doi: 10.17221/327/2015-PSE

The silence of the lambs? Plant diversity in abandoned sheep pens

P. Kurek[1], R. Steppa[2], G. Grzywaczewski[3], P. Tryjanowski[4]

[1]*Department of Ecology, Institute of Botany, Polish Academy of Sciences, Krakow, Poland*
[2]*Department of Animal Breeding and Product Quality Assessment, Poznan University of Life Sciences, Suchy Las, Poland*
[3]*Department of Zoology, Animal Ecology and Wildlife Management, University of Life Sciences in Lublin, Lublin, Poland*
[4]*Institute of Zoology, Poznan University of Life Sciences, Poznan, Poland*

ABSTRACT

This study aimed at investigating the species composition and richness of the flora of abandoned sheep pens in comparison to their immediate neighbourhood. Field research was conducted in the Wielkopolska province of western Poland on 25 circular plots (20 m^2) located in the middle of abandoned pens within sheep farms, paired with 25 reference plots established in nearby grasslands. Physicochemical properties of the topsoil were modified considerably by sheep in the past, so some effects continue to this day. Abandoned sheep pens did not differ significantly in plant species richness from control plots, but *Urtica dioica*, *Galium aparine* and *Rumex obtusifolius*, were significantly associated with sheep pens. Similar values of Shannon index and the low Jaccard index of similarity between plot types indicate that although these habitats are not richer in plant species, they are refuges of some characteristic plant species, which are absent or infrequent in neighbouring habitats. Moreover, the changes in physicochemical properties of the soil (higher average ammonium NH_4^+-N and nitrate NO_3^--N content) and vegetation structure are very deep, as they have persisted for 25 years.

Keywords: herbs richness; historical ecology; soil chemistry; disturbance; fertilization

Agriculture in Central Europe has experienced many changes during the last two decades, also in small ruminant (mostly sheep) production (Niżnikowski et al. 2006). After the collapse of Communism, sheep production in Poland severely decreased and most of the functioning sheep farms were closed. The sheep population decline resulted in a new kind of habitats in farmlands: abandoned sheep pens. Habitat heterogeneity seems to be crucial for species diversity in farmlands (Freemark et al. 2002, Benton et al. 2003) and the basis for that are usually field margins. Their origin is often unknown or they are simply wastelands without any history of usage or cultivation. Grassy field margins, linear scrub along field boundaries (hedges), forest patches, ponds, road verges and fallow land (Benton et al. 2003) are mostly mentioned to contribute to the mosaic character of rural landscapes and improve biodiversity by increasing the availability of seminatural habitats. They also play an important role in shaping the populations of many animals, such as butterflies, beetles, spiders (i.e. Baines et al. 1998, Woodcock et al. 2005), birds (Tryjanowski

Supported by the statutory fund of the Władysław Szafer Institute of Botany of the Polish Academy of Sciences, and by the Polish Ministry of Science and Higher Education through the programme for Young Scientists and members of Doctoral Studies under the grant for 2014 for the first author.

doi: 10.17221/327/2015-PSE

et al. 2014), soil macrofauna (Smith et al. 2008) and plants, also invasive ones (Kurek et al. 2015). In respect of plants, field margins may be very important habitats for species needing more than one year to mature (i.e. biennials, perennials) and for species that do not tolerate frequent disturbance, such as ploughing, grazing and mowing.

Sheep pens are places under very strong pressure from sheep, manifested by trampling, high manure inflow and grazing, so they are generally places devoid of vegetation. However, the situation changes when they are abandoned and sheep do not disturb them anymore. Herbaceous plants start to colonize the bare soil surface. The question is: does this new kind of habitat contribute anything special to the rich knowledge of marginal habitats among farmlands? Field margins and their positive impact on biodiversity are commonly known (Marshall and Moonen 2002), but do field margins always play a positive role, as patches with a higher species richness? Especially within permanent grassland, it might be argued that there is less difference between the flora of the field margins and neighbouring habitats (Marshall and Moonen 2002). In parallel research (Kurek et al. – unpublished data) it was revealed that plant communities under electricity pylons were less different from neighbouring habitats when surrounded by meadows, but some species occurred mainly under pylons, e.g. in dense communities dominated by *Phragmites australis*. This shows that in some cases field margins may not play a role as biodiversity islands.

