2011 TERRECO Science Conference
October 2 – 7, 2011; Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany

Plant Communities of Field Margins as related to Management, Connectivity, and Spatial Context

Kang, Wanmo (1); Lee, Dowon (1); Han, Donguk (2)

(1) Department of Environmental Planning, Graduate School of Environmental Studies, Seoul National University, Gwanak-ro 599, Gwanak-gu, Seoul 151-742, Republic of Korea, reomi00@snu.ac.kr
(2) PGA Wetland Ecology Institue, 240-2 Daejang-dong, Deugyang. Goyang, Gyeonggi 412-250, Republic of Korea, ecoguide@paran.com

Abstract: Field margins are an important component of the agro-environment as they contribute to maintaining ecosystem functions and protecting biodiversity. To our knowledge, however, little is known as to how plant community composition and diversity differ depending on type and management of field margins. We surveyed 12 field margins (4 connected intact, 4 isolated intact, and 4 isolated and treated with herbicides and mowing) and recorded the composition of herbaceous and woody vascular plants. Based on the data, the effects of connectivity, weed control management, local and landscape context on the field margin community composition were examined with relevant environmental variables at local and landscape scales using multivariate statistical techniques. The field margin plant community was clearly explained by structural connectivity of the field margin and adjacent forest. The plant composition of a field margin was strongly related to environmental variables at the local and landscape scale. Mean percent cover of the dominant plant species was significantly affected by weed control, but plant community composition was not. There were significant differences in native, exotic, woody and herbaceous richness between connected and isolated field margins. However, all communities had a similar number of nectar plants, which become an important source of ecosystem services. Our results suggest that landscape structure is more important in determining plant community composition than the management practices of field margins. Management practices may be more important in determining species dominance than species composition and richness. Thus, different management regimes are required to conserve biodiversity as well as ecosystem service provided by the nectar-rich flowers in field margins.

Keywords: *agricultural intensification, plant communities, field margin type, structural connectivity, management*

1. Introduction

Agricultural intensification has led to a simplification of agricultural landscapes and significant structural and functional changes of natural ecosystems (Grimm et al. 2000). Nutrient cycling and food webs have been disturbed due to application of chemical fertilizers and pesticides, introduction of nonnative flora and fauna, and conversion of native habitats in an agriculture matrix (Newton 1998 in Marzluff and Ewing 2001). In this way, the ecological footprint of agricultural regions has dramatically increased (MA 2005). Consequently, environmentally sustainable agro-environment schemes are taken into consideration to maintain rural livelihoods, conserve biodiversity of rare and sensitive species, and provide critical ecosystem services (Barraquand and Martinet 2011).

One important component of agro-environment schemes in maintaining ecosystem functions and biodiversity is arable the field margin adjacent to a field (Butler et al. 2007; Vickery 2009). The vegetated margins, both cropped and uncropped, provide valuable wildlife habitats for invertebrates (Moreby and Southway 1999; Kells et al. 2001), birds (Vickery 2002; Douglas et al. 2009; Wuczynski et al. 2011), and small mammals (Tew et al. 1994) across arable farmlands without changing cropping patterns. Field margins act as buffers against dispersal of nutrients and pesticides to adjacent natural ecosystems (de Snoo 1995). Field margins are also an important reservoir of native herbaceous plants (Dajdok and Wuczynski 2008) and flower-rich field margins perform valuable ecosystem services like natural pest control and pollination (Bianchi et al. 2006; Carvell et al. 2007).

Understanding how plant communities within field margins respond to human-caused disturbance and how we can protect and enhance plant diversity will help us maximize their ecological functions. It is well documented that field margin plant communities are affected by adjacent land cover types (Le Coeur et al. 1997) in the surrounding landscape, as well as the width of margin and management practices (Le Coeur et al. 1997; Tarmi et al. 2009). However, despite much research on this subject in recent years, our understanding of how plant community composition differs among field margin types depending on management regimes is still insufficient to provide farmers with specific guidelines for conserving and enhancing ecosystem services. We need to know what local and landscape-level factors drive composition, structure and diversity of plant community according to the nature of field margin.

In this study we compared the plant community composition of three types of uncropped field margins in conventional crop fields: (1) connected intact field margins to adjacent large forest patches, (2) isolated intact field margins, (3) isolated field margins periodically cut or herbicide-treated. We tested if weed control (i.e., herbicide application and mowing), and connections of field margins and forests influence plant species richness and community composition. We further examined the effect of local environmental factors and varying landscape contexts on these field margin plant communities.

