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Analysis of Species Indicator Values in Response to Spatial Environmental Variation of Differently Managed Agro-habitats

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Abstract

This paper investigates species indicator values in response to spatial gradients of environmental indices (light, L; moisture, F; nitrogen, N; temperature, T) in different agro-habitats (crop fields and their boundaries of intensive/conventional farming, IF; organic farming, OF) of Lithuania. All plant species were classified according to indicator values of the Ellenberg scale of general abiotic environmental factors (light, moisture, nitrogen, temperature) available for Central Europe. Multiple Correspondence Analysis was applied to analyze the patterns of relationships between species indicator values and environmental conditions in six different agro-habitats. Variation of N-values (ranging from 2 to 9 and x point) was observed to be the highest between ecological gradients, thus indicating wide spatial dispersion of soil N deposition in the habitats. The presence of particular plant species with medium indicator values (L5-L6, F4-F5, N5-N6, T4-T5) suggests that IF crop habitats are favored for establishment of mezophytes. Crop and margin habitats in OF agro-habitats were found to possess a wider environmental gradient, ensuring higher biodiversity.

Keywords: anthropogenized habitats, ecology, Ellenberg indicator value, MCA

Introduction

Increasing intensity of agricultural land use has led to deterioration of the environment of agro-habitats (Bukacek *et al.,* 2008; Jafariaet *et al.,* 2004; Klimek *et al.,* 2007; Tait, 2001). Lasting for more than five thousand years, the processes of agricultural development in Central Europe resulted in widespread anthropogenic ecological upheaval: old-growth woodland was transformed into a mosaic landscape of agricultural and semi-natural habitats (Waldhard *et al.,* 2003). Nowadays, nearly 40% of the area of the European Union is agricultural land (Bruyas, 2002; MARS, 2009), with most of the remaining area being occupied by forest, settlements and roads. In the middle of the 20th century, traditional and diverse farming practices were replaced by a modern, highly specialized type of agriculture. Intensification of agriculture was achieved by application of high-cropping technologies based on high-yielding cultivars, mineral fertilizers, pesticides, and irrigation in dry regions. As a consequence, the once small-scale mosaic of grasslands and arable fields, which created and sustained high biodiversity, was replaced with heavily managed grasslands or forests (Buhler-Natour and Herzog, 1999). Such intensive and extensive agro-management affects both abiotic (soil, water, air) and biotic (species, communities and biodiversity) resources (Baležentienė, 2010; Cooper, 1993; Tylianakis *et al.,* 2010).

As many authors have reported, floristic cover has declined in terms of diversity over the last few decades in arable fields, grasslands and boundary sites due to the drift of agro-chemicals (Callaway and Maron, 2006; Sutcliffe and Kay, 2000; Stevens *et al.,* 2010). Intensive land use and application of diverse chemicals are associated with declining area, reduced heterogeneity, and loss of cohesion of natural and semi-natural habitats in the agro-environment (Donald and Evans, 2006; Kivinen *et al.,* 2006; Schippers and Joenje, 2002). During the last century these changes have resulted in a significant reduction of biodiversity in anthropogenized or semi-natural habitats of the agricultural landscape (Aavik and Liira, 2009; Billeter *et al.,* 2008). This particularly concerns the diversity of species, biocoenoses and ecosystems (Tylianakis *et al.,* 2008). Therefore, ecologists and environmental scientists often need to monitor and predict biodiversity as well as species presence and response to environmental disturbance, and change over landscape gradients or variance among different habitats (Mičieta and Murín, 2007). Furthermore, such international agreements as the Convention on International Trade on Endangered Species of Wild Fauna and Flora (CITES Secretariat, 2008) stress the importance of these investigations. Species with high-dispersal abilities appear to be driving these biodiversity patterns, because of their recolonization ability (Elzinga *et al.,* 2001; Tsharntke *et al.*, 2005). In recent years, ecological indication has also been recognized as playing an important role in explaining the species richness of a site (Podani and Csányi, 2010). Ecological indication of a species has long been the most popular measure to express species importance in community classification and changes (de Heer *et al.,* 2005; Odland, 2009, Schuster and Diekmann, 2003).

Certain indication scales have been developed and used in environmental evaluation throughout the world (Ditor *et al.,* 2001; Piorr, 2003). The method of Ellenberg (1974, 1996) indicator values is widely used in Central European environment-composition studies (Ewald, 2003; Seidling and Fischer, 2008). Nevertheless, a few problems concerning the original definition of 'species indicator value' still require clarification, and some modifications are also in order so as to exploit the capabilities of the method more fully. In particular, proposals of novel component terms (specificity, concentration and fidelity) are required and could be incorporated in the evaluation of species indicator value (Podani and Csányi, 2010).