Taking into account the origin of sheep pens, these marginal habitats may not play any role in species richness enhancement. However, there is an apparent lack of any opposite data in some papers comparing different types of marginal habitats (Freemark et al. 2002). A variety of plant communities can occur within them but they are not always rich in species. In many cases such marginal habitats may be species-poor islands, but acting as refuges of many characteristic species that are found only within them, e.g. disturbance-sensitive species like shrubs and trees (Kurek et al. 2015).

This paper reports a comprehensive study of the structure and species richness of plant communities in abandoned sheep pens in comparison to reference areas. We set the following aims: (1) to determine if abandoned sheep pens are islands of plant diversity; (2) to verify whether vegetation of abandoned sheep pens differ quantitatively (species abundance) and qualitatively (characteristic species linked only with this habitat type) from plant communities in the immediate neighbourhood of the sheep pens, (3) to assess how long after abandonment we can still observe the effect of sheep presence in the past.

MATERIAL AND METHODS

Field research was conducted in June and July 2014 in the Wielkopolska province of western Poland (centred on 52°N, 16°E). The landscape was dominated by fields with intensive agriculture among numerous, isolated, small forest patches. The vegetation within sheep pens was dominated by ruderal forbs associated with the infrastructure of the sheep farms (pavements, roads, pastures, lawns). As in other parts of Poland, a transitional climate (with continental and marine influences) prevails here, with precipitation of 450–500 mm (Kondracki 2009).

The study was conducted in 25 abandoned sheep farms, in places that were previously under high disturbance level (high sheep concentration, trampling, grazing, manure inflow). Pens area ranged between 100–1000 m^2 with sheep population up to 800 individuals. Circular plots (r = 2.5 m, ~20 m^2) were located in the middle of abandoned enclosures (pens) within the sheep farms. Reference plots of the same area were located not closer than 50 m away, outside the abandoned enclosures. After the abandonment the herb layer of research plots within pens was unaffected by any activity (ploughing, weed control using herbicides, mowing). Only in case of control plots mowing was a very extensive practice.

In each plot (N = 50) the herbaceous plant species composition and species richness were investigated. The cover-abundance of plant species in the herb layer was estimated on the modified Braun-Blanquet scale of 1–6 (1 – < 1% cover; 2 – 1–5% cover; 3 – 6–25% cover; 4 – 26–50% cover; 5 – 51–75% cover; and 6 – > 75% cover). For each plant species, the life history (annuals, biennials, perennials) (Szafer et al. 1967) and vegetation type (ruderal, pastures and others) were recorded (Frank and Klotz 1990). At each location, soil samples representing two levels of animal disturbance were collected: soil in sheep

doi: 10.17221/327/2015-PSE

pens and in the control plots, in the immediate vicinity unaffected by sheep. Controls were located in places excluded from sheep impact and could be affected only by irregular mowing. After removal of the O horizon (organic matter accumulated above the layer of mineral soil), for each plot topsoil samples were taken with a core sampler (3.5 cm in diameter) to 10 cm in depth. For the soil samples, five physicochemical characteristics were measured according to standard methods (Kurek et al. 2014): N_{tot}, C_{tot}, ammonium NH_4^+-N, nitrate NO_3^--N and pH. Extracted ammonium and nitrate ions were analysed chromatographically (DX 100 analyser (Sunnyvale, USA) for ammonium, DX ICS 1100 analyser (Sunnyvale, USA) for nitrate content).

The Jaccard index was calculated:

$$J = S_{ab}/(S_a + S_b - S_{ab})$$

Where: S_{ab} – number of plant species that occurred on plots of both types; S_a, S_b – numbers of plant species that occurred on each plot. J takes values in the range (0, 1), where 1 indicates a high similarity between communities.

Shannon H' index of diversity was calculated according to the formula:

$$H' = -\sum_{i=1}^{S} p_i log_2 p_i$$

Where: S – species richness; p_i – proportion of individuals belonging to the i^{th} species.

