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Xerothermic grasslands of Pilica surroundings – diversity, threats and directions of changes

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Abstract: Xerothermic grasslands from three stands in the surroundings of the town of Pilica in the Kraków-Częstochowa Upland were investigated. It was ascertained that they represent two phytosociological units: *Adonido-Brachypodietum* (with two variants) and *Silene otites-Thymus austriacus* community. Moreover, phytocoenoses with a high contribution of xerothermic plants (*Thymus-Anthyllis vulneraria* community) were found in some places on the abandoned fields. On the basis of the comparison of new data and old phytosociological relevés, only slight changes over 30 years were observed. The differences concerned mostly the coverage of particular species. However, some plants disappeared and other were new (e.g. seedlings of trees and shrubs). Generally, these species were not too frequent and had inconsiderable cover. The changes which occurred manifested themselves also in the differences of mean values of some ecological indicators and in the increase of competitors, as well as clonal species.

Key words: xerothermic vegetation, *Festuco-Brometea*, secondary succession, threats to grasslands, Kraków-Częstochowa Upland

1. Introduction

Xerothermic grasslands are endangered and vanishing plant communities in entire Europe (Willems 1982, 1990; Hutchings & Stewart 2002), including the territory of Poland (Michalik 1990c; Michalik & Zarzycki 1995). Changes in agriculture which result in prevailing cessation of pasturage are the reason of such situation. Semi-natural xerothermic grasslands of the *Cirsio-Brachypodion* alliance underlie succession processes which gradually lead to development of scrub communities, followed by forest communities. These processes were observed and described both in the territory of Poland (Michalik 1990a, 1990b; Kapuściński 1990; Sendek & Babczyńska-Sendek 1990; Świerczyńska 1990; Fijałkowski & Świerczyńska 1991; Poznańska 1991; Załuski 2002; Rutkowski *et al*. 2004; Babczyńska-Sendek 2005b) and in many other European countries (e.g. Ward & Jennings 1990a, 1990b; Poschold & Wallis DeVries 2002; Poschold *et al*. 2005; Butaye *et al*. 2005).

The Kraków-Częstochowa Upland is one of these regions of Poland where xerothermic grasslands are an essential element of vegetation (Kozłowska 1928; Medwecka-Kornaś & Kornaś 1963; Babczyńska 1978; Michalik 1980; Babczyńska-Sendek 1984; Wika 1986). Simultaneously, it underlies unfavorable successional changes which have been especially rapid in recent decades (Dzwonko & Loster 1990, 1992; Michalik 1990a, 1990b, 2009; Bąba 2002/2003; Hereźniak 2004; Medwecka-Kornaś 2006; Babczyńska-Sendek *et al*. 2006; Sołtys & Barabasz-Krasny 2006; Sołtys-Lelek 2009).

Pilica is a little town situated in the eastern margin of the Częstochowa Upland, one of the mezoregions of the Kraków-Częstochowa Upland (Kondracki 2001). The landscape of its surroundings is different from what is specific for the majority of the Upland. There is a lack of rocky outcrops and its characteristic elements are an undulating plateau and distinctly incised valley of the upper Pilica river with dry branch valleys. Upper Jurassic limestones are covered by a loess layer of varying thicknesses (Bednarek *et al*. 1978).

The whole area is typically rural. The majority of it and especially the undulating plateau is occupied by arable fields, whereas on the flat bottom of the Pilica valley, hay meadows dominate. The greater part of them is intensively used. The xerothermic grasslands developed only in some places on the southern and western slopes of the Pilica valley or on its branches, in steep sites,

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where there were no conditions for cultivation and where grazing took place. These communities were not pastured for a long time and this is the reason of their changes observed at present.

The aim of the research was to present the current diversity of grasslands in the vicinity of Pilica, to show their changes during about 30 years, to point out the main threats as well as probable directions of changes of xerothermic vegetation in the nearest future.

2. Material and methods

The present study is based on phytosociological studies carried out in grassland vegetation in the vicinity of Pilica in the years 2007-2009. Moreover, 12 old phytosociological relevés from the period 1979-1980 (Babczyńska-Sendek 1984) were taken in order to present changes in these grasslands.

2.1. Study sites

In both mentioned periods, the research was conducted in xerothermic grasslands in the following three sites (Fig. 1):

- **Pilica (1. Site)**. Scarps on the slopes of a dry, lateral valley which is the right branch of the initial section of the Pilica river valley. These escarpments are steep (30-60°) but generally not very high. In many places, the soils are very skeletal, even in the upper layer. The exposure of the slopes is predominantly south-western but only a small fragment of the scarps is directed towards north-west. At present, they are close to arable fields at the plateau and to fallows and a single-family housing underneath the slopes.
- **Dobra (2. Site)**. The slopes of the other dry lateral valley, north-west of Kolonia hamlet. The escarpments are higher and the soils are less skeletal than in the first locality. The majority of the slopes are facing south-west; only a small fragment is oriented towards north-west. In the vicinity of them, there are some arable fields at the bottom of the valley and partially on the plateau. The remaining part of the plateau is covered by abandoned fields.
- **Wierbka (3. Site)**. The steep, south-facing slope of the Pilica valley in the western part of Wierbka, near a small quarry. The inclination of the slope varies from 15° at the bottom, to nearly 40° in the medium part and 30° close to the top part. The upper layers of the soil are also less skeletal than in Pilica. The Jurassic limestones are covered by a thin layer of loess visible at the outcrop in the quarry. In the surroundings, there are some buildings and the lower part of the slope was formerly an arable field, whereas the plateau is covered by woodlots with abundant occurrence of *Quercus rubra*.

Moreover, the present phytosociological research took into account some patches of communities with high contribution of xerothermic species. They developed within abandoned fields in the neighbourhood of the above-mentioned grasslands and also close to the Syberia – hamlet of Cisowa village, eastwards from Pilica.

