1921 TRANSFORMATIONS IN THE SKAWICA RIVER VALLEY (THE BESKID ŻYWIECKI MTS)

Abstract: The paper presents an attempt at assessment of *Alnetum incanae* LÜDI 1921 transformations in the Skawica River valley. The field studies were carried out in the whole Skawica valley. On the basis of phytosociological relevés, the participation of species which prefer riparian habitats, the number and cover of anthropophytes, including invasive plants, were analyzed. The presence of synanthropic sites was also taken into consideration. The research demonstrated that in the study area phytocoenoses of the *Alnetum incanae* association have primarily retained natural character, in spite of a noticeable influence of human impact. The results suggested that the vicinity of synanthropic sites does not eliminate natural components of phytocoenosis.

Key words: riparian forests, geobotanical indicators, anthropophytes, invasive plants

1. INTRODUCTION

The Skawica is a typical mountain river. Its sources are situated in the area of the Babia Góra National Park and the Biosphere Reserve of UNESCO. It starts from

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the merging point of two source streams: the Marków and the Jałowiecki (Fig. 1). In the vicinity of Juszczyn, the Skawica flows into the Skawa River. In the distance of about 16 km and in the altitudinal zone between 360-590 m a.s.l., its valley has a diversified character. In the upper river section water course is rapidly flowing along a narrow canyon with steep slopes; in the lower one it reaches a valley-floor which is widening, forming the alluvial terraces favorable to vegetation development. On the one hand, there are fluvial forms, on the other, human activities are noticeable. The Skawica River valley is used as a migration route by native as well as alien species.

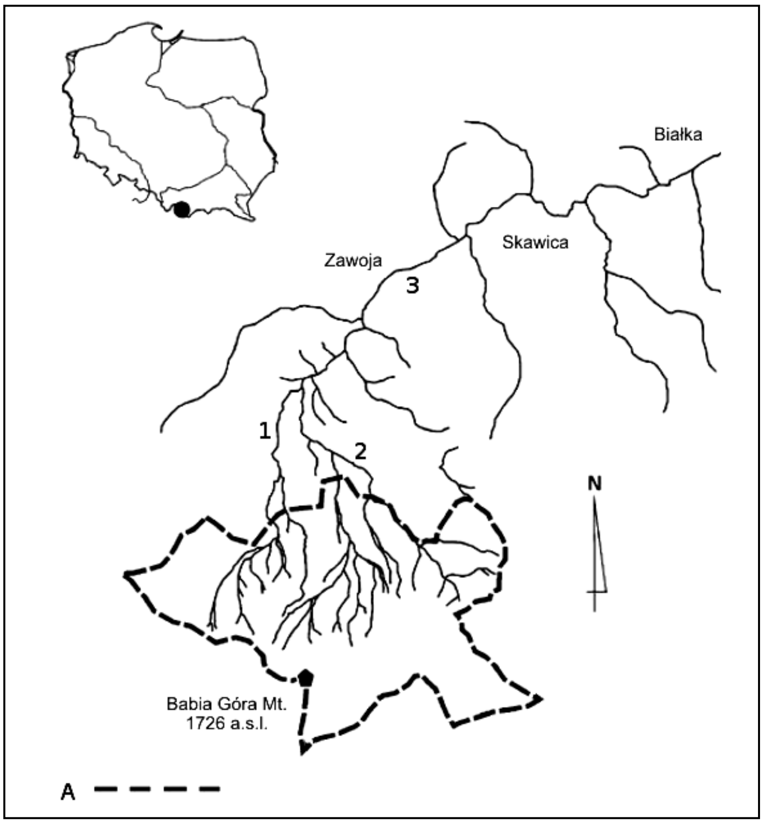

Fig 1. Localization of the investigated area. A – border of the Babia Góra National Park; 1 – the Marków Stream; 2 – the Jałowiecki Stream; 3 – the Skawica River.

Currently, ones of the most valuable plant communities in the Skawica River valley are riparian forests. An alder forest represented by *Alnetum incanae* association is particularly significant element of the valley landscape.

The alder forest has a limited importance in terms of occurrence of protected and rare plant species. However, it plays a crucial role in reducing the damaging effects of flooding, helping to control sediment and erosion as well as in stabilizing stream banks. All of this is especially important in the mountain area (FABIJANOWSKI 1954, after STASZKIEWICZ 1964).

The vegetation of a given area can be an indicator of phenomena and processes occurring as a result of different forms of human impact and natural processes. In the studies on natural environment transformations geobotanical indicators are often used. They regard the indication of both the state and changes of abiotic factors of the environment and, especially, the state and changes of vegetation. Populations of particular plant species or their groups which have common adaptive traits and similar ecological requirements, as well as phytocoenoses formed by these species and responding, by structural and dynamic changes, to the presence or intensity of a factor or to a complex of environmental conditions can be the geobotanical indicators (ROO-ZIELIŃSKA *et al*. 2007).

In this paper the floristic and quantitative analysis based on phytosociological relevés is proposed as a tool for making an assessment of *Alnnetum incanae* transformations in the Skawica River valley.

The aims of this study are: (i) to attempt an assessment of *Alnnetum incanae* transformations in the Skawica River valley, (ii) to verify the hypothesis that the vicinity of synanthropic sites favours elimination of natural components of forest phytocoenosis and encourage the penetration of alien invasive plants, (iii) to determine if the participation of species which prefer a given habitat enhance the penetration of anthropophytes, including invasive plants.

2. MATERIALS AND METHODS

The field survey was carried out between 2006 and 2008 in the entire valley of the Skawica River (in the area of the villages Zawoja, Skawica and Białka). Phytosociological relevés were made in the riverside zone of 15-20 m in width with the use of the Braun-Blanquet's method. Only species noted in the studied forest phytocoenoses were included in the analysis. The name of plant community and its affiliation to the phytosociological units were adopted after MATUSZKIEWICZ W. (2005). The names of vascular plants follow MIREK *et al*. (2002). Archaeophytes were adopted in accordance with ZAJĄC (1979), kenophytes and invasive alien plants after TOKARSKA-GUZIK (2005). Species preferring a riparian habitat are cited according to MATUSZKIEWICZ J.M. (1976, 2002), MATUSZKIEWICZ W. (2005) and ZARZYCKI *et al*. (2002). The set of these species was based on the detailed analyses of the species lists of the following syntaxonomical units: *Alnetum incanae*, *Alnenion glutinoso-incanae*, *Alno-Ulmion*, *Salicetea purpureae*, *Molinietalia*, *Trifolio fragiferae-Agrostietalia stoloniferae*, *Phragmitetea*, *Bidentetea tripartiti*, *Convolvuletalia sepium*, *Glechometalia hederaceae*, *Galio-Urticenea*, *Adenostylion alliariae*, *Betulo-Adenostyletea*.

The assessment of *Alnetum incanae* transformations was based on the following data: (i) the participation of species associated with the dynamic circle of riparian forests, in other words, all herb plants confined to this kind of habitat (e.g. moist meadows, natural and semi-natural nitrophilous edge communities), (ii) the immediate proximity of synanthropic sites (wild rubbish dumps, croplands, roads), (iii) the cover of anhtropophytes, including invasive plants. The values of cover coefficients follow PAWŁOWSKI, WALAS (1949, after DZWONKO 2007). The cover of species which occurred both, in herb and bush layer, was analysed in total. On the basis of phytosociological relevés the collective participation of species associated with riparian habitats in a total number of species was calculated. The collective participation of species group (G) was calculated according to the formula from MEDWECKA-KORNAŚ *et al*. (1972):

$$G = \frac{g}{t} \cdot 100$$

g – a total of occurrences of species from a given group in a table,
t – a total of occurrences of all species in a table.

On the basis of the proposed criteria all vegetation patches were divided into three groups: with large (above 70%), medium (60-70%) and small (below 60%) participation of riparian species.

In order to detect the relationships between the participation of species associated with the dynamic circle of riparian forests and the cover of anthropophytes, including invasive plants, the Spearman's rank correlation coefficient (ŁOMNICKI 2003; STANISZ 2006) was calculated. To verify the hypothesis that the synanthropic sites proximity influences the species composition detrended correlation analysis (DCA) was performed based on cover data (medians of percentage intervals). Next, differences in mean and range of site scores along two first axes of DCA were examined by Mann–Whitney *U* test (ŁOMNICKI 2003; STANISZ 2006) between two groups of relevés. The same test was performed to falsify hypothesis whether presence of synanthropic site affects the natural character of the patch's floristic composition by encouraging penetration of anthropophytes, including invasive plants. For this purpose differences in the mean cover between particular groups of relevés were studied. The statistic and ordination analyses were carried out using MS Statistica version 8.0 software and CANOCO for Windows 4.5 respectively.

3. RESULTS

The analysis of species noted in the studied vegetation patches revealed the presence of 188 species of vascular plants, 13 of which are anthropophytes, including 8 kenophytes (6 invasive plants) and 5 archaeophytes (Tab. 1). The species which achieved the highest cover in the studied patches are *Reynoutria japonica* (0.5 – 55), *Aster x salignus, Hesperis matronalis* and *Solidago canadensis* (0.5 – 17.5). Other plant species appeared as a small admixture in the herb layer, or as single specimens (Tab. 2). *Impatiens parviflora, Reynoutria japonica, I. glandulifera, Solidago canadensis* and *Aster x salignus*, qualified as invasive species, were the most frequent.

Table 1. Anthropophytes found in *Alnetum incanae* patches in the Skawica River valley. Explanations: ane – anemochory, antr – antropochory, aut – autochory, egz – egzochory, end – endochory, hyd – hydrochory, myr – myrmecochory, * after Tokarska-Guzik (2005) and Frank, Klotz (1988).

Succesive No.	Name of species	Status	Family	The way of spread *	Invasiveness	No of sites	Min. and max. cover
1	*Amaranthus sp.*	kenophyte	*Amaranthaceae*	ane egz	-	1	0.5
2	*Aster x salignus*	kenophyte	*Asteraceae*	ane egz antr	+	4	0.5-17.5
3	*Geranium dissectum*	archaeophyte	*Geraniaceae*	ane	-	2	0.5
4	*Hesperis matronalis*	kenophyte	*Brassicaceae*	ane	-	3	0.5-17.5
5	*Impatiens glandulifera*	kenophyte	*Balsaminaceae*	aut ane end hyd	+	5	0.5-5
6	*Impatiens parviflora*	kenophyte	*Balsaminaceae*	aut ane end hyd	+	14	0.5-5
7	*Lamium album*	archaeophyte	*Lamiaceae*	myr aut	-	2	0.5
8	*Matricaria maritima*	archaeophyte	*Asteraceae*	ane myr egz	-	1	0.5
9	*Melilotus alba*	archaeophyte	*Fabaceae*	aut	-	2	0.5
10	*Reynoutria japonica*	kenophyte	*Polygonaceae*	ane egz myr hyd antr	+	7	0.5-55
11	*Robinia pseudoacacia*	kenophyte	*Fabaceae*	end ane antr	+	1	43.5
12	*Solidago canadensis*	kenophyte	*Asteraceae*	ane egz myr	+	5	0.5-17.5
13	*Torilis japonica*	archaeophyte	*Apiaceae*	egz	-	1	5

The DCA carried out on the species abundances data from 35 relevés produced two axes with eigenvalues (0.3424, 0.2602) lengths of gradient (2.5572, 2.2560) and cumulative percentage of variance, which accounted for DCA1 (11.4%) and DCA2 (20.01%) respectively. There are no statistical differences in mean scores for DCA1 ($p=0.067$) and DCA2 ($p=0.96$) between the group of relevés with the synanthropic site in the vicinity and group of relevés without it.

The analysis of the contribution of species associated with riparian habitats shows that 11 (31%) from among 35 relevés were marked by the large participation of these plants, 17 (48%) – medium and 7 (20%) – small. The vicinity of synanthropic sites was noted in the case of 12 patches. Here, the mean participation of riparian species is 61.9% and it does not statistically differ from the mean

Table 2. Comparison of the participation of species associated with the dynamic circle of riparian forests, cover of anthropophytes as well as invasive plants and the proximity of synanthropic sites in individual relevés, * (herb layer + bush layer).

Succesive No.	No of relevé	The participation of species from dynamic circle of riparian forests [%]	The synanthropic site proximity	Cover of all anthropophytes (in total)	Cover of invasive plants (in total)	Cover of individual anthropophytes
1	42	77.14	+	18.00	0.50	(17.5) *H. matronalis;* (0.5) *A. x salignus*
2	10	72.09	+	0.50	0.50	*I. parviflora*
3	45	70.97	+	5.50	5.50	(5) *R. japonica*; (0.5) *A. x salignus*
4	46	70.73	+	0.00	-	-
5	67	62.86	+	55.50	55.50	(55) *R. japonica*; (0.5) *A. x salignus*
6	20	62.16	+	0.50	0.50	*I. parviflora*
7	86	61.29	+	18.00	17.50	(17.5) *S. canadensis*; (0.5) *L. album*
8	80	58.54	+	10.50	10.50	(5.5) *R. japonica*; (5) *S. canadensis*
9	51	55.56	+	6.00	5.50	(5) *I. glandulifera;* (0.5); *M. alba, I. parviflora*
10	22	54.00	+	0.00	-	-
11	17	52.63	+	24.50	23.00	(5.0+17.5)* *R. japonica;* (0.5) *H. matronalis, M. maritima, I. parviflora, M. alba*
12	64	45.16	+	2.50	2.50	(1) *R. japonica*; (0.5) *S. canadensis, I. glandulifera, I. parviflora*
13	34	78.79	-	1.00	0.50	(0.5) *S. canadensis, G. dissectum*
14	12	77.78	-	0.00	-	-
15	47	76.67	-	0.00	-	-
16	56	75.00	-	0.00	-	-
17	16	71.88	-	0.00	-	-
18	76	70.59	-	1.00	1.00	(1) *R. japonica*
19	53	70.59	-	0.00	-	-
20	54	68.97	-	0.50	0.50	*I. parviflora*
21	29	68.97	-	0.50	-	*G. dissectum*
22	72	68.57	-	0.00	-	-
23	71	67.65	-	1.00	0.50	(0.5) *Amaranthus sp., I. parviflora*

Table 2. *(Continued)*

24	23	66.67	-	0.00	-	-
25	43	66.67	-	5.50	0.50	(5) *H. matronalis;* (0.5) *R. japonica*
26	61	65.31	-	0.00	-	-
27	36	64.10	-	6.00	5.50	(5) *I. parviflora*; (0.5) *S. canadensis, M. alba*
28	52	63.83	-	0.00	-	-
29	8	62.96	-	1.00	1.00	(0.5) *I. parviflora; I. glandulifera*
30	55	62.71	-	6.00	5.50	(5) *T. japonica;* (0.5) *L. album, I parviflora*
31	25	61.29	-	0.50	0.50	*I. parviflora*
32	24	60.00	-	5.00	5.00	*I. parviflora*
33	28	60.00	-	0.00	-	-
34	18	56.60	-	43.50	43.50	(5.0+37.5)* *R. pseudoacacia;* (0.5) *I. parviflora, I. glandulifera*
35	65	51.92	-	23.00	23.00	(17.5) *A. x salignus. (5) I. glandulifera; (0.5) I. parviflora*

participation of these species in patches without the proximity of synanthropic sites (Tab. 3). There are statistical significant differences between the cover of anthropophytes as well as invasive plants in the patches in the vicinity of synanthropic sites and in the patches not in such vicinity (Tab. 3). *Impatiens parviflora* and *I. glandulifera* are the most frequent invasive plants in the patches where no synanthropic sites were observed.