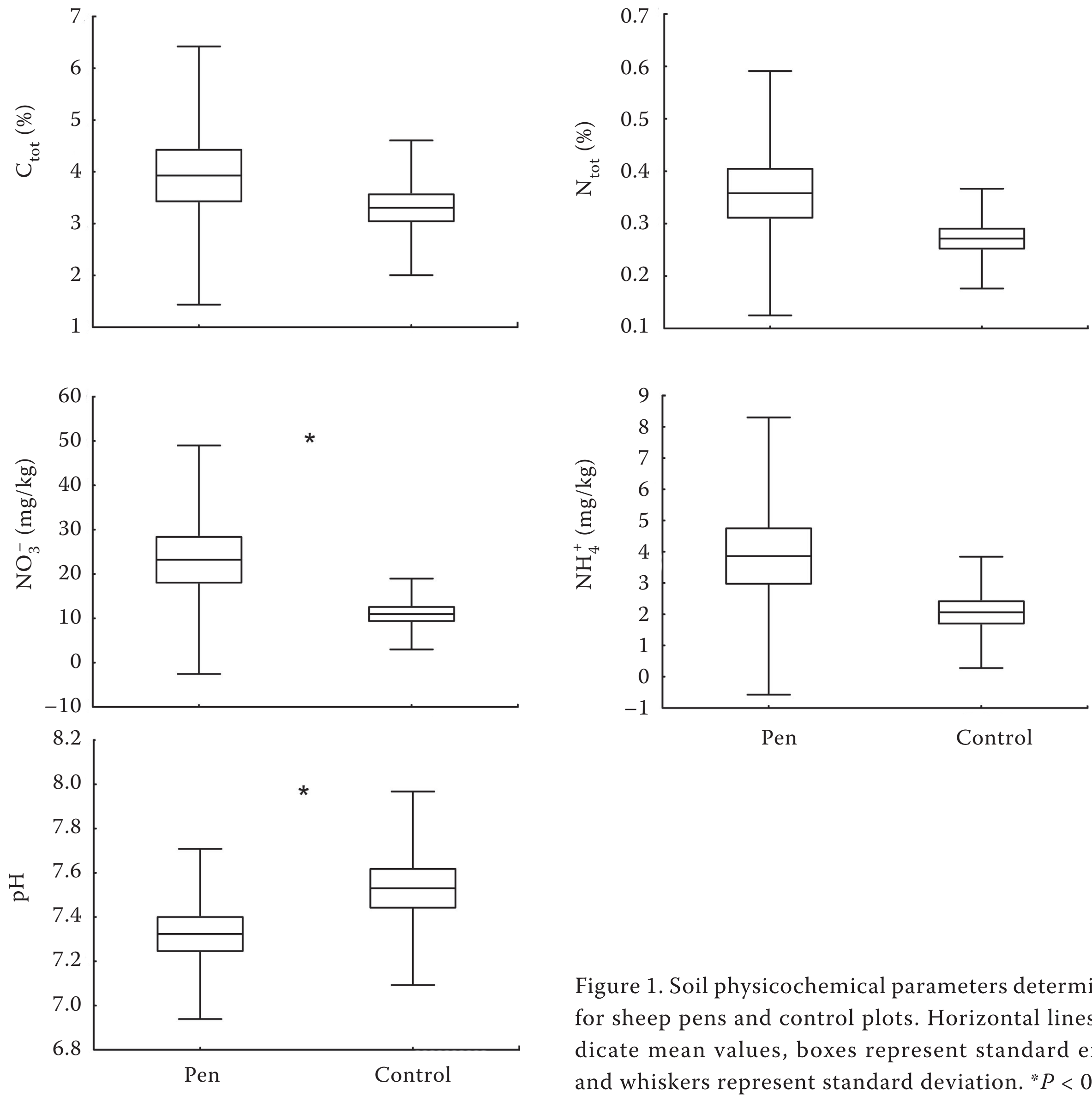


Figure 1. Soil physicochemical parameters determined for sheep pens and control plots. Horizontal lines indicate mean values, boxes represent standard error and whiskers represent standard deviation. *P < 0.05

doi: 10.17221/327/2015-PSE

Indicator species analysis (Dufrene and Legendre 1997) was performed using the 'indval' function from the labdsv package (Roberts 2012) to reveal species preference for plot type (sheep pens and control plots).

