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Vegetation differentiation and secondary succession on abandoned agricultural large-areas in south-eastern Poland

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Abstract: In Poland, the largest stretches of abandoned agricultural areas were formed at the end of the 1980s, along western and eastern borders, among others, in Przemyśl Foothills (Pogórze Przemyskie). Therefore, the research on the diversity of plant communities from abandoned agricultural areas as well as main directions and the rate of succession after the cessation of management was undertaken in the vicinity of twelve municipalities in south-eastern Poland. This research revealed that the dominating direction of changes of the abandoned agricultural area vegetation was vanishing of plant groups with segetal and meadow species and spreading of shrub communities. A general increase in the forestation rate of the researched abandoned agricultural areas from 10-40% of the area in 1970-1971 to about 30-70% in 2003-2004 may be the evidence of the occurrence intensity of those phenomena.

Key words: cessation of management, environmental conditions, fallows, fields, meadows, pastures, succession

1. Introduction

At the beginning of 1970s, the largest number of State Agricultural Farms (Polish: Państwowe Gospodarstwo Rolne – PGR) operated in south-eastern Poland. With the passing of time, they became a serious problem because their production proved to be unprofitable and more expensive than in other regions of Poland (Angerman 1998). After their closure at the beginning of 1990s, land of former farms was sold by the Agricultural Property Agency to private owners. Majority of new owners reintroduced the newly acquired land to agricultural production; however, significantly large territories remained without any farming activity, which resulted in the formation of abandoned agricultural large-areas. The problem of abandoned agricultural large-areas occurred earlier in West European countries and the United States. The appearance of such areas stimulated scientists to study rates, directions and courses of secondary succession processes.

Detailed studies of successional series on abandoned fields (Dubiel 1984; Faliński 1980a, 1980b, 1986) and meadows (Falińska 1989a, 1989b, 1991; Michalik 1990) appeared in Poland only in 1980s and 1990s. Another direction comprised studies relating to various environmental factors that affect vegetation succession processes (Kołos 1991; Kornaś & Dubiel 1990, 1991; Kotańska 1993a, 1993b; Barabasz 1997; Baryła & Urban 1999). However, research into the succession occurring on abandoned large-scale lands had not been conducted earlier.

The aim of the research undertaken on abandoned agricultural large-areas in south-eastern Poland was to recognise: (*i*) diversity of plant communities, (*ii*) habitat conditions and ecological factors that brought about formation of the present vegetation in this area, (*iii*) the main directions and rate of succession changes since the cessation of management.

2. Material and methods

2.1. Study area

The researched abandoned agricultural areas were situated around municipalities located in west (Jawornik Ruski – 49° 43' 43" N 22° 18' 13" E, Piątkowa – 49° 45' 38" N 22° 21' 42" E) and south-east parts of Przemyśl Foothills (Cisowa – 49° 42' 9" N 22° 35' 1" E, Olszany – 49° 44" 37" N 22° 38' 13" E, Łodzinka Górna – 49° 40' 28" N, 22° 31' 49" E, Posada Rybotycka – 49° 39'

44” N, 22° 36’ 56” E, Kopyśno – 49° 41’ 2” N 22° 39’ 1” E, Rybotycze – 49° 39’ 23” N 22° 38’ 41” E, Huwniki – 49° 39’ 21” N 22° 42’ 16” E, Leszczyny – 49° 37’ 11” N 22° 40’ 41” E, Sopotnik – 49° 36’ 44” N 22° 40’ 49” E, Paportno – 49° 35’ 43” N 22° 41’ 32” E). Leszczyny, Sopotnik and Paportno were the south-easternmost locations. According to the geobotanical division, this territory is included in the Wooded Carpathians District (Karpaty Lesiste) and in the Sub-districts of Przemyśl Foothills (Pogórze Przemyskie) and East-Carpathian Foreland (Przedgórze Wschodniokarpackie) (Wład 1996). In the geomorphological division, it is included in Dynów Foothills (Pogórze Dynowskie) (Klimaszewski & Starkel 1972) and in the physio-graphic division – in Przemyśl Foothills (Pogórze Przemyskie) (Kondracki 2000).

Ridge and valley mountains constitute the main components of the area of the Przemyśl Foothills (Janicki 1996). The hills are criss-crossed by numerous stream valleys, with the WE course, which is characteristic for Przemyśl Foothills (Wład 1996). The geological bed is built of Carpathian flysch and Skolska nappe is the tectonic unit of this area. It is made up of overthrust folds running north, covered with Quaternary sediments (Alexandrowicz 1999; Gilewska 1999). The soil cover occurring there consists of soils built of weathered sedimentary compact rocks. Acid and leached soils, brown soils and luvisols, such as: loamy, dusty, clay, less frequently gravel and sandy soils belong to them. The soils cover is varied and alluvial soils, chernozem, muck soils, as well as rendzinas can be found (Prusinkiewicz & Bednarek 1999). The climate of the area is of transitional, between mountain and lowland, character. It is significantly affected by mountains and modified by the continental influence (Niedźwiedź & Obrębska-Starkel 1991).

2.2. Methods

500 phytosociological relevés were collected in the examined abandoned agricultural areas of various age in summers of 1998-2000 and 2003-2005. The relevés were made by means of the Braun-Blanquet’s method. All phytosociological relevés were entered into the phytosociological database TURBOVEG (Hennekens & Schaminée 2001) and subjected to hierarchical numerical classification (Dzwonko 1977; Sokal & Rohlf 1981; Gauch 1986; Jongman *et al.* 1995). The process of classification was carried out twice: based on species abundance according to 6-grade Braun-Blanquet’s scale (the value of 0.5 was assumed as +) and according to species presence/absence (binary scale 0, 1). In the first case, similarities were calculated using the van der Maarel’s formula, in the second case – the formula of Euclidean distance was applied. Grouping was done by means of the Ward’s method – minimum variance clustering. The package of MULVA – 5 software was applied for classification (Wildi & Orlóci 1996). Comparison of the obtained dendrograms made it possible to distinguish groups of similar relevés, regarding both the species abundance and the species presence/absence in communities (Dzwonko & Loster 1990, 1992).

To characterise habitat conditions for all communities, the weighted means of Ellenberg’s indices were calculated in relation to cover-abundance values (light – L, soil moisture – F, soil acidity – R, soil nitrogen – N; Ellenberg *et al*. 1992), and then the arithmetic means for whole communities were calculated for all relevés. The indicators, such as: general diversity of species H, uniformity J and domination C were also compared among the communities (Simpson 1949; Shannon & Weaver 1963; Pielou 1975).

Analyses of vegetation succession changes were carried out at community scale to observe changes in species composition and species abundance in the same abandoned agricultural area within the period of five years. 65 phytosociological relevés were taken in the “Bobowiska Mount” abandoned agricultural area (“Góra Bobowiska”) in Cisowa – 35 relevés were made in 2000 and 30 replicated in 2005 and they were numerically ordered by means of Detrended Correspondence Analysis DCA (Hill & Gauch 1980). The same method was applied to order the species of all relevés taken in this area. The software CANOCO version 3.12 was applied for both processes. Changes of the species coverage index (D) observed in relevés in 2000 and 2005 taken in the abandoned agricultural area “Bobowiska Mount” were also analysed (Tüxen & Ellenberg 1937).