The statistical analysis reveals a negative medium correlation between the participation of species associated with the dynamic circle of riparian forests and the cover of invasive plant species (Spearman correlation rs = -0.52, p = 0.0012). The negative, mediocre correlation (Spearman correlation rs = -0.43, p = 0.009) was found between the participation of riparian species and the cover of all anthropophytes.

4. DISCUSSION

The vegetation development and transformations occur in response to human activity as well as to natural phenomena. This is the major subject of the contemporary geobotanical research. For that reason, natural and transformed phytocoenoses should be distinguished. Moreover, new methods, which will make it possible to make an assessment of advances and trends of transformations, should be sought out and recommended. From a theoretical point of view, it is certainly important to identify patches of real vegetation objectively, as well as understanding the diversity of current vegetation (OLACZEK 1974).

Table 3. Comparison of mean participation of species associated with the dynamic circle of riparian forests, an average cover of anthropophytes and invasive plants depend on proximity of synanthropic sites.

The proximity of a synanthropic site	Mean± SD	n	P
Participation of species associated with dynamic circle of riparian forests			
not	66.8±6.7	23	0.15
yes	61.9±9.4	12	
Cover of invasive plant species			
not	3.8±10.0	23	0.04
yes	10.3±16.1	12	
Cover of anthropophytes			
not	4.1±9.8	23	0.03
yes	11.8±16.1	12	

It is difficult to find which of the features of the vegetation patch most clearly reflect the reaction to transformations. Phytocoenoses include sets of species which are relatively uniform, relatively constant and instantly recognizable, which can be helpful in attempting an assessment of vegetation transformations. The changes in the floristic composition, but also in the community structure, can function as a main indicator of vegetation transformations (ROO-ZIELIŃSKA *et al.* 2007).

Human activities, on the one hand forest management (ZARZYCKI 1956), logging for specific wood types (grey alder) and pasturage in the past (SURMIŃSKI 1980, after PIĄTEK, PANCER-KOTEJA 2004), on the other, bank reinforcement, wild rubbish dumps, recreational activities or illegal gravel digging at present, have strongly influenced the development of mountain riparian communities. The characteristic feature of riparian communities is the exposure to floodwaters flowing down the mountains. It is recognized as a factor conditioning the existence of this type of vegetation (MATUSZKIEWICZ 2005). What is more, it makes the floristic composition richer and more diversified, due to the fact that the flowing water permits various species to migrate. These migrant species are linked to many kinds of alluvial communities which constitute one of the most changeable circles of vegetation (UZIĘBŁO, CIAPAŁA 2006).

It should be emphasized that none of the processes affects riparian forests in an adverse way. The assessment of transformations occurring within that kind of community should be made on the basis of an objective evaluation of what is normal for the functioning of a community as well as what disturbs its equilibrium (ŁASKA 2001).

In the case of alder forests, the selection of species which are characteristic of a given association as well as of other syntaxonomic units (OLACZEK 1974) can be insufficient to make an assessment of riparian communities transformations. The division of all noted species into two groups, associated and not associated with the dynamic circle of riparian forests, seems to be a better solution.

A number of species associated with alder forests are not considered to be characteristic of riparian associations or higher syntaxonomic units, but typical of other communities, mainly tall herbs, nitrophilous edge communities or 'veil communities'. Nevertheless, such species can be regarded as natural components of riparian communities. Owing to the analysis of the floristic composition of riparian communities (MATUSZKIEWICZ 1976, Tab. 1), it can be stated that species associated with moist meadows, nitrophilous edge communities or 'veil communities', are constant components of riparian phytocoenoses.

Phytocoenoses of *Alnetum incanae* in the Skawica River valley retained the natural character in spite of evident signs of the human impact. On the basis of the results obtained by means of the analyses and field observations, it was stated that the proximity of synanthropic sites both the old ones (e.g. croplands) and the ones whose age cannot be determined (e.g. wild rubbish dumps) does not eliminate natural components from vegetation patches. According to DCA results, the differences in species composition in the vicinity of a synanthropic site are minor, however, it has influenced the penetration of alien species into the patches of alder forest (Tab. 1). In the phytocoenoses in question the herb layer is species-rich, lush and dense. Its structure is diverse, ranging from small perennials (*Galium palustre*) through huge tall herbs species (*Petasites kablikianus*) to creeping ones *(Glechoma hederacea)*, clinging ones *(Galium aparine)* and the ones covering ground surface. Describing the alder communities in the Jaworze mountain range, STASZKIEWICZ (1964) points to the patch with dense, almost natural vegetation, in spite of the fact that it is localized in the vicinity of a railway station and a village.

The rate of transformations of *Alnetum incanae* phytocoenoses in the Carpathian Mountains area is difficult to follow on the basis of literature. The oldest phytosociological papers usually describe well-developed patches (ZARZYCKI 1955, 1956; STUCHLIK 1968; PANCER-KOTEJA 1965, 1973). In the case of the Pieniny Mts alder forest, authors mention the prolific growth of *Rubus caesius*, which seems to have been caused by clearing away of trees in the past (PANCER-KOTEJA 1973). The descriptions of fragmentary *Alnetum incanae* phytocoenoses transformed by human impact are found in the latest geobotanical studies. Here, due to lack of well-developed patches, more detailed analyses are not carried out.

The anthropogenic transformation of the vegetation is indicated by the presence as well as the cover of alien plants. A small contribution (7%) of anthropophytes to the total species number of the forests prove that alien species currently have a minor influence on the *Alnetum incanae* transformation, however their presence is a cause of concern. *Reynoutria japonica* with the highest cover and with high frequency, as well as two other frequent species *Impatiens parviflora* and *I. glandulifera*, can pose some threat not only to riparian forests in the Skawica River valley, but to the vegetation of the Babia Góra National Park as well. All the species mentioned above are invasive and can spread in many different ways (Tab. 1). The Skawica River valley is used as a migration route by each of these species, which is important for penetration processes, especially for *I. glandulifera* (DAJDOK, ANIOŁ-KWIATKOWSKA 1998; TOKARSKA-GUZIK 2005; TICKNER 2001). However, Himalayan balsam is not considered to be disruptive to phytocoenoses which it penetrates (DRESCHER, PROTS 2002; KASPEREK 2004; HEJDA, PYŠEK 2006).

Impatiens parviflora is the most frequently found, but not abundant, species in the *Alnetum incanae* phytocoenoses in the Skawica River valley. Similarly, PIĄTEK, PANCER-KOTEJA (2004) find individual specimens of this species in virtually every patch of *Alnetum incanae* phytocoenoses in the Pieniny Mts. Individual specimens of *I. parviflora* were observed sporadically in the mountainous alluvial communities in the mid-20th century (STUCHLIKOWA, STUCHLIK 1962; ZARZYCKI 1956). The adverse effect of this plant on the vegetation is still small (even after 50 years from its first occurrence). The strong native competitors, supported by a wet productive habitat, do not leave much space for potential invaders (GRIME 1979; DEL MORAL 1983, after REJMÁNEK 1989). Therefore, small-sized specimens of *I. parviflora* have probably been defeated by large-sized plants associated with alluvial vegetation.

The appearance of *Reynoutria japonica* seems to be of great importance in *Alnetum incanae* transformations. This plant has been quite frequently found in river valleys in Poland especially in the Oder River valley (DAJDOK, KĄCKI 2003; TOKARSKA-GUZIK *et al*. 2007). Forming dense clusters *R. japonica* eliminated other plants (FALIŃSKI 1969). In alder forest of the study area it usually occurs with a large cover. New shoots of this alien plant appear immediately at the beginning of spring and defeat other species, even *Petasites hybridus* and *P. kablikianus*. The species has a tendency to spreading.

In this study we noted negative relationship between native species i.e. species of the dynamic circle of riparian forests and species of alien plants including those which are considered invasive ones. Such relationship was found in many types of vegetation and was reported by numerous authors (REJMÁNEK *et al*. 2005 and cited literature therein). It is also known to be dependent on a plot size (STOHLGREN *et al*. 1999). On a large spatial scale and in some cases e.g. abandoned agricultural land, the positive relationship was detected (MEINERS *et al*. 2004). The negative relationship is said to be a result of biotic resistance or competition ability of invasive species, which lead to the decrease in abundance of native species and finally their replacement. Only observations over time can allow us to answer the question what the trend of changes in vegetation is.

5. CONCLUSIONS

- Phytocoenoses of *Alnetum incanae* in the Skawica River valley primarily retained natural character in spite of apparent signs of human impact.
- The obtained results proved that the proximity of synanthropic sites has a major impact on the process of penetration of alien species into phytocoenoses. However, this proximity does not eliminate the natural components of phytocoenoses.
- Alluvial forest communities characterized by the large participation of species associated with the dynamic circle of riparian forests are more resistant to the penetration of anthropophytes.

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TRANSFORMATION OF FOREST VEGETATION AFTER 40 YEARS OF PROTECTION IN THE TOMCZYCE NATURE RESERVE (CENTRAL POLAND)

Abstract: The Tomczyce nature reserve is characterized by a degenerated forest vegetation. We assume that the regeneration process was possible to launch after the establishment of the nature reserve in 1968. The vegetation of the Tomczyce forest complex was characterized for the first time by JAKUBOWSKA-GABARA (1976) whose studies were taken as a basis of our research. The phytocenoses after 40. years of protection have a greater participation of species with higher trophic and moisture requirements. The regeneration process in communities with pine trees is caused by an expansion of broad-leaved trees and shrubs. Transformation of forest vegetation causes a decrease in cover of thermophilous and heliophilous species. On the other hand, species of oak-hornbeam forests as well as anthropophytes are in expansion. Planning of the protection activities in the nature reserve needs to include these dynamic tendencies of the vegetation.

Key words: forest regeneration, mixed pine-oak forest, nature protection, Central Poland

1. INTRODUCTION

Natural forest communities develop in cycles which particular phases differ considerably from each other (KOOP 1989; OLIVER, LARSON 1996). The

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developmental phases, connected with the dynamics of small gaps, occurred in primeval lowland forests of Europe (PICKETT, WHITE 1985; MITCHELL 2005; MOORE 2005). These forest communities were also formed by quite extensive and large natural disturbances. However, in European lowland forests, they usually did not occur in the same spatial scale or in constant intensity (SZWAGRZYK 2000).

The present forest landscape is predominantly formed by anthropogenic disturbances which not only result in impoverishment of the dynamic structure of communities but also in changes in habitat conditions and species composition of forest stands (ELLENBERG 1988). Forest management in Europe, lasting for many centuries, has resulted in the development and existence of specific plant communities. Anthropopressure as an ecological factor has caused the formation of substitute communities representing different phases and forms of degeneration (FALIŃSKI 1966; OLACZEK 1972). The abandonment of the old ways of forest use observed in the last several decades and the implementation of the ecological silviculture have brought about spontaneous regeneration of forest communities, that in turn led to their renaturalization (DZIEWOLSKI 1991; SZWAGRZYK 1996; KUROWSKI 2004 a; ŁASKA 2006).

Protected areas are useful objects for studying such spontaneous regeneration because human activity is limited or restricted there. Moreover, the vegetation in nature reserves and national parks was studied in the past. Due to these basic studies, these areas are convenient research objects (SZWAGRZYK 1994; HERBICH 1999; PAWLACZYK 1999; HOLEKSA 2005; MATUSZKIEWICZ 2007). Registration of changes in nature reserves puts forward information about the undergoing processes after limitation of anthropopressure, as well as about the transformations of natural environment. It also proves useful while verifying the targets and methods of protection (SZWAGRZYK 1994; OLACZEK, KURZAC 1995; PAWLACZYK 1999). The transformation of forest communities in protected areas has been studied by many researchers in Poland (FALIŃSKI 1986; JAKUBOWSKA-GABARA 1995; KUROWSKI 2004 b; HOLEKSA, SZWAGRZYK 2006; MATUSZKIEWICZ 2007; BRZEZIECKI 2008 and others). Changes in prominently anthropogenic phytocenoses are among important aspects of regeneration of forest communities (OLACZEK 1998; FALIŃSKI 2000).

Most of the protected areas were established to preserve quite natural phytocenoses. In other cases, where landscape, geological, geomorphologic or zoological values are the main conservation objectives, plant communities may have more anthropogenic character.

The Tomczyce nature reserve was established for the protection of specific geomorphological forms on the valley-side of the Pilica River and the old pine-stand – characterized by strongly transformed vegetation (JAKUBOWSKA-GABARA 1976). The Tomczyce nature reserve is situated in the south-eastern part of Central European Lowland, in the physico-geographical region of the Białobrzegi Valley, which includes the lower part of the Pilica River valley – the left-side tributary of the Vistula River (KONDRACKI 2002). According to the regional geobotanical division, it is located in the Great Valleys Zone in the southern part of the Masovian Region, in the district of Rawa (SZAFER, ZARZYCKI 1977).

The investigated forest complex is situated on a steep slope of the Pilica River valley and includes the high plain as well as a narrow strip of the floodplain. The valley-side is cut through by many deep flat-bottomed accumulation valleys directing to the river (Fig. 1). Both the occurrence of such landforms and the location on the slope contribute to a great variety of topography (GRABDA 1935; JAKUBOWSKA-GABARA 1976). The small forest complex, which includes the Tomczyce nature reserve, borders the Tomczyce village and the old manor dating from the middle of the 19th century. It is supposed that part of this forest area was used as a manor park in the past. There is a share of some planted alien species in the studied phytocenoses. We assume that the regeneration process started in 1968 after the establishment of the nature reserve in the area of 57.99 ha.

The aim of this study was to investigate the present state of the vegetation, directions and the rate of its changes during last 40 years after cessation of the forest use and in relation to its initial state. The vegetation of the Tomczyce forest complex was characterized by JAKUBOWSKA-GABARA (1976) whose results were taken as a reference point in this study.

2. MATERIALS AND METHODS

Results of the Jakubowska-Gabara's studies (1976)

Jakubowska-Gabara studied the vegetation of the Tomczyce forest complex in 1971-1973 (JAKUBOWSKA-GABARA 1976). Her attention was drawn to many old pine trees occurring in the nature reserve which were over 100 years old. These trees were very characteristic with their much-branched and curved boughs. High plain, slopes and upper parts of the flat-bottomed accumulation valleys were occupied by phytocenoses of *Querco roboris-Pinetum* and *Pinus sylvestris* xerothermic community of uncertain syntaxonomic affiliation. Flat bottoms of the accumulation valleys and their slopes were covered by small patches of *Tilio-Carpinetum typicum*. A small part of the floodplain was occupied by phytocenoses of *Fraxino-Alnetum*.