2. Methods

2.1 Study Site

Twelve (4 connected intact, 4 isolated intact, and 4 isolated and treated with herbicides and mowing) field margins were selected in Yanggu-gun, South Korea (region A: 38°17´N, 128°8´E; region B: 38°5´ N, 128°3 E) (Fig. 1). All the field margins were located in an altitude range of 300 to 600 m. In farm fields, typical vegetables like onion (*Allium cepa* L.), lettuce (*Lactuca sativa* L.), radish (*Raphanus sativus* L.) etc., were cultivated under conventional conditions. The connected intact field margins that were adjacent to large forests and the isolated field margins were found in open landscapes. The closest distances between field margins and forests range from 0 to 91 m. Four of the isolated field margins were treated with herbicides and mowing in spring 2010.

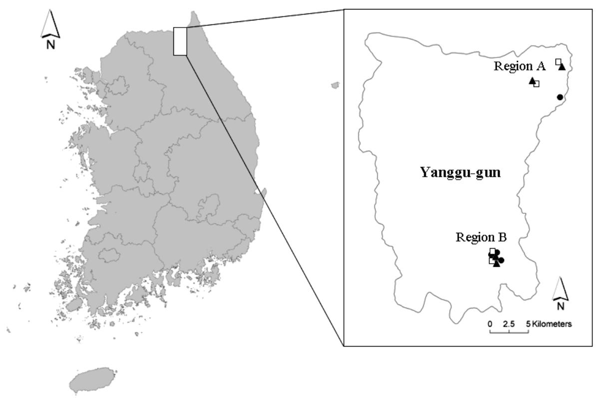

Figure 1. Location of study sites in Yanggu-gun, Korea. (Symbols: ● Connected structural, not treated; □ Isolated structural, not treated; ▲ Isolated structural, treated with herbicides or mowing).

2.2 Data Collection

2.2.1 Plant data

Three 10 m wide line transects were placed across the field margin, from the field boundary to the forest edge. All herbaceous and woody vascular plants were surveyed along 36 line transects in June and July 2010. There was no significant difference in the field margin's width among the three field margin types (ANOVA, $F_{2,\ 33}$ = 2.059, p = 0.144). In each line transect, we recorded species present within a radius of 0.5 m along the traverse line. Observed species were classified into plant groups: herbaceous and woody species, native and exotic species, and nectar species. Classification of native and exotic species was based on Kim et al. (2000). Plant coverage was measured in the field margins, representing the total distance intercepted by each species along a transect. Percent coverage was calculated by dividing the total distance intercepted by each species by the total transect length.

2.2.2 Environmental Variables

We gathered a set of local-scale environmental variables for each field margin, including elevation, aspect, slope, solar radiation, wetness index, and field margin width, which are abiotic factors affecting plant growth. We used a Garmin GPS 60 Cs to determine exact field margin elevation. Aspect, slope, and wetness index were calculated from a 30-m digital elevation model using ArcGIS 9.1 (ESRI). DiGeM 2.0 was used to estimate the potential sum of solar radiation per year (Conrad, 1998). We also measured landscape-scale environmental variables using ArcGIS 9.1. A land cover map (TERRECO, 2010) was used to estimate the fraction of land cover (forest, grass, and agriculture) around center locations of line transects within different buffer classes (50, 100, 200, 500, and 1,000 m). Forest cover includes hardwood, pine, and mixed forest. Grass and agricultural land cover types are dominated by herbaceous plants and farm fields, respectively.

2.3 Data Analyses

To examine changes in plant community composition, we used multivariate statistical methods, which allowed us to (1) identify discrete plant communities relative to field margin type, (2) examine relationships between plant species and environmental variables, and (3) reveal ecological and functional differences between discrete communities.

