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Changes in the plant cover of the dune hill in Folusz near Szubin (NW Poland) between 1959 and 2013: the problem of preservation of xerothermic grasslands in the agricultural landscape

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Abstract. The dune hill in Folusz is one of the most interesting sites with xerothermic vegetation in the Polish lowland. It is different from other sites by the fact that xerothermic vegetation covers a single dune located amidst large areas of *Molinia* meadows rather than slopes of river valleys. Vegetation occurring on the hill represents a cold *Stipa* steppe with rare species of floodplain meadows and has long aroused the interest of botanists. In the 19th century and in the early 20th century, observations in this area were carried out by German botanists (L. Kühling, F. Spribille, H. Miller, W. Bock). In the 1930s, the investigation was continued by botanists from the University in Poznań. After World War II, it was one of the main research sites for botanists and ecologists from the University in Toruń, and recently also from the universities in Bydgoszcz. Floristic lists were compiled by all the aforementioned researchers, which describe the state of flora in the subsequent periods, and when collated in tables, they help to determine the directions of changes occurring in the area over a hundred years. Not all the materials obtained in the past were published. A lot of interesting data were preserved in the Toruń centre in the form of actual vegetation maps and relevés. This paper presents the comparison of vegetation from 1959, plotted on the unpublished vegetation map by J. Wilkoń-Michalska, with the vegetation in 2013. Changes in the land cover were also analysed through a series of aerial photographs from 1961, 1975, 1986 and 2005. The GIS and GPS technology was used in the spatial analysis. Furthermore, the analysis of flora changes was performed, including the comparison of data presented in ecological literature with unpublished data collected by J. Wilkoń-Michalska in 1956–1964. In addition, numerical analysis of relevés from both these periods and from 2012 was performed. The objective of all the analyses was to determine how the changes were affected by spontaneous development of oak trees on the dune and destructive human activity related to exploitation of the sand, afforestation of the dune with pine, birch and oak, and planting of common lilac. An effort was also made to assess the importance of including the Folusz dune hill within the Natura 2000 site − PLH040027 „Molinia meadows in Folusz" − for preventing further degradation of xerothermic vegetation.

Key words: xerothermic grasslands, real vegetation maps, aerial photos, afforestation, flora changes, plant communities, phytosociology, numerical classification, special protection area.

1. Introduction

Frequent clusters of xerothermic vegetation with diverse, often very rich floristic composition occur in central and northern Poland, on high slopes of the Lower Vistula and the Toruń-Eberswalde ice-marginal valley with the Noteć River flowing through the valley, as well as in the regions of Kujawy and Pałuki, at a certain distance from the main streams of the aforementioned rivers. Species of the xerothermic vegetation represent various floristic elements, including the Irano-Turan element and the so-called Sarmatian and Mediterranean element. The occurrence, as well as floristic and phytosociological diversity of this vegetation was described in detail by Sulma and Walas (1963), and Ceynowa (1968).

One of the most interesting sites with the xerothermic vegetation in the aforementioned area is located in the Noteć River valley, in the village of Folusz, south of the Szubin town. Xerothermic vegetation covers the dune hill situated amidst vast meadows. Favourable exposure of the southern slope provides favourable conditions for the vegetation representing the cold *Stipa* steppe. Interesting enough, *Stipa joannis*, *Anemone sylvestris*, *Avenastrum pratense*, *Linosyris vulgaris*, *Scorzonera purpurea*, *Hieracium echioides*, *Silene chlorantha*, *Veronica spicata* occurred together with species typical of periodically inundated wet meadows from the order *Molinietalia*, such as *Galium boreale*, *Gentiana pneumonanthe* and *Iris sibirica*. According to Sulma and Walas (1963), the common occurrence of the two, so different groups of plants sheds new light on migration capabilities of the continental element, representing the cold *Stipa* steppe.

Botanists from Toruń have been interested in xerothermic vegetation of Folusz since the 1950s, i.e. almost since the beginning of the Nicolaus Copernicus University. Apart from the aforementioned studies by Prof. Walas and Prof. Ceynowa-Giełdon, the research was also conducted by Prof. Jadwiga Wilkoń-Michalska and Prof. Ryszard Bohr who reported the occurrence of a new species – *Linum perenne* L. – in the planned nature reserve (Wilkoń-Michalska & Bohr 1960). Botanist from Toruń compared also the occurrence of some contemporary flora components with the previous states described in the literature by German botanists. Rare steppe plants were observed in this area by Kühling (1866) and Spribille (1887), and comprehensive floristic notes were made by Miller (1902). The latter German florist listed the site with *Stipa pennata* in his report, later confirmed by Bock (1908).

Naturalists from the University of Toruń also supported the motion put forward by Urbański (1935) to include the Folusz hill in the active legal protection plan due to the fact that aspen and other species of trees regularly overgrow the xerothermic grasslands, and due to the long-term sand exploitation by the local population. Furthermore, in 1959, botanists and ecologists from the Nicolaus Copernicus University created a map of vegetation growing on the dune hill in Folusz, and relevés were made in different types of plant communities. Some of the locations where relevés were made became permanent research sites. At each site, inventory of species and their abundance was repeated at different time intervals. In the same years, relevés were made also in other places where most typical plant communities developed, or plant communities interesting due to xerothermic species present. The preserved cartographic material and most of the relevés have not been published yet. Due to the unique flora of the dune hill in Folusz, we have decided that this material should be analysed with the use of new research methods and published. The analysed material can be compared with the flora and vegetation of this area from the beginning of the 21st century surveyed by botanists from Bydgoszcz universities. In 2001–2002, the list of species and the list of syntaxa occurring on the Folusz hill and its immediate vicinity were compiled by Halina Ratyńska. Both lists were published in the paper by Banaszak et al. (2004) who described also the fauna of aculeate insects (Hymenoptera: Aculeata: Apoidea, Scolioidea) associated with this vegetation. The study of the aforementioned researchers and the work by Ewa Krasicka-Korczyńska from the Bydgoszcz centre and Lucjan Rutkowski from the Toruń centre on a large complex of meadows surrounding the described hill (Krasicka-Korczyńska & Rutkowski 2005), a nature path designed in this interesting area (Krasicka-Korczyńska 2004), as well as efforts made by other people of science, social workers and representatives of local authorities, contributed to the fact that in 2010 „Molinia meadows in Folusz" (code PLH040027, 230.32 ha in area) were included on the list of new special protection areas for habitats in Poland. The described dune hill covered with xerothermic vegetation is located in the eastern part of this area.

The preliminary fieldwork at the site in Folusz was carried out by the authors of this paper and by Wilkoń-Michalska during the growing seasons of 2001 and 2002, and again by the authors in 2012–2014. In 2012, floristic and phytosociological observations, and mapping of the actual vegetation were performed. In 2013, cartographic work was repeated. In 2014, lichenological observations were conducted.

Based on the information obtained in the course of fieldwork, as well as based on the historical material collected by Prof. Wilkoń-Michalska and floristic and phytosociological data included in the paper by Banaszak et al. (2004), the synthesis of all data was performed with the following objectives:

a – a computer map of actual vegetation growing on the Folusz dune hill in 1959 based on a draft prepared by Wilkoń-Michalska (unpublished data),

b – a computer map of vegetation as at 2013 based on our draft,

c – determination of differences in the vegetation cover based on the comparison of both vegetation maps and time series analysis of the existing aerial photographs,

d – determination of the spatial and temporal variability of the association *Potentillo-Stipetum* and description of the forest vegetation development process on permanent research plots after pine, birch and oak were planted in some parts of xerothermic grasslands,

e – determination of the list of species observed by Wilkoń-Michalska in 1956–1964 and comparison with the list of species identified before 1935 by the Polish and German florists, and with the list of species compiled by Ratyńska in 2001–2002 (Banaszak et al. 2004).