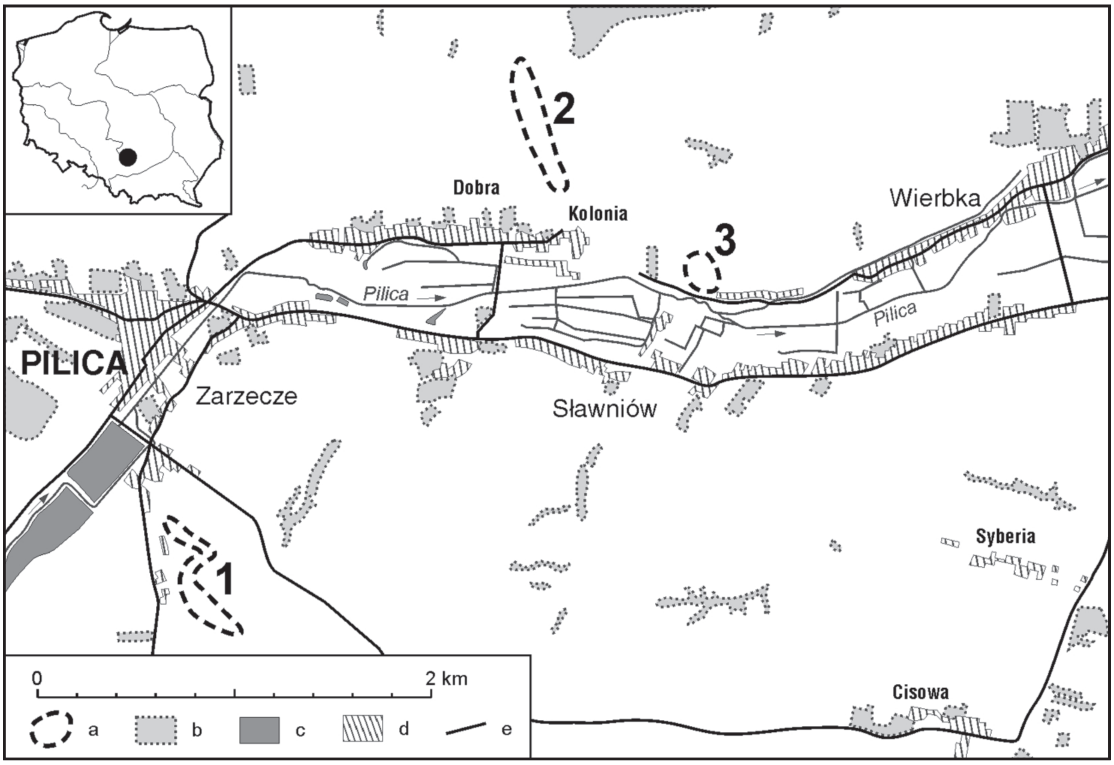

Fig. 1. Localization of xerothermic grasslands in the vicinity of Pilica
Explanations: a – patches of investigated grasslands, b – forests and woodlots, c – water reservoirs, d – built-up areas, e – roads

2.2. Field methods and data analysis

In periods: 1979-1980 and 2007-2009 phytosociological relevés were made using Braun-Blanquet's method, mostly at plots of 50 m^2, rarer of 30 or 40 m^2 areas. The current diversity of xerothermic grasslands from the Pilica surroundings is presented in the synoptic table including 31 new phytosociological relevés. The syntaxonomical affiliation was adopted after Matuszkiewicz (2001) and, in the case of the *Cirsio-Brachypodion* alliance, after Filipek (1974). The names of plant species follow Mirek *et al.* (2002).

In order to study changes in grassland phytocoenoses caused by cessation of pasturage, the species composition of old and new phytosociological relevés was compared. Due to the fact that there were fewer old relevés, the new ones were selected in such a way, that the number of relevés to be compared was similar. The chosen relevés were taken in approximately the same places or, at least, in the same parts of slopes. From Pilica, 6 old and 6 new relevés were included, from Dobra – 5 relevés from each period and from Wierbka – 1 old and 1 new relevé. In order to show changes over the 30-year-period, the floristic composition and quantitative participation of species in old and new investigated phytocoenoses were presented in Table 2. Moreover, old and new phytosociological relevés from Pilica and Dobra were arranged along the first and second axes of Principal Components Analysis (PCA) (Jongman *et al.* 1995; ter Braak & Šmilauer 2002). The materials from Pilica and Dobra were analyzed separately and only presence-absence data were subjected.

Furthermore, vascular plant species occurring in the grasslands of Pilica surroundings were analyzed in terms of their habitat requirements and selected characteristic features of their biology. The Ellenberg indicator values for light (L), moisture (F), soil reaction (R) and nitrogen (trophy) (N) (Ellenberg *et al.* 1991), life strategies (Grime 1979) and life forms (Zarzycki *et al.* 2002) were taken into account. The resistance to grazing (www.ufz.de/biolflor/index.jsp), the growth form (annual, biannual, perennial) (Szafer *et al.* 1976) and the way of reproduction, especially the ability of vegetative reproduction and the presence of rhizomes or stolons (www.ufz.de/biolflor/index.jsp, www.ecoflora.co.uk) were also analyzed. On the basis of the above-mentioned plant traits, vascular plant species were classified into three groups: (*i*) non-perennial (annual and biennial) reproducing only sexually, (*ii*) perennial (perennials, shrubs and trees) propagating using seeds, (*iii*) clonal species which are capable of reproducing in a vegetative way. Next, the floras of grassland communities from particular stands were compared in relation to mean Ellenberg indicator values, resistance to grazing and participation of specific groups of species.