2.3.1 Community Composition

We used nonmetric multidimensional scaling (NMDS) to identify variation in the composition of plant communities inhabited in the three field margin types. This is a nonparametric ordination technique that doesn't need assumptions about the shape of the species distribution or the relationships between species occurrences and the environmental gradients. NMDS graphically depicts patterns of ecological communities, via maximizing the rank-order correlation between distance measures and distances in reduced ordination space (Clarke 1993). NMDS also provides a useful method for overlaying environmental factors. NMDS was performed using a Sorensen's (Bray-Curtis) similarity index derived from relative differences in species richness among field margin types. Species found in < 5% of the line transects were removed from the ordination analysis to avoid spurious effects of rare species (McCune and Grace 2002). We performed a Monte Carlo permutation test with 100 randomizations to determine overall significance of the ordination. Plant species communities among field margin types were compared by using multi-response permutation procedures (MRPP; Mielke 1991) based on Sorensen's index. MRPP is a nonparametric procedure that tests the hypothesis of no difference in species composition between groups (i.e. field margin types). All Statistics were commuted with R 2.12.0 (R Development Core Team 2010). We used the function *MetaMDS* and *MRPP* in R with the package vegan (Oksanen et al. 2008). The function *envfit* (vegan package) was also used to overlay environmental variables and examine the relationship between environmental variables and in the ordination of species distributions and sample sites.

2.3.2 Community Comparison

We calculated the number of species in each of the species groups at each site. Differences in species richness of each group among field margin types were tested using a linear mixed model ANCOVA with field margin width as a covariate. Field margin type was fixed effect. Because transects were nested within field margin, field margin identity was considered a categorical random effect. We also used Tukey's multiple comparison procedure to test differences between pairs of communities. The linear mixed model was implemented using the function *lme* from the R package nlme (Pinheiro et al. 2008). Tukey's multiple comparison was performed via the package multcomp (Hothorn et al. 2008). Prior to analysis, we checked the assumptions of normality and homogeneity of variance in the statistical models. Only native species richness was log-transformed to meet the requirements of normality and homoscedasticity. Because transformed woody species richness didn't meet these assumptions, we performed the multiple comparison tests after Kruskal-Wallis rank sum test using the package pgirmess (Giraudoux 2006). Fisher's exact test was also used to test weed control treatment's effect on mean percent cover of 10 dominant species in isolated field margins with and without weed control application. The species were chosen because they exist generally as dominant species in open landscapes.

3. Results

3.1 Plant Communities

There were a total of 110 species present in the field margins. We excluded 39 species which occurred at fewer than 5% of the line transects from the ordination analysis. However, all 110 species were included in the plant community comparisons. 85 and 25 species were herbaceous and woody plants, respectively. 70% of the total plant species were nectar plants. 87 species were native species and 23 species were exotic species.