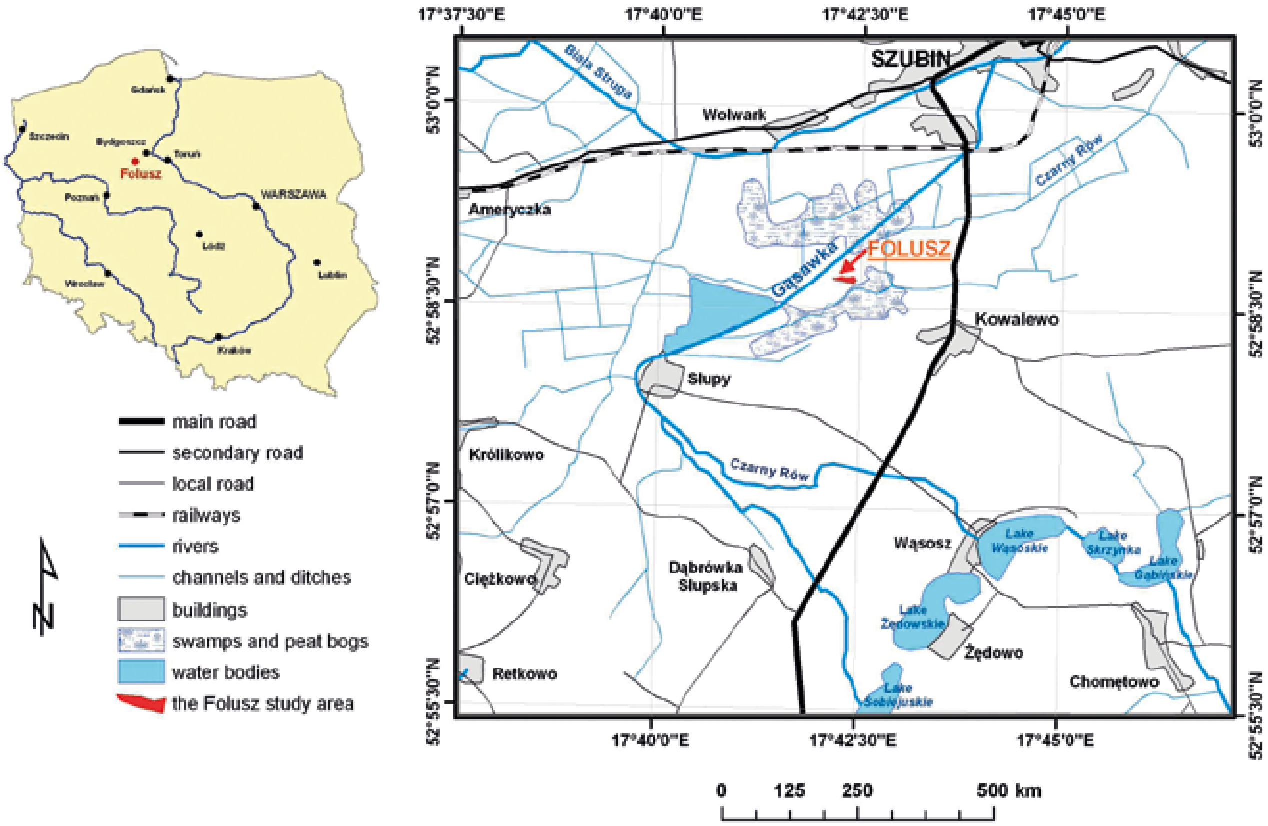

Figure 1. Location of the Folusz study area

2. The study area

The Folusz dune hill covered with xerothermic vegetation is situated in the western part of the Kujawy-Pomerania province, ca. 30 km south-west of the Bydgoszcz city, at a distance of ca. 4 km from the railway station in Szubin in SW direction (Fig. 1). A small agricultural housing estate called Folusz (previously known as Folusz Młyn with a mill closed at present) is situated in the immediate vicinity of the western end of the hill, on the Gąsawka River – a left-bank tributary of the Noteć River.

According to Kondracki (2000), the region of Folusz belongs to the Szubin-Łabiszyn Plain (code 315.353) located in the Toruń Basin. The hill in Folusz is one of the many sandy dunes in this region rising over a vast area of peaty meadows in the Noteć ice-marginal valley. The wedge-shaped dune tapering towards the west is ca. 3 ha in area. The length of the dune is over 300 m and the maximum width is nearly 100 m (Wilkoń-Michalska & Bohr 1960). The south-western part of the dune hill slopes gently towards the meadows, and the eastern part rises to a height of 5 m above the level of the surrounding peaty meadows in the Noteć River valley. The meadows are represented mainly by the order *Molinietalia* (Krasicka-Korczyńska & Rutkowski 2005). In the past, until the mid-1950s, the highest part of the dune was exploited for sand extraction and a road dividing the area into two parts was built – the sunlit south-eastern part with almost no trees and the western part covered with a grove composed of pedunculate oak, Scots pine, common aspen, silver birch and crab apple. Larger areas of grasslands with no trees, covered mostly with grasses like *Calamagrostis epigejos*, *Bromus inermis* or *Brachypodium pinnatum*, have been preserved to this day between clusters of tall trees, including populations of the aforementioned steppe species.

The soil at the studied nature site consists of fine, loose and decalcified sand, which in deeper layers turns into more compact loamy sand. The soil reaction determined in the past ranged in the upper soil layers from pH 5 to 5.5, while in the deeper layers – pH 6.5 (Wilkoń-Michalska & Bohr 1960).

The lack of legal protection for the Folusz hill in the previous decades resulted in the afforestation of the hill carried out in 1996 by the Forest Division of Szubin, which partly owns the studied area. Most of the afforestation was carried out on the exposed sands of the south-eastern part of the dune, in places of former sand excavation. This part of the dune was afforested by Scots pine; a few rows of silver birch were planted only along the road cutting through the dune (a subdistrict of forest section 66A, 0.60 ha in area). Birch was planted also on the other side of the road (a subdistrict 0.12 ha in area).

Two years later, the western part of the dune hill was afforested with pine, i.e. the part facing the village of Folusz (a subdistrict, 0.32 ha in area). A plantation of *Quercus robur* at the eastern side of the pine growth was not very successful and survived to this day in the form of several rows of furrows ploughed in N-S direction with only few small oak specimens.

Apart from the interesting vascular plant flora, a relatively rich biota of lichens is observed on trees growing at the site in Folusz, particularly on old oak and birch trees occurring at the northwestern side of the road crossing the site. A total of 28 epiphytic lichen species were identified during the fieldwork carried out on September 16th, 2014, including those associated with the following phorophytes: *Acer platanoides*, *Betula pendula*, *Populus tremula*, *Pinus sylvestris*, *Prunus serotina*, and *Quercus* spp. The largest number of species (18) was found on old oak and birch trees (15 species); the latter occur far less frequently than oaks. On numerous but young specimens of *Populus tremula*, 11 lichen species occurred. The least number of lichen species was found on *Acer platanoides*, *Padus serotina* and *Pinus sylvestris*, i.e. 8, 7 and 6 species, respectively. Low taxonomic richness of lichens on the first two phorophytes resulted from small abundance of these tree species. Whereas small diversity of epiphytic lichen biota on very frequent pine trees was correlated with young age of plantations. On all six aforementioned species of trees, one lichen species *Xanthoria polycarpa* was found, out of the total number of 28 species occurring on the bark of these trees. Three species were found on the bark of five tree species, apart from *Pinus sylvestris*. Those were: *Parmelia sulcata*, *Scoliciosporum chlorococcum* and *Xanthoria parietina*. Noteworthy was also noted a significant contribution of nitrophilous and coniophilous species in epiphytic lichen biota, such as taxa from the genera *Physcia* s.l. and *Xanthoria.* The complete information about all lichen biota on the hill in Folusz is presented in a separate paper (Adamska & Adamski 2014, this issue).

3. Methods

The cartographic material was processed applying the GIS technology. The plan of vegetation distribution created by Wilkoń-Michalska in 1959 for the Folusz hill was superimposed on the topographic map using the software ArcGIS 9.3. The actual vegetation map presenting the situation in 2002 was plotted as a next information layer. Also the location of relevés and the occurrence of rare and protected plant species determined in 2012 by a Garmin GPS receiver were plotted on the map.

The time series of aerial photographs from 1961, 1975, 1986 and 2005 was yet another source of data in the system of information on the vegetation of the Folusz dune hill. Maps and aerial photographs from different years allowed to determine changes in the size and location of different plant communities, as well as changes in the location of populations of certain species between 1959 and 2012.