In statistical analyses *R* v2.13.1 software (R Development Core Team, 2009), MVSP 3.1 software (Kovach 1999) and Statistica 9 were used. Prior to statistical tests, the data were transformed with logarithmic or exponential functions to obtain a normal or at least symmetric distribution. GLM (general linear models) application was used to examine the sheep disturbance level effect with time of pens abandonment as continuous predictor and the Tukey's post-hoc test. Chi square test was used to examine differences in proportion between plant species numbers representing different life histories and habitats in both plot types (Table 2 × 3).

RESULTS

Topsoil physicochemical properties were modified considerably by sheep in the past and some effects remain remarkable to this day. The average ammonium NH_4^+-N and nitrate NO_3^--N content of the soil in pens were higher than in reference areas ($F_{ammonium}$ = 0.199, P = 0.144; $F_{nitrate}$ = 0.170, P = 0.012, Figure 1). In contrast, pH values were higher on

Table 1a. Relative frequency of herb plants species for pens (N = 25) and control (N = 25) plots

Species	Frequency		Species	Frequency	
	pen	control		pen	control
Species present in both habitat types					
Urtica dioica	0.88	0.44	*Phleum pratense*	0.16	0.08
Taraxacum officinale	0.56	0.76	*Viola tricolor*	0.16	0.04
Poa pratensis	0.52	0.60	*Chenopodium album*	0.16	0.04
Galium aparine	0.48	0.16	*Convolvulus arvensis*	0.12	0.16
Carduus acanthoides	0.44	0.24	*Galium mollugo*	0.12	0.04
Dactylis glomerata	0.40	0.52	*Potentilla anserina*	0.12	0.36
Agropyron repens	0.40	0.44	*Matricaria inodorum*	0.08	0.24
Rumex obtusifolius	0.40	0.12	*Ballota nigra*	0.08	0.24
Achillea millefolium	0.32	0.68	*Calamagrostis epigejos*	0.08	0.16
Artemisia vulgaris	0.32	0.44	*Heracleum sphondylium*	0.08	0.12
Lactuca serriola	0.32	0.12	*Arenaria serpyllifolia*	0.08	0.08
Conyza canadensis	0.32	0.08	*Apera spica venti*	0.08	0.04
Geranium sanguineum	0.28	0.28	*Plantago lanceolata*	0.04	0.20
Melandrium album	0.28	0.24	*Festuca rubra*	0.04	0.16
Bromus inermis	0.28	0.24	*Lamium album*	0.04	0.12
Deschampsia caespitosa	0.28	0.16	*Bromus sterilis*	0.04	0.08
Trifolium pratense	0.24	0.44	*Carduus sp.*	0.04	0.08
Lolium perenne	0.24	0.24	*Daucus carota*	0.04	0.08
Arhenatherum elatius	0.24	0.24	*Galium aristatum*	0.04	0.08
Anthriscus sylvestris	0.24	0.16	*Galium saxatile*	0.04	0.08
Arctium tomentosum	0.20	0.24	*Malva moschata*	0.04	0.08
Stellaria media	0.20	0.12	*Amaranthus retroflexus, Agrostis pratensis, Bromus carinatus, Calystegia sepium, Chelidonium majus, Cicoria intybus, Festuca pratensis, Glechoma hederacea, Holcus mollis, Trifolium repens, Torilis japonica*	0.04	0.04
Plantago major	0.20	0.12			
Capsella bursa pastoris	0.20	0.04			
Rumex thyrsiflorus	0.16	0.28			
Bromus mollis	0.16	0.24			
Cerastium tomentosum	0.16	0.08			

doi: 10.17221/327/2015-PSE

Table 1b. Relative frequency of herb plants species for pens (N = 25) and control (N = 25) plots