3.2 Community Composition

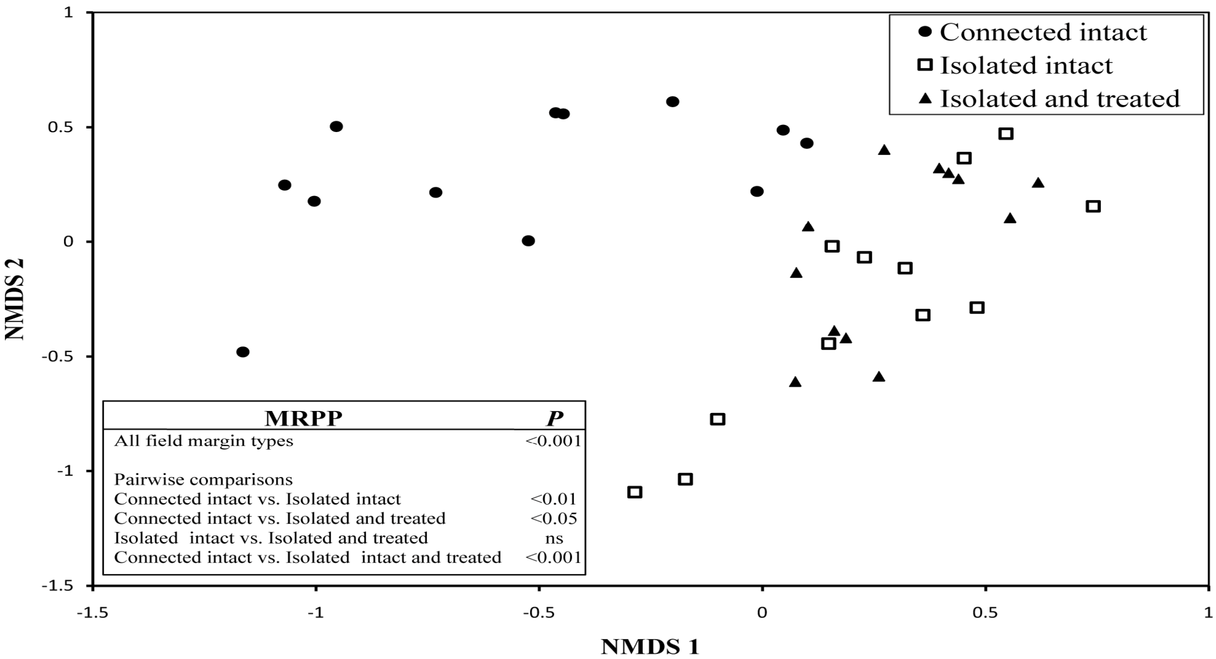

Figure 2. NMDS ordination of plant species communities in 12 field margins. With the exception of the pair Isolated intact-Isolated and treated, community composition among the three field margin types significantly differed (based on familywise α = 0.05) based on overall and pairwise comparisons based on MRPP results (inset).

We used a three-dimensional solution with a stress of 15.0 because the change in NMDS stress was < 5 with additional dimensions (Monte Carlo test, p < 0.01; McCune and Grace, 2002). The three axes together represented 85.2% of the variance in plant communities, using a linear fit-based R^2 measure (Oksanen et al. 2008). Field margins tended to group together according to the field margin types in ordination plot, indicating a similarity in plant community composition (Fig. 2). The MRPP analyses confirmed substantial overlap in field margins in isolated intact and treated field margins in ordination plot indicated compositionally similar species assemblages (A = -0.0058, p = 0.604; Fig. 2). Plant communities differed significantly between connected intact and isolated field margins, regardless of weed control application (A = 0.0865, p < 0.001; Fig. 2). Vectors overlaid onto the ordination plot using environmental variables showed the direction of the change in community patterns relative to the local- and landscape-scale environmental variables as well as the maximum correlation with the NMDS ordination (Figs. 3a, 3b). A correlation analysis confirmed that sites and species sort strongly according to not only local but also landscape-scale variables (Figs. 3a, 3b, 3c, and 3d). The most important local- and landscape-scale variables were aspect, elevation, slope, and solar radiation and amount of forest, grass, and agriculture cover, respectively. Particularly, slope, solar radiation, and amount of forest and agriculture cover were correlated with NMDS axis 2 that drove trends in species composition (Figs. 3c, 3d). In other words, communities are clearly separated by these local- and landscape-scale variables.