In this article, it has been tried to estimate the variation of certain ecologic indicators across different farming management types. The central question was whether it is possible to apply a given standard set of indicators and Multiple Correspondence Analysis (MCA) to generate a meaningful assessment of the impact of farming management mode on agro-habitats. In order to determine environmental factors that control vascular plant species richness and composition in agro-ecosystems, better understanding of the functional roles of the species-abiotic pattern present in communities is needed (Bonis *et al.* 2005; Laliberté and Tylianakis, 2010). Therefore, estimation of relationships between environmental factors and plant diversity may contribute to evaluation of direct and indirect multifunctional interactions among many change drivers in agro-habitats (Mulder and de Zwart, 2003; Tintnera and Klug, 2011). However, limited knowledge of the relative importance of habitat and landscape-scale management on biodiversity makes reliable recommendations difficult. Therefore, the main aim of this study was to evaluate the response of species indicator values to spatial gradients of environmental conditions (light, L; moisture, F; nitrogen, N, and temperature, T) in different agro-habitats (crop fields and their boundaries of intensive/conventional farming, IF, and organic farming, OF) by applying the Ellenberg scale (1974) of species indicator values available for Central Europe. Application of MCA enabled evaluation of the relationships between species indicator values, local field management (conventional and organical) and agro-habitat type (crop fields and their margins). This flora can be classified into groups of species differing by their degree of negative environmental tolerance, and also by their response to management mode.

Materials and methods

Relevés were carried out at different sites under different farm management types, thus forming the pattern for further analysis. Explanatory variables describing certain characteristics of the species investigated were recorded according to Ellenberg (1974, 1996). MCA was used to evaluate the joint impact of farming type and site on biodiversity.

Study sites

Lithuania is located in a temperate zone of Central Europe, with a transition from an oceanic climate to a continental climate and belongs to hardiness zone 5 (Peel *et al.*, 2007). Annual average temperature ranges between 5.5-7.5°C, with a humidity of 670 mm (Bukantis, 2004). The following criteria were used as the basis for plant relevance: species diversity/abundance, graduation environmental factors by species indicator value in six anthropogenized

Tab. 1. Characteristics of study sites of different anthropogenizing levels

Management type	Location	Habitat	Plant cover	Acronym	Fertilizing	Soil classification
Intensive farming (weed control by tillage and herbicide)	Research Station 54°52'8.40"N 23°50'11.99"E	Crop	Barley	IF RS C	$N_{90}P_{50}K_{60}$	Hapli-Epihypogleyic Luvisol
Intensive farming (grass cut)	Research Station 54°52'26.32"N 23°51'56.48"E	Margin	Sown perennial grass mixture	IF RS M	0	Hapli-Epihypogleyic Luvisol
Intensive farming (weed control by tillage and herbicide)	Training Farm 54°51'57.66"N 23°48'40.00"E	Crop	Oat-vetch	IF TF C	$N_{120}P_{90}K_{90}$	Albi-Epihypogleyic Luvisol
Intensive farming (plant cover annual removal)	Training Farm 54°52'21.92"N 23°51'40.02"E	Margin	Ruderal/segetal species	IF TF M	0	Albi-Epihypogleyic Luvisol
Organic farming (*certified 15 yrs)	Training Farm 54°52'28.44"N 23°51'52.39"E	Crop	Oat-pea	OF C	Manure, 80 t ha^{-1}	Hapli-Epihypogleyic Luvisol
Organic farming (grass cut)	Training Farm 54°52'30.92"N 23°51'40.02"E	Margin	Sown perennial grass mixture	OF M	0	Hapli-Epihypogleyic Luvisol

* Organic certification by the EKOAGROS (Lithuanian Committee for Organic Agriculture)

habitats of differently managed (IF and OF) crop fields (C) and their margins (M) (Tab. 1). The initial test data were obtained during summer (June-July) in crop fields and in uncropped cultivated margins at the Training Farm (TF) and Research Station (RS) of the Lithuanian University of Agriculture (54°52′58″N, 23°50′21″E, total area ca. 200 ha). The latter two locations represent agro-habitats under IF. Only certified, environmentally sustainable agro-technical measures were applied in OF, in contrast to the chemical fertilizers and pesticides applied in IF, RS and TF. Stratified sampling was carried out on sandy moraine loam humic horizon of Calcari-Epihypogleyic Luvisol, LVg-p-w-cc (FAO/UNESCO 1997). The soil pH varied from 7.1 to 7.0 and humus content was medium (2.3-2.5%). Annual fertilizing with $N_{120}P_{90}K_{90}$, $N_{90}P_{50}K_{60}$ or 80 t ha^{-1} of manure was used in the conventional (TF and RS) and OF systems, respectively. In addition, pesticides were applied (1-1.56 times per yr) in IF.

Field sampling

Species richness was registered by the most widely used method of habitat generalist vs. specialist at alpha-diversity scale (Krauss *et al.,* 2004; Liira *et al.*, 2008). The *relevés* plot size was selected to be 1.0 m^2 due to relatively low species diversity. *Relevés* in 5 replications were set out along transects in sections of 20-25 m at each study site (Kent and Coker, 2003). Altogether, on habitats of different anthropogenization intensities 30 phyto-sociological *relevés* were conducted (Tab. 2).

The registered plant species were listed and grouped according to commonly used taxonomic and nomenclatural interpretation of European (Tutin *et al.,* 1968-1980) and national (Jankeviciene, 1998; Gudzinskas, 1999) flora. The species relevance (combined presence: cover, Cov.; abundance, Ab.) followed the Braun-Blanquet (1964) classification scale ranging from 1 to 6.

The Central European phytocenotical syntaxon system is recognized as being flexible and fair, because its units (association, sub-association, variable) comprise all plant species that reflect the ecological information; therefore, this system was used for identification of the *relevés* communities (Böttcher, 1971).