Species	Frequency		Species	Frequency	
	pen	control		pen	control
Species present exclusively in sheep pens			**Species present exclusively in control plots**		
Galinsoga officinallis	0.12	0.00	*Geranium pusillum*	0.00	0.12
Geum urbanum	0.12	0.00	*Medicago sativa*	0.00	0.12
Sisymbrium loeselii	0.12	0.00	*Rannunculus lanuginosus*	0.00	0.12
Myosotis sp.	0.08	0.00	*Rubus sp.*	0.00	0.12
Epilobium sp.	0.08	0.00	*Plantago media*	0.00	0.08
Hordeum sp.	0.08	0.00	*Potentilla aurea*	0.00	0.08
Leonurus cardiaca	0.08	0.00	*Tragopogon dubius*	0.00	0.08
Phragmites australis	0.08	0.00	*Vicia villosa*	0.00	0.08
Poa trivialis	0.08	0.00	*Vicia sp.*	0.00	0.08
Polygonum aviculare	0.08	0.00			
Veronica arvensis	0.08	0.00			
Sonchus sp.	0.08	0.00			
Silene inflata, Veronica chamaedrys, Berteroa incana, Agrostis stolonifera, Agrostis gigantea, Anthoxanthum aristatum, Chenopodium hybridum, Echinochloa crus galli, Echinocystis lobata, Equisetum arvense, Erodium cicutarium, Lathyrus tuberosus, Myosotis palustris, Poa annua, Rannunculus acris, Papaver rhoeas	0.04	0.00	*Anthylis vulneraria, Artemisia absinthum, Artemisia pratensis, Carex hirta, Euphrasia sp., Galium intermedium, Helichrysum arenarium, Mycelis muralis, Phalaris arundinacea, Rumex acetosella, Vicia tetrasperma*	0.00	0.04

reference plots (F = 5.66, P = 0.026). Also total C_{tot} and N_{tot} content between plot categories differed (F_C = 1.522, P = 0.605; F_N = 0.282, P = 0.194), but not significantly.

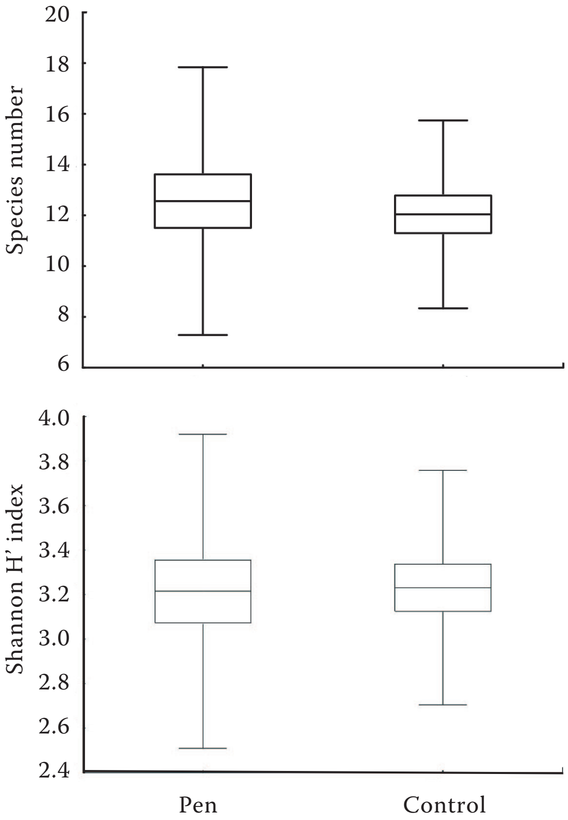
Out of the 107 species listed in the survey, as many as 28 were recorded exclusively in sheep pens, 20 were found exclusively in control plots, and the remaining 59 were present in plots of both types (Tables 1a,b). Abandoned sheep pens did not differ significantly from the control plots in plant species richness (F = 0.071, P = 0.793) and herb layer cover (F = 0.575, P = 0.456). *Urtica dioica*, *Galium aparine* and *Rumex obtusifolius* were significant indicators of sheep pens, whereas *Achillea millefolium* indicated control plots (Table 2). Plant species diversity was similar in both types of plots, as mean Shannon H' index for sheep pens and control plots equaled 3.21 and 3.23, respectively (F = 0.026, P = 0.873, Figure 2). The low mean value of J = 0.278 (SD = 0.128) confirmed that the plant species composition of abandoned sheep pens differed from that of control plots. There were more ruderal forbs in sheep pens than in control plots (42 and 34 plant species, respectively, χ^2 = 1.107, df = 2, P = 0.575). Plant communities also did not differ in plant life history (24 and 19 species, respectively, χ^2 = 0.671, df = 2, P = 0.714, Figure 3). In case of soil physicochemical properties and vegetation characteristics there were no interactions with time of abandonment.