Apart from that, comparison of floristic composition in all distinguished communities, their abundance, habitat conditions, farming history, stages of overgrowing known from literature were carried out. The comparison allowed the author to determine the main succession directions occurring in south-eastern Poland. The comparative analysis was based, among others, on such works as: Dubiel (1984), Faliński (1986), Falińska (1989a, 1989b), Kornaś and Dubiel (1990, 1991).

Succession changes occurring on landscape scale were illustrated by the comparison of the area share of forest and non-forest communities in the whole investigated area during different periods. Aerial photos taken in the analysed area in the periods of 1970-1971 and 2003-2004, and also cadastral maps of 1983 and 1993 were applied in that case. Surfaces of various categories of land usage were measured planimetrically on the cadastral maps and on air photos by means of AutoCad program. The analysis comprised 22 aerial photos from 1970-1971 and 26 pictures from 2003-2004, showing the state of land usage approximately 10 years after closing State Agricultural Farms (PGR) in the area. It resulted in creating land usage maps of the investigated areas and measuring the area of particular usage categories in three time periods. Proportion of thickets and forest areas to non-forest areas: fields, meadows and pastures etc., was assumed as an indicator of the succession rate. The nomenclature of plants species followed Mirek *et al.* (2002) and affiliation of species to syntaxonomic units was determined on the basis of Matuszkiewicz (2007).

3. Results

3.1. Classification of plant communities

Numeric classification of relevés allowed the author to distinguish 16 types of communities:

Class: *Epilobietea angustifolii* R. Tx. et Prsg 1950
1. Community with *Calamagrostis epigejos*

Class: *Artemisietea* Lohm., Prsg. et R. Tx. 1950
2. Community with *Solidago gigantea*
3. Community with *Rudbeckia laciniata*

Order: *Glechometalia hederaceae* R. Tx. in R. Tx. et Brun-Hool 1975
4. Community with *Urtica dioica*

Class: *Molinio-Arrhenatheretea* R. Tx. 1937
5. Community *Cirsium arvense-Elymus repens*
6. Pine thickets (with meadow species in herbs layer)
7. Birch-hornbeam thickets (with meadow species in herbs layer)

Order: *Arrhenatheretalia* Pawł. 1928

Alliance: *Arrhenatherion* (Br.-Bl. 1925) Koch 1926
8. *Arrhenatheretum elatioris* (Br.-Bl. 1919) Oberd. 1952 (*A. medioeuropaeum*)
   Arrhenatheretum elatioris:
   a. variant with *Angelica sylvestris*
   b. variant with *Prunus spinosa-Crataegus monogyna*
   c. variant with *Phleum pratense*
   d. poor variant

   A. e. brizetosum mediae:
   a. dry variant
   b. periodically wet variant
9. Community with *Vicia tetrasperma*
10. Community *Hypericum perforatum-Torilis japonica*

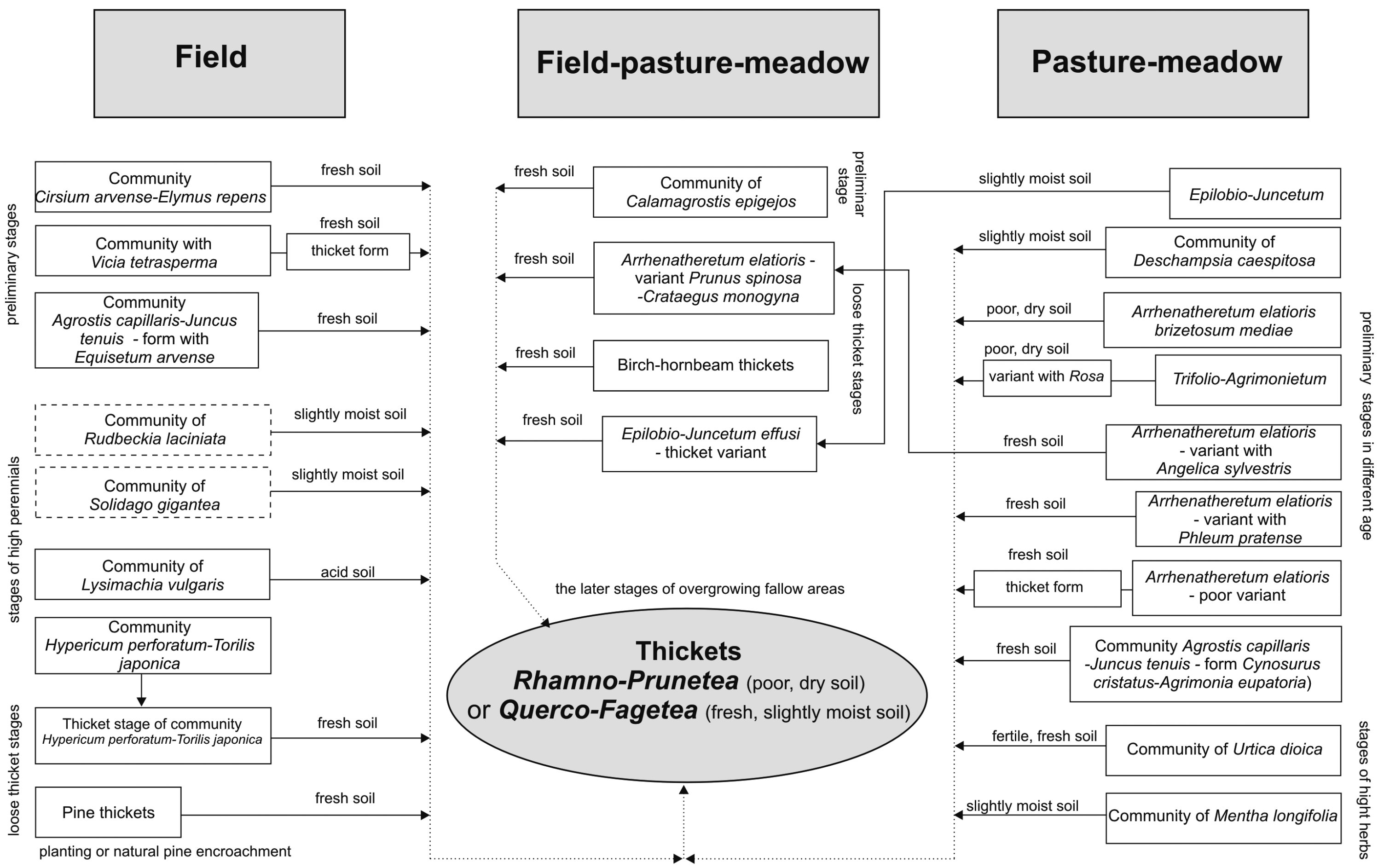


Fig. 1. Relationship between plant communities and the type of fallow land on the abandoned, large-size agricultural areas in south-eastern Poland (Przemyśl Foothills – Pogórze Przemyskie)