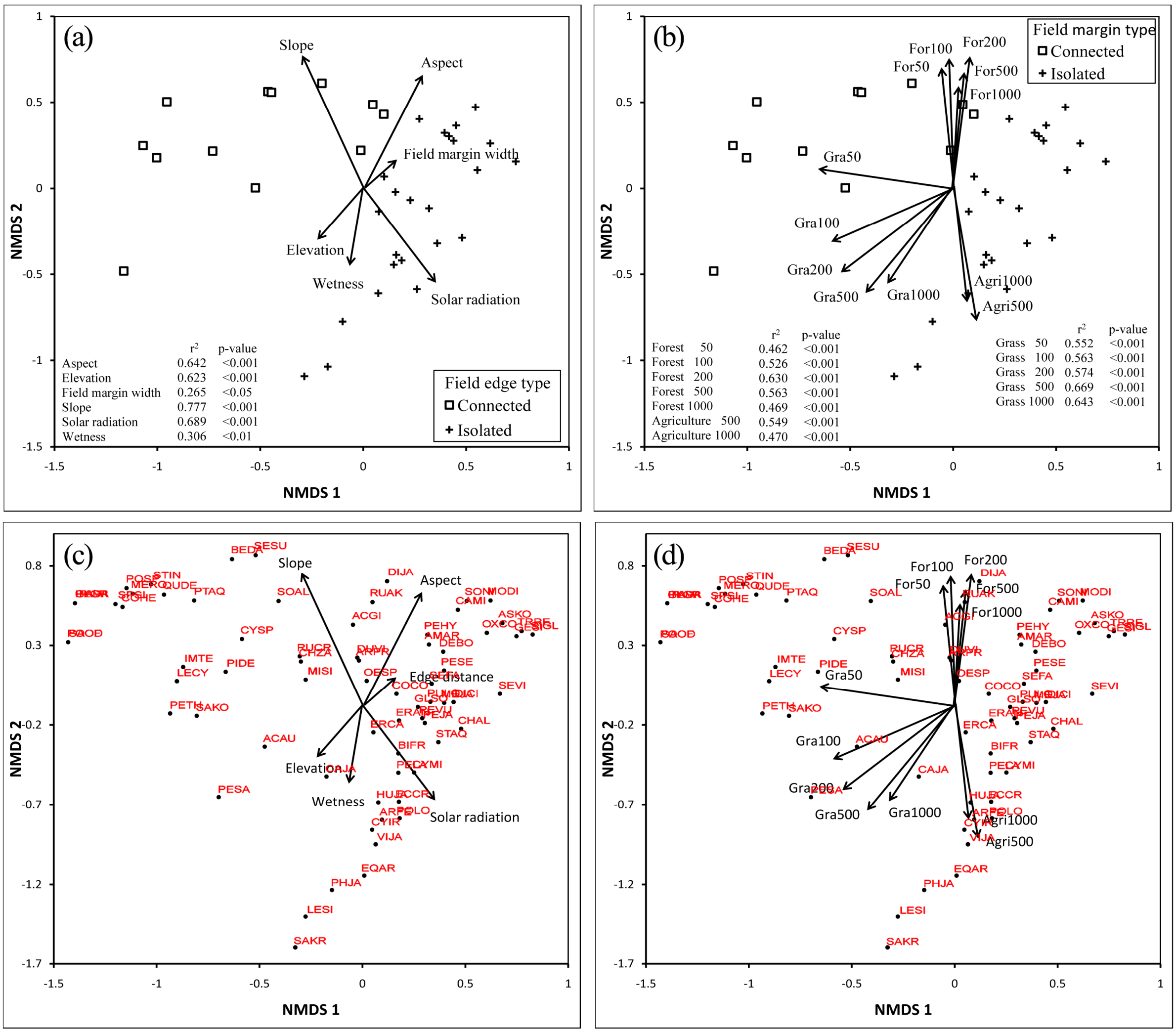

Figure 3. NMDS ordinations of sites of connected and isolated field margins, with (a) local-scale environmental variables and (b) landscape-scale environmental variables (only variables with $r^2 > 0.4$ are shown), of plant species, with (c) local-scale environmental variables and (b) landscape-scale environmental variables.

3.3 Community Comparison

Mean species richness over all communities was 13.8 and was not statistically different between the three field margin types (Fig. 4). There were no significant differences in community guilds between two types of isolated field margins. Communities in connected intact field margins had the highest number of woody species and communities in isolated field margins had a high number of herbaceous species. Native species were statistically more common in communities of connected intact field margins than in isolated and treated field margins, and exotic species were more common in communities in isolated field margins than in connected field margins. All communities had similar numbers of nectar species. Mean percent cover of dominant species of isolated intact field margins was significantly different from that of isolated and treated field margins (Fisher's exact test: $p < 0.001$).