Table 2. Major plant species present in sheep pens (N = 25) and control plots (N = 25), their frequency over all 50 plots, indicator values, and the significance level P of the maximum indicator values

Plant species	No. of plots	Indicator values		P
		pens	control	
Urtica dioica	33	74.6*	6.7	0.001
Galium aparine	16	37.5*	3.5	0.016
Rumex obtusifolius	13	32.9*	2.1	0.037
Achillea millefolium	25	7.4	52.2*	0.007

*P < 0.05

doi: 10.17221/327/2015-PSE



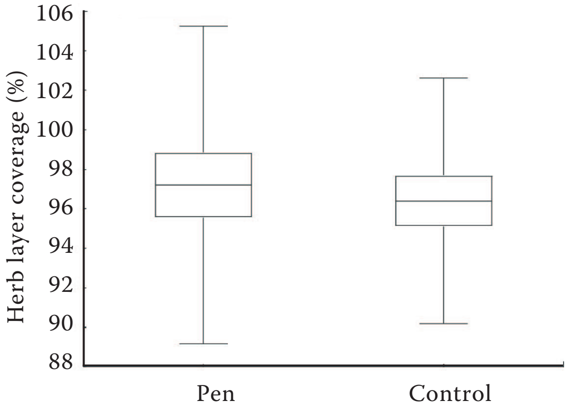


Figure 2. Vegetation parameters determined for sheep pens and control plots. Horizontal lines indicate mean values, boxes represent standard error and whiskers represent standard deviation

DISCUSSION

Most papers concerning marginal habitats among farmlands focus on their great role in increasing biodiversity and emphasize their higher species richness in comparison to surrounding areas (Czarnecka 2006). On the scale of landscape with many types of marginal habitats, they apparently increase species diversity and species richness. As some authors reported (Benton et al. 2003), the heterogeneity is the key factor. It seems that special attention should be paid to abandoned sheep pens as a new type of habitats with a great impact on soil chemical properties, and hence also on plant associations, clearly visible for long periods after abandonment. These marginal habitats do not necessarily increase species richness, but they may support some interesting species.

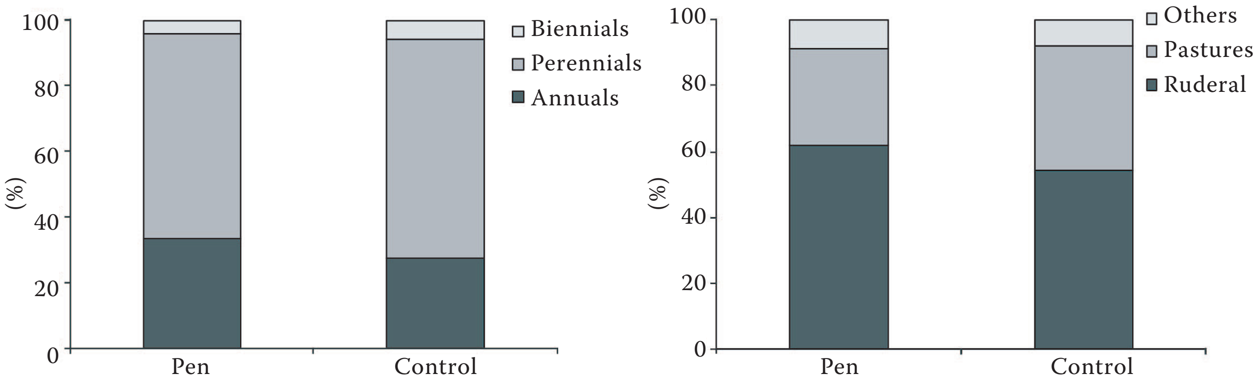


Figure 3. Proportions of species of different life history types (annuals, perennials and biennials) and habitat types (ruderal, pastures and others) in sheep pens and control plots