3. Results

3.1. Geobotanical values of grasslands

3.1.1. Phytosociological diversity

The analysis of the phytosociological material from years 2007-2009 revealed that grassland phytocoenoses in the vicinity of Pilica were slightly diversified (Table 1). It was connected with the isolation of these patches (they were distant from each other and surrounded by arable fields, fallows or buildings) as well as with certain habitat differences occurring in grasslands on particular slopes. All grassland communities represent the *Cirsio-Brachypodion* alliance. The majority of them can be classified as the *Adonido-Brachypodietum* association, which represents its south-eastern-Jurassic geographical variety (Babczyńska-Sendek 1984). Some grassland phytocoenoses from Wierbka were included into a separate unit in the rank of plant community. Moreover, some phytocoenoses with high percentage of xerothermic species, developed on abandoned fields which were situated not far from xerothermic grasslands. These patches were classified as separate plant community. The systematics of the distinguished communities, is presented below:

Class: *Festuco-Brometea* Br.-Bl. et R. Tx. 1943
- Order: *Festucetalia valesiacae* Br.-Bl. et R. Tx. 1943
  - Alliance: *Cirsio-Brachypodion pinnati* Hadač et Klika 1944 em. Krausch 1961
    - *Silene otites-Thymus austriacus* community
    - *Adonido-Brachypodietum pinnati* (Libb. 1933) Krausch 1961
      - *A.-B.p.* variant with *Dianthus carthusianorum*
      - *A.-B. p.* variant with *Carex flacca*
    - *Thymus-Anthyllis vulneraria* community

Silene otites-Thymus austriacus community

Some patches of xerothermic grassland from the slope in Wierbka were classified to this community. They were characterized by low percentage of *Brachypodium pinnatum* but *Phleum phleoides* – another xerothermic grass – played a higher role here. Also three species of thyme (*Thymus austriacus*, *Th. glabrescens* and *Th. pulegioides*) as well as other short forb species (*Hieracium pilosella*, *Euphorbia cyparissias*, *Fragaria viridis*, *Anthyllis vulneraria*) scored the highest cover-abundance. Moreover, *Silene otites* was recorded only in phytocoenoses of this community. Patches of the above-mentioned grassland overgrew the middle and lower parts of high slope in Wierbka with the inclination of 15-20° and, exceptionally, of 40°. Some of them, in the bottom part of the slope, could have been an arable field in the past.

Table 1. Floristic differentiation of present-day grassland communities from Pilica surroundings

Number of a table	1	2	3	4
Type of site	Xerothermic grasslands			Abandoned fields
Association or community	*Silene otites - Thymus austriacus*	*Adonido-Brachypodietum*		*Thymus-Anthyllis vulneraria*
Variant with		*Dianthus carthusianorum*	*Carex flacca*	
Number of relevés in the table	4	5	12	10
I. D. association, community and variants:				
Thymus pulegioides	4 [1200]	II [110]	III [21]	III [1250]
Galium verum	4 [475]	III [460]	III [21]	.
* *Centaurea stoebe*	4 [40]	II [20]	.	II [230]
* *Artemisia campestris*	4 [40]	I [10]	.	.
* *Silene otites*	3 [38]	.	.	I [5]
Euphrasia stricta	3 [38]	.	.	I [55]
* *Thymus austriacus*	4 [1088]	V [140]	II [12]	II [185]
* *Phleum phleoides*	4 [700]	IV [560]	I [8]	III [1675]
* *Dianthus carthusianorum*	4 [265]	V [480]	.	II [555]
Hieracium pilosella	3 [1000]	III [120]	I [8]	III [25]
* *Carex caryophyllea*	2 [138]	IV [400]	I [8]	III [115]
Silene vulgaris	2 [138]	II [20]	.	I [5]
* *Viola rupestris*	1 [125]	II [20]	.	I [5]
* *Koeleria macrantha*	1 [438]	I [10]	.	.
* *Veronica spicata*	2 [562]	V [570]	III [104]	II [530]
* *Pimpinella saxifraga*	1 [12]	III [30]	I [1]	II [110]
° *Brachypodium pinnatum*	2 [562]	V [5750]	V [6250]	IV [960]
* *Medicago falcata*	3 [38]	V [1220]	V [958]	III [70]
Carlina acaulis	.	IV [130]	V [1188]	II [235]
* *Helianthemum nummularium* subsp. *obscurum*	1 [125]	IV [810]	V [554]	I [10]
* *Asperula cynanchica*	2 [25]	IV [470]	IV [288]	II [230]
* *Poa angustifolia*	.	II [20]	III [200]	II [60]
Convolvulus arvensis	.	II [20]	III [62]	I [10]
° *Potentilla heptaphylla*	.	I [10]	II [12]	II [20]
Dactylis glomerata	.	II [20]	I [8]	II [16]
* *Allium oleraceum*	.	I [10]	II [12]	.
° *Melampyrum arvense*	.	I [100]	I [146]	III [450]
Peucedanum oreoselinum	.	I [750]	I [46]	II [775]
° *Anthericum ramosum*	.	I [100]	I [146]	.
* *Chamaecytisus ratisbonensis*	.	I [10]	I [46]	I [55]
* *Galium album*	1 [12]	III [460]	V [408]	IV [35]
Knautia arvensis	1 [12]	II [110]	V [121]	IV [170]
Carex flacca	.	.	V [117]	II [105]
* *Agrimonia eupatoria*	3 [38]	.	V [83]	IV [545]
Linum catharticum	3 [38]	III [30]	V [42]	IV [35]
Primula veris	.	.	IV [358]	I [5]
Leucanthemum vulgare	.	.	IV [71]	I [50]
° *Peucedanum cervaria*	.	.	III [1025]	I [5]
° *Filipendula vulgaris*	.	.	III [462]	.
Betonica officinalis	.	.	III [283]	.
° *Campanula glomerata*	.	I [10]	III [104]	III [195]
Carex montana	.	I [10]	III [96]	.
Trifolium pratense	.	.	III [25]	.
Prunella vulgaris	.	.	III [22]	I [5]
Inula salicina	.	.	II [542]	.
Centaurea jacea	.	.	II [92]	I [10]
* *Campanula sibirica*	.	.	II [17]	I [180]
° *Trifolium montanum*	.	.	II [17]	.
Arrhenatherum elatius	3 [38]	I [100]	I [4]	V [985]
Picris hieracioides	.	.	I [8]	III [365]
II. Ch.*_Festuco-Brometea_ (°_Cirsio-Brachypodion_):				
Euphorbia cyparissias	4 [1125]	V [140]	V [158]	V [860]
Sanguisorba minor	4 [50]	V [140]	V [83]	IV [480]
Thymus glabrescens	4 [1012]	V [570]	IV [254]	IV [1530]
° *Fragaria viridis*	4 [700]	V [230]	IV [75]	IV [980]
Coronilla varia	4 [50]	V [140]	IV [34]	IV [130]
Scabiosa ochroleuca	4 [50]	V [50]	IV [34]	IV [175]
Anthyllis vulneraria	3 [1812]	V [140]	III [554]	V [1760]
° *Seseli annuum*	4 [50]	IV [40]	IV [212]	II [65]
Centaurea scabiosa	4 [1438]	II [110]	IV [392]	IV [385]

Table 1 (cont.)