Explanations: dashed line boxes – communities documented with a small number of relevés, the dotted line – the presumed direction of succession

Table 1. Averages and ranges of Ellenberg's indicator values for communities occurring in the studied abandoned agricultural areas

Type of community	Number of relevés	Average Ellenberg's indicator values			
		Light (L)	Soil moisture (F)	Soil pH (R)	Soil nitrogen (N)
Community of *Calamagrostis epigejos*	11	6.83 6.59-7.08	5.14 4.71-5.63	6.45 5.45-7.14	5.37 4.45-6.09
Community of *Solidago gigantea*	3	6.95 6.82-7.04	5.70 5.61-5.86	5.04 4.31-6.14	5.87 5.24-6.62
Community of *Rudbeckia laciniata*	3	6.85 6.71-7.12	6.33 5.88-6.92	6.68 6.48-6.78	6.23 5.83-6.81
Community of *Urtica dioica*	17	6.72 6.47-7.05	5.73 5.30-6.34	6.81 6.25-7.06	7.57 6.61-8.05
Community *Cirsium arvense-Elymus repens*	18	7.00 6.66-7.46	5.45 4.82-6.43	6.60 5.85-7.19	6.23 5.44-7.12
Pine thickets	17	6.73 6.45-6.95	5.29 4.86-6.06	6.02 5.21-7.04	5.24 4.27-5.66
Birch-hornbeam thickets	17	6.65 6.09-7.02	5.52 5.14-6.08	5.42 4.30-6.56	5.28 4.74-5.62
Arrhenatheretum elatioris – variant with *Angelica sylvestris*	19	6.95 6.79-7.27	5.05 4.76-5.43	6.76 6.33-7.08	5.45 4.83-6.10
A. e. t. – variant *Prunus spinosa-Crataegus monogyna*	19	6.83 6.64-7.07	5.12 4.68-5.32	6.46 5.83-7.16	5.47 4.95-5.91
A. e. t. – variant with *Phleum pratense*	16	6.85 6.58-7.08	5.41 5.10-5.64	6.24 5.61-6.83	5.86 5.47-6.45
A. e. t. – poor variant	23	6.83 6.51-7.14	5.48 4.90-6.07	5.68 4.56-6.43	5.44 4.11-6.16
A. e. brizetosum mediae	32	6.90 6.68-7.37	4.92 3.97-5.59	6.00 4.33-6.77	4.09 3.15-4.88
Community with *Vicia tetrasperma*	32	6.92 6.66-7.25	5.15 4.64-5.59	6.40 6.04-6.94	5.46 4.79-6.36
Community *Hypericum perforatum-Torilis japonica*	24	6.72 6.50-7.04	5.54 5.27-5.90	6.32 4.92-7.10	5.92 5.22-6.42
Thicket stage of community *Hypericum perforatum-Torilis japonica*	23	6.69 6.20-7.00	5.56 5.19-6.13	6.46 5.74-7.18	5.89 5.44-6.47
Community *Agrostis capillaris-Juncus tenuis*	32	6.83 6.43-7.08	5.39 4.93-6.21	5.80 5.03-6.68	5.11 4.41-5.86
Community of *Mentha longifolia*	22	6.76 6.44-7.12	6.28 5.73-7.05	7.10 5.55-7.74	6.21 4.93-6.72
Community of *Deschampsia caespitosa*	16	6.66 6.44-6.95	5.60 5.11-6.13	6.35 5.46-6.89	4.84 4.15-5.83
community of *Lysimachia vulgaris*	9	6.44 6.03-6.91	6.01 5.45-6.22	4.80 4.00-5.44	5.20 4.59-6.28
Epilobio-Juncetum	18	6.87 6.60-7.18	6.09 5.50-6.82	5.63 4.91-6.77	5.19 4.46-5.93
Epilobio-Juncetum – thicket variant	28	6.78 6.48-7.10	5.52 4.92-6.10	5.89 4.83-6.62	5.63 4.81-6.45
Trifolio-Agrimonietum	18	7.05 6.87-7.29	4.61 4.04-5.14	7.01 6.57-7.54	4.41 3.70-5.31

Explanations: the highest and the lowest values of the index are marked in grey

Thicket stadium community *Hypericum perforatum-Torilis japonica*

11. Community *Agrostis capillaris-Juncus tenuis*
    Order: *Trifolio fragiferae-Agrostetalia stoloniferae* R. Tx.1970
    Alliance: *Agropyro-Rumicion crispi* Nordh. 1940 em. R. Tx. 1950
12. Community with *Mentha longifolia*
    Order: *Molinietalia* Koch 1926
13. Community with *Deschampsia caespitosa*
    Alliance: *Filipendulion ulmariae* Segal 1966
14. Community with *Lysimachia vulgaris*
    Alliance: *Calthion* R. Tx. 1936 em. Oberd. 1957
15. *Epilobio-Juncetum effusi* Oberd. 1957
    Epilobio-Juncetum effusi
    a. wet variant
    b. dry
    c. thicket variant

Class: *Trifolio-Geranietea sanguinei* Th. Müller 1962
Alliance:*Trifolion medii* Th. Müll. 1961

16. *Trifolio-Agrimonietum eupatoriae* Th. Müll. 1961

Three of them represent associations of *Arrhenatheretum elatioris, Epilobio-Juncetum*, *Trifolio-Agrimonietum*, known from literature.

Comparison of mean values of the Ellenberg's indicator proved that the communities belonged to moderately photophilous ones. Due to soil nitrogen occurrence, they remained in limits between poor and rich in nitrogen; however, most of them were at the medium level. The soil pH was weak acid, close to neutral or neutral. Most of the soils belonged to fresh or, less frequently, wet ones. Only *Arrhenatheretum elatioris brizetosum mediae* and *Trifolio-Agrimonietum* occurred on dry soils (Table 1).

Table 2. Values of general diversity (H), uniformity (J) and dominance (C) indicators for communities of abandoned, large-size agricultural lands in south-eastern Poland (Przemyśl Foothills)

