The Role of Field Margins in Agro-biodiversity Management at the Farm Level

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Abstract

The agroecosystem could be considered as a mosaic so large to involve fields with annual and perennial crops, pastures, spots of wildwood, semi-natural habitats, vegetation in the edges of fields. In the agroecosystem these ecological infrastructures have a positive effects on the crops because of the exchange among community of organisms, materials and energy.

The aim of this research is to evaluate the effects of field margins on some biodiversity components (plant species and carabid beetles) of four farms located in Val d'Orcia (Tuscany). We compared three types of field margins: 1. Cultivated margin strips; 2. Sown grass margin strips; 3. Wild margin strips with hedgerow. In a very simplified typology of farming system, like the one studied (Val d'Orcia), the presence of field margins (hedges, margin strips and semi-natural habitats associated with the boundary) is very important for its ecological effects: it improves the planned biodiversity, gives habitat, refuge, food and corridors for the movement to the different species of organisms in the area.

Applying the multivariate analysis to the experimental data, we can notice a positive effect of the presence of field margins on the trend of both components of biodiversity. This positive effect, which support the mechanisms of autoregulation of the agroecosystems, is very important especially for organic and biodynamic agriculture, where the use of pesticides is not allowed.

Key-words: agroecosystem, biodiversity, field margin.

1. Introduction

A high proportion of biodiversity exists on land dedicated to the production of food: thus agricultural intensification is the principal cause of biological simplification of the farm environment. The level of biodiversity in the different agroecosystems depends on several elements: the kind of vegetation within and around the field; the crop rotation; the input intensity of the farming system and the level of isolation of the agroecosystem from the wild species (Southwood and Way, 1970).

Especially in organic agriculture, farms need a more complex agroecosystem structure, with semi-natural habitats and field margins, which consist of hedgerows or some other structures, such as wild or sown grass margin strips in the hedge bottom (Hole et al., 2005; Lazzerini et al., 2004).

Greaves and Marshall (1987) define "a field margin" as "whole of the crop edge, any margin strip present and the semi-natural habitat associated with the boundary". The different habitats found in field margins give food (prays/hosts), water, refuge, favourable microclimate, shelter from pesticides and a winter reproduction site for natural enemies of pests. The kind of vegetation around field margins has a different effect on the presence and efficiency of useful insects. Lewis (1965) asserts that hedgerows give hospitality to a larger diversity of entomofauna than the neighbouring crops and that some types of hedgerows can improve the population of useful insects within a certain distance. The typology of boundary, for example, is strongly correlated with the presence of carabids, which prefer more complex ecological

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infrastructures, such as hedgerows, than field margins or strips covered with grasses (Sotherton, 1984).

In a simplified farming system, the presence of "field margins" is very important to improve the components of biodiversity (flora and fauna). Some researches provide evidences that non crop habitats (areas with natural or sowed plants suitable as refuge and winter site for predators) offer dispersal corridors and islands in otherwise fragmented landscape. Different are the proposals for the creation of these areas: for example, using narrow raised ground strips around fields (Thomas e Wratten, 1990) or creating 3-8 metres large "strips" with wild plants every 50-100 metres (Nentwing, 1988). These strips are defined "ecological compensation areas" and permit to increase the biodiversity of insects and allow to bolster natural predator populations (Soil Association, 1999). Some researchers established grass strips in autumn-winter cereal crops: one of the results was the increasing of genetic diversity and richness of spiders and carabid insects (Helenius et al., 1995; Sunderland and Samu, 2000; Altieri et al., 2003).

Because the management of agricultural systems can dramatically affect overall levels of biodiversity, as well as the success of particular species, the purpose of the present research is to establish the effects of different kinds of field margins on flora and fauna (carabids) components of 4 agroecosystems characterized by different management.

2. Materials and methods

2.1 *Characteristics of the studied farms*

The research was performed in 4 different farms located in Val d'Orcia (SI) – South of Tuscany. In this agricultural area, farming is mainly based on cereals as a part of short rotation schemes; landscape is very unusual and homogeneous, with a few ecological infrastructures.

Of the studied farms, one is conventional (farm 1), one is a farm in conversion to organic (farm 2) and the last two are organic (farm 3 and 4). Farms 1 and 3 are of limited size, with a few ecological infrastructures, while farms 2 and 4 are of medium-large size and richer as to natural and seminatural habitats (Tab. 1).

In each of the farms the effect of the presence of field margins was studied. The considered typologies of field margins are the following:

1. Cultivated margin strips (farms 1 and 4)
2. Sown grass margin strips (farms 2 and 3)
3. Wild margin strips with hedgerow (farm 4).

In the different strips, a sampling of vegetation was conducted in the period between April and June (years 2004 and 2005) throwing randomly a square metal frame (0.25x0.25 m) (6 repetition for strip) (Vazzana and Raso, 1997). The soil macrocrofauna (carabid beetles) sampling was conducted on the different field margins during the year 2004 between March and June, using for each strip three couples of pitfall traps (6 traps in total) at 50 m distance, every traps at 10 m from the others (Fig. 1). Five samplings were carried out. All collected beetles were identified. Data were used to elaborate flora and fauna indicators: species richness defined as $S = n_i$, where n_i = species i (Vereijken, 1995) and a diversity indicator defined as $H' = p_i \log_2 p_i$, where p_i = frequency of the species i (Shannon and Weaver, 1963).

2.2 *Statistic analysis methods*

The aim of the statistic analysis was to correlate the presence of different type of field margins with the richness and diversity of flora and fauna. Plant species have been classified each

Table 1. Principal characteristics of the four studied farms.