Species indicator values (with scales ranging from 1 to 9 or 12) reflecting the need for solar radiation (light, L), temperature (T), soil nitrogen (N), and moisture (F), as well as plant life-form (LF) were attributed to all vascular plant species present in each of the *relevés* analyzed, according to Ellenberg (1974, 1996). Each *relevés*, and thus both the specific farming type and habitat type, were assigned appropriate indicator variables describing the species found in those locations.

Alpha-diversity was evaluated by the Shannon-Wiener method (Kent and Coker, 2003). The Shannon-Wiener biodiversity index H' ($H'=-\Sigma\, p_i \ln p_i$) of non-cultivated species richness or alpha-diversity with relative abundance, expressed as a proportion of total cover (p_i), was used.

Statistical analysis

The selection of variables, namely species indicator values with regard to gradients of N, L, T, F; farming and habitat type, was based on ecological relevance. In order to reveal major vegetation and environment gradients, multiple correspondence analysis (MCA) was applied (Greenacre, 1984), using the statistical package STATISTICA of StatSoft. The main aim of this method is the analytical description of data that correspond to qualitative variables without *a priori* constraints and limitations. This method also allows the discovery of new complex variables that characterise the data as a whole. In addition, the application of MCA ensures the overall description of the phenomenon under analysis. MCA relies on measurement of χ^2 distances between categorical variables. Each environment factor analysed was identified by Ellenberg indicator values. These values were generalized by transforming them into three classes as described below. Hence, each of the three classes described certain part of the Ellenberg scale of certain indicator. Therefore, the environmental factors were mapped into class I, class II or class III thus reducing the number of investigated variables and enabling to reveal more generalized patterns of relationships between them (Tab. 3). Hence, the MCA was applied for the three indicator classes and habitat variables.

Results and discussion

In total, 96 herbaceous vascular plant species were recorded at the 30 *relevés* of differently anthropogenized habitats (Fig. 1). Nonetheless, the relevant species number is always lower due to sampling of some indifferent species without respective indicator values in a number of plots. Species indifference mostly occurred for temperature (29

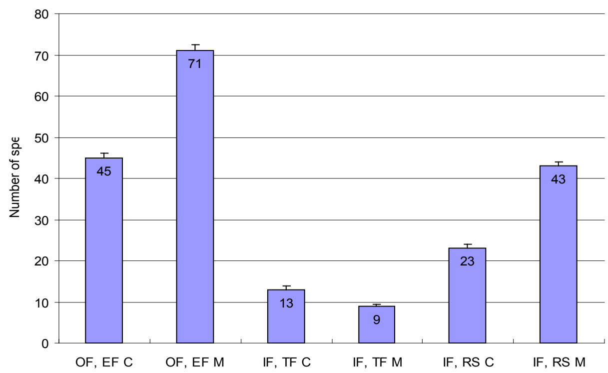


Fig. 1. Biodiversity in habitats of different anthropogenic levels and farming types (mean ± SD intervals, p <0.05). OF, EF C-organic farming, crop habitat in Ecologic Farm; OF, EF M-organic farming, margin habitat in Ecologic Farm; IF, TF C-intensive farming, crop habitat in Training Farm; IF, TF M-intensive farming, margin habitat in Training Farm; IF, RS C-intensive farming, crop habitat in Research Station; IF, RS M-intensive farming, margin habitat in Research Station

Tab. 2. Agro-environment scheme management options included in this study

Site / habitat	Management options			No. of *relevés*	Rotational
	OF	IF TF	IF RS		
M	Regularly cut margin, no chemical fertilizers or pesticides (5 *relevés*)	Spring fallow, herbicides (5 *relevés*)	Regularly cut margin, chemical fertilizers and pesticides (5 *relevés*)	15 (5x3)	No
C	Regularly cultivated field, only certified (organic) fertilizers (5 *relevés*)	Regularly cultivated field, chemical fertilizers and pesticides (5 *relevés*)	Regularly cultivated field, chemical fertilizers and pesticides (5 *relevés*)	15 (5x3)	Yes
Total no. of *relevés*	10 (5x2)	10 (5x2)	10 (5x2)	30	

Tab. 3. Conversion of species indicator values into appropriate classes with regard to the some environmental factors

Class	Light (L1-L9)	Temperature (T1-T9)	Moisture (F1-F12)	Nitrogen (N1-N9)
I	≤ 6	≤4	≤4	≤4
II	7-8	5-6	5-6	5-6
III	9	≥7	≥7	≥7

sp.), moisture (17 sp.) and nitrogen (27 sp.). The least indifferent species number (5 sp.) was observed for the essential plant environment factor - light. Recorded plant diversity was represented by 21 families of *Magnoliophyta* (*Angiopsermae*) and 1 family of *Equisetophyta*, depending on the farming system and habitat. Taxonomic abundance of *Magnoliopsida* predominated over *Liliopsida*. The diversity of *Liliopsida* (*Monocotyledonae*) was peculiar in having the lowest abundance, i.e. 3 families, whereas the *Poaceae* family was represented by the largest number of genera (4-13) and species (7-16).