Number of a table		1	2	3	4
Type of site			Xerothermic grasslands		Abandoned fields
Association or community		*Silene otites -*	*Adonido-Brachypodietum*		*Thymus-*
Variant with		*Thymus austriacus*	*Dianthus carthusianorum*	*Carex flacca*	*Anthyllis vulneraria*
Number of relevés in the table		4	5	12	10
° *Plantago media*		3^{262}	II^{200}	IV^{458}	III^{285}
Salvia verticillata		1^{12}	II^{20}	III^{133}	II^{400}
° *Polygala comosa*		1^{12}	II^{12}	III^{18}	III^{30}
Achillea collina		4^{50}	I^{100}	III^{21}	V^{95}
Carlina vulgaris		3^{38}	II^{20}	II^{12}	II^{20}
Thalictrum minus		1^{438}	I^{10}	I^{4}	.
° *Viola hirta*		.	I^{100}	II^{129}	I^{6}
III. The others:					
Rosa canina	b/c	1^{12}	I^{10}	III^{104}	II^{60}
Briza media		4^{700}	V^{570}	V^{488}	V^{385}
Plantago lanceolata		3^{262}	III^{120}	II^{12}	IV^{345}
Leontodon hispidus		3^{575}	I^{10}	III^{58}	III^{415}
Festuca rubra		2^{25}	III^{460}	III^{358}	II^{385}
Lotus corniculatus		2^{25}	II^{20}	II^{12}	III^{285}
Hypericum perforatum		2^{25}	I^{10}	III^{29}	I^{5}
Medicago xvaria		1^{12}	I^{10}	I^{4}	I^{10}
Prunus spinosa		1^{12}	I^{10}	I^{8}	I^{5}
Echium vulgare		2^{15}	I^{10}	.	II^{15}
Crataegus monogyna		.	I^{2}	I^{42}	III^{70}
Daucus carota		2^{15}	.	.	III^{120}
Senecio jacobaea		2^{15}	.	.	III^{30}
Cornus sanguinea		1^{125}	.	.	II^{15}
Medicago lupulina		.	.	II^{17}	III^{200}
Vicia cracca		.	.	II^{54}	II^{20}

Species appear with I and II presence degree in 1 or 2 tables: II. *Ajuga genevensis* 2; *Bromus inermis* 1; *Orobanche elatior* 3; *O. lutea* 1; *Poa compressa* 3, 4; *Ranunculus bulbosus* 2, 3; *Verbascum lychnitis* 4; °*Veronica teucrium* 3. **III.** *Agrostis capillaris* 2, 3; *Alchemilla glaucescens* 3; *Avenula pubescens* 3; *Betula pendula* c 3(II); *Calamagrostis epigejos* 4; *Campanula persicifolia* 4; *C. rapunculoides* 3, 4(II); *Carex hirta* 4; *C. spicata* 4; *Carpinus betulus* c 3; *Centaurium erythraea* 3; *Cichorium intybus* 1, 4; *Cirsium arvense* 3; *C. vulgare* 4; *Clinopodium vulgare* 4; *Corylus avellana* c 2; *Crataegus monogyna* c 4; *Equisetum arvense* 4; *Euphorbia esula* 2, 3; *Erigeron acris* 4; *Festuca pratensis* 3; *Fraxinus excelsior* c 1; *Galium boreale* 3; *Juniperus communis* c 4; *Luzula campestris* 4; *Melilotus alba* 4; *M. officinalis* 4; *Myosotis arvensis* 4; *Origanum vulgare* 4; *Phleum pratense* 4; *Pinus sylvestris* c 3, 4; *Quercus robur* c 3, 4; *Q. rubra* c 2; *Ranunculus repens* 3; *Rubus caesius* 3; *Rumex acetosa* 4; *R. acetosella* 4; *Salix caprea* c 4; *Sedum acre* 4; *Sorbus aucuparia* c 2; *Trifolium alpestre* 2; *T. medium* 3, 4; *T. repens* 4; *Vicia hirsuta* 4; *Viola canina* 4

Adonido-Brachypodietum pinnati (Libb.1933) Krausch 1961

This is the association which was represented by the majority of grassland patches from the vicinity of Pilica. Their characteristic feature was high percentage of *Brachypodium pinnatum*. Other major components were some dicotyledonous plants with colorful flowers. The phytocoenoses of *Adonido-Brachypodietum* from Pilica surroundings revealed certain diversity which warranted identification of two variants: with *Dianthus carthusianorum* and with *Carex flacca* (Table 1).

The group of species shared with the *Silene otites-Thymus austriacus* community as well as higher contribution of *Veronica spicata* and *Pimpinella saxifraga* were observed in the patches of the first of them. They were rarer and usually occupied higher parts of the southern or south-western slopes, with inclination ranging from 15-35° (on the average, almost 30°). The phytocoenoses representing this variant were found on the scarps near Pilica and in Wierbka.

The patches classified as the variant with *Carex flacca* occupied the largest areas. They were distinguished by a group of numerous species. These were both species characteristic and differential of the *Cirsio-Brachypodion* alliance, as well as some meadow plants. The phytocoenoses of this variant were usually associated with south-western facing slopes or, rarely, western or even north-western slopes. They were quite steep – ca. 40° (30-60°).

Thymus-Anthyllis vulneraria community

The phytocoenoses which developed on abandoned fields, mostly in the vicinity of grassland patches, and which were made up of xerothermic species were classified to this community. Their floristic composition was quite diversified but among the most frequently encountered species (V and IV constancy degree), the majority (70%) was characteristic for the *Festuco-Brometea* class. Among them, there were also plants from the *Cirsio-Brachypodion* alliance. The participation of the *Festuco-Brometea* class species was also considerable (65%), if we take into account these with III constancy degree.