Analysis of temporal and spatial variation of plant communities representing the association of *Potentillo-Stipetum* and temporal changes taking place in the forest plantations established in xerothermic grasslands was based on the relevés selected from the source material collected by Wilkoń-Michalska, relevés published by Ceynowa (1968) and the Authors' own material collected in 2002 and 2012. The two sets of relevés, made in different years with the Braun-Blanquet method at varying locations or on permanent research plots, were collated in synoptic tables and time sequences. Although the area of the compared relevés was different, i.e. ranged from 25 m^2 to 160 m^2, numerical classification of each set of relevés was performed using the software MVSP (Kovach 1985–1999; Piernik 2008).

The method of Minimum Variance was used for classification (Oróci 1978, Dzwonko 2007). Preparing data for calculations the transformation of Braun-Blanquet cover-abundance scale into scale of Janssen (1975) and van der Maarel (1979) took place.

4. Results

The series of aerial photographs well reflects the changes in the Folusz vegetation cover, particularly in the tree layer (Fig. 2). In the photo from 1961, one can clearly see a road crossing the dune in NE-SW direction, as well as clumps of deciduous, mostly oak trees. They are particularly frequent in the western part of the research site. In the eastern part, i.e. on the other side of the road, they cover a smaller area. The light spot between the trees reflects the place of sand extraction.

In the photo from 1975, one can see a byroad leading to the sand mine and even stronger growth of trees all over the study area. The photograph shows also changes in the vegetation near the study area. It appears from the photograph that a rectangular, deforested area, adjacent from the east to the study area, was afforested. On the borderline between the study area and the plantation established in the vicinity, there is a sandy area with almost no vegetation.

Differences visible between photos from 1986 and 2005 show that the study area was significantly deforested. The photograph from 2005 shows old oak trees preserved only in the central part and along the north-eastern boundary of the study area, and larger areas between trees, covered with

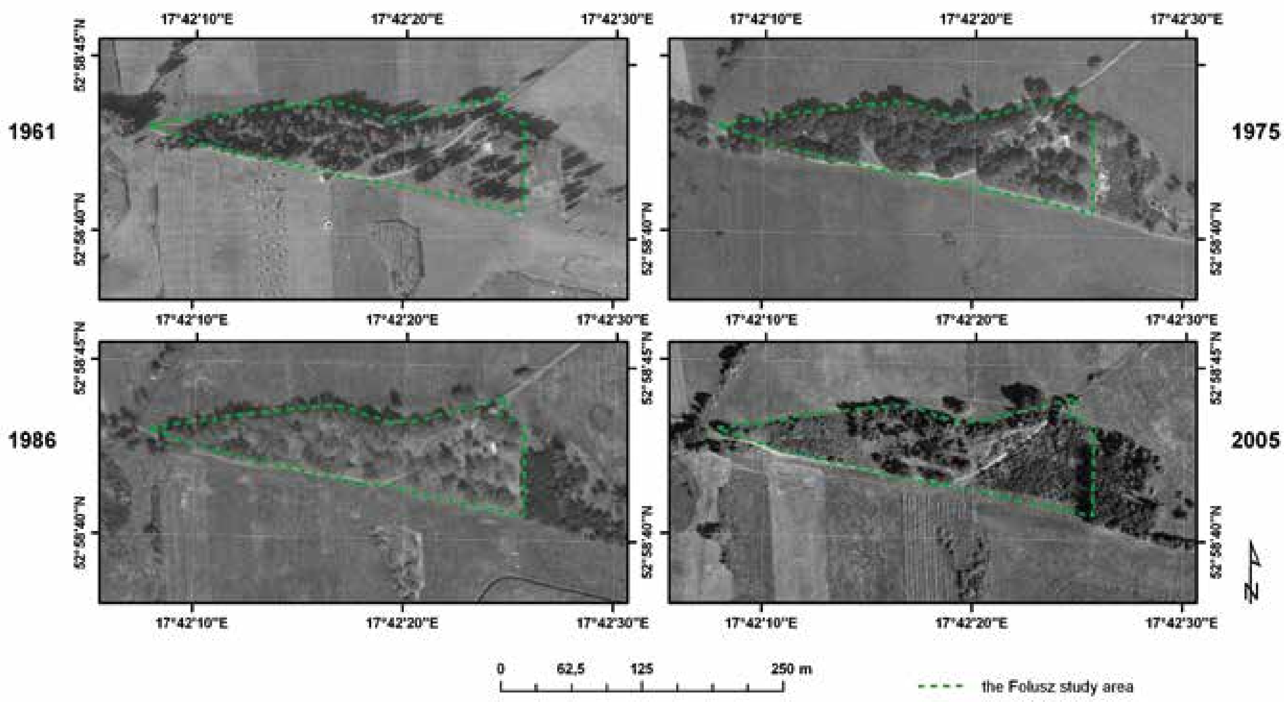

Figure 2. The time sequence of aerial photos of the Folusz study area

grass. There are no old oak trees in the eastern part of the study area, nor in the western part, where young pine plantations were established instead. When comparing these parts of the study site with the previous states, it appears that older trees were cut down before the forest plantations had been established.

Major changes in the vegetation cover are observed also when comparing the real vegetation map created by Wilkoń-Michalska in 1959 with the vegetation map from 2013 (Fig. 3).

The legend of the former and actual map consists of 24 land-cover categories, including 6 categories with open xerothermic grasslands dominated by different grass species, 4 xerothermic grasslands with scattered young trees of pedunculate oak, silver birch, common aspen, black alder and willow (*Salix rosmarinifolia*), and 4 categories of different patches of grass species with 60–100-year old oak trees scattered all over the area. The remaining 10 categories represent the following types of vegetation: 5 patches with compact canopy of *Quercus robur*, *Betula pendula*, *Alnus glutinosa* and *Populus tremula* with different composition of these trees and the dominance of different species in the herb layer, 2 types of tree plantations (with birch or pine growth in forest subunits o, p, and r of unit 66A in the Szubin Forest Division), and three types in one category, i.e. unsuccessful plantation of oak in the patch of *Calamagrostis epigejos*, thickets with *Syringa vulgaris* and bare sand without vegetation (Fig. 3).

A total of 15 cover categories were distinguished on the vegetation map from 1959, and 11 categories on the vegetation map from 2013. In both studied periods, two vegetation categories occurred (in Fig. 3, No. 10 and 15).

In 1959, a considerable part of the study area was covered with open xerothermic grasslands (categories 1, 2 and 3) and grasslands dominated by different grass species, rarely overgrown with trees (categories 4, 5, 8, 9, 10, 13 and 15). Vegetation patches with older trees, mainly pedunculate oak, occurred in the central, northern and western part of the study area.

In 2013, a considerable part of the study area was covered with pine and birch plantations with a dense canopy of trees (categories 23 and 24 in Fig. 3). They occurred mostly in the eastern and western part of the study area. Whereas dense forest stands of old trees (14 and 15) occurred in the northern part. Xerothermic grasslands without trees (3 – xerothermic grassland with *Stipa joannis* and categories 6 and 7) have been preserved in the central part of the study area in Folusz. This type of vegetation distribution and comparison with the map from 1959 indicate that logging was conducted in this part of the area. A well-developed clump of *Syringa vulgaris* occurs on the exposed ground (Fig. 3).

The research by Banaszak et al. (2004) contains data on the richness of plant communities at the studied site and their quantitative contribution in the vegetation cover of the Folusz hill. Ratyńska, the co-author of the aforementioned study, distinguished 26 syntaxa present on the