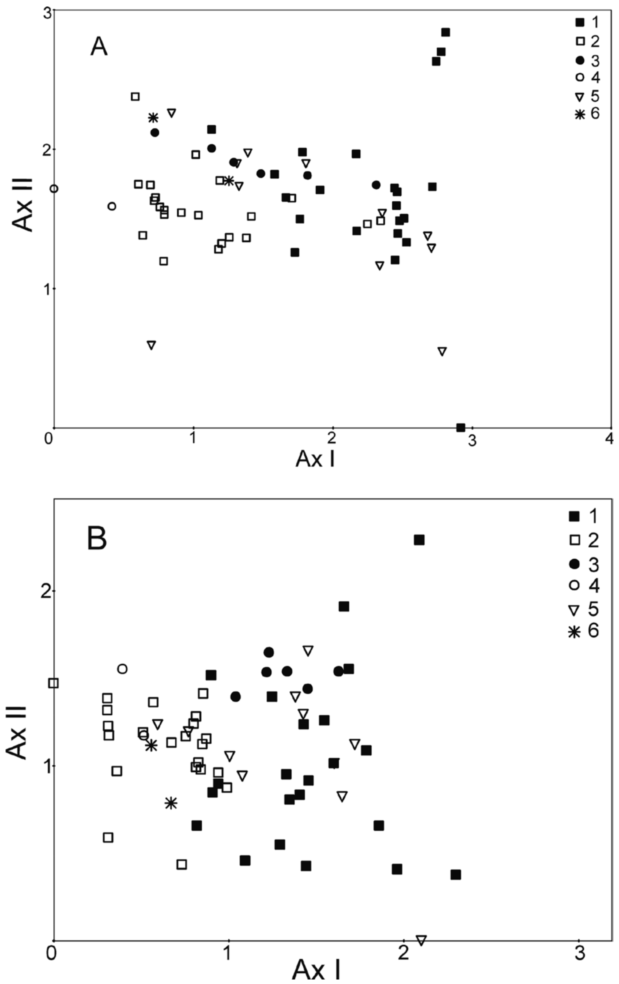
Type of community	Average number of species in relevé	H	J	C
Community with *Calamagrostis epigejos*	32; n = 11	4.17	0.71	0.05
Community with *Solidago gigantea*	20; n = 3	3.02	0.73	0.10
Community with *Rudbeckia laciniata*	27; n = 3	3.70	0.79	0.05
Community with *Urtica dioica*	18; n = 17	3.27	0.57	0.12
Community *Cirsium arvense-Elymus repens*	31; n = 18	4.28	0.68	0.03
Pine thickets	50; n = 17	4.67	0.69	0.01
Birch-hornbeam thickets	41; n = 17	4.54	0.69	0.02
Arrhenatheretum elatioris – variant with *Angelica sylvestris*	44; n = 19	4.56	0.68	0.02
A. e. t. – variant *Prunus spinosa-Crataegus monogyna*	47; n = 19	4.63	0.68	0.01
A. e. t. – variant with *Phleum pratense*	42; n = 16	4.18	0.64	0.02
A. e. t. – poor variant	30; n = 23	4.00	0.61	0.03
A. e. brizetosum mediae	52; n = 32	4.85	0.65	0.01
Community with *Vicia tetrasperma*	42; n = 32	4.57	0.63	0.01
Community *Hypericum perforatum-Torilis japonica*	47; n = 24	4.62	0.66	0.01
Thicket stage of community *Hypericum perforatum-Torilis japonica*	46; n = 23	4.67	0.67	0.02
Community *Agrostis capillaris-Juncus tenuis*	46; n = 32	4.58	0.63	0.02
Community with *Mentha longifolia*	33; n = 22	4.33	0.66	0.03
Community with *Deschampsia caespitosa*	44; n = 16	4.46	0.68	0.02
Community with *Lysimachia vulgaris*	28; n = 9	3.92	0.71	0.04
Epilobio-Juncetum	44; n = 18	4.53	0.68	0.02
Epilobio-Juncetum – thicket variant	44; n = 28	4.61	0.64	0.02
Trifolio-Agrimonietum	54; n = 18	4.82	0.70	0.01

Explanations: the highest and the lowest values are marked in grey, n – the number of relevés for a given community

Table 3. Values of Pearson's correlation (r) between DCA axes, environmental variables and average Ellenberg's indicator values calculated for phytosociological relevés of the fallow field "Bobowiska Mount" in Cisowa

Characteristics	DCA based on species abundance		DCA based on species presence/absence	
	Axis I	Axis II	Axis I	Axis II
Exposure	-0.03	-0.13	-0.07	-0.13
Herbaceous cover	-0.04	-0.09	-0.13	-0.21
Maximum height of herbs	0.47	-0.07	0.56	-0.02
Bryophytes cover	-0.24	-0.31	-0.10	-0.20
Shrubs and trees cover	0.59	-0.04	0.74	-0.32
Maximum height of shrubs and trees	0.55	-0.04	0.78	-0.06
Number of species in relevé	-0.11	-0.23	-0.12	-0.25
Ellenberg indicator values:				
Light L	-0.23	-0.17	-0.36	-0.01
Soil moisture F	-0.17	-0.12	-0.33	-0.07
Soil reaction (pH) R	-0.15	-0.10	-0.29	-0.01
Soil nitrogen N	-0.19	-0.12	-0.31	-0.04

Explanation: the highest correlation values are marked in grey



A relatively high value of Shannon-Weaver index (H) in all communities indicated the species richness, which proved dynamic changes in vegetation in those areas (Table 2). Succession changes in the abandoned fields proceeded from communities representing initial stages of succession, characterised by segetal species occurrence, through communities with a high share of tall perennial plants to communities representing early grass-shrub stages with species of *Molinio-Arrhenatheretea* still dominating in the herbs layer. The succession directions in the abandoned meadows and pastures started from communities representing the species composition typical for neglected phytocoenoses of fresh meadows, pastures and forest-edge communities, through communities with dominating tall herbal vegetation to shrub-herbal ones (Fig. 1).

3.2. Numerical ordination of relevés

Numerical ordination of relevés made in 2000 and 2005 at Cisowa in the abandoned agricultural area "Bobowiska Mount" ("Góra Bobowiska") along two first DCA axes enabled the author to arrange communities from the least shrub-covered with a relatively low

Fig. 2. Ordination of phytosociological relevés made in "Bobowiska Mount" (Cisowa) in 2000 and 2005 according to I and II DCA axes; A – based on species abundance, B – based on species presence/absence

Explanations: 1 – thicket stage of community *Hypericum perforatum-Torilis japonica* (most of relevés made in 2005), 2 – community *Hypericum perforatum-Torilis japonica* (all relevés made in 2000), 3 – pine thickets (all relevés made in 2005), 4 – community *Cirsium arvense-Elymus repens* (all relevés made in 2000), 5 – transitional stages (most of relevés made in 2005), 6 – *Epilobio-Juncetum* – thicket variant (all relevés made in 2000) herb layer (the left side of the diagram) to the most densely covered by tree species with tall perennial plants dominating in the herb layer (the right side of the diagram) – Fig. (2). Ordination of species arranged them from weeds connected with farming and pasture management recorded in 2000 to plants typical for perennial fallow lands with majority of phanerophytes occurring in 2005 (Table 3, Fig. 3).

A decrease in the coverage index (D) of all segetal species, majority of meadow species and several ruderal ones were observed in the relevés made at "Bobowiska Mount" in 2005 when compared to the state of 2000. During the same time, an increase in the coverage index of shrub species, some forest and forest-edge species occurred there (Table 4). 9 segetal species, 12 meadow ones became extinct in the area in the period of 5 years, while 3 ruderal species, 11 shrub and 4 forest ones appeared.