Table 2. Changes in the xerothermic grasslands of Pilica surroundings in the period 1979-2009

	Locality	Pilica		Dobra		Wierbka	
	Year	1980	2008	1980	2007	1979	2009
	Number of relevés in the table	6	6	5	5	1	1
	Number of species in the table or in one relevé	66	66	67	67	35	40
	Herbaceous plants:						
	Brachypodium pinnatum	V 5500	V 5833	V 5250	V 5750	4.4	4.5
	Helianthemum nummularium subsp. *obscurum*	V 400	V 550	V 480	V 570	2.2	2.2
	Briza media	V 192	V 683	V 320	V 500	2.2	1.1
	Convolvulus arvensis	IV 33	V 125	II 20	II 20	+	+
	Anthyllis vulneraria	II 17	III 25	II 20	III 210	+.2	+.2
	Carex flacca	II 92	III 25	III 120	IV 130	.	.
*	*Betonica officinalis*	II 10	II 167	II 20	III 120		.
	Potentilla heptaphylla	II 17	I 8	II 20	II 20	+	.
	Lotus corniculatus	I 8	I 8	II 20	II 20	.	.
	Salvia verticillata	V 192	V 192	II 200	II 110	.	.
	Chamaecytisus ratisbonensis	I 83	II 92	.	.	1.2	1.2
	Trifolium alpestre	I 8	I 83	.	.	.	.
*	*Filipendula vulgaris*	.	.	IV 470	IV 560	.	.
	Prunella vulgaris	.	.	IV 32	III 30	.	.
	Carlina vulgaris	.	.	III 112	III 30	.	.
	Campanula rapunculoides	.	.	I 10	II 20	.	.
*	*Galium boreale*	.	.	I 750	I 750	.	.
	Potentilla collina	.	.	.	.	+.2	+
*	*Galium album*	V 475	V 1050	III 30	V 140	.	+.2
	Thymus glabrescens	I 8	IV 467	III 210	IV 130	2.2	3.3
	Veronica spicata	I 8	III 458	I 10	III 30	+	1.1
*	*Seseli annuum*	.	II 17	III 14	V 50	.	+
*	*Asperula cynanchica*	.	I 8	V 140	V 480	.	1.2
*	*Knautia arvensis*	IV 33	V 200	III 30	V 140	.	.
	Primula veris	III 25	IV 392	.	IV 380	.	.
*	*Peucedanum cervaria*	II 375	III 1675	.	II 450	.	.
	Plantago lanceolata	.	III 100	.	I 10	.	.
*	*Medicago falcata*	V 267	V 2125	V 230	V 390	+.2	1.2
	Festuca rubra	II 17	V 708	I 100	I 350	+.2	1.1
	Poa angustifolia	.	V 325	.	I 10	1.2	+
	Agrimonia eupatoria	II 10	IV 33	IV 32	IV 130	.	.
	Phleum phleoides	.	III 175	.	.	+	1.2
	Dianthus carthusianorum	II 92	II 375	.	.	+.2	2.2
	Galium verum	.	II 17	II 20	II 20	1.2	2.1
*	*Viola hirta*	II 92	V 342	.	.	.	.
	Dactylis glomerata	.	IV 33	I 10	.	.	.
	Allium oleraceum	II 167	IV 33	.	.	.	.
*	*Peucedanum oreoselinum*	II 92	III 717	.	.	.	.
	Melampyrum arvense	.	II 375	.	.	.	.
	Agrostis capillaris	.	II 17	.	.	.	.
*	*Veronica teucrium*		I 8				
*	*Centaurea scabiosa*	I 8	I 8	III 30	IV 470	.	.
	Hypericum perforatum	II 17	III 25	I 10	IV 40	+	+
*	*Inula salicina*	.	.	.	III 1200	.	.
	Thymus pulegioides	.	I 8	I 100	III 30	.	+.2
	Centaurea jacea	I 8	.	.	II 110	.	.
	Carex montana	.	.	.	II 20	.	.
*	*Arrhenatherum elatius*	.	.	.	I 8	.	+
	Sanguisorba minor	V 408	V 117	V 500	V 50	1.2	+.2
	Linum catharticum	V 192	IV 33	V 230	V 50	+	.
	Leontodon hispidus	III 100	.	V 410	III 30	+.2	.
	Fragaria viridis	V 408	IV 183	IV 1060	IV 40	2.2	2.3
	Pimpinella saxifraga	V 200	III 18	IV 40	.	.	.
*	*Campanula glomerata*	III 667	II 17	IV 560	III 210	.	.
	Campanula sibirica	III 100	(+)	III 120	I 10	.	.
	Hieracium pilosella	III 93	.	III 30	I 10	+.2	+
*	*Daucus carota*	I 8	.	II 12	.	.	.
	Centaurea stoebe	I 8	.	I 10	.	.	+
	Trifolium pratense	III 12	I 8	III 30	III 30	+.2	.
	Allium vineale	III 93	.	.	.	.	.
	Campanula persicifolia	II 17	.	.	.	.	.
*	*Stachys recta*	II 17	.	.	.	.	+
*	*Polygala comosa*	II 17	.	III 22	III 22	.	+

Table 2 (cont.)