doi: 10.17221/327/2015-PSE

Marginal habitats are represented by a variety of many different communities (Marshall and Moonen 2002). Some of them are species-poor habitats (i.e. on dry and sandy, less fertile soils), whose negative effect on plant species diversity is diluted by the highly heterogeneous farmed landscape. In a more detailed analysis, it seems that some types of marginal habitats do not differ in terms of species richness (i.e. quantitatively) from surroundings, but they differ significantly in quality, expressed by species occurring mostly or even only in the given species-poor habitat type. This kind of field margins seems to be at least as important and relevant in functioning of landscape heterogeneity as other, species-rich habitats. It may be crucial for rare species protection, which is one of the most important functions of marginal habitats (Wuczyński et al. 2014). Sheep breeding (current and its after-effects) is known as a factor modifying the environment (Martinsen et al. 2013, Speed et al. 2014). This study provides evidence that even after 25 years of abandonment the sheep effect is still visible in soil chemical properties and plant communities. In our research, abandoned sheep pens were the places of main occurrence of three plant species demanding disturbed and highly fertilized soils: *Urtica dioica*, *Galium aparine* and *Rumex obtusifolius*. In contrast, only one species *Achillea millefolium* was characteristic of control plots. Indicator value analysis evidenced that abandoned sheep pens induced only qualitative changes in plant communities (Stránská 2004). Quantitative changes (in species number) were not detected. Additionally, the low Jaccard index between plot types confirmed that although abandoned sheep pens are not richer in plant species, they are refuges of some characteristic plant species, which are absent or infrequent in neighbouring habitats (Table 1). This is the evidence for importance of abandoned sheep pens for diversity shaping in broader scale.

Concentrations of both nitrogen forms in soils of sheep pens were still higher, even after 25 years of abandonment. Nutrient input (here generated by sheep manure and urine) may influence species richness (Mrkvička and Veselá 2002), also negatively (Kleijn and Verbeek 2000), so the highly fertilized soils probably are one of the reasons of the low plant species richness in our study. Also the lack of any cultivation practices (e.g. mowing) in our research plots is known to favour tall herbs. Species with tall stature and high rate of nitrogen consumption may be very effective competitors, able to dominate the plant community (e.g. *Urtica dioica*). Such competitive exclusion may prevent colonisation of the sites by other plants and not allow species richness to increase (Orczewska 2009, Kurek et al. 2015).

In our study the apparent effect of disturbance exclusion (manure inflow, trampling and grazing by animals) after 25 years is still manifested in different plant species composition (low values of the Jaccard index) and higher topsoil physicochemical properties (ammonium, nitrate, N_{tot} and C_{tot} levels).

REFERENCES

Baines M., Hambler C., Johnson P.J., MacDonald D.W., Smith H. (1998): The effects of arable field margin management on the abundance and species richness of Araneae (spiders). Ecography, 21: 74–86.

Benton T.G., Vickery J.A., Wilson J.D. (2003): Farmland biodiversity: Is habitat heterogeneity the key? Trends in Ecology and Evolution, 18: 182–188.

Czarnecka J. (2006): Roadsides as plant diversity refuges in agricultural landscape. Ecological Questions, 7: 37–46.

Dufrene M., Legendre P. (1997): Species assemblages and indicator species: The need for a flexible asymmetrical approach. Ecological Monographs, 67: 345–366.

Frank D., Klotz S. (1990): Biologisch-ökologische Daten zur Flora der DDR. Halle-Wittenberg, Martin-Luther-Universität.

Freemark K.E., Boutin C., Keddy C.J. (2002): Importance of farmland habitats for conservation of plant species. Conservation Biology, 16: 399–412.