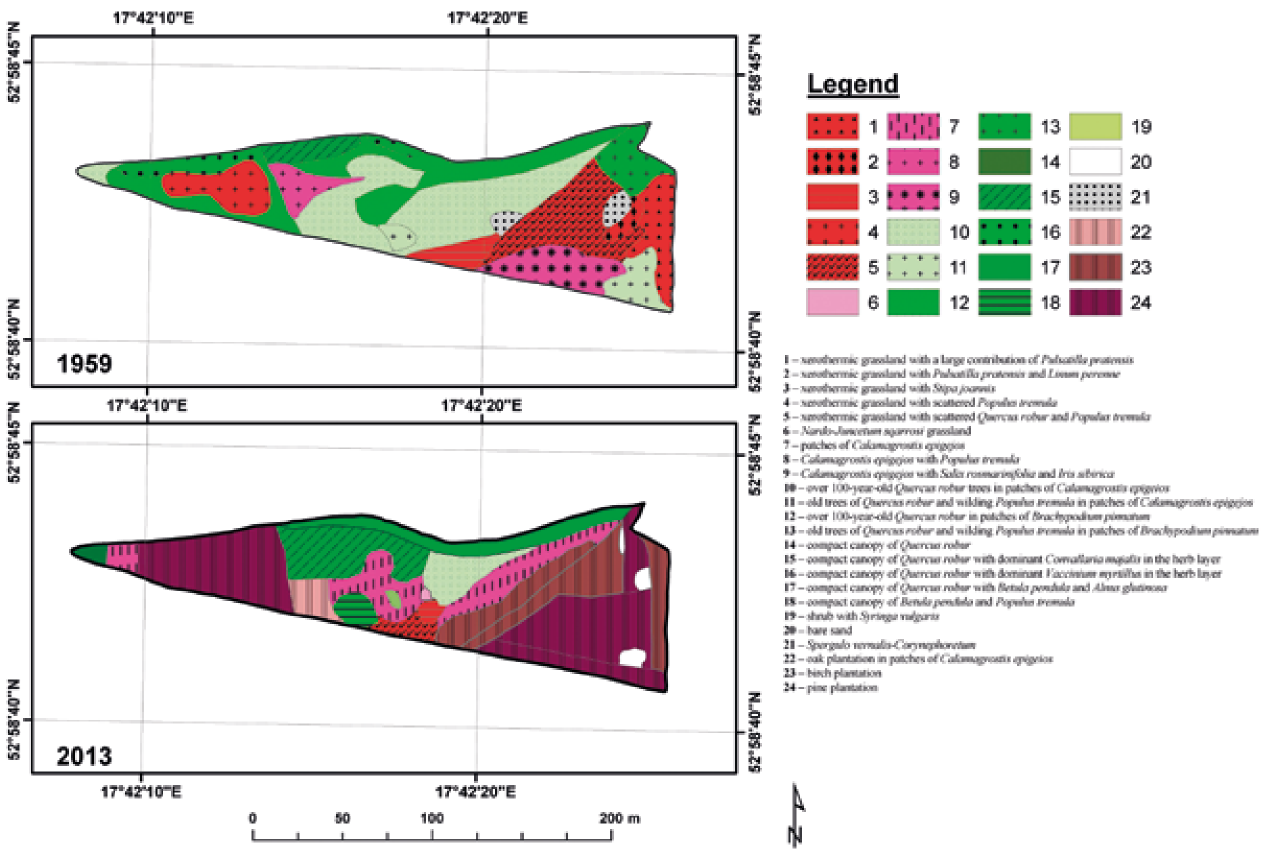

Figure 3. Land cover of the Folusz study area in 1959 and 2013

hill, including 19 associations and 7 syntaxa at the level of plant community or forest plantation. The list does not include the association of *Potentillo-Stipetum*, which was described from the Folusz site by Ceynowa (1968) and was represented by relevés included in the data collection of Wilkoń-Michalska. In her study from the 1960s, Ceynowa (1968) listed two other syntaxa distinguished based on the relevés from Folusz, i.e. associations *Peucedano-Coryletum* and *Adonido-Brachypodietum pinnati.* They probably represented only a small part of all syntaxa occurring at that time on the Folusz hill. Apart from syntaxa distinguished by Ratyńska during our field research conducted in 2012, we found a small patch of *Potentillo-Stipetum* and some related communities, and the community with *Calamagrostis epigejos*. Figure 4 presents the distribution of some relevés made in the vegetation patches classified into these two syntaxa, and on five permanent plots established in places where pine plantations occur today.

In the classification dendrogram obtained with the minimum variance method for the set of relevés made in the association *Potentillo-Stipetum* and in the corresponding community, the new relevés, i.e. from 2012, are grouped in a separate cluster (PS-2012 and rc-2012) connected with other relevés at the level corresponding to a large distance (Fig. 5). They differ from other relevés in small abundance or even absence of *Stipa joannis*, a significant contribution of grasses: *Festuca trachyphylla* and *Deschampsia flexuosa*, the sedge *Carex praecox*, and tall thermophilic perennials, such as *Peucedanum oreoselinum* (Table 1). The earlier relevés form two subsets; the first one consists of two elements and includes samples PS-2–1956 and rc-1958, and the second one consists of three elements and includes samples PS-1–1956, PS-1962 and PS-1964.

As evidenced by numerical analysis of relevés from the permanent plots, pine introduction had major influence on the communities of xerothermic vegetation. There were large differences between the three subsets of relevés from different periods and they formed three separate clusters (Fig. 6).

Five oldest relevés from 1959 were divided into three subsets. One relevé (A-1959) was most outlying from the others. Two of them, i.e. B-1959 and C-1959, formed a common cluster with relevé C-2002 made in the part of the pine plantation with scattered small trees where *Corynephorus canescens* and other species from the class *Koelerio-Corynephoretea* also dominated in the herb lay-

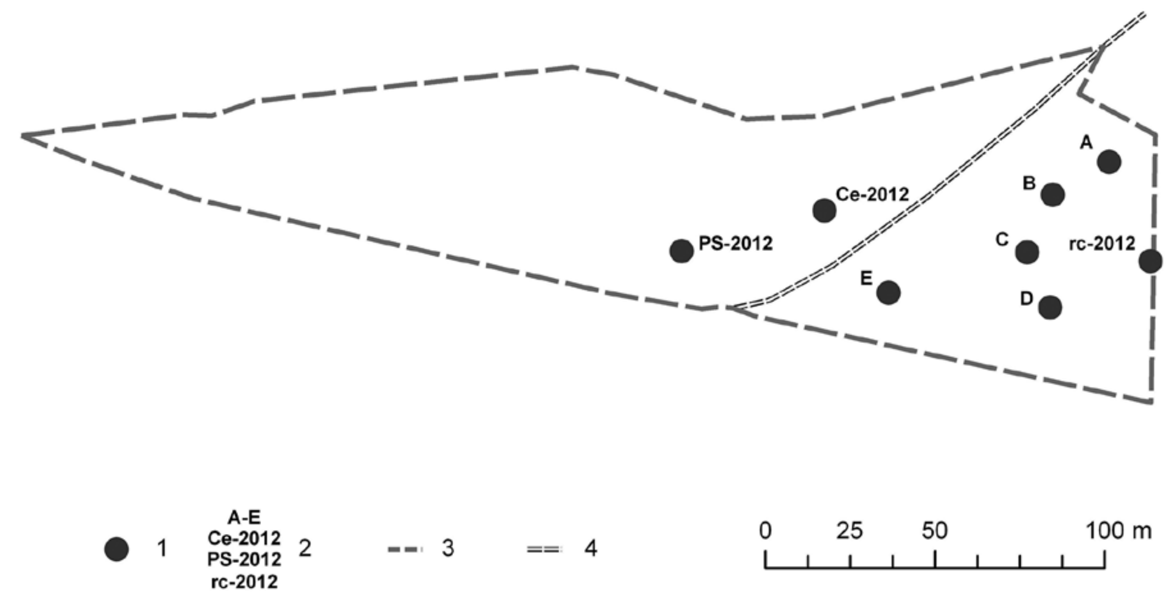

Figure 4. The location of permanent plots/relevés in the Folusz study area. Explanation of symbols: 1 – permanent plots, 2 – symbols of relevés presented in Tables 1 and 2 (Ce – community with *Calamagrostis epigejos*), 3 –boundary of the study area, 4 – road

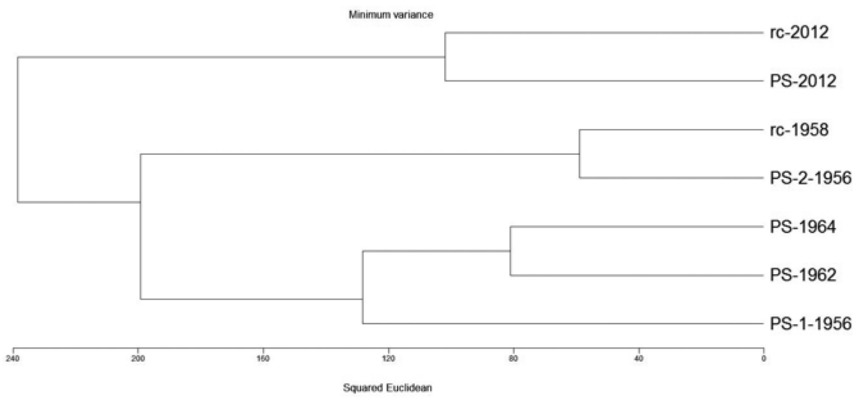

Figure 5. Dendrogram constructed with the minimum variance method for the set of relevés made in *Potentillo-Stipetum* and related plant communities in 1956–1964, 2002 and 2012

er (Table 2). In addition, this relevé is characterized by a smaller contribution of *Calamagrostis epigejos* compared to those made at other sites in 2002.