Locality	Pilica		Dobra		Wierbka	
Year	1980	2008	1980	2007	1979	2009
Number of relevés in the table	6	6	5	5	1	1
Number of species in the table or in one relevé	66	66	67	67	35	40
Acinos arvensis	I ^{8}	.	.	.	.	.
Anemone sylvestris	I ^{8}	.	.	.	.	.
Inula ensifolia	I ^{8}	(+)	.	.	.	.
Potentilla neumanniana	I ^{8}	.	.	.	.	.
Euphorbia cyparissias	V ^{192}	V ^{117}	V ^{820}	V ^{50}	+.2	2.3
Medicago lupulina	I ^{8}	.	V ^{230}	I ^{10}	.	.
Plantago media	IV ^{108}	III ^{383}	V ^{480}	III ^{30}	1.2	1.2
Thymus austriacus	IV ^{183}	IV ^{108}	III ^{460}	I ^{10}	1.2	1.2
Ranunculus bulbosus	II ^{17}	II ^{3}	III ^{30}	.	+	.
Picris hieracioides	.	.	III ^{22}	I ^{10}	.	.
Carex caryophyllea	III ^{25}	IV ^{183}	II ^{20}	.	+.2	+
Carex ericetorum	.	.	II ^{20}	.	.	.
Viola rupestris	.	.	I ^{2}	.	.	.
* *Koeleria macrantha*	.	.	.	.	2.2	+
Carlina acaulis	V ^{1125}	V ^{552}	III ^{460}	V ^{1250}	.	+.2
Coronilla varia	V ^{117}	III ^{100}	III ^{30}	V ^{50}	1.2	+.2
* *Leucanthemum vulgare*	III ^{100}	.	I ^{10}	V ^{50}	.	.
Scabiosa ochroleuca	III ^{25}	V ^{42}	V ^{50}	III ^{22}	+	1.1
Shrubs and trees:						
Rosa sp. div. c	I ^{8}	II ^{17}	.	III ^{120}	.	+.2
Crataegus monogyna	.	I ^{2}	.	I ^{100}	.	.
Pinus sylvestris	.	.	.	II ^{12}	.	.
Betula pendula	.	.	.	I ^{10}	.	.
Prunus spinosa	.	.	.	I ^{10}	.	.
Quercus robur	.	.	.	I ^{10}	.	+
Rubus caesius	.	I ^{8}	.	.	.	.

Explanations: (+) – means that species was observed outsite the phytosociologically investigated patches; * – species sensitive to grazing and species intolerant to sensitive to grazing (values of attribute of grazing tolerance 3 and 2 acording to Biolflor)

In the phytocoenoses of the above-mentioned community, two thyme species (*Thymus glabrescens* and *Th. pulegioides*), as well as some other species (*Anthyllis vulneraria*, *Fragaria viridis*, *Euphorbia cyparissias* and *Brachypodium pinnatum*) had high coverage. *Phleum phleoides* and *Peucedanum oreoselinum* were quite abundant in the patches which were situated at the foot of the scarps with grasslands in Pilica.

3.1.2. Rare elements of xerothermic flora

Xerothermic grasslands from Pilica surroundings are habitats for some rare and protected plant species. In total, eight protected species were found there. Seven of them (*Anemone sylvestris*, *Campanula sibirica*, *Carlina acaulis*, *Centaurium erythraea*, *Gentianella ciliata*, *Orobanche elatior* and *O. lutea*) are strictly protected and one (*Primula veris*) – partially protected (Regulation 2004). Apart from that, some other species, which are rare in the Kraków-Częstochowa Upland, were also recorded. First of all, these are species with the distribution centre in the south-eastern part of the Upland or species which are more frequent in this area (Urbisz 2004, 2008). These included: *Inula ensifolia*, *Koeleria macrantha*, *Thymus austriacus*, *Th. glabrescens*, *Trifolium alpestre*. Moreover, *Alchemilla glaucescens*, *Carex montana*, *Inula salicina* and *Silene otites* should also be mentioned.

3.1.3. Transformations of grassland vegetation of Pilica surroundings

On the basis of the preliminary observations of grassland vegetation in the three examined stands, it can be inferred that it was undergoing changes which were the result of the grazing cessation. On the slopes covered by grasslands, the area occupied by trees and shrubs increased. The smallest participation of trees and shrubs was observed on the scarps in Pilica. A small birch thicket was recorded in the lower part of the north-western slope. The single-family housing estate close to the escarpments is the highest threat to grasslands here. Some houses are placed even on slopes. In Dobra, especially in lower parts of the slopes, small birch woodlots formed. In spite of that, large patches of grasslands remained in their vicinity. Also in Wierbka, some penetration of trees into grasslands was observed. It was caused by former tree plantings on the plateau. Most of individual trees were noted in the upper part of the slope. However, the majority of the slope was covered by well-developed patches of grasslands.

The comparison of floristic composition and coverage of particular plant species in the contemporary patches of grasslands with analogous data from 1979-1980 made it possible to identify changes which took place in these communities as a result of a lack of grazing

(Table 2). It also allowed evaluation of the degree of their transformation and identification of the direction of changes.

On the basis of the synoptic table, it can be concluded that in the compared xerothermic grasslands from the scarps of Pilica, Dobra and Wierbka some changes took place but these communities did not alter significantly. The species composition of the analyzed grasslands changed only subtly. The total number of species remained equal but about 30% of them was replaced.