The following sequence represents the abundance of *Magnoliopsida* (*Dicotyledonae*) families in descending order: *Asteraceae*>*Fabaceae*>*Brassicaceae*>*Caryophyllaceae*>*Rosaceae*>*Polygonaceae*>*Scrophulariaceae*>*Onagraceae*>*Apiaceae*>*Lamiaceae*>*Geraniaceae*>*Plantaginaceae*. The remaining families, namely *Boraginaceae, Chenopodiaceae, Violaceae, Urticaceae, Rubiaceae* and *Equisetaceae*, were represented as monotypic, by a single genus. There were no bryophyte species in the cover of all research areas.

The total plant cover of non-cropped species varied depending on the farming system and anthropogenic level of the habitat. The cover of non-crop species was complete and highest on OF M; the lowest cover (only 15%) was observed on M of IF TF due to annual removal of vegetation. Less intensively managed OF was associated with the highest alpha-diversity, areas where mineral fertilizers and pesticides are not used. The plant cover of OF M had the most closed and even growth compared to IF M. The following sequence represents the total average cover in de-

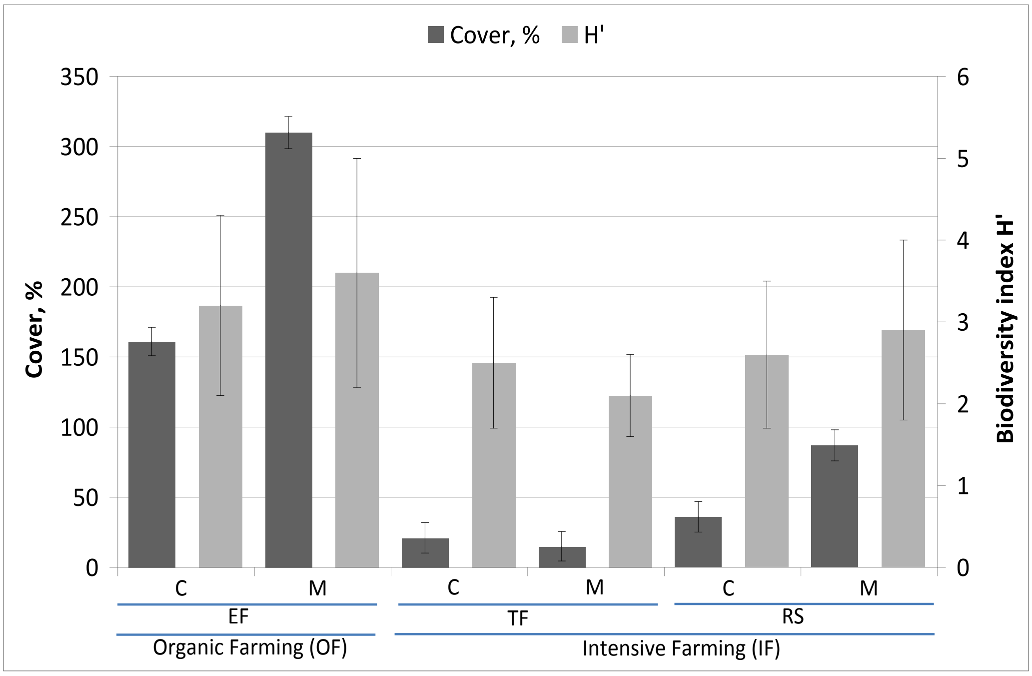


Fig. 2. Farming and habitat impact on alpha-diversity index (H') and total plant cover (P) ($p < 0.05$). OF, EF C-organic farming, crop habitat in Ecologic Farm; OF, EF M-organic farming, margin habitat in Ecologic Farm; IF, TF C-intensive farming, crop habitat in Training Farm; IF, TF M-intensive farming, margin habitat in Training Farm; IF, RS C-intensive farming, crop habitat in Research Station; IF, RS M-intensive farming, margin habitat in Research Station