Two other relevés from 1959 (D-1959 and E-1959) formed a common cluster with a new relevé from site A (A-2012) where the development of pine woods was reduced by former sand extraction and later uprooted by rabbits. A few low trees occurred only around the relevé area. The lack of pine in the tree layer, the dominance of *Festuca trachyphylla*, *Calamagrostis epigejos* and the presence of *Carex praecox* in the herb layer were the main factors determining the high similarity of these sites with relevés made in 1959.

Four relevés (A, B, D, E) from 2002 made in the 7-year-old pine plantation grouped as one cluster. Abundant and dense *Calamagrostis epigejos* occurs between pine rows in the area of these relevés. These four relevés formed a group together with a seven-element cluster consisting of five relevés from 1959, one from 2002, and one from 2012.

The set of new relevés from sites B, C, D and E made in the 15-year old pine wood in 2012 was most different from others (Fig. 6). These relevés are characterised by compact pine cover and small herbaceous vegetation cover with a high constancy of the following synanthropic species: *Fallopia convolvulus*, *Conyza canadensis*, *Galeop-*

Table 1. Species composition and cover coefficients of plant components in the analysed set of relevés made in *Potentillo-Stipetum* and related plant communities in 1956–1964, 2002 and 2012

Successive number of relevé	1	2	3	4	5	6	7
Symbol of relevé in dendrogram	PS-1–1956	PS-2–1956	rc-1958	PS-1962	PS-1964	PS-2012	rc-2012
Author of relevé and data source	Wilkoń-Mi-chalska (unpublished data)	Wilkoń-Mi-chalska (unpublished data)	Wilkoń-Michalska (unpublished data)	Ceynowa (1968)	Wilkoń-Mi-chalska (unpublished data)	this study	this study
Date	14.06.1956	14.06.1956	31.07.1958	5.07.1962	19.06.1964	27.07.2012	27.07.2012
Area of relevé (m²)	150	60	60	25	100	100	50
Density of tree layer a (%)	-	-	-	-	-	-	-
Density of shrub layer b1 (%)	-	-	-	-	-	-	-
Density of shrub layer b2 (%)	-	-	-	-	-	-	<5
Cover of herb layer (%)	95	70	90	80	-	90	95
Cover of moss layer (%)	-	-	-	10	-	-	-
Exposition	S-E	-	-	-	-	SW-W	-
Slope (°)	15	-	-	-	-	10	-
Ch. Ass.							
Stipa joannis	1	+	.	3	1	+	.
Carex praecox	.	.	.	.+	.	2	2
Ch. Festucetalia valesiacae							
Achillea pannonica	+	+	+	+	+	+	1
Potentilla arenaria	.	2	2	+	.	.	.
Ch. *Festuco-Brometea*							
Phleum phleoides	+	+	3	1	1	1	1
Veronica spicata	+	1	1	+	.	+	2
Festuca trachyphylla	.3	3.	3.	1	1	3	3
Avenula pratensis	2	.	.	+	.	1	.
Euphorbia cyparissias	+	+	+	+	+	+	+
Dianthus carthusianorum	+	+	+	.	.	+	1
Asperula tinctoria	+	.	.	+	+	+	+
Galium album	2	+	.	.	.	+	.
Linosyris vulgaris	.	+	+	1	1	.	.
Scorzonera purpurea	+	1	+	+	.	.	.
Centaurea scabiosa	+	+	+	.	+	.	.
Scabiosa canescens	.	+	+	+	.	+	.
Filipendula vulgaris	.	+	+	+	.	.	+
Hieracium echioides	+	.	.	+	.	.	.
Stachys recta	.	+	.	.	+	.	+
Thesium linophyllon 1 (+), *Centaurea stoebe* 4 (+), *Artemisia campestre* 6 (+), *Allium oleraceum* 7 (+)							
accompanying species:							
Ch. *Agropyretea intermedio-repentis*							
Bromus inermis	2	.	.	1	.	.	1
Poa angustifolia	1	+	.	+	1	.	.

Ch. *Trifolio-Geranietea*							
Geranium sanguineum	1	2	3	1	1	1	1
Peucedanum oreoselinum	1	2	1	1	1	2	2
Galium verum	+	1	2	+	1	1	1
Thalictrum minus	+	1	+	1	1	1	1
Anthericum ramosum	+	.	+	.	.	1	+
Veronica teucrium	+	+	+	+	.	.	.
Trifolium alpestre	+	.	.	+	+	.	.
Melampyrum nemorosum 1 (+), 4 (+), *Polygonatum odoratum* 6 (+), *Coronilla varia* 3 (+)							
Ch. *Epilobietea angustifolii*							
Calamagrostis epigeios	+	2	1	2	3	1	2
Betula pendula b2	.	.	.	.	.	.	+
Betula pendula c	.	.	.	.	.	.	1
Populus tremula b	+	+	+	1	1	.	.
Populus tremula juv.	.	.	.	.	.	2	.
Ch. *Koelerio-Corynephoretea*							
Thymus serphyllum	.	2	2	1	.	.	.
Koeleria glauca	.	2	2	.	.	.	.
Rumex acetosella	.	.	+	+	.	.	+
Corynephorus canescans 1 (+), *Trifolium arvense* 3 (+), *Helichrysum arenarium* 4 (+), *Sedum acre* 4 (+)							
other species							
Salvia pratensis	+	1	+	+	1	.	.
Sedum maximum	+	+	+	.	+	1	1
Solidago virgaurea	+	.	.	.	+	+	+
Linaria vulgaris	.	.	+	+	.	.	1
Hypericum perforatum	.	.	+	.	.	2	+
Deschampsia flexuosa	.	.	.	.	.	1	4
Pulsatilla pratensis	+	+	+	.	.	.	.
Trifolium montanum	1	+	+	.	.	.	.
Galium boreale	.	.	+	+	.	.	+
Entodon schreberi d	.	.	.	1	.	.	.
Bryum sp. d	.	.	.	+	.	.	.
Ceratodon purpureus d	.	.	.	+	+	.	.
Polytrichum piliferum d	.	.	.	+	.	.	.

Festuca rubra 1 (+), 4 (+), *Hieracium umbellatum* 4 (+), 6 (+), *Vincetoxicum hirudinaria* 1 (+), 4 (+), *Hypochoeris maculata* 1 (+), 2 (+), *Helianthеum ovatum* 3 (+), 4 (+), *Linum perenne* 1 (r), *Artemisia absynthium* 2 (+), *Hieracium* sp. 3 (+), *Quercus robur* b 5 (+), *Quercus robur* juv. 1 (+), 3 (r), *Sedum boloniense* 2 (1), 3 (+), *Trifolium incarnatum* 1 (+), *Nardus stricta* 6 (+), *Filipendula ulmaria* 1 (+), *Arrhenatherum elatius* 2 (+), *Betonica officinalis* 6 (+), *Knautia arvense* 7 (+), *Rumex acetosa* 7 (1), *Agrostis capillaris* 1 (1), *Carex ericetorum* 2 (+), *Hieracium pilosella* 2 (+), *Carex* sp. 5 (+), *Campanula rotundifolia* 6 (+), *Lychnis viscaria* 6 (+), *Melandrium album* 7 (+), *Veronica chamaedrys* 7 (+), *Conyza canadensis* 7 (+), *Fallopia convolvulus* 7 (+)

Explanations: PS – *Potentillo-Stipetum*; rc – community related to *Potentillo-Stipetum* (without *Stipa joannis*)

Table 2. Species composition and cover coefficients of plant components in the analysed set of relevés made on permanent plots in 1959 (the xerothermic grassland phase), and in 2002 and 2012 (pine plantation phases)