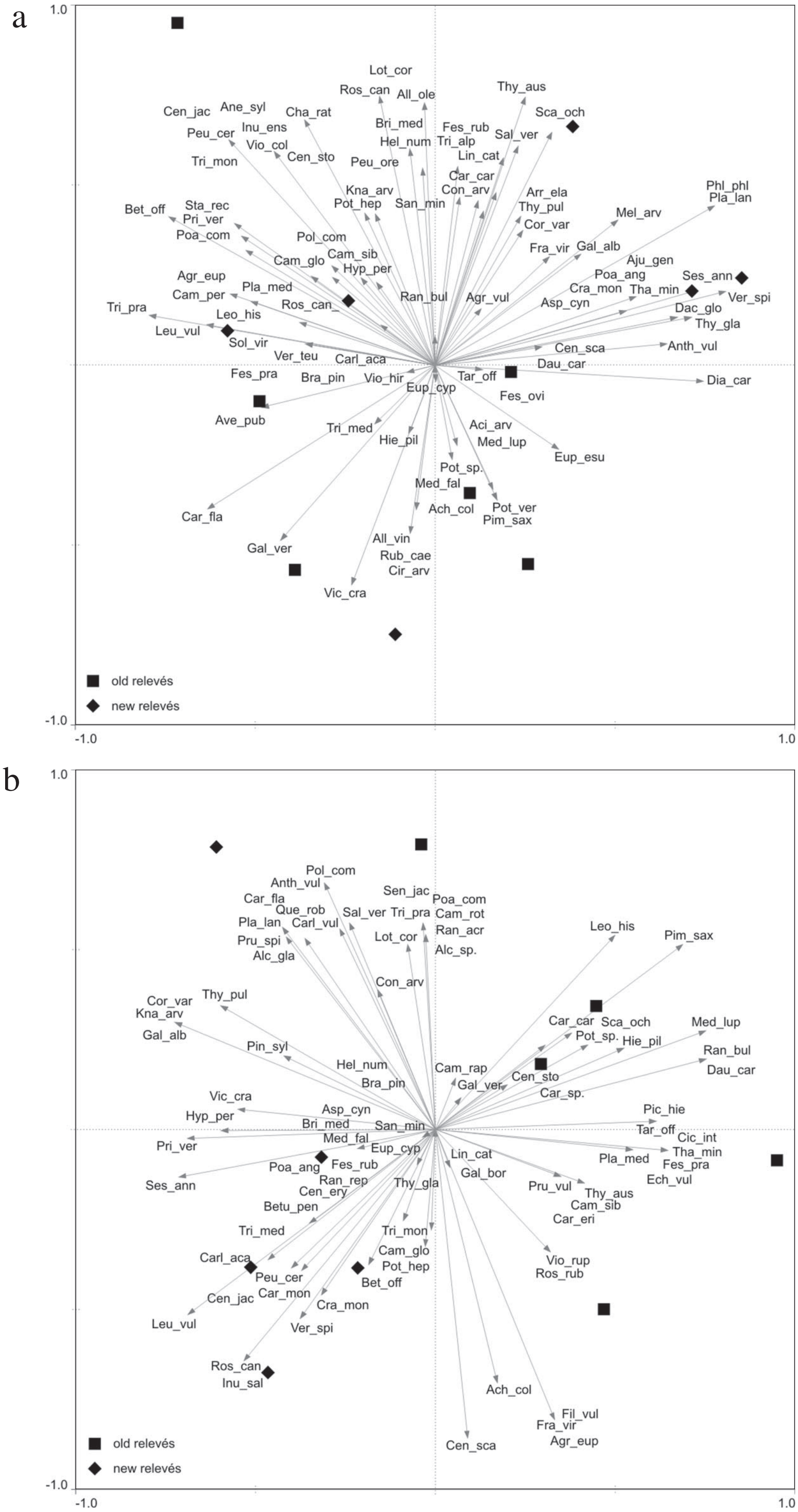

Fig. 2. Ordination of old and new relevés (PCA) from xerothermic grasslands in: a – Pilica, b – Dobra

Table 3. Habitat requirements and biological traits of plants from xerothermic grasslands in the two compared periods

Locality	Pilica		Dobra	
Year	1980	2008	1980	2007
Average number of species in relevé	35	37	29	32
Ecological startegy (mean number of species)				
C	2.83	**3.67**	2.20	**5.40**
CR	1.00	**1.83**	0.80	**1.80**
CS	3.83	**4.17**	2.80	**5.00**
CRS	10.83	**12.67**	14.00	**14.20**
R	**0.33**	0.00	**2.20**	0.40
S	**9.00**	8.67	**10.40**	8.80
SR	**1.33**	1.00	**2.80**	1.80
No data	0.17	**0.33**	0.00	0.00
Life form (mean number of species)				
Therophyte	0.00	**0.33**	0.00	0.00
Geophyte	1.50	**1.83**	0.40	0.40
Hemicryptophyte	25.17	**25.83**	32.00	32.00
Chamaephyte	2.33	**3.67**	2.60	**3.20**
Phanerophyte	0.17	**0.67**	0.20	**1.80**
Growth form and way of reproduction (mean number of species)				
Clonality	13.83	**15.83**	13.80	**16.80**
Perennial	13.17	**14.83**	16.40	**17.40**
Annaual and biennal	**2.00**	1.33	**5.00**	3.20
No data	0.17	0.33	0.00	0.00
Ellenberg's indicators (mean value)				
L (light)	**7.28**	7.24	**7.40**	7.33
F (mousirity)	3.71	**3.81**	3.72	**3.86**
R (soil reaction)	**7.16**	7.12	**7.62**	7.45
N (nutrient)	3.26	**3.46**	2.85	**2.97**
Graizing tolerance				
Mean value of graizing indicator	4.26	**4.36**	**4.93**	4.25

Higher differences concerned cover-abundance of particular species. However, there was a large group of plants whose contribution in the sod of grasslands did not change significantly (Table 2). Some changes could be observed in grasslands in all the compared sites, whereas other ones were distinct only in Pilica or in Dobra. The smallest changes were recorded in the grasslands in Wierbka, but only one pair of phytosociological relevés taken probably in the same site was compared.

Some qualitative changes in patches of grassland were manifested in the results of the analysis of habitat requirements and biological traits (ecological strategies, life forms, type of reproduction) (Table 3).

A small decrease in the mean indicator values for light (L) and soil reaction (R) as well as small increase in values for moisture (F) and trophy (N) were observed. Quite a distinct tendency for the increase in the participation of plants being competitors (C) accompanied by a decrease of species representing strategies R (ruderals) and S (stress-tolerators) were noted. In the abandoned grasslands, proportions of clonal plants and other perennial increased, whereas the participation of annual and biennial species decreased. As a visible process of succession, the presence of seedlings of trees and shrubs was observed.

Changes in the mean value of the indicator of resistance to grazing were not distinct, as evident from Table 3. Despite that, the coverage of the majority of species resistant to grazing increased in grasslands from both areas (Table 2). It concerned, especially, species capable of vegetative reproduction.