3.3. Analysis of cadastral maps, aerial photos

Analysis of cadastral maps and aerial photos showed that the forest-shrub succession was the dominating direction of vegetation changes in the abandoned agricultural large-areas leading to a decline of groups with

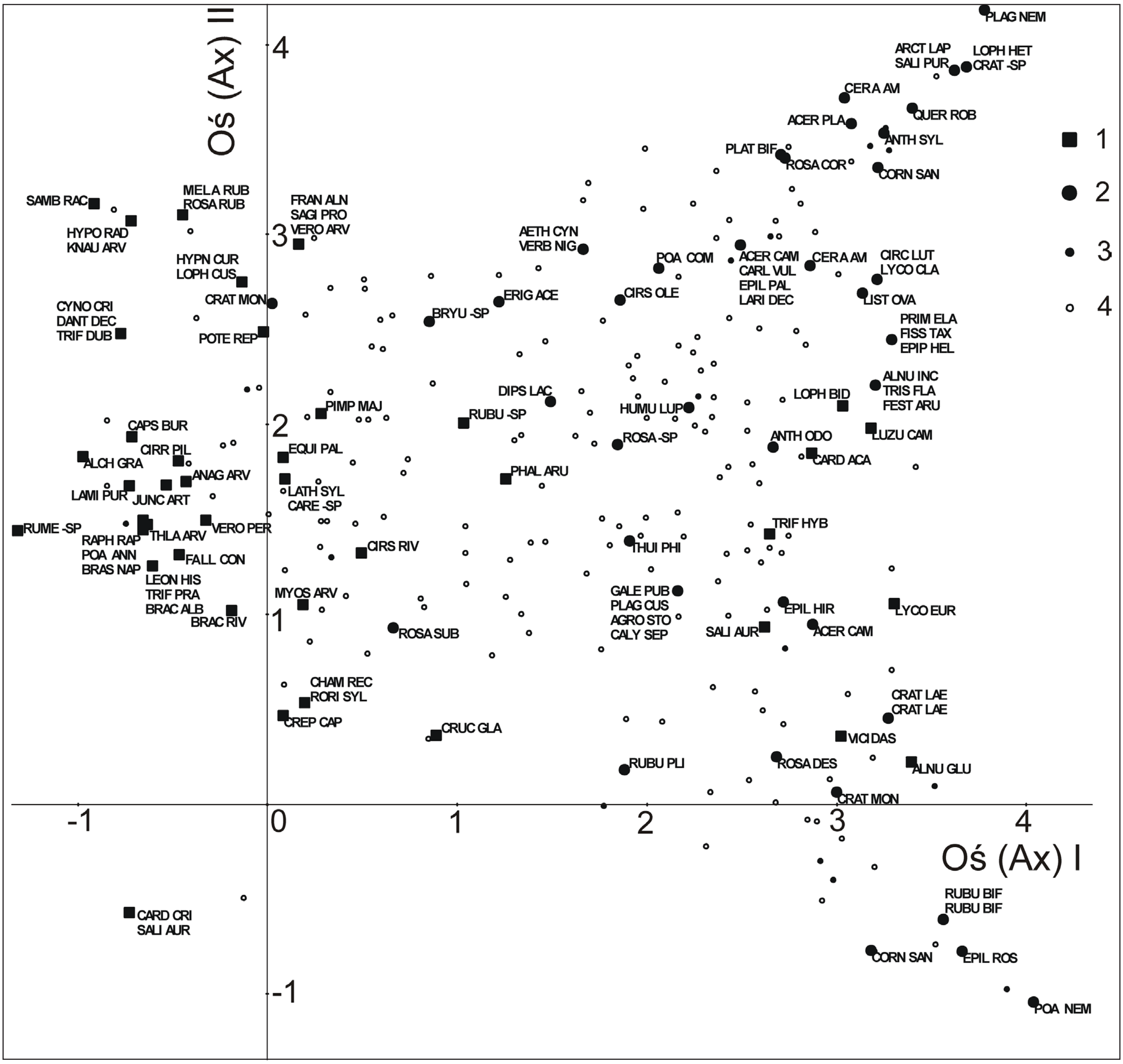


Fig. 3. Ordination of species from phytosociological relevés made in "Bobowiska Mount" (Cisowa) in 2000 and 2005 according to I and II DCA axes, based on species abundance

Explanations: 1 – species found only in 2000, 2 – species found only in 2005, 3 – shrubs found in 2000 and 2005, but in different layers, 4 – common herbaceous species found in 2000 and 2005 segetal and meadow species and propagation of shrub communities (Table 5).

Comparison of percentage cover in various usage categories carried out at three time points proved a significant growth in the forestation rate from 10%-40% of the area in 1970-1971 to approximately 30-70% – in 2003-2004 (Table 6). The biggest changes were found in three localities: Cisowa (Fig. 4), Posada Rybotycka and Piątkowa.

Table 4. Cover indices (D) of species from six ecological/sociological groups occurring in phytosociological relevés of "Bobowiska Mount" (Cisowa) in 2000 and 2005

Groups of species	Cover index		Groups of species	Cover index	
	Years			Years	
	2000	2005		2000	2005
Segetal			Meadow cont.		
Equisetum arvense	995.14	329.33	*Holcus lanatus*	333.71	663.67
Elymus repens	703.14	4.00	*Lysimachia nummularia*	251.71	0.33
Vicia tetrasperma	127.43	73.00	*Arrhenatherum elatius*	194.00	18.67
Tussilago farfara	66.00	1.67	*Daucus carota*	184.00	130.00
Myosotis arvensis	23.43	0.00	*Taraxacum officinale*	182.00	21.33
Lathyrus tuberosus	15.14	0.67	*Potentilla anserina*	165.71	76.00
Convolvulus arvensis	0.57	18.33	*Mentha longifolia*	158.29	1.33
Xerothermic sward			*Cirsium palustre*	150.57	36.00
Hypericum perforatum	490.86	41.33	*Rumex crispus*	121.71	24.00
Senecio jacobaea	159.14	5.00	*Achillea millefolium*	110.57	211.67
Euphorbia cyparissias	94.86	1.33	*Mentha arvensis*	90.00	1.33
Trifolium campestre	51.71	0.67	*Poa pratensis*	89.43	4.33
Clinopodium vulgare	16.29	54.67	*Juncus effusus*	84.29	97.33
Trifolium medium	3.14	35.00	*Galium mollugo*	84.86	620.00
Origanum vulgare	2.29	256.33	*Phleum pratense*	69.43	9.00
Vicia sepium	2.29	35.33	*Lathyrus pratensis*	65.14	2.00
Thickets			*Festuca rubra*	51.14	0.33
Salix caprea (b)	66.29	660.67	*Potentilla reptans*	50.57	0.00
Rosa canina (b)	1.43	19.67	*Juncus articulatus*	50.29	0.00
Pyrus communis (b)	0.86	38.00	*Stachys palustris*	34.29	24.67
Rosa canina var. *corym.* (b)	0.00	17.33	*Angelica sylvestris*	16.86	220.67
Rubus bifrons (b)	0.00	16.67	*Festuca pratensis*	16.29	19.00
Calamagrostis epigejos	1688.86	2302.67	*Carex hirta*	15.43	51.33
Senecio ovatus	1.14	738.00	*Phragmites australis*	0.29	17.00
Fragaria vesca	64.57	77.33			
Carex spicata	0.86	17.33	Ruderal		
Forest			*Cirsium arvense*	1250.57	635.33
Betula pendula (b)	0.29	144.33	*Erigeron annuus*	804.29	480.67
Salix cinerea (b)	0.00	210.00	*Torilis japonica*	740.00	122.33
Pinus sylvestris (b)	0.00	103.00	*Tanacetum vulgare*	179.71	187.00
Rubus hirtus (b)	0.00	16.67	*Urtica dioica*	148.57	91.00
Acer pseudoplatanus (c)	3.43	21.33	*Epilobium parviflorum*	136.29	0.33
Carex remota	15.71	0.33	*Eupatorium cannabinum*	86.00	278.67
Dryopteris filix-mas	14.29	0.67	*Epilobium montanum*	58.86	153.67
Athyrium filix-femina	14.29	0.33	*Picris hieracioides*	50.86	164.33
Carex sylvatica	3.43	19.00	*Geranium columbinum*	46.29	2.00
Salvia glutinosa	0.29	35.00	*Artemisia vulgaris*	44.29	3.00
Meadow			*Dipsacus sylvestris*	32.29	4.00
Agrostis capillaris	518.57	247.00	*Cirsium decussatum*	30.29	1.67
Dactylis glomerata	505.43	305.67	*Epilobium adnatum*	14.86	36.33
Ranunculus repens	467.71	119.67	*Dipsacus laciniatus*	0.00	50.33