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Symbol of relevé in dendrogram	A-1959	B-1959	C-1959	D-1959	E-1959	A-2002	B-2002	C-2002	D-2002	E-2002	A-2012	B-2012	C-2012	D-2012	E-2012
Date	16.06.1959	16.06.1959	16.06.1959	16.06.1959	16.06.1959	28.05.2002	28.05.2002	28.05.2002	28.05.2002	28.05.2002	27.07.2012	27.07.2012	27.07.2012	27.07.2012	27.07.2012
Density of tree layer a1 (%)	25	-	-	15	-	-	-	-	-	-	-	-	-	-	-
Density of shrub layer b1 (%)	30	-		-	-	-	-	-	-	-	-	60	60	95	90
Density of shrub layer b2 (%)	-	-	15	-	-	40	30	30	30	50	<5	<5	5	5	5
Cover of herb layer c (%)	95	70	65	100	-	70	80	60	80	70	95	60	40	5	5
Cover of moss layer d (%)	<5	-	50	-	-	20	20	60	10	5	-	-	-	-	-
Exposition	-	N-E	S-W	-	-	-	-	-	-	-	-	W--SW	-	-	-
Slope (°)	-	nd	nd	-	-	-	-	-	-	-	-	20	-	-	-
Area of relevé (m²)	100	nd	100	100	nd	100	60	50	100	100	50	100	50	100	100
Quercus robur a1	2	+	.	2	.	.	.	.	.	.	.	.	.	.	.
Alnus glutinosa a1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Betula pubescens a1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Pinus sylvestris b1	.	.	.	.	.	.	.	.	.	.	.	4	4	5	5
Pinus sylvestris b2	.	.	2	.	.	3	2	2	2	3	.	.	.	.	.
Ch. *Festuco-Brometea*															
Bromus inermis	.	.	.	.	.	1	2	.	+	.	1	1	2	+	+
Euphorbia cyparissias	1	1	.	1	.	1	+	+	+	.	+	+	+	.	.
Dianthus carthusianorum	+	.	+	+	.	.	.	+	.	.	1	1	.	.	.
Phleum phleoides	.	1	+	.	.	+		+	+		1	+	.	.	.
Veronica spicata	+	.	.	.	.	+	+	+		+	2	+	.	.	.
Artemisia campestre	.	.	1	.	.	.	.	+	.	.	.	1	.	.	.
Asperula tinctoria	1	+	.	+	+	.	.	.	+	+	+	.	.	.	.
Filipendula vulgaris	1	.	.	.	+	+	.	.	+	+	.	.	.	.	.
Carex caryophyllea	+	2	.	+	.	.	.	+	.	.	.	.	.	.	.
Stachys recta	.		+	.	.	+	r	.	.	.	+	.	.	.	.
Scorzonera purpurea	1	2	.	1	.	.	.	.	.	.	.	.	.	.	.
Hieracium echioides	1	.	1	+	.	.	.	.	.	.	.	.	.	.	.
Centaurea stoebe	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.
Galium album	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+
Filipendula vulgaris	.	.	.	.	.	.	.	.	.	.	+	.	.	+	1
Poa bulbosa	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thesium linophyllon	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachypodium pinnatum	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex praecox	.	+	+	.	.	.	.	.	.	.	2	.	.	.	.

Centaurea scabiosa 1 (+), 3 (1), *Scabiosa canescens* 1 (1), 2 (+), *Centaurea stoebe* 7 (+), 8 (1), *Galium album* 13 (1), 15 (+), *Helianthemum nummularium* 1 (1), 6 (+), *Asparagus officinalis* 1 (1), 12 (+), *Achillea pannonica* 11 (1), *Stipa joannis* 2 (+), *Potentilla arenaria* 7 (r), *Allium oleraceum* 11 (+)

Ch. *Trifolio-Geranietea*															
Thalictrum minus	1	.	.	.	.	3	1	+	+		1	2	2	+	+
Geranium sanguineum	2	3	+	+	.	+	.	+	+	+	1	+	1	+	.
Peucedanum oreoselinum	3	3	1	2	+	.	+	1	+	+	2	2	2	1	1
Galium verum	1	.	.	.	+	.	+	+	1	.	1	.	.	.	.
Polygonatum odoratum	+	.	.	+	.	.	.	.	1	.	.	.	.	1	.
Melampyrum nemorosum	+	.	.	+	+	.	.	+	.	.	.	.	.	.	.
Anthericum ramosum	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.
Trifolium alpestre 1 (+), 4 (+), *Veronica teucrium* 1 (+), 5 (+), *Astragalus glycyphyllos* 6 (r), *Inula hirta* 2 (+)															
Ch. *Epilobietea angustifolii*															
Betula pendula b1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Betula pendula b2	.	.	.	.	.	.	+	+	1	+	+	.	+	+	.
Betula pendula c	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Sambucus nigra b2	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.
Sambucus nigra juv.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+
Populus tremula a1	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Populus tremula b1	3	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Populus tremula b2	.	.	.	.	.	.	+	+	.	.	.	.	+	.	+
Populus tremula juv.	+	.	.	.	.	+	.	.	.	.	.	.	1	.	.
Calamagrostis epigeios	+	2	1	2	2	3	3	2	3	4	2	1	.	.	.
Salix caprea b	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Ch. *Stellarietea mediae*															
Fallopia convolvulus	.	.	.	.	.+	+	.	.	.	.	+	1	1	1	1
Conyza canadensis	.	.	.	.	.	+	+	+	+	+	+	+	.	.	+
Galeopsis tetrachit	.	.	.	.	.	+	.	+	.	+	.	.	+	+	+
Viola arvensis	.	.	.	.	.	+	+	.	+	+	.	.	+	.	.
Silene vulgaris	+	.	.	.	.	.	.	+	.	+	.	.	.+	.	.
Stellaria media 12 (1), 15 (1), *Crepis tectorum* 7 (+), *Galeopsis speciosa* 10 (+), *Lamium amplexicaule* 12 (+), *Galinsoga parviflora* 15 (+)															
Ch. *Artemisietea vulgaris*															
Urtica dioica	.	.	.	.	.	+	+	.	.	2	.	1	1	+	+
Fallopia dumetorum	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.
Melandrium album	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.
Alliaria petiolata	.	.	.	.	.	+	.	.	.	.		+	.	.	+
Linaria vulgaris	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.
Chenopodium album 10 (+), *Oenothera biennis* 3 (+), *Anthriscus sylvestris* 15 (+), *Carduus crispus* 15 (+)															
Ch. *Molinio-Arrhenatheretea*															
Rumex acetosa	.	.	.	.	.	+	.	.	.	+	1	+	+	.	+
Poa pratensis	+	.	.	2	.	.	.	.	.	.	.	.	1	.	.
Galium boreale	1	+	.	.	+	+	.	.	+	+	+	.	.	.	.
Betonica officinalis	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.
Achillea millefolium	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.
Iris sybirica 5 (1), 10 (+), *Arrhenatherum elatius* 1 (+), 4 (+), *Knautia arvensis* 1 (+), 11 (+), *Dactylis glomerata* 6 (+), 7 (+), *Cerastium holosteoides* 6 (+), 7 (+), *Taraxacum officinale* coll. 13 (+), 15 (+), *Pimpinella major* 1 (+), *Agrostis gigantea* 1 (+), *Carex gracilis* 5 (+), *Polygonum bistorta* 5 (+), *Alopecurus geniculatus* 9 (+), *Campanula patula* 10 (+), *Galium mollugo* 10 (+), *Serratula tinctoria* 10 (+)															