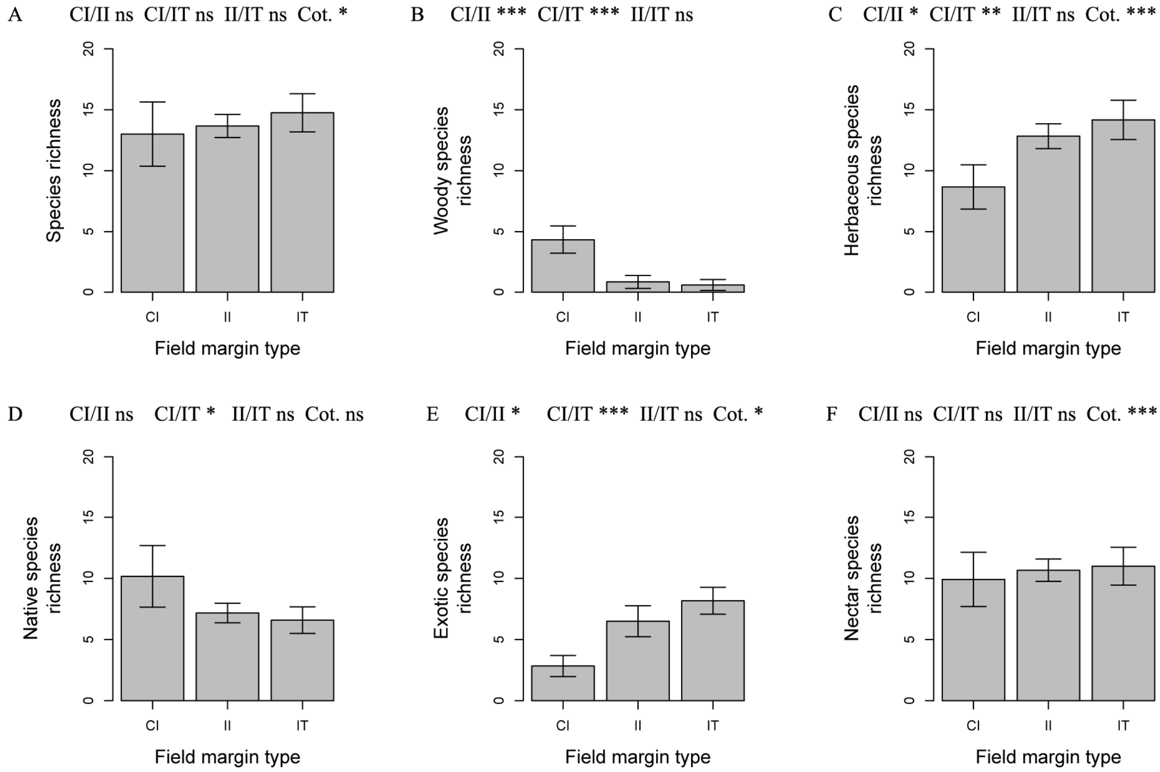

*Figure 4. Richness of (a) species, (b) woody species, (c) herbaceous species, (d) native species, (e) exotic species, (f) nectar species in connected intact (CI), isolated intact (II), and isolated and treated (IT) field margins (mean ± se). Cot: Covariate term. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns: not significant.*

4. Discussion and Conclusions

In our study area, field margin plant assemblage was clearly explained by structural connectivity between field margin and forest. The plant composition of a field margin was linked strongly with not only local but also landscape-level environmental factors. Of particular importance to plant community composition were variables such as local-level aspect, slope, and solar radiation and landscape-level amount of grass and agriculture cover at multiple scales. Although weed control management didn't affect species richness in isolated field margins, communities in isolated and treated field margins were significantly lower in numbers of native species than in connected intact field margins (Fig. 4). Mean percent cover of dominant species was also affected by weed management. Field margin structure and management which affect microclimatic parameters and dispersal patterns have been shown to be important to plant diversity (Le Coeur et al. 1997; Sosnoskie et al. 2007; Fridley et al. 2009; Tarmi et al. 2009). Our analyses revealed distinct species composition and guild composition of field margins according to contiguity with adjacent forest and management. We also identified important surrounding land cover types with varying spatial distance thresholds that were important predictors of the plant community in the agricultural landscape.

The field margin isolation from surrounding forests resulted in a different community composition againstthe connected field margin to adjacent large forests, regardless of weed control application. Although we did not test the effects of weed control treatment in connected field margins, landscape structures such as adjacent land cover types and connectivity may be more important in determining plant community composition than management practices. This is because the adjacency between field margin and forest can create different microclimate influencing plant regeneration and growth and induce different plant colonization mechanisms related to dispersal mode and capacity (Chen et al. 1993; Devlaeminck et al. 2005). We confirmed that community composition was clearly sorted by local-scale environmental variables characterizing a microclimate. Moreover, the amount of forest, grass, and agriculture cover were highly significantly correlated with NMDS axis 1 and 2 (Figs. 3a, 3b), in terms of habitat connectivity, suggesting that plant dispersal by abiotic (unassisted and wind) and biotic means (insects, birds, and mammals) affect the distribution of plants in different communities in the agricultural landscape. Communities in field margins adjacent to forests were highly associated with the percent cover in forest and grass within 50 m of field margin location. Other studies suggest that grass patches within 50 m of each other would be considered connected for plants with unassisted or wind dispersal (Geertsema 2005; Soons et al. 2005). Therefore, most species with abiotic dispersal in connected field margins may have a greater sensitivity to fragmentation (Minor et al. 2009). On the other hand, some communities in isolated field margins had more long-distance association with amount of agriculture cover (Fig. 3d). These plants probably have biotic dispersal (ingestion or adhesion dispersal) and may be less sensitive to habitat fragmentation. Further study is recommended to confirm dispersal spectra of field margin plant community–surrounding landscape structure interactions.