Tab. 4. Syntaxonomical composition of differently anthropogenized agro-habitats

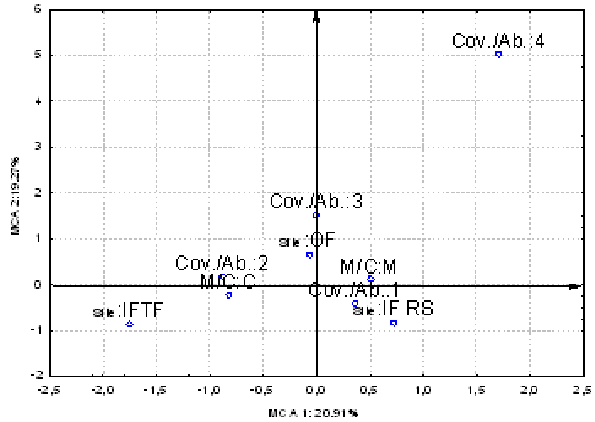
Transect / Habitat	Class	Order	Alliance	Association	Characteristic species
1 and 2 (IF and OF C)	*Stellarietea mediae* (Br.-Bl. 32) Tx. Lohm. Et Prsg, 50	*Secali-Violetalia arvensis* Siss. 43 ap. Br.-Bl. Et Tx. 46	*Aperion spicae-venti* Tx. in Oberd. 49	*Vicietum angustifoliae-hirsutae* Nowinsky 64	*Chenopodium album; Capsella bursa-pastoris; Tripleurospermum maritimum; Stellaria media; Euphorbia helioscopia; Equisetum arvense; Elytrigia repens; Polygonum aviculare; Cirsium arvense; Galeopsis tetrahit*, etc.
3(IF M)	-	-	-	-	
4	*Stellarietea mediae* (Br.-Bl. 32) Tx. Lohm. et Prsg, 50	*Secali-Violetalia arvensis* Siss. 43 ap. Br.-Bl. Et Tx. 46	*Aperion spicae-venti* Tx. ap. Oberd. 49	-	*Vicia angustifolia*; *Matricaria matricarioides*; *Apera spica-venti*; *Viola arvense; Fallopia convolvulus ; Veronica arvensis; Myosotis arvensis; Raphanus raphanistrus; Thlaspi arvense; Lamium purpureum; Sinapis arvensis; Fumaria officinalis*, etc.
5 (OF M)		*Polygono-chenopodietalia* (R. Tx. et Lohm. 50) J. Tx. 61			*Polygonum aviculare ; Chenopodium album; Alopecurusgeniuculatus; Geranium pusillum; Polygonum lapathifolium*, etc.
6 (OF M)	*Molinio Arrenatheretea* Tx.37	*Plantaginetalia majoris* Tx. et Preissin (47) 50	*Polygonion avicularis* Br.-Bl. 31	*Lolio-Plantaginetum majoris* Beger 30 em. Siss. 1969	*Lolium perenne ; Plantago major*; *Poa annua; Polygonum aviculare; Matricaria matricarioides* etc.
				Festuco pratensis-Plantaginetum Balcerk. et Pawlak 2000	*Festuca pratensis*; *Festuca rubra*; *Phleum pratense*; *Poa pratensis*; *Poa trivialis*; *Ranunculis acris*; *Symphytum officinale*; *Taraxacum officinale Trifolium repens*; *Vicia cracca*, etc.

scending order: OF, OF M>OF, OF C>IF, RS M>IF, RS C>IF, TF C>IF, TF M. Statistically significant ($p<0.05$) differences in Shannon diversity index H' were observed over all tested habitats (Fig. 2). A positive diversity response to sustainable organic farming was reported previously (Boutin *et al.,* 2008), and confirmed in this study.

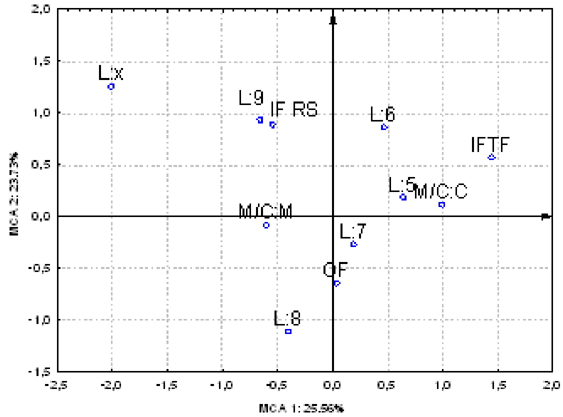
The lower land use intensity in OF predicts the highest biodiversity in OF M and C habitats where the alpha-diversity means were 3.6 and 3.2, respectively. Species richness is negatively associated with intensive land management (Donald and Evans, 2006; Kivinen *et al.,* 2006; Poschlod *et al.,* 2005), therefore the diversity index H' declined in IF, RS, ranging between 2.9-2.6. Regularly mowed road verges (IF TF M habitat) and areas subjected to intensive soil cultivation and widespread use of chemical fertilizers and pesticides (IF TF C habitat) were associated with the greatest loss of biodiversity, and the lowest species diversity was found in IF TF M (H'=2.1) and C (H'=2.5) habitats. Maintaining suitable habitat conditions in field margins (e.g. OF M) will augment species richness and conservation in agricultural settings.

The syntaxon diagnostic method, which is considered to be ecologically informative, was selected for this study (Devineau and Fournier, 2007; Weber *et al.,* 2000). Reliable assignment of the *relevés* to the published phyto-sociological associations cited by Böttcher (1971) was possible in most cases. Vegetation of the *Stellarietea mediae* class was identified in crop habitats of OF (transect 1) and IF (transect 2). Annual segetals, namely *Chenopodium album* and *Lamium rubrum* (in spring communities), were a characteristic species for synanthropic vegetation found in OF crop habitat (due to nitrophilic conditions after manure application) (Tab. 4). Emerging *Vicietum angustifoliae-hirsutae* association in crop habitats (OF and IF) is considered the most prevalent in Lithuania and is adapted to different edaphic conditions, from acidic sands to fertile soils (Baležentienė, 2009). Therefore, the formed association is peculiar with a rather different floral composition. Typical species were frequent crop-weeds: *Fallopia convolvulus, Elytrigia repens, Chenopodium album* etc. for both crop habitats. These species indicate fertile soils with high bioactivity, alkaline and near neutral pH (Ellenberg, 1996, Grime *et al.,* 2007). Noteworthy, these characteristic species of communities were neither constant nor abundant in transects. Association with *Matricaria matricarioides* was based on OF C habitat. This pioneer, stress-tolerant, ruderal species is characteristic of fields that have undergone land reclamation, which has also occurred in the studied area. Also established here are explerent species (*Plantago major, Poa annua, Polygonum aviculare*) that well characterize the class and grow in ruderal habitats. These species indicate initial stages of development of segetal flora and pre-existence of farmhouse sites. The intensive and regular soil cultivation of such species apophytes gives way to typical segetal species, including *Apera-spica venti*.