Ch. *Querco-Fagetea*															
Padus avium b2	.	.	.	.	.	.	.	.	+	+	.	+	.	+	.
Ulmus minor juv. 12 (+), *Polygonatum multiflorum* 12 (+), *Viola reichenbachiana* 13 (+), *Euonymus europaea* juv. 14 (+), *Acer platanoides* juv. 15 (+)															
Ch. *Koelerio-Corynephoretea*															
Koeleria glauca	+	2	2	.	.	.	.	+	.	.	.	.	.	.	.
Thymus serphyllum	+	+	2	.	.	.	.	.	.	.	.	.	.	.	.
Corynephorus canescens	.	.	2	.	.	.	.	2	.	.	.	.	.	.	.
Cerastium semidecandrum	.	.	.	.	.	+	2	+	+	.	.	.	.	.	.
Sedum acre	.	+	+	.	.	.	+	+	.	.	.	.	.	.	.
Helichrysum arenarium	.	.	+	.	.	.	+	.	.	.	.	+	.	.	.
Agrostis capillaris	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.
Armeria maritima ssp. *elongata* 1 (+), *Rumex acetosella* 11 (+)															
other species															
Festuca trachyphylla	3	3	2	4	+	+	1	2	1		3	2	.	.	.
Poa angustifolia		.	.	.	.	1	1	+	3	2	.	.	.	.	.
Sedum maximum	+	+		+	.	+	+	+	+	.	1	1	1	1	1
Hypericum perforatum	.	.	.	.	.	.	+	.	.	1	+	+	+	.	+
Convallaria majalis	1	.	.	.	.	+	.	.	.	+	.	+	.	.	.
Cardaminopsis arenosa	.	.	.	.	.	.	.	.	.	+	.	1	+	.	+
Deschampsia flexuosa	.	.	.	.	.	.	.	.	.	.	4	2	.	.	1
Vincetoxicum hirudinaria	+	.	.	.	.	+		+	+	.	.	.	+	+	.
Pulsatilla pratensis	2	1	+	.	.	.	.	+	+		.	.	.	.	.
Phragmites australis	.	.	.	.	+	.	.	.	.	1	.	.	+	.	.
Solidago virgaurea	.	.	.	.	.	.		+	+	.	+	.	.	.	.
Solanum dulcamara	.	.	.	.	.	.	+	.	.	.	.	+	.	+	.
Hieracium umbellatum	.	.	.	.	.	.	.	.	+	+		.	+	.	.
Quercus robur b2	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.
Quercus robur juv.	+	.	.	.	.	.	.	.	.	.	.	+	+	+	+
Cladonia pyxidata	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.
Cladonia arbuscula	.	3	3	.	.	.	.	.	.	.	.	.	.	.	.
Camptothecium lutescens	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.
Ceratodon purpureus	.	.	.	.	.	.	1	3	.	.	.	.	.	.	.
Brachythecium sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Peltigera rufescens	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Peltigera canina	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Mnium sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Calamagrostis arundinacea 4 (1), 5 (1), *Salix repens* ssp. *rosmarinifolia* 5 (2), *Salvia pratensis* 1 (+), 2 (1), *Linosyris vulgaris* 1 (2), 2 (+), *Potentilla erecta* 1 (+), *Calluna vulgaris* 4 (+), *Viola canina* 10 (+), *Scorzonera humilis* 4 (1), 9 (+), *Frangula alnus* juv. 14 (+), 15 (+), *Prunus spinosa* b1 1 (+), *Rhamnus cathartica* b1 1 (+), *Cornus sanguinea* b2 13 (+), *Viscaria vulgaris* 9 (+), *Vicia* sp. 1 (+), *Linum perenne* 1 (+), *Vaccinium myrtillus* 4 (+), *Capsella bursa-pastoris* 7 (+), *Hypochoeris maculata* 8 (+), *Oenothera* sp. 8 (+), *Veronica chamaedrys* 11 (+), *Mycelis muralis* 13 (+), *Dryopteris carthusiana* 13 (+), *Padus serotina* juv. 14 (+), *Campanula rotundifolia* (+)

Explanations: r – very rare; nd – non determined

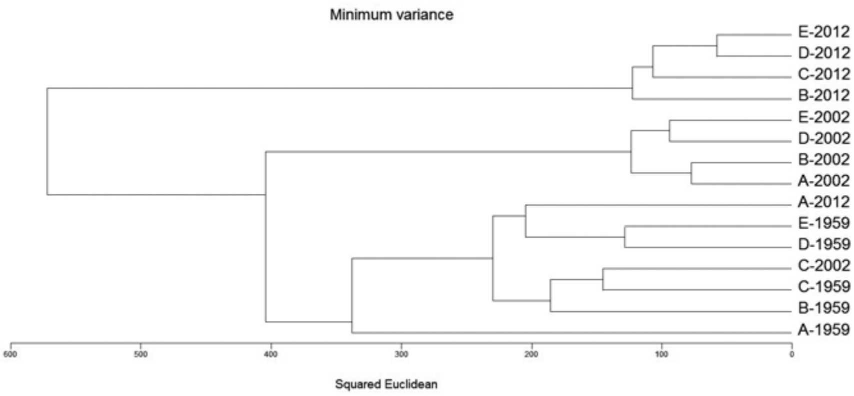

Figure 6. Dendrogram constructed with the minimum variance method for the time sequence of relevés made on permanent plots in 1956–1964 (the xerothermic grassland phase), and 2002 and 2012 (pine plantation phases)

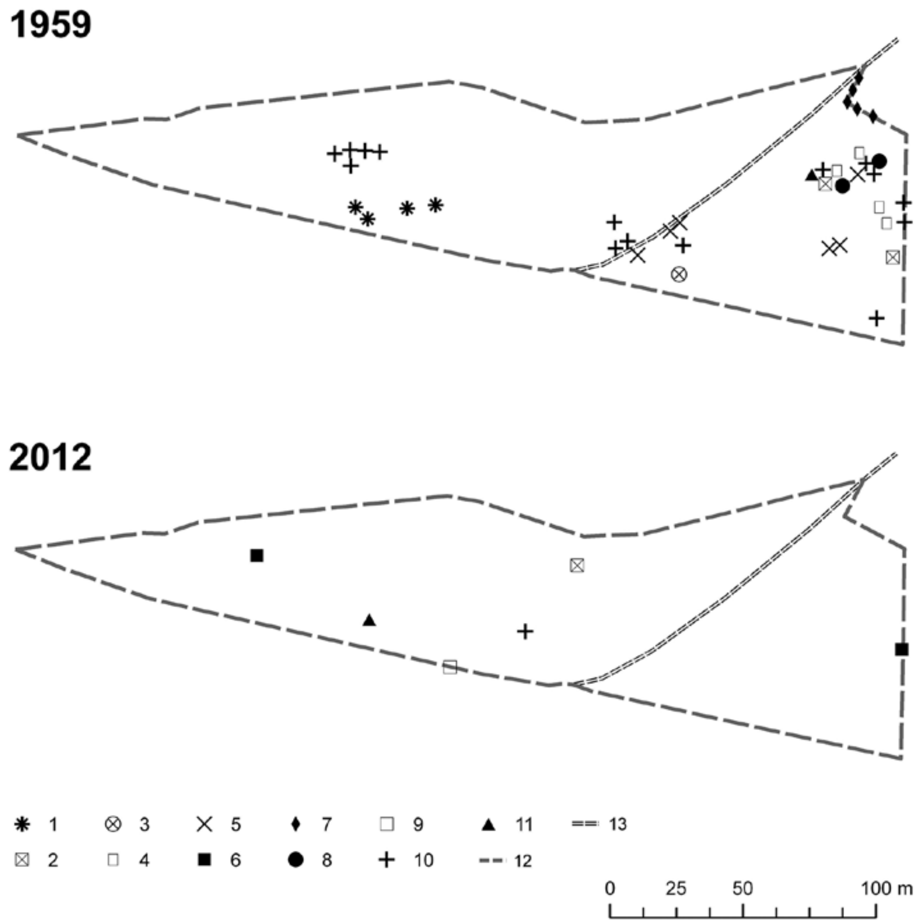

Figure 7. Spatio-temporal changes in the location of selected plant species in 1959 and 2012. Explanations of symbols: 1 – *Anemone sylvestris*, 2 – *Inula hirta*, 3 – *Iris sibirica*, 4 – *Linosyris vulgaris,* 5 – *Linum perenne*, 6 – *Peucedanum cervaria,* 7 – *Pulmonaria angustifolia*, 8 – *Scabiosa canescens*, 9 – *Seseli minima*, 10 – *Stipa joannis,* 11 – *Thesium linophyllon*, 12 – boundary of the study area, 13 – road

sis tetrahit, *Urtica dioica* and *Rumex acetosa* (Table 2). Helophytes, including *Thalictrum minus* and *Geranium sanguineum*, *Peucedanum oreoselinum*, and psammophilous grasses, e.g. *Bromus inermis* or *Calamagrostis epigejos* developed in places with less dense pine cover and larger gaps in the canopy. This mostly homogenous cluster consisting of four relevés is connected with the subset of 11 relevés at a high value of the squared Euclidean distance.