Changes in flora of grasslands after almost 30 years are also shown by PCA (Fig. 2). In Dobra, such species as *Centaurea jacea, Crataegus monogyna, Inula salicina, Peucedanum cervaria, Pinus sylvestris* and *Rosa canina* were present only in relevés from 2007 and the other group (*Campanula sibirica*, *Leontodon hispidus*, *Plantago media*, *Thymus austriacus*) were much more frequent in older relevés. In Pilica, changes in species composition of grasslands were slightly lower than in Dobra. These differences were associated not only with time but also with the internal diversity of these phytocoenoses, both currently and in the past. *Asperula cynanchica*, *Melampyrum arvense*, *Phleum phleoides*, *Plantago lanceolata*, *Poa angustifolia*, *Seseli annuum* and a few other plants appeared in the new relevés here. Moreover, some other species (e.g.: *Thymus glabrescens*, *Veronica spicata*, *Scabiosa ochroleuca* and *Festuca rubra*) were more frequent.

4. Discussion and conclusion

The xerothermic grasslands from surroundings of Pilica resemble communities from adjacent areas, both in relation to floristic composition and to species richness. They differ with respect to the participation of such species as *Campanula sibirica*, *Thymus austriacus* and *Th. glabrescens* in comparison to *Adonido-Brachypodietum* described from the areas of the Częstochowa Upland situated north and west of Pilica (Hereźniak *et al*. 1970; Babczyńska 1978; Babczyńska-Sendek 1984; Babczyńska-Sendek *et al*. 1998), as well as from the Silesian Upland (Babczyńska-Sendek 2005a). The above-mentioned plants were more frequent in areas located to the south and east of Pilica and in grasslands from there (Medwecka-Kornaś & Kornaś 1963; Głazek 1968, 1987; Zając & Zając 1998, 2001).

The variant with *Dianthus carthusianorum* distinguished within *Adonido-Brachypodietum* from Pilica resembles to a certain extent *A.-B. phleetosum* from the Silesian Upland (Babczyńska-Sendek 2005a). However, these grasslands were not classified to this syntaxon due to high coverage of *Brachypodium pinnatum* and much lower proportion of *Phleum phleoides* in their sod. The phytocoenoses of the variant with *Carex flacca* have a lot in common with the patches of *A.-B. typicum* from the Silesian Upland (Babczyńska-Sendek 2005a) and they can be classified to this subassociation. The *Silene otites-Thymus austriacus* community is to a certain degree similar to *Koelerio-Festucetum sulcatae* described from the Nida Valley (Medwecka-Kornaś 1959) and Ojców National Park (Medwecka-Kornaś & Kornaś 1963). However, there was a lack of *Festuca rupicola* in its patches and *Koeleria macrantha* showed low participation. The similarity concerns large contribution of *Thymus austriacus* and *Th. glabrescens*.

The *Thymus-Anthyllis vulneraria* community growing on the abandoned fields is also interesting. It is not only a new element of vegetation in Pilica surroundings but also an example of fast encroachment of xerothermic species into open habitats on carbonate soils. Such penetration of xerothermic species into abandoned fields was observed e.g.: in South Limburg (souther part of the Netherlands) (Hennekes *et al.* 1982) and on the Transylvanian Lowland in Romania (Ruprecht 2005, 2006).

The appearance of seedlings of trees and shrubs, which later developed into woodlots, is a commonly known phenomenon in ungrazed grasslands. It was also observed in the area of the Kraków-Częstochowa Upland (Dzwonko & Loster 1990, 1992; Michalik 1990a, 1990b; Babczyńska-Sendek *et al.* 2006; Medwecka-Kornaś 2006; Sołtys & Barabasz-Krasny 2006). The initial stages of this process can be observed in grasslands in the neighbourhood of Pilica and, especially, in Dobra and in Wierbka. It seems that it is rather slow there. According to Willems (1985), litter accumulation can be the factor which inhibits intense development of tree and shrub seedlings in grassland communities. Also Dzwonko & Loster (1990, 1998a) pointed to such role of a thick litter layer.

Changes in grasslands are reflected by values of selected Ellenberg indicators calculated both for old and new grasslands. The differences between them are not large but are similar to those observed in *Origano-Brachypodietum* (Kaźmierczakowa & Grodzińska 2006) in the Pieniny Mts. and in the nature reserve "Skołczanka" near Kraków (Dzwonko & Loster 1998a, 1998b, 2007). The increase of nitrogen value in the patches of seminatural plant communities under succession process i.e. so called "auto-euthrophication" was pointed out by Moog *et al.* (2002) and Prévosto *et al.* (2011).

Also the results of the analysis of participation of species representing various Grime's ecological strategies were very interesting. The tendency of increasing role of C-strategists was observed in other abandoned grasslands (Dzwonko & Loster 1998a, 1998b; Moog *et al.* 2005; Prévosto *et al.* 2011), likewise a decrease of S- and R-strategists (Moog *et al.* 2005; Prévosto *et al.* 2011). The increase of the importance of vegetatively reproducing species was observed also in grasslands under succession in Baden-Wüttemberg (Kahmen *et al.* 2002) and in southern Poland (Dzwonko & Loster 2007). This group is considered the most slowly vanishing in abandoned grasslands (Fischer & Stöcklin 1997). The observations which were conducted in Swiss Jura (Fischer & Stöcklin 1997) confirm the tendency, noted in this study, to decrease proportion of annuals and biennials.

Over the last 30 years, some quantitative and qualitative changes took place in xerothermic grasslands in the surroundings of Pilica, but the character of these phytocoenoses did not change in a considerabe way, which gives reason to conclude that, in grasslands associated with strongly xerothermic habitats, succession does not happen very quickly. The investigations carried out in Britush chalk grasslands showed that the magnitude of changes in floristic composition of grasslands decreased with angle of slope and with radiation index (Bennie *et al.* 2006). Due to the lack of grazing, it can be expected that species composition in the grasslands from the vicinity of Pilica will be changing in the following years and even succession will be probably faster. At present, these communities are seriously threatened by human activity. It especially concerns the grasslands on scarps southwards of Pilica where the area occupied by single family housing is still increasing, whereas in Wierbka, the possible further exploitation of limestones in a small quarry may be a threat to grassland vegetation.

Xerothermic grasslands are very valuable and important components of rural vegetation in the Pilica surroundings. Protected and regionally rare species connected with them are very valuable and significant components of the regional species pool in the sense of Zobel (1997). The areas covered with floristically rich grasslands are local 'hot spots' which are of great importance for the maintenance of the regional biodiversity.

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