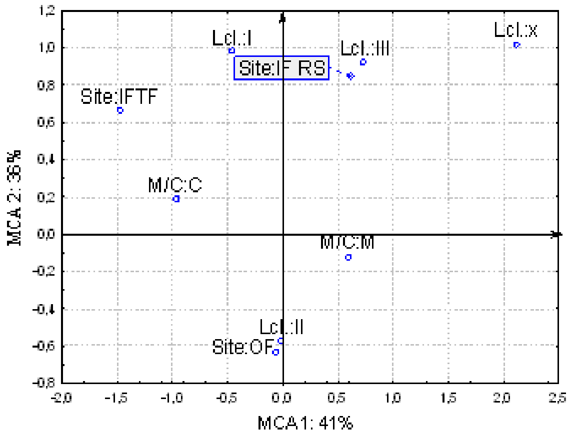
The largest number of species and communities was observed in OF and IF margin habitat. Permanent vegetation (grasses and perennials) tended to be associated with



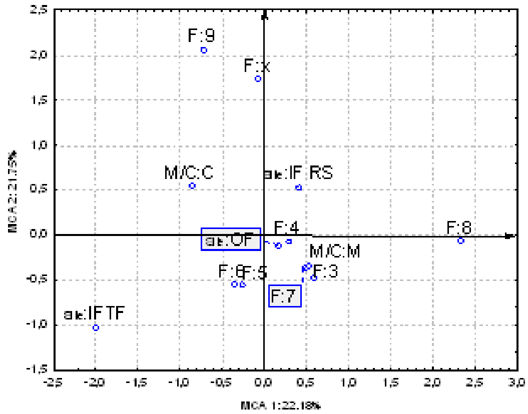
3.1. Combined presence (cover/abundance) of species



3.2. Dispersion of species ecological groups according to light gradient



3.3. Relationship between distribution of species indicator value class (I-III, x) according to light (L) gradient



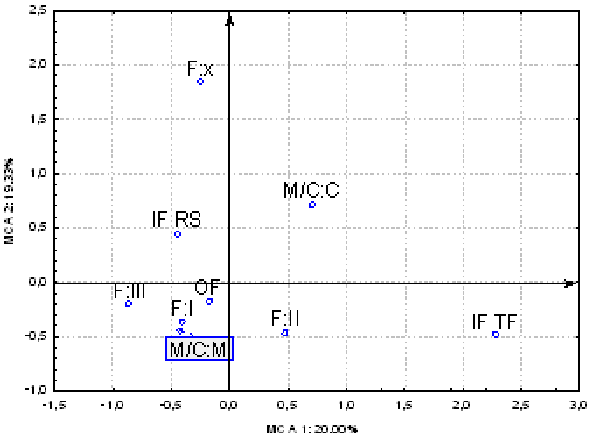
3.4. Relationship between distribution of species indicator value according to soil moisture (F3-9, x) gradient

Fig. 3. Correspondence analysis of species combined presence and distribution

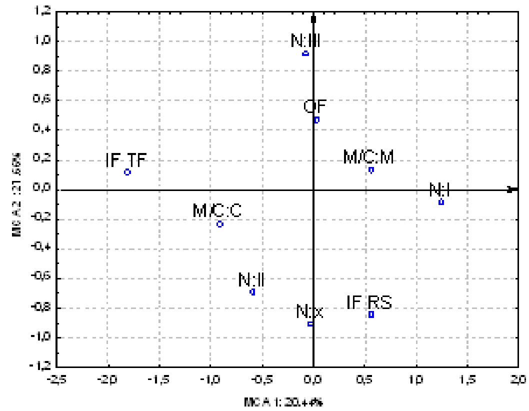
the less cultivated and uncropped margins of OF. The established associations of *Lolio-Plantaginetum majoris* and *Festuco pratensis-Plantaginetum* had dominating perennials with wide ecological range: *Festuca rubra*, *Lotus corniculatus, Plantago lanceolata, Dactylis glomerata* and *Achillea millefolium* agg. Nonetheless, plant communities have not developed due to annual destruction of vegetation cover on the margin habitat of IF TF (transect 3). Poor presence of ruderals *Poa annua, Tripleurospermum maritima, Plantago major* emerged there. Ruderal vegetation of *Secali-Violetalia arvensis* and *Polygono-Chenopodietalia* (*Stellarietea mediae* class) originated in one margin segment of OF (transects 4 and 5). The enumerated communities composed of successive vegetation indicate fertile soil, which was identified at the studied site. In addition, these associations indicate an initial vegetation stage of margin habitats (OF).