Explanation: the increased index values in 2005 compared to 2000 are marked in grey

Table 5. Comparison of the area [ha] of different land use categories in the studied areas of south-eastern Poland (Przemyśl Foothills) from years 1970/1971, 1983 and 1993, 2003/2004

Category of use/Years	1970/1971	1983 and 1993	2003/2004
Field	1160.48	903.43	317.05
Field/pasture	-	1.85	-
Barren field	-	-	179.53
Barren field sporadically mown	-	-	304.19
Barren field/loose thickets	-	-	316.41
Meadow	201.04	216.86	4.18
Meadow-pasture	152.09	-	0.84
Meadow/field	-	4.90	-
Barren meadow/loose thickets	-	2.20	-
Barren meadow	-	-	81.54
Barren meadow sporadically mown	-	-	58.57
Barren meadow/loose thickets	-	-	26.27
Pasture	520.82	626.30	1.63
Pasture/loose thickets	152.67	71.72	0.38
Barren pasture	-	-	163.19
Barren pasture sporadically grazed	-	-	1.86
Barren pasture sporadically mown	-	-	142.64
Barren pasture/loose thickets	-	-	181.03
Orchard	-	73.68	19.41
Orchard/pasture	-	11.71	-
Orchard/barren pasture	-	-	5.30
Orchard/barren field	-	-	25.32
Loose thickets	63.61	44.79	89.09
Loose thickets /field	-	2.40	-
Forest	331.45	376.97	508.96
Forest/loose thickets	1.61	-	49.63
Tree plantation	-	-	20.10
Area prepared for artificial tree plantation	-	-	9.90
Wasteland/baulks	13.19	3.12	7.74
Total	2596.95	2339.94*	2514.78

Explanations: * – only the fragments owned by the State Agricultural Farms were included, which resulted in the lower land area than indicated by aerial photographs

4. Discussion

4.1. Causes of plant community diversity in abandoned agricultural areas

Formation of all communities in the investigated area resulted from the exclusion of land from agricultural usage. The diversity of species composition of the communities was influenced by four main factors: type, age of the abandoned agricultural area, habitat conditions and communities directly adjacent to the area.

The type of abandoned agricultural area is a consequence of agricultural management carried out for many years and it affects the diversity of the species composition of communities (Meisel 1978; Reif & Lösch 1979; Dubiel 1984; Faliński 1986; Myster & Picket 1990; Tscharntke *et al.* 2011; Sojneková & Chytrý 2015). The last crop residue may remain in plant communities for about 10 years after ceasing the cultivation. Remnants of other agricultural activities appear in the composition of plant communities occurring in the abandoned agricultural areas (Picket & Cadenasso 2005). In the case of the study area, patches of *Arrhenatheretum elatioris* variant with *Phleum pratense* developed as a result of meadow regeneration by undersowing of pasturable grass in the former usage areas. Such method of regeneration is applied in pastures and meadows, as it allows maintenance of high yields and good quality fodder (Baryła & Urban 1999).

Patches of *Epilobio-Juncetum* association were another example of remnants of the previous, not necessarily proper, farming practices. They developed as a result of intensive grazing, without appropriate conservation treatments (Fig. 1). Rushes, an important element of such type of pasture, do not belong to species preferred by cattle and sheep. When intensive defoliation of fodder species occurs, they may colonize the habitat without any restraints (Nowiński 1967; Barabasz 1997). The