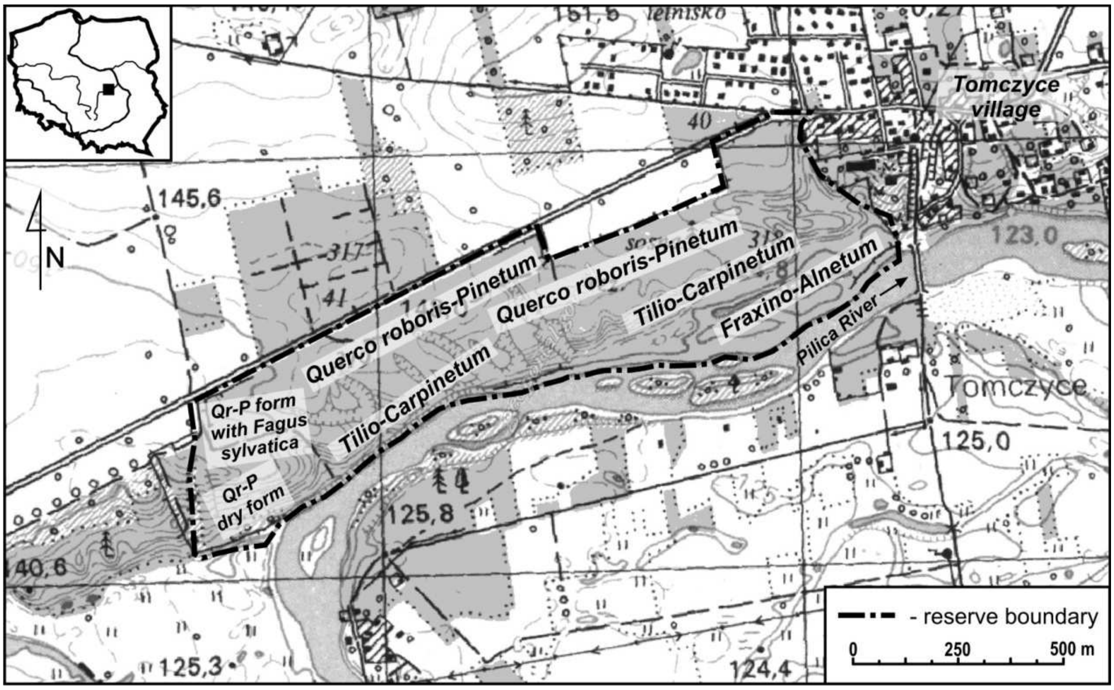

Fig. 1. Location of the Tomczyce nature reserve (based on the topographic map; scale: 1:25000, national coordinate system "1965") and distribution of the main forest associations in 2008.

The phytocenoses of *Querco roboris-Pinetum* were characterized by a domination of *Pinus sylvestris* in tree stands which were mainly planted in the studied area. Due to the characteristic crown shape of pine trees we cannot exclude that some of them could grow spontaneously in the deforested area. Moreover, *Betula pendula* was a common component of the forest stands. The understorey layer was well-developed and rich in species. The upgrowth of *Quercus robur* was the most frequent. *Juniperus communis, Corylus avellana* and *Padus serotina* was also present. The herb layer was mainly composed of: *Vaccinium myrtillus, Melampyrum pratense*, *Festuca ovina*. The presence of species from *Vaccinio-Piceetea* class and the domination of *Pinus sylvestris* indicated that phytocenoses had an acidophilic character.

The xerothermic community with *Pinus sylvestris* occurred on steep slopes of the Pilica River valley in the southern part of the nature reserve. The forest stand was a monoculture of 70 years old pine trees. The understorey layer was poorly developed with some upgrowths of *Quercus robur, Juniperus communis* and *Sorbus aucuparia*. The sparsely developed herb layer consisted of species from different syntaxonomic groups with participation of xerothermic and heathland species. The participation of species from *Koelerion glaucae* alliance (*Koelerio-Corynephoretea* class) characterized this community. The moss layer was well-developed.

In patches of *Fraxino-Alnetum*, about 40 years old *Alnus glutinosa* tree stands occurred. The understorey layer was fully-stocked and rich in species. It was mainly *Padus avium* and *Euonymus europaea, Sambucus nigra* or *Fraxinus excelsior*. A neophyte, *Acer negundo,* was quite frequent. The abundant herb layer was dominated by species from *Querco-Fagetea* and *Molinio-Arrhenatheretea* classes. *Stellaria nemorum, Galium aparine, Glechoma hederacea* and *Poa trivialis* had the greatest coverage in the ground layer.

To document the variety of plant communities in the nature reserve, JAKUBOWSKA-GABARA (1976) made 12 phytosociological relevés with the standardized phytosociological method (PAWŁOWSKI 1977; DZWONKO 2007). These plots were located in places which were homogeneous and representative for the communities occurring in the nature reserve. Only the phytocenoses of *Tilio-*

Carpinetum were discounted by the authoress because of their excessive fragmentation. The location of the phytosociological relevés was given in the paper of JAKUBOWSKA-GABARA (1976) by putting the numbers of forest compartments.

Field studies in 2008

The studies of Jakubowska-Gabara were repeated in 2008 with the use of the same method. By penetrating the nature reserve, the variety of vegetation was evaluated. 13 phytosociological relevés were made to document the whole variety of vegetation. It was unachievable to situate the plots exactly in the same places as in the past. However, where it was possible, the most probable locations of the relevés from 1970s had been trying to be found. It was made on a basis of an analysis of the historical and actual composition of the forest stands. The locations of the repeated phytosociological relevés were marked on trees during the field work as well as the geographic coordinates of the centre points of the plots were noted. The coordinates (WGS 84) of the relevés for the following syntaxa are: *Querco roboris-Pinetum* dry form – 20˚ 40' E, 51˚ 37' N: 19.03", 24.42"; *Qr-P* typical form - 20˚ 40' E, 51˚ 37'N: 38.50", 35.67"; 53.28", 39.43"; 55.46", 42.06; 20˚ 41' E, 51˚ 37' N: 3.71", 41.34"; 9.30", 41.35"; 18.36", 43.03"; *Qr-P* form with *Fagus sylvatica* - 20˚ 40' E, 51˚ 37'N: 19.88", 30.77"; *Fraxino-Alnetum* - 20˚ 41' E, 51˚ 37' N: 31.26", 40.18"; 20.44", 37.43"; *Tilio-Carpinetum* - 20˚ 40' E, 51˚ 37' N: 38.60", 31.42"; 49.84", 34.55"; 20˚ 41' 21.51" E, 51˚ 37' 40.26" N.

Methods of the data's analysis

The present variety of the forest vegetation in the nature reserve was compared with the historical vegetation from 1970s. The comparison and analysis was made with the Juice 7.0 and R 2.9.0 programme (TICHÝ, HOLT 2006; ZELENÝ, TICHÝ 2006). Phytosociological tables were prepared and plant associations were named. The syntaxonomic affiliation of species is given according to MATUSZKIEWICZ (2001). The Detrended Correspondence Analysis (DCA) of the actual and historical phytosociological relevés was done in order to support the classification of the distinguished plant associations (HILL, GAUCH 1980). The indirect gradient analysis based on the DCA ordination according to the gradients which are responsible for the ecological variability of the flora's composition was adopted, too. This method is based on the analysis of relevés in the ordination diagram according to habitat factors which were estimated with the use of the ecological numbers according to ELLENBERG *et al.* (1992).

The analysis of changes in the species composition was made for the best documented community which is *Querco roboris-Pinetum*. Seven phytosociological relevés of JAKUBOWSKA-GABARA (1976) and seven relevés from the present studies (the form with *Fagus sylvatica* was discounted only) were used. The analysis was based on the average cover of chosen species and syntaxonomic groups in the community. The average species' cover was calculated with the Barkman's formula (1989). The nomenclature of species is given according to MIREK *et al.* (2002) and the nomenclature of plant association according to MATUSZKIEWICZ (2001).

3. RESULTS

3.1. Changes of the syntaxa in time

The historical and present vegetation in the nature reserve is divided into four main syntaxa. These are three associations (*Querco roboris-Pinetum, Tilio-Carpinetum* and *Fraxino-Alnetum*) and one community (*Pinus sylvestris* xerothermic community) of an uncertain phytosociological position (Tab. 1, Fig. 2).

Any phytocenoses which could be classified as the xerothermic community with *Pinus sylvestris* from 70s were found in the Tomczyce nature reserve in 2008. In present studies, three forms of the mixed forest *Querco roboris-Pinetum*: typical, dry and form with *Fagus sylvatica* were found (Tab. 1, Fig. 2). The *Tilio-Carpinetum* oak-hornbeam forest is a community, which undergoes a regeneration. Its fragments with a patchy herb layer were described in 70s but without any phytosociological relevés. After 40 years of protection, due to the regeneration of the oak-hornbeam forests occurring at the flat bottoms and slopes of the accumulation valleys, we were able to collect three phytosociological relevés.

Table 1. Forest vegetation syntaxa in the Tomczyce nature reserve. Numbers of the vegetation units are same as in Figure 2.

1971-1973 (JAKUBOWSKA-GABARA 1976)	**2008**
1 – *Pinus sylvestris* xerothermic community	-
2 - *Querco roboris-Pinetum* (most patches were similar to dry form from 2008)	*Querco roboris-Pinetum* 3 – dry form 4 – typical form 5 – form with *Fagus sylvatica*
6 - *Fraxino-Alnetum*	7 - *Fraxino-Alnetum*
Tilio-Carpinetum – fragmentarily developed (information only from the text, lack of relevés from the Tomczyce nature reserve)	8 - *Tilio-Carpinetum*, regenerative form

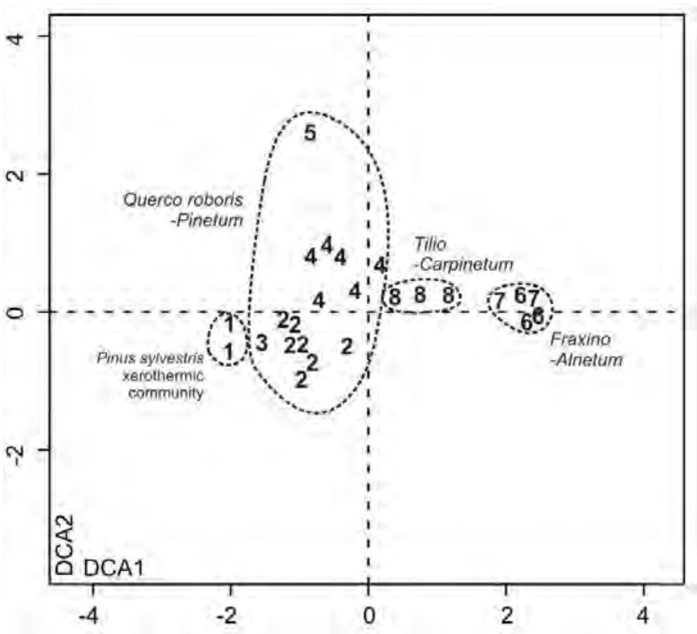

Fig. 2. DCA ordination of phytosociological relevés recorded in the Tomczyce nature reserve in 1970s and 2008. 1- *Pinus sylvestris* xerothermic community (1971-73), 2 - *Querco roboris-Pinetum* (1971-73), 3 – *Qr-P* dry form (2008), 4 – *Qr-P* typical form (2008), 5 – *Qr-P* form with *Fagus sylvatica* (2008), 6 – *Fraxino-Alnetum* (1971-73), 7 – *F-A* (2008), 8 – *Tilio-Carpinetum* (2008).

Generally, the vegetation of the Tomczyce nature reserve in 2008 was represented by patches with a greater share of species with higher trophic and moisture requirements than in the 1970s. The phytocenoses 40. years ago were composed of species which required more light and higher temperature (Fig. 3). The disappearance of *Pinus sylvestris* xerothermic community and emergence of the oak-hornbeam forests in the phytosociological material is an effect of the indicated changes.

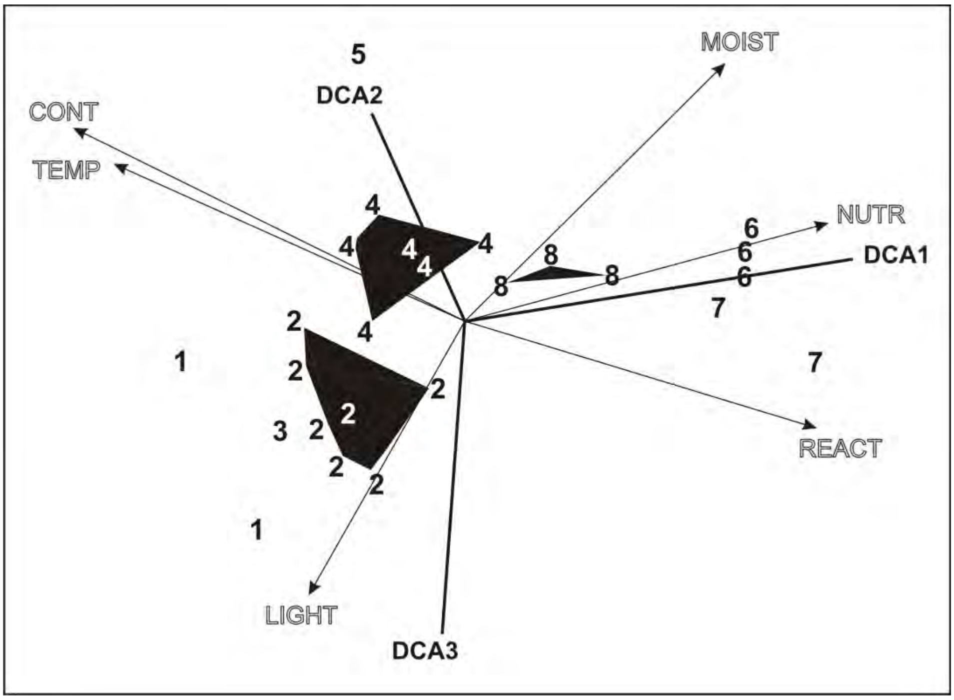

Fig. 3. DCA indirect gradient analysis of the vegetation in the Tomczyce nature reserve - based on Ellenberg indicator values. CONT – continentalism, TEMP – temperature, MOIST – moisture, NUTR – nutrients, REACT – reaction. For numbers of the vegetation units see Figure 2.

3.2. Changes in the floristic composition of the mixed oak-pine forest

The composition of species in the mixed oak-pine forest does not differ much between 1970s and 2008. These two groups of relevés are located closely in the ordination diagram (Fig. 2). Especially, a patch of the "dry form" (3) from 2008 is similar to relevés from 1970s. It is a specific "relict" of the historical vegetation in this nature reserve. The form with *Fagus sylvatica* (5) found in 2008 was considerably different from the historical and present *Querco roboris-Pinetum* phytocoenoses. That was the reason why this single, different patch was not taken for the following analysis.