Gradients of ground water and soil compactness led to formation of two associations of class *Molinio Arrenatheretea* in sown OF margins along transect 6. Association *Festuco pratensis-Plantaginetum* was formed of characteristic species: *Festuca pratensis*, *Festuca rubra*, *Phleum pratense*, *Poa pratensis*, *Poa trivialis*, *Ranunculis acris*, *Symphytum officinale*, *Taraxacum officinale*, *Trifolium repens*, *Vicia cracca*. Association *Lolio-Plantaginetum* was formed on the compacted soil of a country road. Besides *Lolium perenne* and *Plantago major*, perennial meadow species *Polygonum aviculare, Matricaria matricarioides* etc. have become established in this margin habitat.

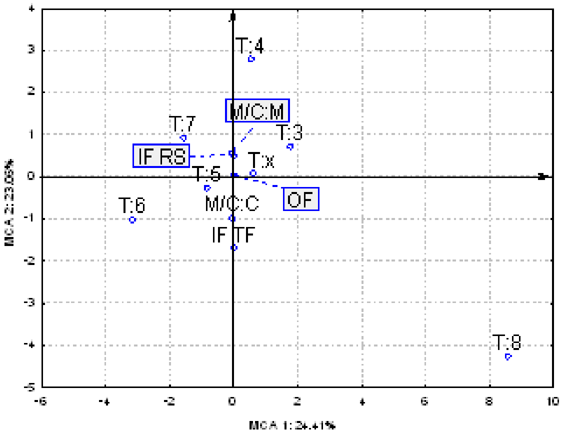
MCA explained approximately 40% of the total variation and enabled to retrieve the pattern of relationships between anthropogenized variables [i.e. habitat site (C, M), and farmi-ng types (IF, OF)] and species combined presence (Fig. 3.1). The two factorial axes discriminated three groups of variables describing certain features of appropriate habitats. The first group contains correlated variables identifying areas of IF margins and species of the lowest (class 1) relevance (combined presence), thus indicating the most unfavorable conditions for plant establishment due to vegetation removal there. The second group encompasses more favorable agro-habitats for plant establishment in the Ecological Farm (OF), with plant species of mean combined presence class 3. The third correlated group contains Training Farm (IF) crop field habitats with combined presence class 2.



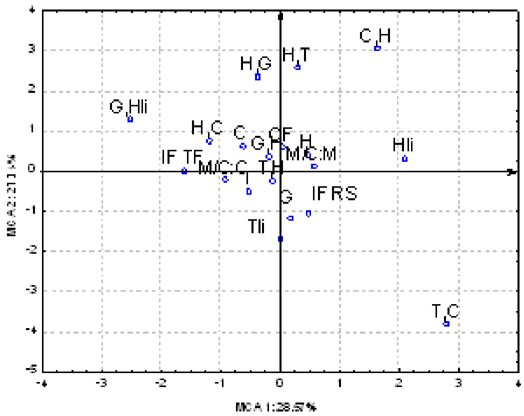
3.5. Relationship between distribution of species ecological classes (I-III, x) according to soil moisture (F) gradient



3.6. Relationship between distribution of species ecological groups (2-9, x) according to soil nitrogen (N) gradient



3.7. Relationship between distribution of species ecological groups (3-8, x) according to temperature (T) gradient



3.8. Relationship between distribution of species life forms (LF) ecological groups

Fig. 3. Correspondence analysis of species combined presence and distribution (Continous)

Surveys of the floristic composition of the overground vegetation testify to lower species diversity in the intensively managed agro-habitats (crop fields) than that in sustainable organic farming habitats. The ways in which such farming types impact vegetation diversity and cover have been discussed by a number of researchers (Boutin *et al.,* 2008; Büchs, 2003; Bruyas, 2002).

However, vegetation cover shift toward more abundance was observed in IF RS as compared with commodity-based IF TF, possibly due to higher doses of agro-chemicals applied in IF TF and annual cover removal in field margins (Liira *et al.,* 2008). It is obvious that the highest vegetation combined presence occurred (classes 1 and 2) in both IF (TF and RS) habitats (C and M). The OF site, especially the field margins, is associated with higher plant diversity and cover abundance. The MCA results of habitat vegetation associated cover and abundance (3-4 class) with OF margin habitats. In regard to some previous studies (Crichley *et al.,* 2004; Kivinen *et al.,* 2006; Piorr *et al.,* 2003), such habitats of high species diversity and closed coverage perform a specific support function as a green-veining source. Reduction of species diversity and cover in habitats can be related to the general characteristics of agricultural intensification, namely relatively high loads or frequent use of agro-chemicals and loss of semi-natural habitats. On the other hand, increasing diversity, especially that of autochthonous species, would indicate the presence of a positive and environmentally sustainable land management type (Aavik and Liira, 2009; Ditor *et al.,* 2001).

Results of MCA of species eco-group dispersion along light factor gradients in agro-habitats showed two blocks emerging from all available sites (Fig. 3.2). Strong relationships were observed between OF M and heliophilous (L7-L9) as well as light-indifferent (Lx) plant eco-groups. Crop shade caused less favorable light conditions for establishment of heliophilous non-cropped species due to higher crop-plant height and density than those in margins (Hyvönen, 2007). The other block is composed of similar half-shadow eco-groups (L5-L6) which correlate with C habitats.

Generalized classes of light indicator values are correlated with all measured parameters, indicating dependencies of plant available light within the habitats (Fig. 3.3).