The presented changes in the land-use methods and the intentional changes in the vegetation resulted in major changes in the flora of the studied hill. On her map from 1959, Wilkoń-Michalska plotted also the occurrence of some species at the Folusz study site. Distribution of eleven species was marked inside the contours of the site boundaries (Fig. 7, the upper map). Those are species which do not occur in 2012, i.e. *Anemone sylvestris*, *Iris sibirica*, *Linosyris vulgaris*, *Linum perenne*, *Pulmonaria angustifolia*, as well as the former and present-day location of *Scabiosa canescens*, *Seseli minima*, *Stipa joannis* and *Thesium linophyllon*, and the present location of *Peucedanum cervaria* (Fig. 7, the lower map). The last species was not observed in 1959.

From the analysis of relevés collated in Table 2, it appears that other significant species occurring at the Folusz site in 1959, which were not found in 2012, include: *Hieracium echioides*, *Pulsatilla pratensis* and *Scorzonera purpurea*. They occurred in relevés A-1959, B-1959, C-1959 and D-1959, and the location of these relevés at the site of Folusz is presented in Figure 4.

In taxonomic studies conducted in the 1960s and the 1970s by Ceynowa-Giełdon (1976), the population of *Stipa joannis*, at present withdrawing from the site in Folusz, was characterized by the highest distinctiveness compared to the populations of this species at other locations in Poland. On this basis, Ceynowa-Giełdon (1976) distinguished *Stipa joannis* var. *cujavica*, probably endemic to Kujawy.

Based on the analysis of the notes made by J. Wilkoń-Michalska and J. Ceynowa, and papers published by Wilkoń-Michalska and Bohr (1960) and Ceynowa (1968), it was concluded that in 1959–1964, a total of 152 vascular species occurred at the site in Folusz. Whereas Ratyńska in her report on i.a. the flora in 2001 and 2002 (Banaszak et al. 2004) on the hill and partially in the surrounding meadows, listed 216 taxa. After excluding the species occurring in the surroundings, the list for the hill included 194 taxa. Thus, compared to Ratyńska's adjusted list of the flora from the Folusz hill (Banaszak et al. 2004), the number of taxa was reduced by 42. Based on the comparison of the flora in 2001/2002 with the lists of species reported for the Folusz hill until 1935 (Spribille 1887; Miller 1902; Bock 1908; Urbański 1935), Ratyńska confirmed the disappearance of 20 species. The absence of 10 species was also reported by Wilkoń-Michalska in her study conducted between the late 1950s and the early 1960s. Her notes include only information about 10 other species. Our research conducted in 2012 proved the occurrence of two species (*Linosyris vulgaris* and *Thesium linnophyllon*), which were found both before 1935 and by Wilkoń-Michalska. Although the site with *Linum perenne* was described from Folusz by Wilkoń-Michalska and Bohr (1960), the species was not found during our study and was not included on the list made by Ratyńska (Banaszak et al. 2004). Furthermore, species: *Inula hirta*, *Seseli perennae* and *Silene otites* observed by Wilkoń-Michalska in 1956–1964, were not on the list of Ratyńska (Banaszak et al. 2004). The first two species were observed by us in 2012, whereas neither of the three species was present in the source material from 1887–1935.

5. Discussion and conclusions

Based on the performed analysis, it was found that sand exploitation triggered off major changes in the flora and vegetation covering the Folusz dune hill. It contributed to the maintenance of pioneer plant communities, such as *Corynephoretum.* The delay in the designation of the nature reserve and consequently, no decision about the legal protection favoured the long-term exploitation of the ground. Exploitation was interrupted not by a legal statute, but by the process of partial afforestation of the hill and in particular the sand mine, implemented by the Forest Division of Szubin.

Pine plantations have led to homogeneity of the vegetation cover over a relatively large area and a decline in the species diversity. In young pine stands, mainly on less fertile habitats, usually only few species occur in the herb layer. Such an effect was observed in the plantations established in Folusz. We have observed a similar effect leading to the disappearance of many species (including the protected ones) also in other areas, e.g. on the Zadroże Dune near the city of Toruń (Nienartowicz et al. 2010). Afforestation was probably the main cause of the loss of several species at the site in Folusz, including rare, endangered and protected species, which although dominated in the determined collection of taxa but were not found by Ratyńska (Banaszak et al. 2004).

On the other hand, favourable conditions (not observed in the past) for penetration of new plant species were created in the studied area by human activity. New species include mostly apophytes and their encroachment is facilitated by i.e. transportation of crops from meadows and arable fields to farmsteads and delivery of raw material to the mill via the road cutting through the study area. The threat posed by this factor was also indicated by Ratyńska (Banaszak et al. 2004) who reported that most of the alien plants are found along the roadside.

Despite the land-use treatments carried out on the Folusz hill and the infrastructure consisting of the road cutting through the study area and the mill operating in the vicinity, several rare, endangered and protected species have been preserved in this area. The following protected species were found in 2012: *Pulsatilla pratensis*, *Stipa joannis* and *Helichrysum arenarium*.

This paper presents only a small fraction of data related to comparisons of flora occurring at the site of Folusz in the 20th and 21st century. The complete lists of vascular plant species occurring in subsequent periods, based on which we can determine i.a. which of the species recorded by Wilkoń-Michalska in 1956–1964 were not recorded by Ratyńska in 2001–2002 and which species were found during our field research in 2012, will be presented in a separate paper.

Despite a destructive impact exerted by the local human population at the site of Folusz, some rare and endangered plant communities occurred until 2001–2002. According to the list of syntaxa prepared by Ratyńska, they included thickets with *Salix rosmarinifolia*, *Potentillo albae-Quercetum*, *Corniculario-Corynephoretum*, *Festuco-Koelerietum glaucae*, *Trifolio-Melampyretum nemorosi*, *Sileno otitae-Festucetum trachyphyllae*, or *Armerio elongatae-Festucetum ovinae*. Some of them belong to habitat types protected by the Regulation of the Minister of the Environment dated 14 August 2001. In 2013, the above-mentioned plant communities were not observed, their developmental stages were merely similar to typical forms of an association or covered too small area to be mapped according to the scale applied.

The floristic and phytosociological analysis of changes occurring during the last several years revealed that the designation of the Natura 2000 site „*Molinia* meadows in Folusz" and the incorporation of the study site effectively protected the vegetation growing on the hill from the human impact. The positive effects of the undertaken protection measures include re-occurrence of the protected species *Linosyris vulgaris* and the rare species *Thesium linophyllon* (according to the Regulation of the Minister of the Environment dated 3 September 2001), which has not been observed by Ratyńska during her fieldwork conducted in 2001–2002.

In order to protect the vegetation covering the Folusz hill, measures have already been undertaken and consisted in the designation of the Natura 2000 site and ex situ protection of some species as reported by Ratyńska. It is active protection, however, which determines the preservation of valuable species and plant communities. It should rely on prevention of spontaneous encroachment of woody vegetation and excessive sodding caused mostly by *Calamagrostis epigejos* (Banaszak et al. 2004). Prevention of land afforestation should include removal of Scots pine plantings. The positive effects of such treatments are evidenced by observations carried out in certain nature reserves with planted trees removed, and they were described, for instance, by Dzwonko and Loster (1998a, b). Removal of woodlots at the site of Folusz should not, however, apply to oak trees growing on the studied hill. Perhaps grazing, which is applied in open areas with scattered trees, could be an effective form of active protection of the vegetation on the hill.

The analysis performed on the basis of old and new material has allowed us to realize the effectiveness of observations on floristic and phytosociological changes conducted on permanent research plots, and usefulness of numerical classification methods for assessing the extent of changes. These relevés should be made over the area of equal size. Although the present study clearly shows the differences between the subsets prepared in different periods despite the fact that relevés were made at sites of different size, similarities or differences can be assessed more precisely using the same area of relevés. In addition, the result of numerical classification presented in this study was also affected by the fact that relevés were made by different persons.

As evidenced by Dzwonko and Loster (1990, 1992, 1998a, b), the methods of numerical classification are useful for analysis of grassland vegetation changes monitored at protected sites on permanent research plots, also after active conservation had been applied consisting in removal of trees. Our intention is to conduct further observations of vegetation changes on the Folusz hill with a larger number of plots applying numerical classification methods, including techniques applied by the aforementioned authors.

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