Pesticide application in fields has been shown to be important to biological diversity (Fisher and Milberg 1997; De Snoo 1999). In our study sites, community composition and guild species richness between isolated intact and isolated and treated field margins communities were not different. In addition, there was only significant difference in native species richness between connected intact and isolated and treated field margins. This means that species richness in a field margin in an open landscape is resilient to mowing and pesticide use disturbance. Weed control management affected mean percent cover of dominant species, indicating this disturbance can influence herbaceous plant succession and colonization rates witihin field margins. Thus, management practices may be more important in determining species dominance than species richness.

Connected field margin communities were statistically higher in numbers of native species and lower in herbaceous species than isolated and treated field margin communities. On the other hand, isolated field margin communities had statistically higher numbers of exotic species and lower number of woody species than connected field margin communities. Interestingly, despite these significant differences in plant guilds, all communities had similar numbers of nectar plants, which become an important source of ecosystem services. Thus, while all communities are the subject of conservation concern for agricultural ecosystem services, different management regimes are required to conserve biodiversity as well as ecosystem services provided by the nectar-rich flowers in field margins.

Decline and deterioration of field margin habitats and their fragmentation (Barr et al. 1991) present threats to the conservation of plant diversity in agricultural landscapes. Although our analysis addressed the impact of landscape structure and management practices on species composition and richness, we didn't consider it's time-scale impacts. Further studies are needed on the effects of field margin structure, management, and connectivity on temporal variation in plant community composition and diversity. In addition, our results point to the need to quantify and compare biodiversity-driven agroecosystem functioning and services provided by different field margin community compositions.

References

Barr C., Howard D., Bunce R., Gillespie M. Hallam C., 1991. Changes in hedgerows in Britain between 1984 and 1990. In: Report to Department of the Environment, Institute of Terrestrial Ecology, Merlewood Research Station, Grange-over-Sands, UK, p. 13.

Barraquand F., Martinet V., 2011. Biological conservation in dynamic agricultural landscapes: Effectiveness of public policies and trade-offs with agricultural production. *Ecological Economics*, 70:910-920.

Bianchi F., Booij C., Tscharntke T., 2006. Sustainable pest regulation in agricultural landscapes: A review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal. Society B*, 273:1715-1727.

Butler S.J., Vickery J.A., Norris K., 2007. Farmland biodiversity and the footprint of agriculture. *Science*, 315:381-383.

Carvell C., Meek W.R., Pywell R.F., Goulson D., Nowakowski M., 2007. Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. *Journal of Applied Ecology*, 44:29-40.

Chen J., Franklin J.F., Spies T.A., 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. *Agric. For. Meteorol*, 63:219-237.

Complex Terrain and Ecological Heterogeneity (TERRECO). 2010, International Research Training Group.

Conrad O., 1998. Derivation of hydrologically significant parameters from digital terrain models. Thesis. Dept. for Physical Geography. University of Göttingen, Göttingen. Available at: http://www.geogr.uni-goettingen.de/pg/saga/digem/ (accessed June 15, 2011).

Clarke K.R., 1993. Nonparametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18:117-143.

Dajdok Z., Wuczynski A., 2008. Alien plants in field margins and fields of southwestern Poland. *Biodiv. Res. Conserv*, 9-10: 19-34.

De Snoo G.R., 1999. Unsprayed field margins: effect on environment biodiversity and agricultural practice, *Landscape Urban Plan*. 46:151-160.

Devlaeminck R., Bossuyt B., Hermy M., 2005. Seed dispersal from a forest into adjacent cropland. *Agriculture, Ecosystems & Environment*, 107:57-64.

Douglas DJT, Vickery JA, Benton TG (2009) Improving the value of field margins as foraging habitat for farmland birds. *Journal of Applied Ecology*, 46:353-362.

Fisher A., Milberg P., 1997. Effects on the flora of extensified use of field margins, *Swed. J. Agric. Res*, 27:105-111.

Fridley J.D., Senft A.R., Peet R.K., 2009. Vegetation structure of field margins and adjacent forests in agricultural landscapes of the North Carolina Piedmont, *Castanea*, 74(4):327-339.

Geertsema W., 2005. Spatial dynamics of plant species in an agricultural landscape in the Netherlands. *Plant Ecology*, 178:237-247.