The first two factorial axes explained ca. 77% of total variation of the analyzed variables. The two factorial axes discriminated three groups of variables describing radiation features of appropriate habitats. The first group encompasses crop habitats in TF (IF). Low radiation (L-class I) was attributed to these habitats due to high density of the crop stand. Other groups contain correlated variables of higher radiation classes (L II or L III) and marginal habitats in RS (IF) and OF. Mawdsley and O'Malley (2009) reported habitat light condition as being a comparatively general ecological feature across phyto-geographical units or habitat types.

The analysis revealed that a strong relationship exists between species T-and F-indicator values in agro-habitats (Fig. 3.4). Noteworthy, crop stands with medium soil moisture values (F5-F6) coincide with low light conditions, in contrast to the habitats of field margins (Seidling and Fischer, 2008). Species with higher (F7-F8) and lower (F3-F4) moisture indicator values occurred in field margins, where levels of moisture can vary widely. Species with high (F9) or indifferent moisture indicator values are typical of crop habitats in the RS due to some swamp areas there (Poschlod *et al.,* 2005). Optimal water supply (medium soil moisture, F5-F6) coincides with superior crop habitats in the Training Farm (IF) compared to habitats in other examined sites.

Reducing the number of investigated moisture variables and grouping them into classes resulted in a decreased moisture gradient in the margin-crop field direction due to more suitable conditions (FII) becoming established after land drainage (Fig. 3.5).

Strong correlations between essential plant nutrient soil nitrogen and species indicator values have previously been found (Ellenberg, 1996). However, some authors argue that N-indicator values are significantly correlated with other environmental parameters, indicating dependencies of available nitrogen within soil, particularly with pH in the organic layer (Seidling and Fischer, 2008). Nonetheless, cation exchange capacity and variation of soil parameters produce high pattern variability and increase nitrogen deposition both in agro-habitats and in other habitats (Stevens *et al.,* 2010).

Accordingly, a high dispersion pattern of N deposition was observed in the studied areas (Fig. 3.6). MCA revealed nitrogen indicator species (N8 and NIII class) to be associated with conventional farming practices at the Training Farm. The presence of highly distinct N9 and N2 species indicates an uneven pattern of application of hard manure at OF. Species of N5-N6 indicator values indicate soils with mostly intermediate N-content in crop habitats. Margin habitats in the RS (IF) were characterized by different patterns of N deposition (N3-N4, N7; N II class) possibly due to soil pattern variation or fertilizer leakage from crop fields.

Loacker *et al.* (2007) provide evidence that climate warming after 1970 also could impact species establishment and extension of the growing area. The species investigated in the present study indicate an intermediate-warm (T5-T7) climate environment (Fig. 3.7), which is typical in Central Europe (Ellenberg, 1996). This pattern of dispersion mostly depends on microclimate variation related with micro relief in crop-field and margin habitats.

Climatic types can be characterized by the prevailing life-forms in plant communities growing under a given climatic regime, by using the proportions of species in each life-form (LF) class or the biological spectrum (Raunkiaer, 1934). Predominance of a temperate climate results in high proportions of herbaceous life-forms that avoid unfavorable conditions by losing their aerial parts (hemicryptophytes, cryptophytes, and herbaceous terophytes). The establishment of geophytes, hemi-cryptophytes or terophytes (G, H, C) observed in the present study is consistent with a temperate climate in the evaluated territory (Fig. 3.8).

Both agro-environment habitat and the farming system influenced species LF diversity. Extensive organic land-management therefore has great importance to preserve floristic diversity through maintenance of sustainable environmental conditions (Bonis *et al.,* 2005).

Conclusions

The anthropogenic level of the habitat had a great effect on species diversity and composition. The field margins of both intensive and organic farming systems (with the exception of IF, TF UCM) were significantly more diverse (alpha-diversity ranged between 2.9-3.6) than conventionally managed cereal crops (alpha-diversity ranged between 2.5-3.2). Semi-natural habitats of margins presumably are colonization sources of ruderal and perennial forb species for arable fields. Permanent vegetation (grasses and perennials) tended to be associated with the less cultivated and uncropped margins of the OF. Different agricultural disturbances might also be a possible explanation for the variation observed between cultivated (crops) and uncropped (margins) areas. The data presented in this study demonstrate the importance of the herbaceous component in empirical application of Ellenberg scale of plant species indicator values for agro-habitat indication. MCA application confirmed existing relationships among respective species indicator values (radiation, temperature, soil moisture, nitrogen) and agro-habitats. Annuals of synanthropic vegetation predominated in crop habitats (both IF and OF) and thus indicated proper land management, which, in turn, supported sufficient available nitrogen content within soil, neutral pH, and light condition. The presence of species with medium indicator values (L5-L6, F4-F5, N5-N6, T4-T5) suggests that IF crop habitats are more favorable for mezophyte establishment. Hence, crop and margin habitats in the OF type possess a wider environmental gradient ensuring higher biodiversity. The wide difference in species ecological behavior in agro-habitats of different anthropogenic impact urges caution in the use of indicator values and their extrapolation to other habitats and regions. However, the results give a useful impression of the different habitat vegetation influenced by management practices. This flora can be classified into groups of species differing by their degree of negative environmental tolerance and also their response to management mode. Therefore agro-ecological parameters of habitat could be simplified by the vegetation ecology approach.

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