Kleijn D., Verbeek M. (2000): Factors affecting the species composition of arable field boundary vegetation. Journal of Applied Ecology, 37: 256–266.

Kondracki J. (2009): Polish Regional Geography. Warszawa, Wydawnictwo Naukowe PWN.

Kovach W.L. (1999): MVSP – A Multivariate Statistical Package for Windows, ver. 3.1. Pentraeth, Kovach Computing Services.

Kurek P., Kapusta P., Holeksa J. (2014): Burrowing by badgers (*Meles meles*) and foxes (*Vulpes vulpes*) changes soil conditions and vegetation in a European temperate forest. Ecological Research, 29: 1–11.

Kurek P., Sparks T.H., Tryjanowski P. (2015): Electricity pylons may be potential foci for the invasion of black cherry *Prunus serotina* in intensive farmland. Acta Oecologica, 62: 40–44.

Mrkvička J., Veselá M. (2002): Influence of fertilization rates on species composition, quality and yields of the meadow fodder. Rostlinná Výroba, 48: 494–498.

doi: 10.17221/327/2015-PSE

Marshall E.J.P., Moonen A.C. (2002): Field margins in northern Europe: Their functions and interactions with agriculture. Agriculture, Ecosystems and Environment, 89: 5–21.

Martinsen V., Grund F., Ness Kjeve M., de Wit H.A., Austrheim G., Mysterud A., Mulder J. (2013): Differences in the quality of seepage water and runoff caused by plant community and grazing at an Alpine site in Hol, southern Norway. Water, Air, and Soil Pollution, 224: 1649.

Niżnikowski R., Strzelec E., Popielarczyk D. (2006): Economics and profitability of sheep and goat production under new support regimes and market conditions in Central and Eastern Europe. Small Ruminant Research, 62: 159–165.

Orczewska A. (2009): Migration of herbaceous woodland flora into post-agricultural black alder woods planted on wet and fertile habitats in south western Poland. Plant Ecology, 204: 83–96.

R Development Core Team (2009): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available at http://www.r-project.org

Roberts D.W. (2012): Package 'labdsv': ordination and multivariate analysis for ecology. R package version 1.5-0. Available at http://ecology.msu.montana.edu/labdsv/R

Smith J., Potts S.G., Woodcock B.A., Eggleton P. (2008): Can arable margins be managed to enhance their biodiversity, conservation and functional value for soil macrofauna? Journal of Applied Ecology, 45: 269–278.

Speed J.D.M., Martinsen V., Mysterud A., Mulder J., Holand Ø., Austrheim G. (2014): Long-term increase in aboveground carbon stocks following exclusion of grazers and forest establishment in an alpine ecosystem. Ecosystems, 17: 1138–1150.

Stránská M. (2004): Successional dynamics of *Cynosurus* pasture after abandonment in Podkrkonoší. Plant, Soil and Environment, 50: 364–370.

Szafer W., Kulczyński S., Pawłowski B. (1967): The Flora of Poland. Warszawa, Państwowe Wydawnictwo Naukowe PWN. (In Polish)

Tryjanowski P., Sparks T.H., Jerzak L., Rosin Z.M., Skórka P. (2014): A paradox for conservation: Electricity pylons may benefit avian diversity in intensive farmland. Conservation Letters, 7: 34–40.

Woodcock B.A., Westbury D.B., Potts S.G., Harris S.J., Brown V.K. (2005): Establishing field margins to promote beetle conservation in arable farms. Agriculture, Ecosystems and Environment, 107: 255–266.

Wuczyński A., Dajdok Z., Wierzcholska S., Kujawa K. (2014): Applying red lists to the evaluation of agricultural habitat: Regular occurrence of threatened birds, vascular plants, and bryophytes in field margins of Poland. Biodiversity and Conservation, 23: 999–1017.

Received on May 19, 2015
Accepted on December 11, 2015

Corresponding author:

Dr. Przemysław Kurek, Polish Academy of Sciences, Institute of Botany, Department of Ecology, Lubicz 46, 31 512 Krakow, Poland; e-mail: p.kurek@botany.pl