After 40 years of protection, the phytocenoses of mixed oak-pine forests have a greater participation of species with higher trophic and moisture requirements (Fig. 3). It is visible as an increased participation of species characteristic for *Querco-Fagetea* class (the average cover index changed from 9.0 to 22.1 - Tab. 2). A spontaneous change in domination of main tree species has occurred in the Tomczyce nature reserve. In comparison to 1970s, the expansion of broad-leaved trees and shrubs has taken place. The *Querco roboris-Pinetum* phytocenoses in 2008 had a greater participation of oaks *Quercus robur* and *Q. petraea*, trees and shrubs characteristic for *Querco-Fagetea* class – particularly hazel *Corylus avellana*. The pine tree *Pinus sylvestris* and the juniper *Juniperus communis* are less stocked.

Table 2. Changes of the average cover (Barkman`s index) of phytosociological classes in the *Querco roboris-Pinetum* phytocoenoses in the Tomczyce nature reserve. Phytosociological classes: *V-P – Vaccinio-Piceetea. K-C – Koelerio-Corynephoretea, N-C – Nardo-Callunetea, M-A – Molinio-Arrhenatheretea, Epil. – Epilobietea, T-G – Trifolio-Geranietea, F-B – Festuco-Brometea, Q-F – Querco-Fagetea, Artem. – Artemisietea, Stel. – Stellarietea, Agrop. – Agropyretea*.

Phytosociological classes	1971-73 (n=7) Average cover ±SD	2008 (n=7) Average cover ±SD
V-P	98.8 ±44.2	86.3 ±35.2
K-C	21.0 ±11.0	4.3 ±6.1
N-C	15.0 ±5.8	6.3 ±9.3
M-A	8.4 ±9.3	1.1 ±3.0
Epil.	6.1 ±6.8	2.3 ±2.1
T-G, F-B	3.8 ±4.8	1.0 ±1.9
Q-F	7.2 ±6.5	22.1 ±19.8
Artem., Stel., Agrop.	5.1 ±4.2	8.6 ±16.2
R-P	1.0 ±2.0	1.1 ±2.3

The mixed oak-pine forests in 2008 were characterized by a smaller share of plants which are typical for open communities with more light (Fig. 2). There were a smaller participation of grassland and meadow species characteristic for *Koelerio-Corynephoretea*, *Nardo-Callunetea* and *Molinio-Arrhenatheretea* classes (Tab. 2).

In 2008 mixed oak-pine forests had a greater share of kenophytes (Tab. 3). Trees and shrubs such as: *Padus serotina, Quercus rubra* and *Amelanchiaer* sp., probably planted in the past, are now spontaneously self-seeding and have appeared in higher forest layers (Tab. 3).

Table 3. Changes of the average cover (Barkman`s index) of kenophytes in the *Querco roboris-Pinetum* phytocoenoses in the Tomczyce nature reserve.

Species name	1971-73 (n=7) Average cover ±SD		2008 (n=7) Average cover ±SD
Aesculus hippocastanum [c]	0.3 ±0.8	↓	0.0
Padus serotina [a+b+c]	3.6 ±5.9	↑	20.3 ±15.3
Amelanchier sp. [b+c]	1.4 ±2.4		15.1 ±27.3
Quercus rubra [a+b+c]	1.0 ±1.9		2.4 ±2.4
Impatiens parviflora	0.0		6.4 ±14.0
Prunus cerasifera [c]	0.0		0.6 ±1.0
Conyza canadensis	0.0		0.3 ±0.8
Malus domestica [c]	0.0		0.3 ±0.8
All kenophytes	**6.3** ±6.0		**45.4** ±40.1

4. DISCUSSION

Vegetation changes which have occurred in the Tomczyce nature reserve reveal a general tendency of fertilization which take place in Polish and European forests. In the case presented here, the effect of these changes, indicating the habitat fertilization, is the transformation of communities from coniferous forests to mixed forests and the mixed oak-pine forests to oak-hornbeam forests.

One of the main mechanisms initiating the regeneration or succession processes in forest communities with pine trees plantations is an expansion of broad-leaved trees and shrubs (OLACZEK 1974; CZEREPKO 2001; KUROWSKI 2004 a, KIEDRZYŃSKI 2008). The development of dense tree stands and undergrowth is an effect of a luxuriant growth of oaks, hornbeams, maples, lindens and shrubs of hazel under pine trees. That in turn causes a limitation of light reaching the forest ground and litter enrichment in quickly decomposing biomass. Such changes can be observed in the Tomczyce nature reserve, particularly in the mixed oak-pine forests. This process is the fastest in the flat-bottomed accumulation valleys and on steep and shady slopes, and slower on gentle, dry and sandy slopes as well as in the high plain. Similar changes were observed in the Babsk nature reserve by OLACZEK and KURZAC (1995) after 30 years of protection. The transformation of coniferous forests was also described by KUROWSKI (2004 b) from the Jaksonek nature reserve near the Pilica River where particular dynamics of hazel and oaks was observed. The author described the transformation of mixed oak-pine forests into oak-hornbeam forests and fresh pine forests into mixed oak-pine forests.

Other studies on dynamics of phytocenoses of *Querco roboris-Pinetum* and *Tilio-Carpinetum* in Białowieża National Park indicated great dynamic changes described as a substitution of birches, pine trees, spruces and oaks with lindens and hornbeams (BRZEZIECKI 2008). The habitat fertilization was also observed by KOWALSKI (1994), BERNADZKI *et al.* (1998), BRZEZIECKI (1999) and PALUCH (2001). Changes of microclimatic and habitat conditions following the development of trees and broad-leaved shrubs in the Tomczyce nature reserve – as well as in the quoted research – have led to a greater cover of species characteristic for mesophilous forests with higher trophic and moisture requirements.

The expansion of oaks is significant in natural restructuring of forest stands in the study site. Similar processes are observed in numerous areas in the whole lowland part of Europe (KIENAST 1991). Oaks often build layers under pine stands and this spontaneous process is sometimes used in silviculture as well. Dynamic restocking of oaks occurs in the regeneration process of phytocenoses under the influence of planted pine trees on more fertile habitats (OLACZEK 1972; CZEREPKO 2001; KUROWSKI 2004 a; ŁASKA 2006) or during vegetation succession (inter alia BOMANOWSKA, ADAMOWSKI 2009). Both of these processes may take place in the Tomczyce nature reserve due to the probable partial deforestation of the studied area. A few oaks, which are about 150 years old and have been preserved in the nature reserve, are the sources of diaspores. In most cases, the expansion of oaks takes place with the use of birds (jays) which spread acorns (DANIELEWICZ, PAWLACZYK 2006).

Some authors connect the appearance of species characteristic for more fertile habitats with general changes in environmental conditions leading in turn to habitat fertilization. It is said that the main factors responsible for that are the climate warming and ambient concentration of nitrogen compounds (inter alia BRZEZIECKI 2008; KOWALSKI 1994). We cannot exclude that the processes of vegetation transformation in the Tomczyce nature reserve are also under the influence of general factors and the observed fertilization can be accelerated by them.

Encroachment of broad-leaved tree species and habitat fertilization cause often a decline in thermophilous and heliophilous species which occurrence may be connected with management of forests in the past (MATUSZKIEWICZ 2007) or an early stage of forest succession (DÖLLE *et al.* 2008). The disappearance of *Pinus sylvestris* xerothermic community and retreating of grass, heathland and meadow species from other communities was observed in the studied area. Similar tendencies are the cause of disappearance of some communities from Polish forest landscape, such as thermophilous oak forest *Potentillo albae-Quercetum*, subboreal mixed forest *Serratulo-Pinetum* and pine forests with pasque-flowers *Peucedano-Pinetum pulsatilletosum* (JAKUBOWSKA-GABARA 1993; SOLON 2007; SZCZYGIELSKI 2007). In Polish conditions, retreating of heliophilous species occurs most often in protected areas where forest management was ceased (MATUSZKIEWICZ 2007).

The present studies has revealed a greater participation of anthropophytes than in former studies in the Tomczyce nature reserve. The presence of such tree and shrub species as *Amelanchiaer sp.*, *Padus serotina* and *Quercus rubra* is also in line with the trend of increasing participation of broad-leaved species in the communities. A higher cover and moving to higher layers of forest phytocoenoses confirm that described species have found here favorable habitats. Their participation modifies the regeneration process and their relatively fast growth probably accelerates it. The former management of the studied area, leading to a greater importance of *Pinus sylvestris*, was conducive to neophytization. In the Białowieża Primeval Forest the greatest numbers of alien species with the largest populations were found in oak-hornbeam forest habitats under pine plantations (ADAMOWSKI *et al.* 1998). Many authors have indicated that *Padus serotina* and *Quercus rubra* are the cause of communities' degeneration and reduction of species richness (HEREŹNIAK 1992; TOBISCH *et al.* 2003; GODEFROID *et al.* 2005; OTRĘBA, FERCHMIN 2007; JAKUBOWSKA-GABARA, WOZIWODA 2009). *Impatiens parviflora* is also a threat because its range in the nature reserve has increased significantly. It has been proved that *Impatiens parviflora* after entering a community initially enriches the species composition but subsequently it exerts a reductive influence on other elements of the herb layer (KUJAWA-PAWLACZYK 1991; ORCZEWSKA 2000). A large number of alien species is associated with habitat transformation and community degeneration (ADAMOWSKI *et al.* 1998; WOZIWODA 2007), therefore, we can forecast that the presence of alien species in the Tomczyce nature reserve may be a factor which finally will inhibit the regeneration of forest phytocoenoses. The occurrence of the planted *Fagus silvatica* in a higher located part of the nature reserve can have a significant role for the vegetation that will form here in the future. Many authors observed a reduction in flora's diversity in the phytocenoses of mixed oak-pine forests and thermophilous oak forests with planted *Fagus sylvatica* (OLACZEK, KURZAC 1995; DANIELEWICZ, PAWLACZYK 2006; KIEDRZYŃSKI 2008).

Vegetation changes had undoubtedly an influence on the impoverishment of flora in the Tomczyce nature reserve. Some valuable heliophilous species have decreased their abundance. On the other hand, species of oak-hornbeam forests are in expansion. Planning of protection activities needs to include dynamic tendencies of vegetation. These tendencies can be used in the pursuit and revision of the chosen targets or we can try to stop them, however, we have to take them into consideration (PAWLACZYK 1999). The present state of vegetation cover in the Tomczyce nature reserve and the necessity of preserving the forest vegetation on steep slopes of flat-bottomed accumulation valleys and in the river valley should be of key importance while undertaking protection activities in the nature reserve. We may consider removing of *Fagus sylvatica* which is planted here outside its natural range and alien species from such places which would not endanger the stability of the slopes in the flat-bottomed accumulation valleys. A decision is to be made whether a passive observation of the regeneration changes may be of greater value in this case, taking into consideration the fact that in the meantime this may lead to an increased importance of neophytes in the nature reserve.

5. CONCLUSIONS

- The expansion of broad-leaved trees and shrubs, particularly oaks, is the main mechanism initiating transformation of the vegetation and caused disappearing the pine-xerotermic community from Tomczyce nature reserve.
- The encroachment of mesophilous forest species and the declining of thermophilous and heliophilous species is a symptom of mixed oak-pine and oak-hornbeam forests regeneration.
- Despite the probability of increasing participation of alien species in the nature reserve in the future, the passive protection and an observation of processes without interfering in the structure of forest stands needs to be taken into consideration.

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REACTION OF CONIFEROUS FOREST VEGETATION TO PARTICULATE DEPOSITION UNDER ALKALINE PRESSURE

Abstract: The aim of this study was to determine direction, rate and character of the changes in coniferous forest communities caused by anthropogenic stress factors (alkaline emission and imission) changing with time. To fulfil this goal, we have performed comprehensive studies of soils and plants at the study sites located in coniferous forest communities remaining under direct influence of cement and lime industry in the Świętokrzyskie Voivodeship. There were differences in the accumulation of elements in pine needles collected at alkalized sites in comparison with needles from the control site: Ca content was 2.5 times higher and Cu, Pb and Sr contents were 2-3 times higher, while Al and Fe, and Mn contents were twice and 10 times lower respectively. SEM analysis of morphological features of pine needle surface, in particular degree of preservation of epicuticular waxes can be as an indicator of assimilatory organ degeneration caused by dust deposition which induces wax layer erosion. Declining species number and biodiversity, particularly conspicuous at the Sitkówka site, was a general tendency observed over the study period (from 18 to 10 years). Other noticeable processes include slow regenerative changes of the community with a tendency towards higher contribution of acidophilic coniferous forest species with lower light and temperature requirements and suppression of meadow, ruderal and associated taxa. Further studies are required in order to define succession rate and direction of changes in species composition of these communities.

Key words: Scotch pine forests, cement dust emission, needles, reaction

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1. INTRODUCTION

Air pollution caused by acid deposition and photochemical oxidizer poses a serious threat to many ecosystems. In recent years, their effect has been studied in different aspects (e.g. EAGER, ADAMS 1992; GRESZTA *et al*. 2002; STASZEWSKI 2004). In contrast, an impact of alkaline deposition on plant communities rarer was the focus of research. The reaction of coniferous forest stands and soils to the pollution of this type was the subject of many-year monitoring studies conducted in the Świętokrzyskie Voivodeship (ŚWIERCZ 2005a).

The aim of this study was to determine direction, rate and character of the changes in coniferous forest communities caused by anthropogenic stress factors (alkaline particulate emission and imission) changing with time. To fulfill this goal, we have performed comprehensive studies of plants at the study sites: Sitkówka (since 1989), Małogoszcz (since 1997), Ożarów (since 1998), located in coniferous forest communities remaining under direct influence of cement and lime industry in the Świętokrzyskie Voivodeship. The aim of this study was examining of the reaction of vegetation after considerable lowering the alkaline emission and the possibility of return to the composition of typical pine forest communities.

2. MATERIAL AND METHODS

The studies were conducted at three forest sites located in the vicinity of cement plants in Sitkówka (currently Dyckerhoff Polska Ltd.) Małogoszcz (Lafarge Cement S.A.) and Ożarów (Ożarów Group S.A.; Fig. 1). All sites were located at similar distance away from particle emission source, in pine forests of *Dicrano-Pinion* alliance (degenerative forms), in fresh coniferous forest habitats. The distance of study sites from the Cement Factory (Sitkówka, Małogoszcz, Ożarów) carried out ~ 0,5 km (in the direction on the wind NW-SE).

