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Importance of edaphic, spatial and management factors for plant communities of field boundaries

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ABSTRACT

Plant communities of 57 field boundaries, in four regions of Finland, were sampled for this study focusing on factors affecting species diversity and community composition. All the boundaries were buffer strips established following the guidance of an Agri-Environmental Support Scheme. Data on edaphic factors, boundary management practices and spatial coordinates were used as explanatory variables in the data analyses using variation partitioning by Redundancy Analysis and univariate statistics.

The variation of the plant species composition and diversity was found to be strongly spatially structured. On the variation of species composition, spatial variables alone explained 35.0% and jointly with environmental factors 32.4% of the variation in species composition. Moreover, mowing, soil pH and P content and boundary width were shown to be important factors determining species composition. The species diversity was the lowest where the land use for agricultural production was most intensive and classification of species traits indicated high soil nitrogen levels.

On the basis of this study, biodiversity in boundaries could be enhanced by appropriate management techniques and greater boundary width. Regional differences in agricultural land use should also be taken into account when planning practices for improving biodiversity.

1. Introduction

At the local scale, low soil fertility (Kleijn and Snoeijing, 1997; Janssens et al., 1998) and wide boundaries (Ma et al., 2002; Marshall et al., 2006) have been found to favour plant species diversity. On a broader spatial scale, landscape heterogeneity (Le Coeur et al., 1997; Luoto, 2000; Benton et al., 2003; Kivinen et al., 2006) and historical landscape connectivity (Lindborg and Eriksson, 2004) are important factors affecting species diversity.

In Finland, the establishment of widened field boundaries is supported by the Agri-Environmental Support Scheme (AESS) that aims to hinder nutrient leaching and agrochemical drift from fields to waterways (Wallenius, 1996). It is also hoped that field margins support agro-biodiversity (Kuussaari et al., 2008).

In an earlier study, Tarmi et al. (2002) estimated the biodiversity value of field boundary communities based on the species ecological characteristics and classification of the vegetation. This study presents more detailed analyses on the factors affecting species composition and species diversity. Specifically, we expected species diversity to be higher in wide field boundaries with low fertility. Edaphic, management and spatial factors were expected to explain the variation in the species composition.

2. Materials and methods

The study areas were located in Yläneenjoki (Southern Finland, primarily cereal and rape), Lepsämänjoki (Southwest, cereal, rape and cabbage), Lestijoki (West), and Taipaleenjoki (East) both with dairy production and mixed cropping. Habitat diversity was highest in Taipaleenjoki, and this area had more patchy and linear semi-natural habitats than the other study areas (Luoto, 2000). All boundaries were buffer strips along waterways and had been established according to the AESS. Most boundaries already existed before 1995 and had been widened under the AESS by natural regeneration or by sowing grassland seed mixtures containing mainly *Phleum pratense*, *Festuca pratensis*, *Lolium perenne*, *Dactylis glomerata* and *Trifolium pratense*. The boundaries were selected without regard to the use or farming system in the adjacent field. In this study, a boundary was defined as the semi-natural habitat from crop edge to the slope of the waterway.

Botanical studies were conducted on 57 boundaries in June–July 1997 and in July 1998. The total sample size for analysing species diversity in each boundary was 1.25 m^2, comprising five 0.25 m^2 sample quadrats located 20 m from each other. Species

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abundance as percentage cover was estimated using a scale of nine classes: 1 < 0.8%, 2 = 0.8–1.6%, 3 = 1.6–3.1%, 4 = 3.1–6.3%, 5 = 6.3–12.5%, 6 = 12.5–25%, 7 = 25–50%, 8 = 50–75%, 9 = 75–100% (Oksanen, 1981). Another dataset was collected from the whole boundary area for exploring the species composition by multivariate analyses. Species were recognised during the first end-to-end walk of the boundary. During the second end-to-end walk, estimates of abundances by species were made using five classes of cover (1 < 1%, 2 = 1–5%, 3 = 5–10%, 4 = 10–50%, 5 > 50%). Species nomenclature followed Hämet-Ahti et al. (1998). The length and width of the boundary were measured during sampling. As the whole area of each boundary was surveyed, the sampling area varied according to the width and length of each site (Table 1), but no correlation between the number of species and the area of boundary was found ($R = 0.221$, df = 1, $P = 0.109$).

Soil data were collected in July 1995 and July 1997. Soil samples were taken from the corners of the quadrats for plant species diversity sampling by using a soil borer to extract a sample to the depth of 20 cm. The 20 sub-samples per boundary were mixed together to compose one sample for soil analyses. Acid ammonium acetate (pH 4.65) was used to extract exchangeable magnesium, potassium, and calcium and easily soluble phosphorous (Vuorinen and Mäkitie, 1955), and water was used for pH measurements. The first three elements were measured using the ICP method, and the phosphorus was measured using Bran & Luebben autoanalysator. Measured soil types were categorised into three classes: clay (clay content more than 30%), organic (mull) and coarse (Table 1).

Data were gathered on management practices (no mowing, mowing, combined mowing and grazing), the establishment method (sown grassland, newly established natural vegetation,

Table 1
Characteristics of field boundaries in the four study areas of Finland.

Variable	Type[d]	Code	South-western	Southern	Western	Eastern
Number of boundaries			16	17	10	14
Soil	N	Clay	10	14	0	1
		Coarse	5	3	10	10
		Organic	1	0	0	3
pH	R	Mean	5.8	5.8	5.5	5.5
		S.E.	0.08	0.05	0.16	0.13
P (mg/l)	R	Mean	7.2	6.8	6.4	3.0
		S.E.	0.7	0.8	0.9	0.6
K (mg/l)	R	Mean	187	207	83	95
		S.E.	15	20	15	7
Mg (mg/l)	R	Mean	392	399	144	195
		S.E.	41	32	24	33
Ca (mg/l)	R	Mean	1530	1864	697	888
		S.E.	276	100	78	100
Establishment[a]	N	Sown	5	10	10	3
		New	4	3	0	0
		Old	5	3	0	9
Length (m)	R	Mean	240	320	170	230
		S.E.	21	31	19	28
Width (m)	R	Mean	1.5	2.0	3.0	2.7
		S.E.	3.2	3.3	2.6	5.2
Management[b]	N	No	14	11	0	0
		Mo	2	5	3	12
		Mo_h	0	1	2	1
		Graz	0	0	5	1
Herbicide use[c]	O	0	2	4	9	4
		1	1	1	1	3
		2	8	5	0	1
		3	1	4	0	5
		4	4	3	0	1
Species richness	R	Mean	12.4	17.9	19.2	27.7
		S.E.	1.12	1.38	1.89	1.60
Species dominance	R	Mean	0.34	0.20	0.18	0.15
		S.E.	0.06	0.02	0.03	0.02
Ellenberg values						
pH	R	Mean	6.3	6.3	5.3	5.5
		S.E.	0.13	0.06	0.11	0.10
Nitrogen	R	Mean	6.0	5.9	5.5	5.2
		S.E.	0.11	0.06	0.10	0.12

[a] Establishment: Sown = established by sowing grassland seed mixture (typically *Phleum pratense*, *Festuca pratensis* and *Trifolium pratense*); New = bare soil until vegetated naturally; Old = boundary has existing vegetation.
[b] Management: Counted from the four study years. No = no management; Mo = mowed in one or two years or grazed in one year; Mo_h = mowed and harvested at least in two years; Graz = grazed at least two years.
[c] Herbicide use: The number of years (0–4) that the adjacent field was sprayed with herbicides.
[d] Type: Variable type: N = nominal scale, O = ordinal scale and R = ratio scale.