Giraudoux., P 2006. Pgirmess: data analysis in ecology. R package version 1.2.2. Available at http://lbe.univfcomte.fr/telechar/div.html.

Grimm N.B., Grove J.M., Pickett S., Redman C.L., 2000. Integrated approaches to long-term studies of urban ecological systems. *Bioscience*, 50:571-584.

Hothorn T., Bretz F., Westfall P., 2008. multcomp: simultaneous inference in general parametric models. R package version 1.0-0. R Foundation for Statistical Computing, Vienna, Austria.

Kim M.J., Lym Y.J., Jeon W.S., 2000. The naturalized plant species in Korea. Science books, Seoul.

Kells A.R., Holland J.M., Goulson D., 2001. The value of uncropped field margins for foraging bumblebees. *Journal of Insect Conservation*, 5:283-291.

Le Coeur D., Baudry J., Burel F., 1997. Field margins plant assemblages: variation partitioning between local and landscape factors. *Landscape and Urban Planning*, 37:57-71.

Newton I., 1998. Bird conservation problems resulting from agricultural intensification in Europe. In Marzluff J.M., Sallabanks R., (eds) Avian Conservation: research and management. Island Press, Washington D.C, pp.307-322.

Millennium Ecosystem Assessment (MA)., 2005. Ecosystems and human well-being: synthesis. Washington, DC: World Resources Institute.

McCune B., Grace J.B., 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon, USA.

Mielke P.W., 1991. The application of multivariate permutation methods based on distance functions in the earth sciences. *Earth Sci Rev*, 31:55-71.

Minor E.S., Tessel S.M., Engelhardt K.A.M., Lookingbill T.R., 2009. The role of landscape connectivity in assembling exotic plant communities: a network analysis. *Ecology*, 90:1802-1809.

Moreby S.J., Southway S., Boatman N.D., 1999. The importance of the crop edge compared to the mid-field in providing invertebrate food for farmland birds. In: Boatman N.D., Davies D.H.K., Chaney K., Feber R., de Snoo G.R., Sparks T.H. (Eds.), Field Margins and Buffer Zones: Ecology, Management and Policy. Aspects Appl. Biol. 54:217–222.

Oksanen, J., Kindt R., Legendre P., O'Hara B., Simpson G.L., Henry M., Stevens H.H., Wagner H., 2008. Vegan: community ecology package. R package version 1.13-1. R Foundation for Statistical Computing, Vienna, Austria. http://vegan.r-forge.r-project.org/

Pinheiro J., Bates D., DebRoy S., Sarkar D., R Core Team. 2008. nlme: linear and nonlinear mixed effects models. R package version 3.1-89. R Foundation for Statistical Computing, Vienna, Austria.

R Development Core Team., 2010. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Soons M.B., Messelink J.H., Jongejans E., Heil G.W., 2005. Habitat fragmentation reduces grassland connectivity for both short-distance and long-distance wind-dispersed forbs. *Journal of Ecology*, 93:1214-1225.

Sosnoskie L.M., Luschei E.C., Fanning M.A., 2007. Field margin weed-species diversity in relation to landscape attributes and adjacent land use, *Weed Science*, 55(2):129-136.

Tarmi S., Helenius J., Hyvönen T., 2009. Importance of edaphic, spatial and management factors for plant communities of field boundaries. *Agriculture, Ecosystems & Environment*, 131(3-4):201-206.

Tew T.E., Todd I.A., MacDonald D.W., 1994. Field margins and small mammals. In field margins: Integrating agriculture and conservation (Boatman N.D., ed.), pp. 85-94. BCPC Monograph 58. Farnham, Surrey: British Crop Protection Council.

Vickery J., Carter N., Fuller R.J., 2002. The potential value of managed cereal field margins as foraging habitats for farmland birds in the UK. *Agriculture, Ecosystems and Environment*, 89: 41-52.

Vickery J.A., Feber R.E., Fuller R.J., 2009. Arable field margins managed for biodiversity conservation: A review of food resource provision for farmland birds, *Agriculture, Ecosystems & Environment*, 133(1-2):1-13.

Wuczynski A., Kujawa K., Dajdok Z., Grzesiak W., 2011. Species richness and composition of bird communities in various field margins of Poland. *Agriculture, Ecosystems & Environment*, 141: 202-209.