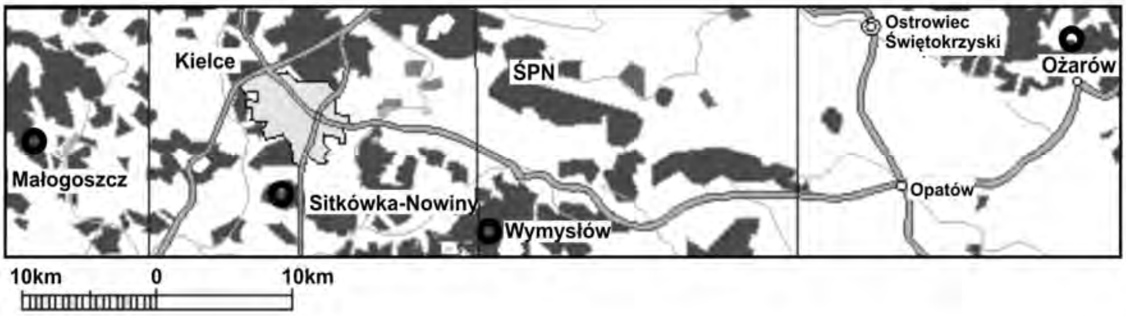

Fig.1. Location of the study sites (empty circles).

For comparison, we a site overgrown by forest of *Leucobryo-Pinetum* association located near the village of Wymysłów in the Cisowsko-Orłowiński Landscape Park, beyond industrial emission range (20 km from the nearest Ożarów Cement Factory). The age of trees on all investigated areas was comparable about 60 years).

At all study sites, was analysed *Haplic Podzol* and *Albic Arenosol* developed from loose to weakly clayey Pleistocene sands were identified. Phytosociological relevés were recorded and one- and two-year-old needle samples were collected. Needle samples collected from four *Pinus sylvestris* trees 40-70 years old were mixed for each site. The samples were dried in a dryer at 40^0 C for 24h, then ground in a Fritsch mill and ashed in an electrical furnace at 450^0C. Then, the samples were suspended in HCl-HNO_3, and total contents of selected elements were determined with ICP-AES. The state of needle surface structure was also investigated. Middle parts needles were coated in gold and photographs were taken with a JSM-5400 scanning electron microscope at magnification 2000, 1000, 500 x.

Form each of 4 surfaces 3 one-year and 3 two-year-old needles was taken for SEM examination only selected photographs of needles surfaces was presented in the paper.

Phytosociological relevés were recorded at study sites in: 1990, 2003, 2008 (Sitkówka); 1997, 2003, 2008 (Małogoszcz); 1998, 2003, 2008 (Ożarów); 1992, 2003, 2008 (Wymysłów). Quantitative changes in phytocenoses were represented by mean cover-abundance index for a species according to the formula: Iśr = $\Sigma p/n$, where p is coverage value for a given species according to a 6 point scale (from 5 to

+), while n is the total number of releves in the table. It was decided that coverage designated by + was 0.5 in order to increase significance of sporadic species which frequently play an important role in succession. Systematic constancy of groups D (PAWŁOWSKI 1977) was calculated for the distinguished groups of syngenetic species, and mean indicator values: light (L), temperature (T), humidity (W), pH (R) and fertility – organic matter content (H) were calculated for every community at each study site (ZARZYCKI *at al*. 2002). Phytosociological relevés covering about 400 m^2 was performed on each of surfaces. It was redeated in the next years of investigation in the same sites.

3. RESULTS AND DISCUSSION

3.1. Pine tree: wax surface structure of needles

SEM images of pine needles collected during this study in alkalized areas and examined under 500x and 1000x magnification (Photo 1 and 2) showed a significant loss of the crystalline epicuticular wax network in comparison with needles collected in the control area (Photo 3 and 4). The surface of needles from alkalized area was classified into class III which suggests almost complete decay of wax structure in interstomatal space (according to the classification of TURUNEN *et al*. 1992). Deposition of dust aerosols weakened needle health status. The wax layer was discontinued, strongly eroded, locally collapsed while originally crystalline epicuticular wax became amorphic (BAČIĆ et al. 1998; STASZEWSKI 2004; ŚWIERCZ 2005a). Needles devoid of natural protection were easily attacked by filamentous fungi (Fig. 3 and 4). The degradation of needle surface wax structure influenced also their mean lifespan. It was observed that pines growing in alkalized areas shed older needles. According to the studies of MÄKELÄ and HUTTUNENA (1987), this is a necessity allowing the trees to maintain water balance since older needles show greater cuticular and stomatal transpiration. Due to defoliation, crowns of some pine trees growing in the vicinity of the cement plant are markedly opened. Openness

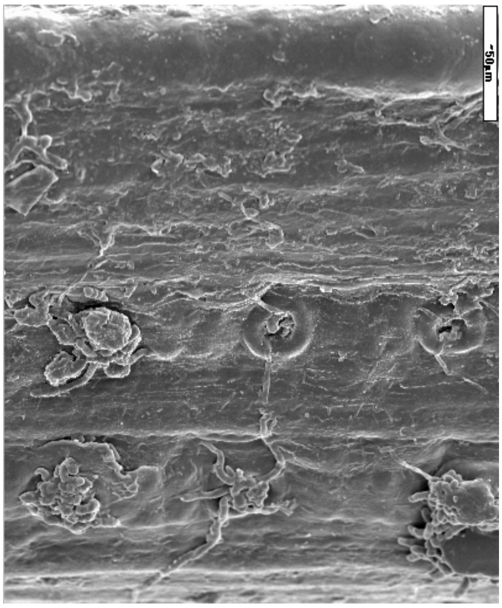

Photo 1. Wax layer of 2-year-old pine needle, Ożarów area (500x).

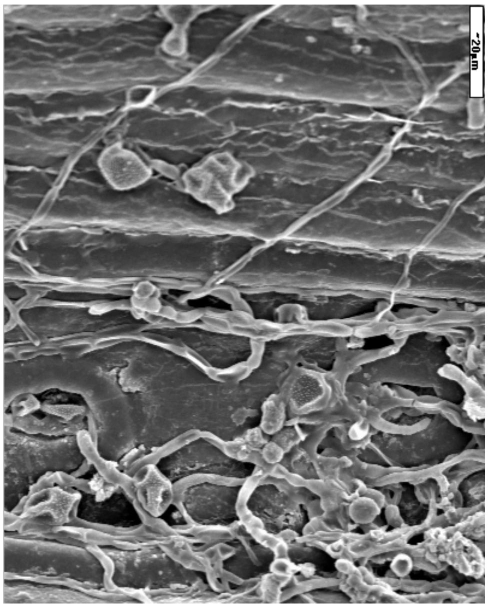

Photo 2. Wax layer of 2-year-old pine needle, Ożarów area (1000x).

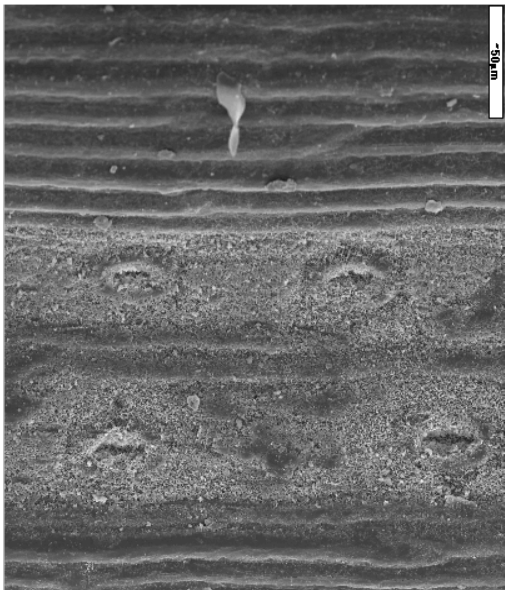

Photo 3. Wax layer of 2-year-old pine needle, Wymysłów area (500x).

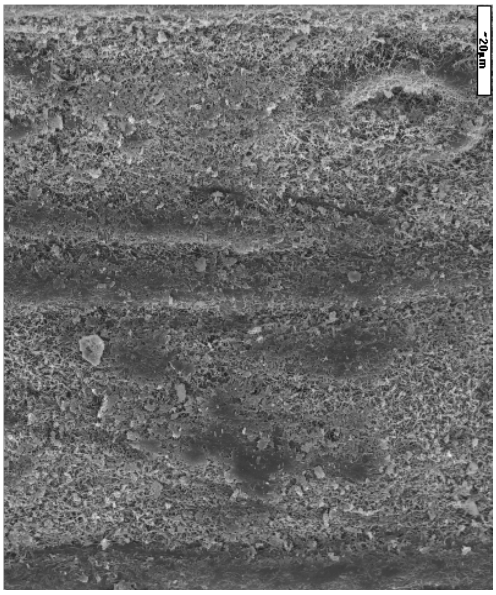

Photo 4. Wax layer of 2-year-old pine needle, Wymysłów area (1000x).

type can be classified as arch-shaped or bottom-up type (LESIŃSKI *et al*. 1992). SEM image analysis confirmed that wax network structure of pine needles collected from Wymysłów (control area) was well-preserved (Photo 3 and 4). Their crowns were dense with complete needle foliage retained.

The study presented particulate pollutants deposited on needle surface can cause erosion of the wax structure (GRILL, GOLOB 1983) and clog the surface structures, impairs intensity of gas absorption, decreases intensity of light reaching the surface, thereby limiting intensity of photosynthesis even by up to 30 % (AUCLAIR 1977; LARILAND *et al*. 1978; GRESZTA *et al*. 2002). The natural process of stomata filling with a network of wax fibers begins in the second year of needle life, then it gradually undergoes erosion that lasts up to 4-6 years (TURUNEN, HUTTUNEN 1990). Anthropogenic factors including particulate air pollution greatly accelerate wax structure degradation leading to complete decay of stomata filling with crystalline wax network. This process was used by TURUNENA *et al*. (1992) to develop the method of epicuticular wax assessment. Wax structure was scored according to the 6-point scale: class 0 (undeveloped wax structure), class I (100 % stomatal wax cover) class II (71-100% stomatal wax cover), class III (31-70% stomatal wax cover), class IV (0-30% stomatal wax cover) and class V (0% stomatal wax cover).

3.2 Pine tree: total contents of selected elements in needles

Chemical analysis of needles aimed to evaluate nutritional status of trees. Heavy metal contents were determined to assess degree and range of environmental load with industrial emissions. Mean contents of the elements under study in needles collected at study sites varied in a wide range, depending on sampling site and needle age (Tab. 1). Mean calcium contents showed the greatest variability. Calcium ions are stored in older organs and their contents strongly depend on the concentration in soil. The highest Ca contents in two-year-old pine needles were observed at the Sitkówka study site (mean 10 350 mg/kg d.w.) which has been the longest and the strongest exposed to alkalization. The Ca contents there were 2.5 times higher in comparison with the control site (Wymysłów). Pine needles from alkalized habitats contained also elevated potassium contents and increased concentrations of some heavy metals: copper, lead (3-fold) and strontium. In contrast, contents of several elements: were markedly decreased in needles from habitats remaining under pressure of cement and lime industry: Al, Fe (2-fold on average) and Mn (even 10-fold in two-year-old needles; Tab.1).

Lead content in one-year-old needles from the Sitkówka site fluctuating between 21 do 42.5 mg/kg (mean: 29.5 mg/kg) were particularly alarming. Although lead does not play any physiological role in plants, it can slow down metabolic processes, especially when its content oscillates within toxic range for plants, i.e. 30 mg/kg (KABATA-PENDIAS, PENDIAS 1999).

Values of pH in pine needles measured in H2O and KCl (median, Tab.1) were elevated at alkalized sites in comparison with the control site. It can be assumed that pH of the needles, like bark, is a good indicator of habitat alkalization (SPOREK 1995; KUPČINSKIENE 2001; ŚWIERCZ 2005b).

3.3 Transformation of forest community – species dynamics

Transformations of species composition of studied forest communities induced by alkalization were investigated in three periods. All studied communities belonged to *Dicrano-Pinion* alliance, represented fresh coniferous forests growing on podsolic soils and rusty podsolic soils formed on loose to weakly clayey Pleistocene sands. Forty to seventy years old pine trees were the main component of these communities (mean 60 years old). Cover of tree layer did not significantly change throughout the study period 1990 – 2008 and amounted to 60 %. Cover of the understory showed greater fluctuations and was slightly lower at alkalized sites (from 36 % at the Ożarów site to 28 % at the Małogoszcz site), while for the control site in Wymysłów it stabilized at 20 % (Fig. 2). Shrub layer at the transformed sites was composed of pine saplings, *Juniperus communis*, *Rhamnus catharticus*, *Frangula alnus*. In the study period, the contribution of the taxa *Sorbus aucuparia*, *Quercus robur*, *Frangula alnus* increased slightly while that of *Quercus petraea*, *Juniperus communis*, *Rhamnus catharticus* decreased. No significant changes in the layer B have been identified on the comparative surface.

Table 1. Median pH values and mean content of selected elements in pine needles.

Study area	Needles	pH_{H2O} median	Al	Ca	Fe	K	Mg	Na	Ba	Cu	Mn	Pb	Sr	Ti	Zn
			mg/kg s.m												
Sitkówka	One-year-old	6.45	67.5	7475.0	72.5	7925.0	805.0	30.0	3.3	13.0	88.8	18.0	6.3	3.0	35.8
	Two-year-old	6.20	70.0	10350.0	112.5	6475.0	690.0	45.0	6.3	8.8	71.5	29.5	18.3	6.3	61.5
Mało-goszcz	One-year-old	5.00	76.8	2538.0	51.0	6243.0	877.0	9.8	5.0	6.5	87.0	2.4	1.8	2.5	37.5
	Two-year-old	4.83	137.0	6817.5	96.5	4600.0	811.6	10.5	3.5	4.5	141.8	3.8	5.3	4.3	35.5
Ożarów	One-year-old	5.90	53.0	7412.5	33.8	6675.0	767.5	19.8	1.5	7.3	78.8	8.5	4.3	2.5	29.5
	Two-year-old	5.65	155.5	9025.0	85.3	5575.0	657.5	28.5	2.8	8.0	125.8	17.8	6.8	8.0	46.3
Wymysłów	One-year-old	3.72	200.3	2122.5	114.5	5757.5	956.8	98.8	8.0	4.5	447.8	3.8	1.3	1.3	49.5
	Two-year-old	4.05	301.3	4127.5	225.0	4445.0	625.3	121.3	10.0	5.8	890.8	8.0	3.5	3.5	63.5

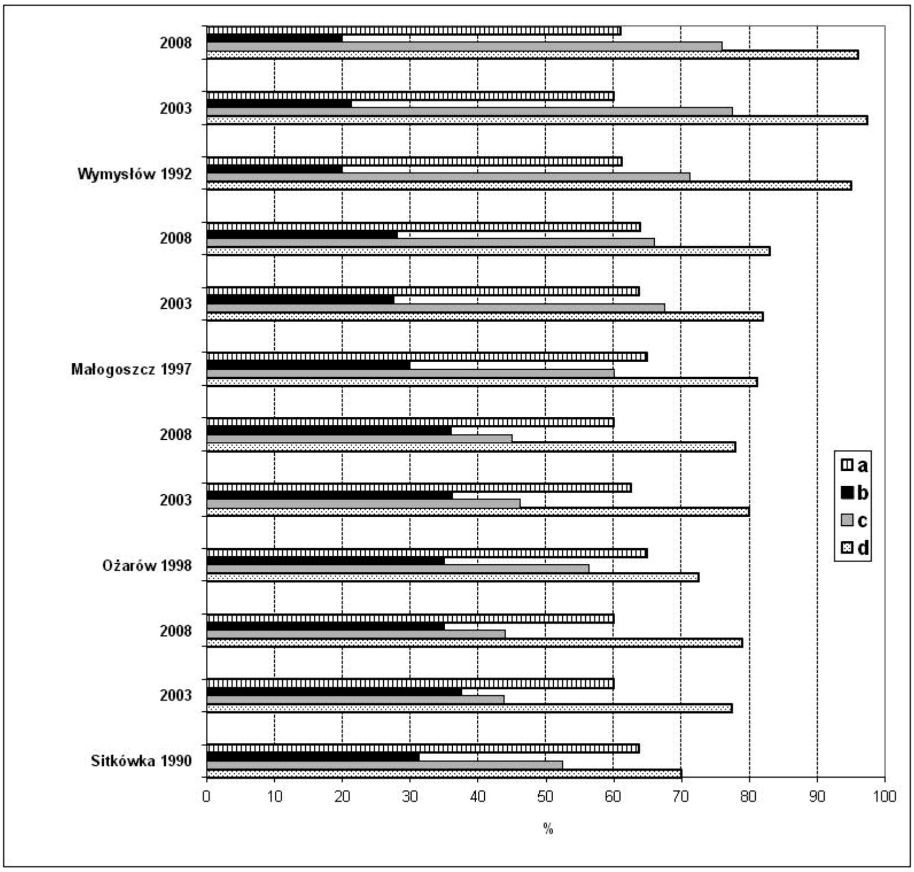

Fig. 2. Layer structure of forest communities in the study area. a – trees, b – shrubs, c – herbaceous plants, d – mosses.