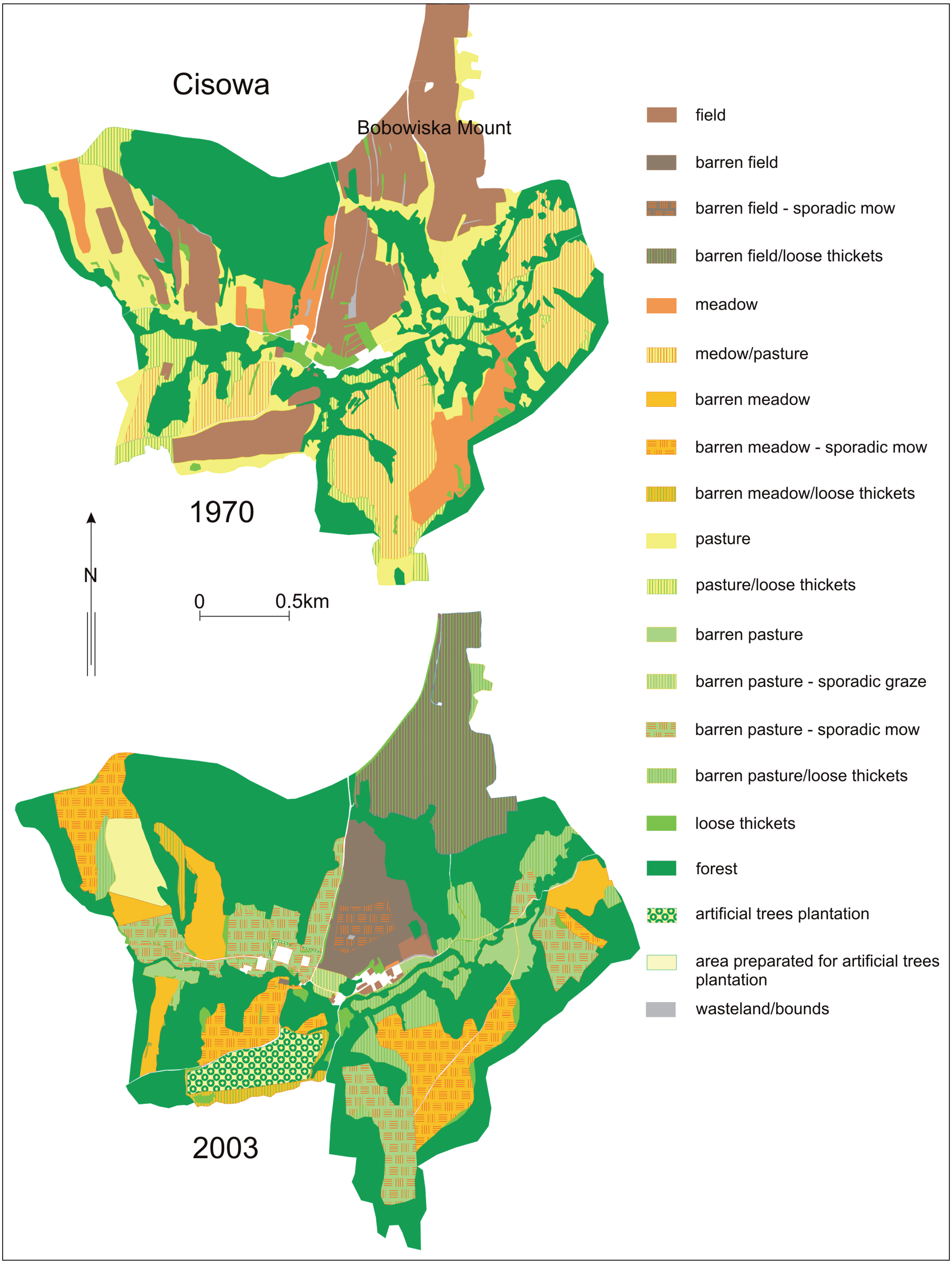


Fig. 4. Land use types in the vicinity of the village of Cisowa in 1970 and 2003, in the areas of former State Agricultural Farms

Table 6. Percentage participation of forest, shrubs and non-forest areas on the studied abandoned agricultural lands in south-eastern Poland (Przemyśl Foothills), in the years: 1970-1971, 2003-2004, 1983 and 1993

Village	Year	Area [%]	
		Forest and shrub area	Non forest area
Cisowa	1970	39.96	60.04
	1993	46.63	53.37
	2003	63.48	36.52
Huwniki	1970	13.89	96.11
	1993	17.00	83.00
	2003	35.01	64.99
Jawornik R.	1970	11.83	88.17
	1993	19.25	90.75
	2003	44.70	55.30
Kopyśno	1971	15.51	94.49
	1993	16.71	93.29
	2003	37.48	62.52
Leszczyny	1971	43.99	56.01
	1983	25.08	74.92
	2003	46.89	53.11
Łodzinka Gr.	1970	28.18	71.82
	1993	22.61	77.39
	2003/2004	44.01	55.99
Olszany	1970	16.40	83.60
	1983	28.83	71.17
	2003	35.46	64.54
Piątkowa	1970	17.72	82.28
	1993	12.72	87.28
	2003	64.50	35.50
Posada R.	1970	16.82	79.91
	1993	65.51	34.49
	2003	69.69	30.31
Rybotycze	1971	16.82	93.18
	1993	14.95	95.05
	2003	31.52	68.48

Explanation: the major changes are marked in grey

lack of conservation treatments contributed also to the formation of communities with *Deschampsia caespitosa* (Fig. 1). Such community develops in the areas where water and oxygen relations are not regulated and they continue to deteriorate due to the lack of proper usage (Le Brun *et al.* 1949).

The period of fallowing is another factor having influence on plant community diversity in abandoned lands (Faliński 1980a, 1980b, 1986; Falińska 1989a, 1989b). According to Dubiel (1984), three stages of succession can be distinguished in fallow fields, depending on their age and composition of the dominant species: stage I – with dominance of *Cirsium arvense* and *Elymus repens*, which occur in the fallow period, i.e. in the first or second year after termination of the agricultural usage, stage II – with *Agrostis capillaris* and *Holcus mollis* dominance occurring in the third – fourth year of the fallowing, stage III – with dominance of high perennials, e.g. *Solidago virgaurea* and *Hieracium umbellatum* (or others) occurring in the fifth year of fallowing. Studies in the south-eastern Poland (Przemyśl Foothills) showed that communities occurring there constituted different age stages of fallows overgrowing (Fig. 1). The *Cirsium arvense-Elymus repens* community with meadow plants and arable weeds in the species presence developed in the old fields. It corresponded to the earliest stage of Wierzbanówka Valley (Dolina Wierzbanówki) in southern Poland (Dubiel 1984). There was also a post-agricultural form (with *Equisetum arvense*) of *Agrostis capillaris*-*Juncus tenuis* community there, but with a smaller share of *Holcus mollis.* The high perennials stage was represented by a community with *Lysimachia vulgaris*. Tall perennials dominated in the community, like in the fifth year stage from Wierzbanówka Valley, and a three-layer structure of green growth could be observed there. The *Hypericum perforatum-Torilis japonica* community also referred to the stage of tall perennial plants, which was characterized by the occurrence of several species co-dominating or dominating in different patches. The relevés made again in the patches of *Hypericum perforatum-Torilis japonica* communities after a 5-year period contained a layer of shrubs, whose maximum coverage could reach up to 85%. A reduction of species abundance among the former dominants could be observed in the herbs layer. This was a following stage of succession of the above-mentioned communities, which evolved in the study area about 10-12 years after cessation of agricultural usage (Figs. 1-2, Table 4).

According to Falińska (1989a, 1989b, 1991), shrub and herbaceous species start to invade abandoned meadows 3 years after ceasing the agricultural usage. As a result, about 10 years after abandonment, herbaceous stages with first representatives of willow trees occur and after further 10-15 years – scrub stages form. Certain similarities can be found comparing the results of Falińska's research with the results obtained in Przemyśl Foothills (Fig. 1). Such communities as: *Epilobio-Juncetum*, *Arrhenatherum elatioris* variant with *Phleum pratense*, *A. e. brizetosum mediae*, were characterized by a typical floristic composition for the meadow-pasture phytocoenoses. They represented early initial stages of succession. Significant dominance of high herbaceous plants appeared in some meadow-pasture communities (community with *Urtica dioica* or with *Mentha longifolia*). They were probably herbaceous stages, which had their optimum development 10 years after the area abandonment. Shrub species dominance, which occurred in the meadows about 10-15 years after abandonment, was accompanied by a reduction of pasturable species and increase of high herbaceous plants abundance. This could be already observed, for example, in some patches of the *Epilobio-Juncetum* shrub stage.

The greatest diversity and species richness in the abandoned lands in Przemysl Foothills were recorded in communities occurring in areas of lower water availability. Patches of *Arrhenatheretum elatioris brizetosum mediae* and *Trifolio-Agrimonietum* were characterized by the greatest species richness and the species growing there confirmed dry nature of the substrate (Tables 1-2). Many species occurring in those communities, especially *Festuco-Brometea* and *Trifolio-Geranietea* classes, tolerated water deficit, due to physiological and morphological adaptations. In this case, light availability was a factor restraining plant growth, because all meadow-sward species tolerate shade worse than periodical water deficit (Knappová *et al.* 2012).