The number of species and species diversity were the highest at the Sitkówka site where in total 150 species were identified (58 per relevé on average) in 1990. The number of species showed a regressive tendency when alkaline dust emission to soil decreased. In 2008, the total number of species was 122 (52 species per relevé on average). Similar tendency was observed at the Ożarów and Małogoszcz sites (Fig. 3). The number of species at control site totaled 40, and the mean ranged from 17 to 29 species per relevé (what is the typical phenomenon for pine forest MATUSZKIEWICZ and MATUSZKIEWICZ 1973) This value did not significantly change within study period from 1993 to 2008 (± 2 species).

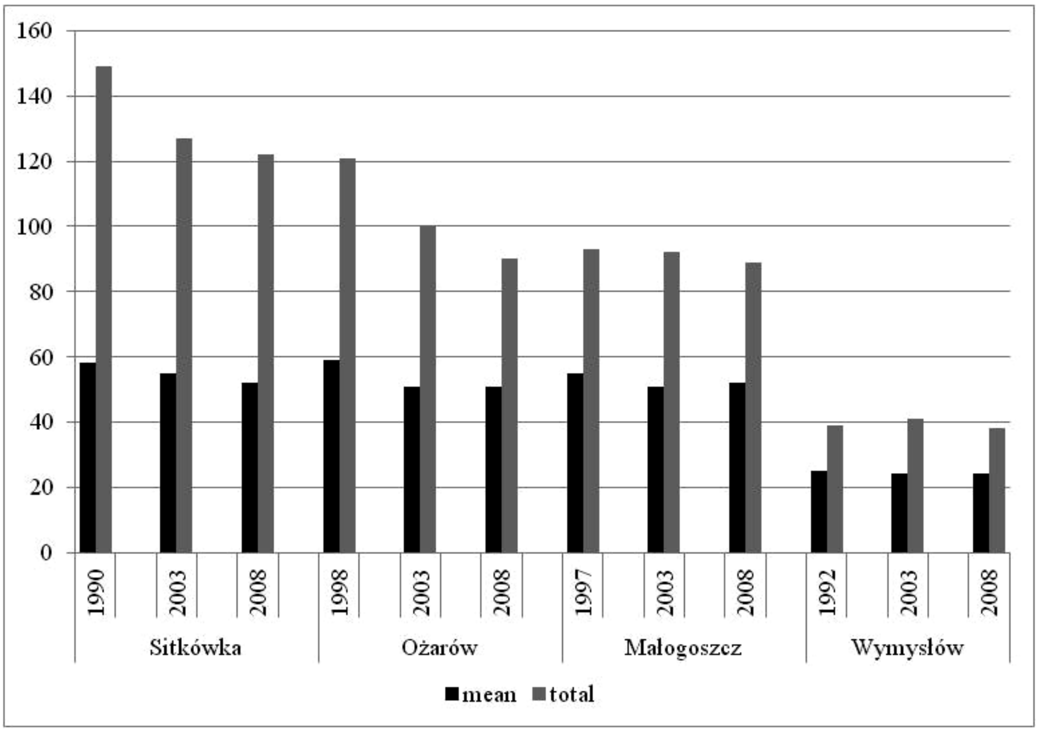

Fig. 3. Changess in the number of species in the studied sites.

A majority of species (from 40% to 62 %) occurring at sites under alkaline pressure were characterized by low constancy values. A small number of species (from 7 % to 9 %) with the highest constancy (group V) indicates labile structure of the community. The contribution of species belonging to the highest constancy groups increased slightly in the period 1990-2008 (Fig. 4). Out of high-constancy species, *Vaccinio-Piceetea* class was represented only by *Orthilia secunda*, besides pine tree, *Querco-Fagetea* – *Epipactis helleborine*, *Sedo-Scleranthetea* – *Festuca ovina* and *Hieracium pilosella*, *Epilobietea angustifolii* association – *Fragaria vesca*, while a very abundant group of accompanying species contained *Solidago virgaurea* and *Epipactis atrorubens*.

Species composition of the communities under analysis did not allow for their precise syntaxonomic classification. The communities were exceptionally rich. Anthropogenic communities having developed in fresh coniferous forest habitats, producing degenerative forms of pine forests of *Dicrano-Pinion* alliance.

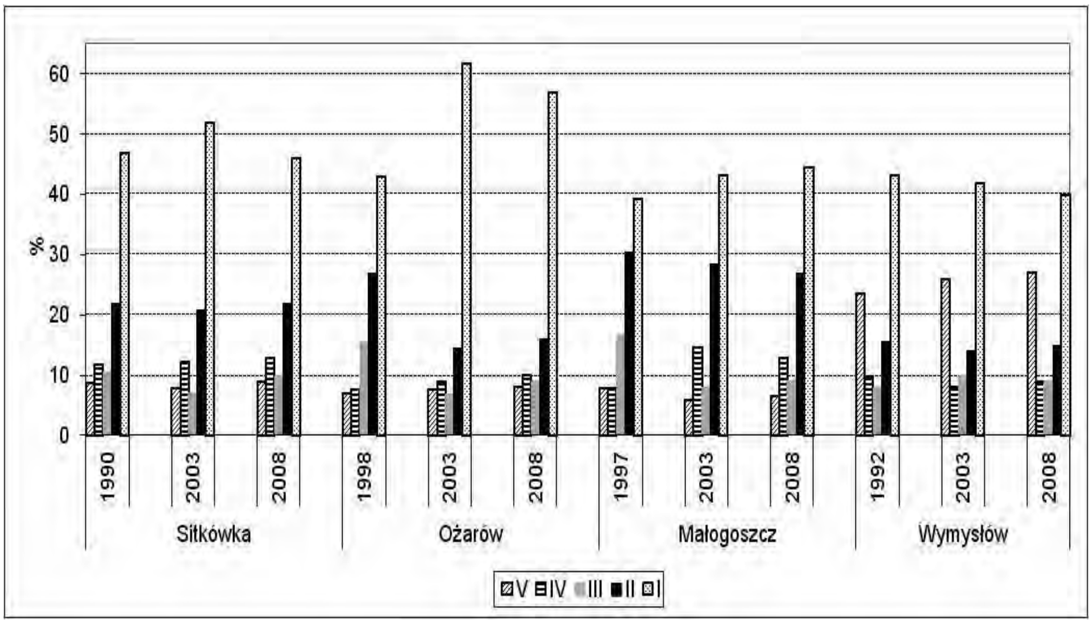

Fig. 4. Share of constancy clasess in forest communities in studies sites.

At the beginning of studies, the species number and diversity of the communities showed a relationship with increasing deposition of alkalizing compounds. It was associated with the apparent richness of habitat. Since 1990s, the number of taxa has declined with progressing habitat regeneration. Systematic values and mean constancy of the distinguished species groups indicated that none of these groups dominated in the structure of communities exposed to alkaline deposition (Tab. 2).

Systematic value of the species group characteristic of *Vaccinio-Piceetea* class growing at alkalized sites was low. It amounted to from 4.0 (Ożarów site) to 4.4 (Sitkówka site) in the period 1989 – 1990. In 2008, the systematic value for this species group was higher and ranged from 6.4 to 8.4. This is the result of a considerable lower imission of cement and lime dust to soil and opportunity for coniferous forest species to slowly return to presently more acidic habitats. Over the period 1992 – 2008, systematic value for species characteristic of *Vaccinio-Piceetea* classat the control site in Wymysłów changed negligibly from 33.2 to 31.4.

Table 2. Synthetic values for phytosociological groups in the study area. Explanations: z – number of species, D (%) – systematic values, G (%) – total percentage of group of species, S (%) – mean of group of species.

Studies sites	Index (%)	Group of species (Ch. Cl.)										
		Vaccinio-Piceetea	*Nardo-Callunetea*	*Sedo-Scleranthetea*	*Molinio-Arrhenatheretea*	*Querco-Fagetea*	*Trifolio-Geranietea sanguinei*	*Rhamno-Prunetea*	*Festuco-Brometea*	*Epilobietea*	*Rudero-Secalietea*	Towarzyszące
Sitkówka	z	12	6	7	23	15	8	10	18	4	7	40
1989	D	4.4	0.5	2.5	3.6	1.6	1.2	3.3	3.6	1.8	0.6	8.0
	S	44.8	20.8	44.6	29.3	24.2	28.1	42.5	33.3	50.0	21.4	33.7
	G	9.8	2.3	5.7	12.3	6.6	4.1	7.7	10.9	3.6	2.7	23.9
Sitkówka	z	10	3	7	24	15	11	9	14	4	3	27
2003	D	5.6	0.2	2.9	4.2	2.2	1.0	5.1	3.6	2.2	0.4	8.0
	S	53.8	16.7	46.4	30.2	27.5	21.6	54.2	36.6	53.1	25.0	39.4
	G	10.3	1.0	6.3	13.9	7.9	4.6	9.4	9.9	4.1	1.4	20.4
Sitkówka	z	11	3	6	23	14	10	8	15	4	3	25
2008	D	6.4	0.3	2.9	4.2	2.1	0.8	4.7	3.1	1.7	0.4	9.3
	S	54.6	20.8	50.0	30.4	32.7	20.0	54.7	32.5	46.9	25.0	43.5
	G	11.7	1.2	5.9	13.7	7.6	3.9	8.6	9.5	3.7	1.5	21.3
Ożarów	z	11	4	8	22	12	8	9	10	4	8	25
1998	D	4.0	0.3	4.3	4.1	1.6	0.5	1.9	1.3	2.6	2.0	8.6
	S	39.8	18.8	48.4	28.4	24.0	15.6	30.6	23.8	53.1	32.8	38.5
	G	10.1	1.7	9.0	14.5	6.6	2.9	6.4	5.5	4.9	6.1	22.3
Ożarów	z	12	1	5	18	10	3	8	6	4	7	26
2003	D	5.9	0.1	3.7	3.3	2.0	0.3	2.3	0.6	4.7	3.4	8.3
	S	44.8	12.5	55.0	27.1	28.8	20.8	34.4	20.8	68.8	44.6	36.1
	G	13.2	0.3	6.8	12.0	7.1	1.5	6.8	3.1	6.8	7.7	23.1
Ożarów	z	13	2	5	16	8	3	7	5	3	5	22
2008	D	8.4	0.1	4.6	3.1	2.9	0.2	2.3	0.7	5.9	3.9	8.9
	S	50.0	12.5	60.0	27.3	37.5	16.7	35.7	22.5	87.5	55.0	39.8
	G	16.7	0.6	7.7	11.3	7.7	1.3	6.4	2.9	6.8	7.1	22.5
Małogoszcz	z	12	4	5	15	15	5	6	5	3	6	17
1997	D	4.2	0.9	3.8	4.1	2.9	0.4	0.9	0.9	3.2	2.3	8.5
	S	35.4	28.1	52.5	31.7	26.7	17.5	22.9	25.0	62.5	37.5	42.6
	G	11.7	3.1	7.2	13.1	11.0	2.4	3.8	3.4	5.2	6.2	20.0
Małogoszcz	z	13	4	4	19	10	3	6	4	3	8	18
2003	D	8.4	1.3	3.6	2.2	3.4	0.2	0.7	0.7	2.9	2.0	6.8

Table 2. *(Continued)*

	S	48.1	34.4	56.3	20.4	35.0	16.7	20.8	25.0	58.3	29.7	36.8
	G	17.5	3.9	6.3	10.9	9.8	1.4	3.5	2.8	4.9	6.7	18.6
Małogoszcz	z	15	4	4	17	11	3	5	4	3	7	16
2008	D	8.4	1.9	3.9	2.0	2.3	0.3	0.7	0.9	1.7	1.6	6.5
	S	45.0	40.7	59.4	20.6	27.3	16.7	22.5	28.1	45.8	28.6	38.3
	G	18.6	4.5	6.5	9.6	8.3	1.4	3.1	3.1	3.8	5.5	16.9
Wymysłów	z	18	4	6	6							8
1992	D	33.2	5.5	2.3	1.9	_	_	_	_	_	_	2.7
	S	65.3	56.3	41.7	27.1							28.1
	G	50.8	9.7	5.4	7.0							9.7
Wymysłów	z	21	3	3	5							5
2003	D	32.5	7.3	2.2	1.6	_	_	_	_	_	_	3.4
	S	59.5	75.0	41.7	27.5							40.0
	G	53.8	9.7	5.4	5.9							8.6
Wymysłów	z	22	4	3	5							5
2008	D	31.4	8.0	1.8	1.6	_	_	_	_	_	_	3.8
	S	58.0	79.1	37.5	27.5							42.5
	G	54.3	10.1	4.8	5.9							9.0

Species characteristic of *Nardo-Callunetea* class almost completely vanished (D value ranged from 0.1 to 1.3). Only species like *Carex pilulifera*, *Luzula multiflora*, *Viola canina* having low constancy values were able to exist in extremely disadvantageous conditions for this group. A slight increase in species belonging to this class (expressed by the sum of coverage) was noted in the study period only at the Małogoszcz site. Among species distinguishing of *Querco-Fagetea* class, *Epipactis helleborine*, *Viola reichenbachiana*, *Geum urbanum* dominated. A slight progression of *Querco-Fagetea* classes, and a decreased number of species of *Trifolio-Geranietea sanguinei* and *Festuco-Brometea* classes was observed at the Sitkówka site over 18-year observation period and at the Ożarów site over 10 years. The contribution of the species *Epipactis helleborine*, *Orthilia secunda*, *Fragaria vesca*, *Torilis japonica* and a bryophyte *Hylocomnium splendens* slightly increased in the phytocenoses under analysis in alkalized habitats. In spite of more favourable habitat conditions at the Sitkówka site, *Vaccinum myrlillus* and *V. vitis-idaea* were not found. Bilberries occurred only at the Małogoszcz site, the least transformed by alkaline deposition (lingonberries were encountered only sporadically). The physicochemical proprieties of soils changed radically. Arose new conditions not favourable for acidophilic pine forest vegetation.

Analysis of mean indicator values for full species composition of the communities under study occurring at alkalized sites confirmed elevated significance of species characterized by greater environmental requirements for light, acidity and temperature and lower requirements for humidity and organic matter content in soil (Fig. 5). Along with the decrease of alkaline deposition to soil, the contribution of thermophilous species preferring full light and higher soil pH values.

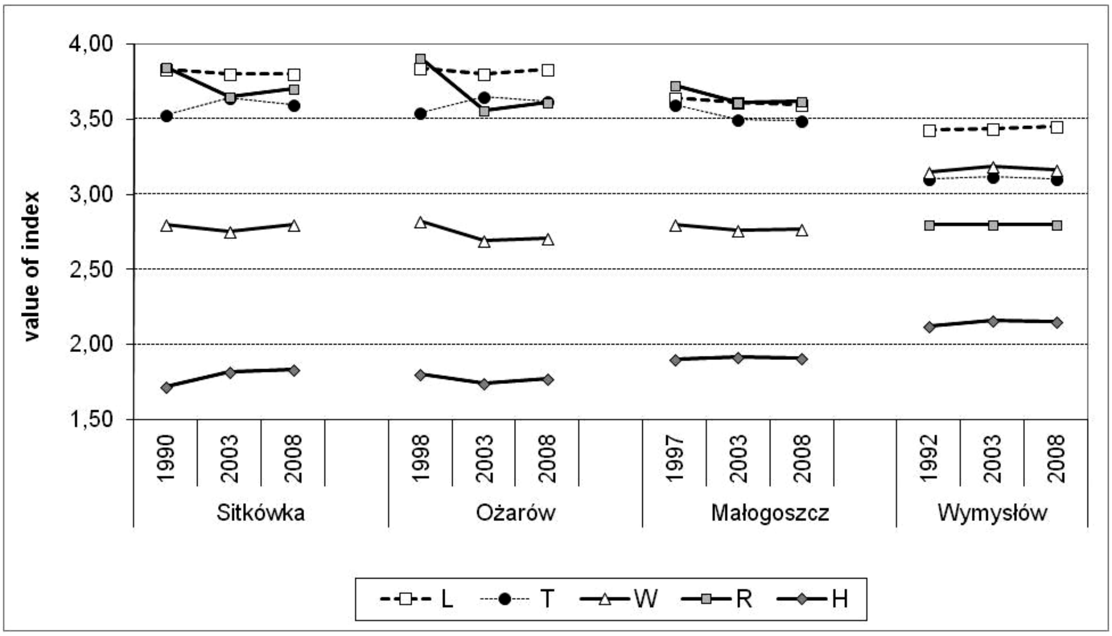

Fig. 5. Changes in mean values of ecological indices in 1989-2008 in studies forests. L – light, T – temperature, R – reaction, H – humus, W – moisture.

Anthropogenically transformed habitats can be a dwelling place for many rare and endangered taxa (BOX 1999). Study sites modified by imission of cement and lime dust were found to be the habitat of 8 herbaceous species under strict protection: *Chimaphilla umbellata, Epipactis helleborine, Epipactis atrorubens, Goodyera repens, Cephalanthera longifolia, Platanthera bifolia, Anemone sylvestris, Campanula sibirica* and 3 species under partial protection: *Frangula* *alnus, Viburnum opulus, Primula veris*. Coniferous forest vegetation developing in alkalized habitats over the last 18 years at the Sitkówka site and 10 years at the Małogoszcz and Ożarów sites have undergone significant transformations.

The present communities state is the effect of "an unintended experiment" (FALIŃSKI 2001) provoked by human activity. The first period of exposure of the forest communities under study to cement and lime industry emission was distinguished by conspicuous explosion of biodiversity caused by intromission of marginal and meadow species ecologically alien not only to coniferous forests but also to forests in general (ŚWIERCZ 2005a) and by regression of species preferring acidic, shady, humid habitats rich in organic matter. Species diversity and specific species composition of phytocenoses under study developed under strong anthropopressure and exploitation of coniferous forests in the past. Thus, human activity overlain on natural diversity of communities can contribute either to greater heterogeneity of forest communities (ŁASKA 1996) or reduced biodiversity (CHRISTIANSEN, EMBORG 1996; NIENARTOWICZ *et al*. 2001). Set out results show that the biological variety grew up markedly under the influence of alkalization on studies areas.

In parallel with the declining alkaline deposition, species composition slowly stabilizes and still barely noticeable regenerative tendency appears which consists in progression of some acidophilic species (*Trientalis europaea*, *Calluna vulgaris*) and regression of some calciphilous species, like *Trifolium alpestre, Agrimonia eupatoria, Coronilla varia.* No new species were identified in the communities under study in 2008.

Long-term and directed vegetation transformations are superimposed on fluctuations induced by variable often difficult to define causes. They may be provoked by weather conditions, particularly water availability, fluctuations in species biology and habitat conditions (BAKER 1990; SOLON, ROO-ZIELIŃSKA 2001; FALIŃSKI 2001). Species diversity in forest communities is also increased by general environmental factors, like the presence of diaspore sources (DZWONKO, GAWROŃSKI 1994; NIENARTOWICZ *et al*. 2001). All studied phytocenoses (except Wymysłów site) are located in the vicinity of human residential quarters and farms which also facilitates penetration of alien species, e.g. from fields, and trampling or bringing new species.

4. CONCLUSIONS

- Reduced cement and lime deposition in soil has the strongest effect on the state of pine assimilatory organs and species composition of forest communities developing under alkaline pressure.
- Older pine needles having accumulated higher heavy metal contents are more useful as indicators for environmental studies.
- There were essential differences in the accumulation of elements in pine needles collected at alkalized sites in comparison with needles from the control site.
- SEM analysis of morphological features of pine needle surface, in particular degree of preservation of epicuticular waxes can be helpful as an indicator of assimilatory organ degeneration caused by dust deposition which induces wax layer erosion.
- Other noticeable processes include slow regenerative changes of the community with a tendency towards an increase in the contribution of acidophilic coniferous forest species with lower light and temperature requirements and suppression of penetration of meadow, ruderal and associated taxa. Further studies are required in order to define succession rate and direction and tendency of changes in species composition of these communities.

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ESTIMATION OF POPULATION SIZE OF *DENTARIA ENNEAPHYLLOS* IN THE VICINITY OF THE BEŁCHATÓW BROWN COAL MINE AND THE ATTEMPT OF ITS METAPLANTATION

Abstract: The impact of anthropopressure on the flora in the vicinity of the Bełchatów Brown Coal Mine in Central Poland has been substantially strong. Consequently, certain changes in habitat conditions have been observed, leading to a decline in particular species stands. Mechanical damage, as well as the mine and power plant expansion have contributed to further species decline in the area. *Ex situ* conservation, e.g. metaplantation from native to secondary localities seems an efficient method of ensuring the species survival in the local flora. One of the species is to be found in Wola Wydrzyna (under the Forest District Administration of Bełchatów) is Drooping Bittercress *Dentaria enneaphyllos*. Its population was first recorded in the area in 1979. However, since 2009 the forest complex has undergone a regular expansion of the Bełchatów Brown Coal Mine. The forest area is to be utilised for the future Szczerców coal deposit. Therefore, in 2000 the method of *Dentaria enneaphyllos* metaplantation was applied.

Key words: metaplantation, *Dentaria enneaphyllos*, Central Poland, the Bełchatów Brown Coal Mine

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1. INTRODUCTION

Rising of widespread industrial areas is often related to destruction of valued ecosystems or causes negative, irreversible changes in habitat conditions. In that kind of areas there is a necessity of *ex situ* conservation of valuable and rare species. Transfering them to secondary habitats ensure their survival and gene pool. One of the efficient method is a metaplantation experiment. This instrument ought to be obligatory for investors as a nature compensation. At the beginning of investments some rare and endangered species should be taken away from planned industrial areas. The procedure, terms and conditions of metaplantation, its purposefulness were described (ŁUKASIEWICZ 1984; OLACZEK 1986; KLASA 1991; TESKE 1992). PAWLACZYK and JERMACZEK (2008) payed attention to sources of difficulty and hazard related to creating new, artificial stands of important spieces. Suitable rules of law which would regulate problem of transfering valuable spieces or endangered populations from industrial areas haven't been created so far.

An example of the area where the impact of anthropopressure has been substantailly strong, resulting in irreversible changes in forest ecosystems, is the vicinity of the open-pit Bełchatów Brown Coal Mine. The main causes of such transformations include: drainage of the brown coal deposit, large area felling facilitating the spread of the mine’s and power plant’s infrastructure, dust and gaseous pollution, peat exploitation, construction of canals replacing natural river sections and leading away the drained water (KUROWSKI 1984, 1993, 2007a, b). In the vicinity of the coal mine there are situated stands of *Dentaria enneaphyllos* which is rare in Central Poland.

Drooping Bittercress is a geophyte blooming in April and May (SZAFER *et al.* 1988; RUTKOWSKI 2006). In Poland it chiefly occurs in the Sudety Mountains, the West Carpathians, the Kraków-Częstochowa Upland and the Świętokrzyskie Mountains (ZAJĄC, ZAJĄC 2001). The species is characteristic for fertile mountain beech forests *Dentario enneaphylli-Fagetum* and *Dentario glandulosae-Fagetum* (MATUSZKIEWICZ 2007). As for the lowlands, the main places of its occurrence are the oak-hornbeam and beech forests (ZAJĄC 1996).

In Central Poland *Dentaria enneaphyllos* occurs in rare and isolated populations. Furthermore, the species is categorised as VU (vulnerable) in the List of Threatened Species of the area (JAKUBOWSKA-GABARA, KUCHARSKI 1999). Drooping Bittercress has been recorded in four stands, two of which are situated in the vicinity of the Bełchatów Brown Coal Mine, i.e. in the forest complexes of Wola Wydrzyna and Stróża in Forest District Administration of Bełchatów (KUROWSKI 1984; JAKUBOWSKA-GABARA 1989). Two other stands are to be found in the Spała Forests, i.e. in the Sługocice forest-floristic reserve (OLACZEK 1978) and in the Forest District of Białobrzegi (KIEDRZYŃSKI 2000).

The population in Wola Wydrzyna is to be destroyed in the near future. The outset of mining activity in the Szczerców coal deposit will lead to annihilation of the forest complex. Consequently, the flora's gene pool in the region will be impoverished. Wola Wydrzyna is one of the most valued areas in the vicinity of the open-pit mine, not only due to occurrence of the investigated population of *Dentaria enneaphyllos*, but also to the forest's remarkably rich flora and significant variety of its phytocoenoses. If it were not to be destroyed, the area should be classified as a nature reserve (KUROWSKI 1984). What is also worth mentioning, Drooping Bittercress co-exist there with *D. bulbifera*, which is also rare in Central Poland. Furthermore, the forest complex of Wola Wydrzyna is home to such species as: *Corydalis cava* (with an area of ca. 1 ha), *Lathraea squamaria, Viburnum opulus, Ribes nigrum, Asarum europaeum, Daphne mezereum* and *Hepatica nobilis*. Patches of *D. enneaphyllos* are spread over the area of above 0.9 ha (KIEDRZYŃSKI, KUROWSKI 2011), and the individulas total coverage amounts to ca. 0.13 ha. In the face of the future annihilation of the Drooping Bittercress stand, the method of metaplantation has been applied in the forest complex of Wola Wydrzyna since 2000. Problem of metaplantation were presented for such species as *Cochlearia polonica* (KWIATKOWSKA 2001), *Aldrovanda vesiculosa* (KAMIŃSKI 1995), *Dianthus gratianopolitanus* (WĘGLARSKI, JAŃCZYK-WĘGLARSKA 2000), *Echium russicum* and *Irys aphylla* (DĄBROWSKA *et al*. 1995), *Polemonium coeruleum* (DĄBROWSKA *et al*. 2011). The method has already been successfully applied in the Łódź region, e.g. with regard to *Linnaea borealis* (KUROWSKI 2004; WITOSŁAWSKI 2004). There are also known examples of metaplantation from industrial areas (JERMACZEK 2007; KRASICKA-KORCZYŃSKA, KORCZYŃSKI 2007; ŻÓŁKOŚ *et al*. 2010).

The main goals of this work include:

- estimating population size of *D. enneaphyllos* in its native stands,
- describing the condition of *D. enneaphyllos* new population in its secondary stand,
- pointing to practical problems regarding *ex situ* conservation and discussing difficulties concerning the application of metaplantation method, as well as emphasizing lack of any programmes that would enable the transfer of particular populations of rare and endangered species away from areas of future widespread investitions.

2. MATERIALS AND METHODS

In 2009, in the forest complex of Wola Wydrzyna were conducted observations of *Dentaria enneaphyllos* in its native stand. Estimating the population size involved both assessing the area of particular patches and determining the species percent coverage in each of them. Furthermore, individual stances of Drooping Bittercress have been distinguished in a number of representative areas, all characterised by varying density. The area of a single study plot was 1 m^2 (FALIŃSKA 2002).

In the year 2000 metaplantation was attempted by transferring *D. enneaphyllos* 10 km away from its native stand, situated in the forest complex of Wola Wydrzyna, to the projected Kluki nature reserve (named after Henryk Baksalerski). In the spring, separate soil lumps with *D. enneaphyllos* are transferred to a new location in the phytocoenosis of moist oak-hornbeam forests *Tilio-Carpinetum stachyetosum*. The metaplantation of Drooping Bittercress involves both measuring the total area covered by the species, and estimating the number of its flowering shoots. Since 2008 sterile shoots have also been taken into account.

3. RESULTS

It has been estimated that *Dentaria enneaphyllos* covered the area of 1280 m^2 in the forest complex of Wola Wydrzyna (including 430 m^2 in the 156 forest section and 850 m^2 in the 157 forest section; Phot. 1, Fig. 1, 2). The population size of *D. enneaphyllos* in the 156 forest section amounted to 57300 shoots (including 24400 flowering and 32900 sterile ones), while the number of shoots in the 157 forest section amounted to ca. 72400 (including respectively 24500 flowering and 47900 sterile ones).

Photo 1. *Dentaria enneaphyllos* in the forest complex of Wola Wydrzyna (photo E. Koczywąs).