The situation was different in groups with hygrophilous species, such as *Rudbeckia laciniata* community, the community with *Mentha longifolia* and *Epilobio-Juncetum* (Table 1). In such places, water shortages may cause regression of hygrophilous plants and spreading of mesophilous ones. An overdry variant of *Epilobio-Juncetum* and a dry form of a community with *Mentha longifolia* were good examples of such situations. When longer periods of reduced water availability occurred, the amount of hygrophilous species from the *Calthion* alliance and the *Molinietalia* order decreased in typical patches of those phytocoenoses. Species of the *Arrhenatheretalia* order, preferring a lower level of soil moisture, started spreading in their place. Nevertheless, such phenomena occur gradually and are most often caused by lowering of the groundwater level, not only by periodical water shortages (Kornaś & Dubiel 1990, 1991; Kotańska 1993a, 1993b).

Soil fertility is an important factor influencing species composition in communities. High content of nutrients in soil, especially nitrogen, causes dominance of nitrophilous species highly productive in terms of plant biomass (Weiner 1990; Kornaś & Dubiel 1990; 1991; Bobbink *et al*. 1998; Bakker & Berendse 1999; Shmith *et al.* 2002; Walker *et al.* 2004). The phenomenon could be observed in a few communities in the abandoned areas in Przemyśl Foothills (e.g., communities with *Rudbeckia laciniata, Mentha longifolia*, or *Cirsium arvense-Elymus repens* community), but it became most apparent in the community with *Urtica dioica* (Tables 1-2). Patches of those phytocoenoses belonged to the poorest as far as the species composition was concerned (Table 2). Nettle, indicator of soils rich in nitrogen (Ellenberg *et al.* 1992), was the dominant species there. Densely growing individuals of *Urtica dioica* overshadowed other species, therefore, their occurrence was restricted mostly to the edges of patches.

4.2. Succession processes in abandoned agricultural areas

Termination of usage or maintenance activities constitute factors disturbing the structure of current vegetation on abandoned agricultural areas (Kornaś 1990; Kornaś & Dubiel 1990, 1991; Barabasz 1994; Barabasz-Krasny 2002). According to Drury and Nisbet (1973), those factors may be treated as causes of high environmental stress that initiate dynamic processes of vegetation. Undoubtedly, the cessation of usage played a key role in initiating vegetation succession in the abandoned agricultural large-areas in south-eastern Poland.

In meadow and pasture areas, vegetation is characterised by large density and, thus, by lack of empty space for colonization (Harper 1977; Gross & Werner 1982; Olson & Richards 1989; Thórhallsdottir 1990). In this case, availability of space is the most important factor limiting dynamics of the vegetation. However, after cessation of mowing, species with clonal growth may complete their full development unperturbed, causing changes in quantitative and spatial relations in plant communities (Brzosko 2000; Albert *et al.* 2014). As a result of changes in habitat conditions and dying of individuals previously inhabiting a given space, gaps are created in the sward. Those gaps are quickly colonized by species from other habitats that use any resulting disruption in the structure of communities (Falińska 1989a, 1989b, 1991).

The situation develops differently on former arable lands, where the problem of empty space for colonisation in the initial stages of the succession is practically not important (Dubiel 1984; Jírová *et al.* 2012). In that case, the dynamic processes of vegetation depend on the seed-bank preserved in soil and on the seed inflow from the adjacent areas (Stearns & Likens 2002). According to Dobrzański (2009), there might be from several dozens to several hundred millions arable weed seeds in the arable layer of a field an area of 1 ha. In unfavourable conditions, the seeds of certain species may survive even several dozens of years without losing their germination capacity (Aldrich 1984; van Acker 2002). Even if diversity of the seed-bank in soil was not preserved due to agrotechnical measures carried out for many years in the abandoned agricultural fields of Przemyśl Foothills, the inflow of propagules of the inhabiting species was still provided by the adjacent forest and meadow areas.

Termination of farming activities influences the type and number of available resources of the habitat (Faliński 1986; Falińska 1989a, 1989b; Kornaś 1990; Kotańska 1993b). Long-term research of the succession of abandoned agricultural fields have shown that some species exist long before, as well as after the domination period, and other species, that have been expected to be eliminated, still remain in some plant communities. Arboreal anemochorous species are frequently early colonists, in spite of their domination in the further stages of succession (Pickett & Cadenasso 2005). The results of research of the abandoned agricultural large-areas of south-eastern Poland also confirmed it. There were species in communities of the abandoned agricultural field of "Bobowiska Mount" ("Góra Bobowiska") whose coverage indices (D) distinctly increased in 2005 in comparison with the state of 2000 e.g. *Calamagrostis epigejos*, *Senecio ovatus*, *Holcus lanatus*, *Angelica sylvestris*, *Eupatorium cannabinum*, *Picris hieracioides* and others (Table 4). Most of them appeared in the early stages of abandoning, but with a significantly smaller coverage. Anemochorous species of trees, such as *Betula pendula*, *Salix caprea* and *Pinus sylvestris*, were also present in the earlier stages of abandoned agricultural areas in 2000. They were distributed in smaller quantity and, in the case of pine, only in the herb layer. Some of them entered the layer of shrubs, mainly in pine shrubs and the shrub stage of the plant community of *Hypericum perforatum-Torilis japonica* not earlier than in 2005 (Fig. 3, Tables 3-4). A group of segetal species that already had a low rate of coverage in 2000 became completely extinct in five years' time (*Chamomilla recutita, Lamium purpureum*, *Veronica persica*, *Anagalis arvensis*, *Fallopia convolvulus*, *Raphanus raphanistrum*, *Thlaspi arvense*, *Myosotis arvensis*). It is thought that the species directly connected with crops disappear most rapidly, although there are exceptions to this rule (Dubiel 1984). In some patches, the segetal species still remained; however, their rate of coverage became significantly lower, e.g.: *Elymus repens*, *Vicia tetrasperma*, *Lathyrus tuberosus* (Table 4).

Appearance and disappearance of species on persitently abandoned agricultural areas leads to transformations in entire plant communities, which, consequently, causes general changes of the landscape. Landscape changes caused by succession processes are currently very well visible on the abandoned agricultural large-areas of south-eastern Poland (Tables 5-6). It applies to all the localities included in the research but, especially, to Posada Rybotycka, Piątkowa and Cisowa (Fig. 4). The percentage of forest and scrub surface there distinctly increased, at the expense of crop fields and grasslands. All previous usage categories disappeared and abandoned or sporadically used areas appeared. As a result of demographic and economic changes, connected with the drop of profitability of agricultural production, the process of re-naturalisation could be observed on the study area. The phenomenon caused, among others, diminishing of the mosaic character of the Przemyśl Foothills landscape (Janicki 1998, 2005).

5. Conclusions

The research on vegetation on abandoned agricultural large-areas of south-eastern Poland showed the scale and complexity of the occurring succession processes. Simultaneously, it illustrated the richness and diversity of successional stages occurring there – altogether 16 types of communities were distinguished (*i*). The cessation of traditional management methods, which initiated the change of environmental conditions and turned on succession exerted the most important influence on the composition of present-day communities. An important role in the course of succession was also played by: the type of abandoned agricultural area, habitat conditions and the communities directly adjacent to the area (*ii*). The disappearance of meadow-pasture communities and the spread of scrub and forest groupings was the dominant direction in the dynamics of vegetation on that area (*iii*).

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