The stand of *Dentaria enneaphyllos* is situated in such phytocoenoses that undergo transformations (mainly resulting from habitat drainage). These are the phytocoenoses of *Carici remotae-Fraxinetum* and *Tilio cordatae-Carpinetum betuli* characteristic for the Małopolska region (their subdivisions are: *Tilio-Carpinetum stachyetosum sylvaticae* and *Tilio-Carpinetum corydaletosum*). *Dentaria* *enneaphyllos* occupies only 1 m^2 in the Stróża forest complex, located to the west from the Wola Wydrzyna, belonging to the above mentioned phytocoenosis of *Tilio-Carpinetum stachyetosum sylvaticae*.

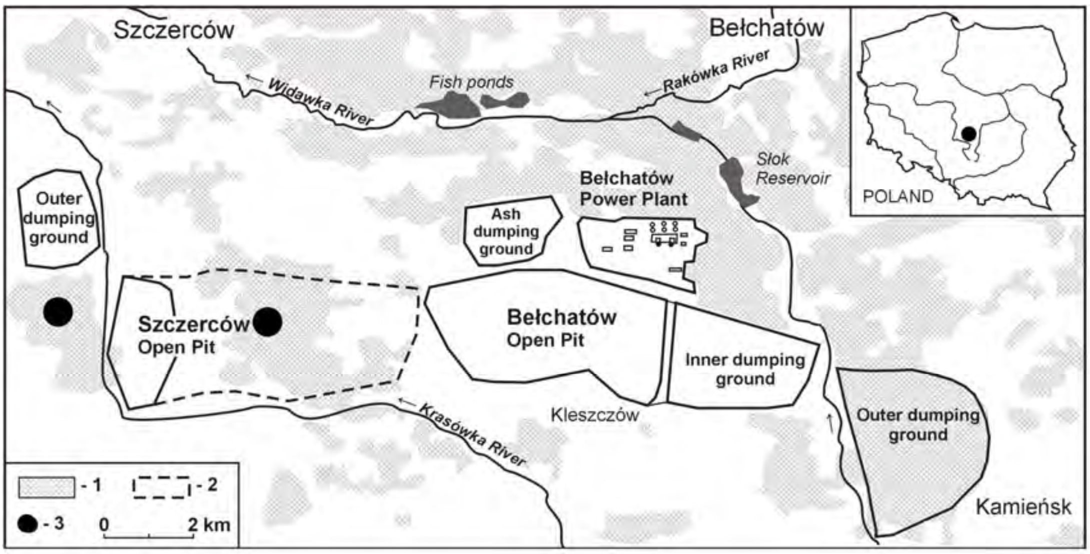

Fig. 1. The vicinity of the Bełchatów Brown Coal Mine (KUROWSKI 2007b, modified) 1 – forests, 2 – future area of the Szczerców Open Pit, 3 – *Dentaria enneaphyllos* stands.

Metaplantation of Drooping Bittercress was conducted in the years 2000-2009, in the phytocoenosis of moist oak-hornbeam forests *Tilio-Carpinetum stachyetosum*. To a secondary stand (forest complex of Kluki near Bełchatów) were transfered 33 soil lumps of *D. enneaphyllos*, amounting to a total area of 6.6 m^2 (Tab. 1).

Table 1. The spread of *Dentaria enneaphyllos* patches over a new territory after metaplantation into the projected Kluki nature reserve.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
The area of transferred soil lumps (m^2) in a given year	1.0	0.4	0.6	1.0	1.0	1.0	0.4	0.4	0.4	0.4
The total area of transferred soil lumps (m^2)	1.0	1.4	2.0	3.0	4.0	5.0	5.4	5.8	6.2	6.6
The size of *Dentaria enneaphyllos* patches (m^2) in the new stand	1.0	0.6	0.7	1.7	2.5	1.4	1.2	1.4	1.8	1.1

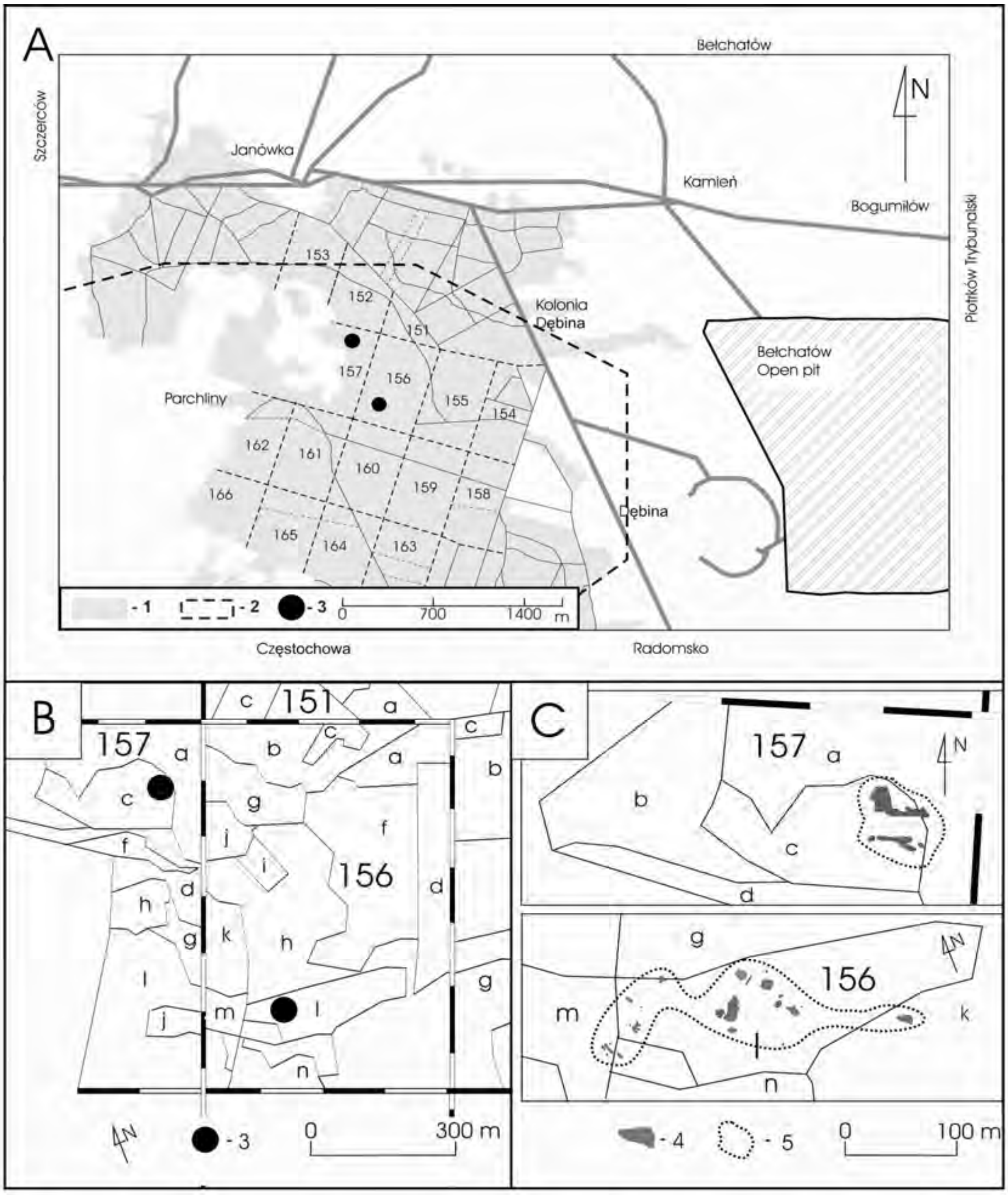

Fig. 2. *Dentaria enneaphyllos* stands in the Wola Wydrzyna. A – localization in forest complex; B – localization in the forest sections; C – distribution of patches; 1 – forests, 2 – future area of the Szczerców Open Pit, 3 – *D. enneaphyllos* stands, 4 – *D. enneaphyllos* patches, 5 – range of *D. enneaphyllos* population.

In 2009 the new territory of *Dentaria enneaphyllos* after metaplantation amounted to ca. 1m^2. The population numbered 261 individuals (including 49 flowering and 222 sterile ones). On the basis of the yearly monitoring it has been estimated that the new population area oscillates between 1 and 2.5 m^2. Since 2005, despite yearly transferring of new soil lumps, the population's expanse has not advanced, the area amounting to more or less 1m^2 (Fig. 3). In comparison with the total amount of transferred soil lumps, 20% of *D. enneaphyllos* has been successfully located into its secondary stand (the situation has been stable since 2004). The 2005 transfer of soil lumps of the same size as in the years 2002-2004 did not cause (opposed to the previous transfers) any expanse in the population's area (Fig. 4).

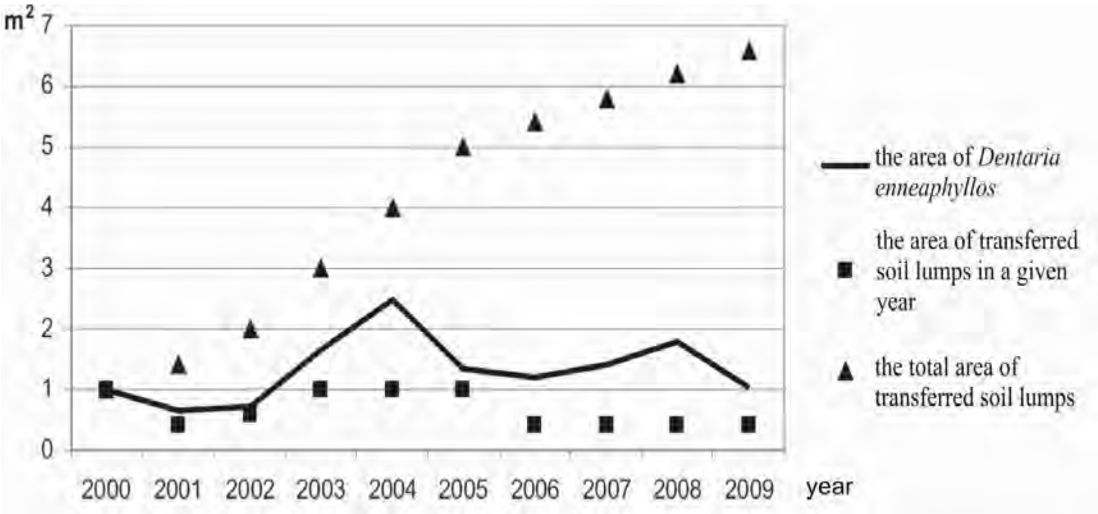

Fig. 3. The dynamics of *Dentaria enneaphyllos* secondary stand after metaplantation in a projected Kluki nature reserve.

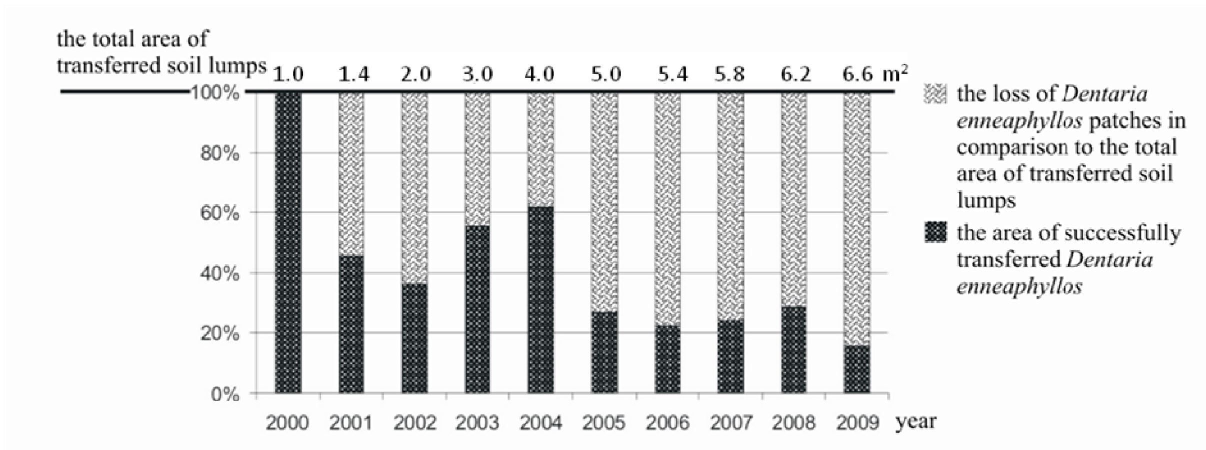

Fig. 4. The percentage of successfully transferred *Dentaria enneaphyllos* area (stable since 2004) in comparison with the total amount of transferred soil lumps.

4. SUMMARY

- The stand of *Dentaria enneaphyllos* in the forest complex of Wola Wydrzyna was first recorded at the end of the 1970s. It took place during investigations carried out by the geobotanists of the University of Łódź (KUROWSKI 1984; JAKUBOWSKA-GABARA 1989). The stand has been monitored on a regulr basis ever since. Currently, the species population covers the largest area ever. Throughout the years, the habitat conditions have changed as a result of the area's drainage (KUROWSKI 1993, 2007a, b). Soil moisture in the area deteriorated, peat decay and extinction of hygrophilous plants have been observed. However, those factors have so far facilitated the growth of *D. enneaphyllos* in Wola Wydrzyna. The decision to begin brown coal extraction in the Szczerców Open Pit made it nessessary to transfer Drooping Bittercress to new, secondary stands.
- In the projected Kluki nature reserve *Dentaria enneaphyllos* population covers the area of ca. $1m^2$. During the blooming phase particular individuals of the species suffer from the attacks of leaf beetles (*Chrysomelidae*) that feed on their leaves. The leaves also bear signs of animals bites. All the factors contributing to the species shoot destruction severly inhibit its ability of generative reproduction.
- Drooping Bittercress should remain under monitoring, its scope widened *via* investigations on the species ecology in the conditions of Central Poland. A suggestion to investigate the mycorrhizal biota similarity between *Dentaria enneaphyllos* and ash trees *Fraxinus excelsior* has been put forward. The latter occur in the forest complex of Wola Wydrzyna, however they cannot be found in the projected Kluki nature reserve. It has been assumed that ash trees may stimulate *D. enneaphyllos* population growth.
- The positive results of metaplantation are determined by a correlation of local factors. Transferring species to a location with similar habitat conditions is not enough to guarantee the success of the operation. It is much more important to ensure the largest degree possible of similarity between the species native and secondary biocenosis.

- There is a necessity of introducing programmes that would enable transferring selected populations of rare and endangered species away from areas planned for future widespread investations. Moreover, the future investors should contribute to such actions. Currently, there is no distinction between species covering large areas in a given region and those occupying single, isolated stands. All the instances are approached in the same manner. There is a need for a legal regulation ensuring the protection of the gene pool of species valuable to a given region. It should be done *via* metaplantation to secondary stands, whereas protection issues should be discussed at the very beginning of planning any future investitions in a given area.
- In the nearest future there is a need to transfer part of the population *D. enneaphyllos* before it will be annihilated, to another forest complex in vicinity which is similar to the original one.

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