	Conventional farm (1)	Farm in conversion to organic (2)	Organic farm (3)	Organic farm (4)
Total Surface (ha)	36.5	168.5	37.3	207.0
Crop surface (ha)	31.6	133.7	34.6	149.0
Rotation	no	Biennial	Biennial	Biennial
Pesticide use	yes	no	no	no
Type of fertilizers	Mineral	Organic	Organic	Organic
Percentage wild areas (%)	3.8	18.6	5.2	24.9

one within a biological group (Montegut, 1982): Therophyte (Th), Hemicryptophyte (Hr), Geophyte (G), rhizomatous Geophyte (Gdr-rh) (Catizone and Zanin, 2001).

The aggregation of carabid beetles was based on their diet; in fact, the kind of food seems to be the main element for the choice of habitat (Kromp, 1999). Therefore, carabids have been classified as granivorous, spermophagous, predators, polyphagous.

Multivariate analysis were carried with: nometric Multi- Dimensional Scaling (MDS), Cluster Analysis (CA), Principal Component Analysis (PCA) using the Primer 6 program (Clarke and Warwick, 1994). The first two methods start from a matrix of similarity coefficient (BC) (Bray and Curtis, 1957).

The Bray-Curtis coefficient (BC) is given:

$$BC_{ik} = 100\left\{1 - \frac{\sum_{i=1}^{p}\left|y_{ij} - y_{ik}\right|}{\sum_{i=1}^{p}\left(y_{ij} + y_{ik}\right)}\right\}$$

Where BC_{jk} is the similarity between the jth and kjth sites, and yij represents the abundance for the ith species in th site.

The third method starts from the dissimilarity matrix of Euclidean distances (Chatfied and Collins, 1980).

For the MDS and CA the Anosim test (analysis of similarity) shows the R statistic that is a useful comparative measure of the degree of separation of sites: if R = 1 all replicates within sites are more similar to each other that any replicates from different sites; if R is approximately zero the null hypothesis is true, so that similarities between and within sites will be same on average (Clarke and Warwick, 1994).

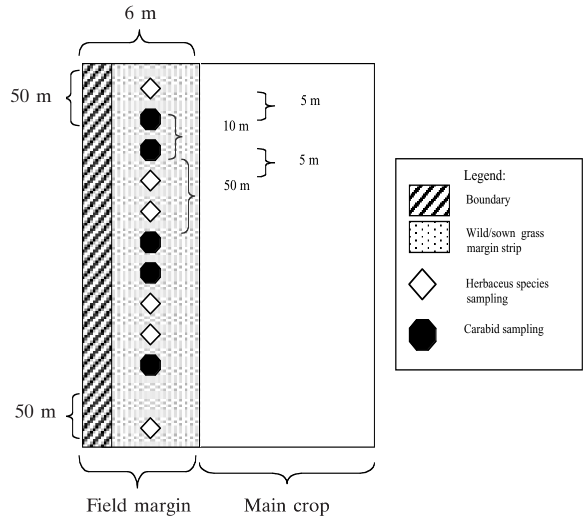

Figure 1. Sampling of the two biodiversity components of field margins.

PCA analysis gives two results (Eigenvector and percentage of variance) which explain the firsts two principal components.

3. Results and discussion

3.1 Plant species

Table 2 shows the values of the biodiversity indicators (richness and species diversity) related to the flora and calculated for the 4 studied farms.

Both for 2004 and 2005 the highest species richness (30 species in 2004, 35 species in 2005) was found in the field margin of the organic farm "4" (plot 3112). This field margin is the

Table 2. Richness and diversity of herbaceous species found in field margins of the four studied farms (years 2004 and 2005).

Farm	Plot number	Number of Families	Richness of species	Diversity (H)	Plot number	Number of Families	Richness of species	Diversity (H)
	2004				2005			
1	321	7	9	1.95	421	4	6	0.93
1	323	6	6	0.91	423	5	5	1.08
2	341	8	19	1.24	441	6	11	1.06
2	342	8	16	1.85	442	4	10	1.01
2	343	8	16	1.50	443	7	13	1.20
3	312	6	21	2.02	412	7	19	1.95
3	316	11	30	2.67	416	15	33	2.36
4	331	11	16	1.77	431	9	19	2.04
4	3312	12	32	3.29	4312	10	35	2.70

most complex, because of the presence of hedgerow and wild margin strip. The same positive effect has been obtained with a field margin of sown grass strip (plot 316) in the organic farm “3”. In fact in this field margin 30 species in 2004 and 33 in 2005 were found (Tab. 2). The lowest species richness for both years, was found in the conventional farm “1”, where field margins have only a cultivated strip (Tab. 2).

Many studies investigating the flora of arable and mixed farming systems recorded higher species richness in field under organic management (Frieben and Kopke, 1995; Hald, 1999). Several researches agree with these results and show the positive effects of field margins to the floristic composition (Frieben e Kopke, 1995; Aalto, 1998; Moonen and Marshall; 2001, Hole et al., 2005).

The same trend, for both years, was found quantifying species diversity using Shannon’s index. The diversity index of field margin with hedgerow and wild strip (plot 3312) was 3.29 in 2004 and 2.7 in 2005 (Tab. 2). Shannon’s index of field margin with sown grass strip (plot 316) was 2.67 in 2004 and 2.36 in 2005 (Tab. 2). The lowest value of diversity (0.93) was noticed for farm “1” and particularly in the year 2005 (Tab. 2).

3.2 Carabid insects

Table 3 shows the values of the biodiversity indicators (richness and species diversity) related to carabid beetles, calculated for the four farms studied in the present work. Several references underline the positive effects of wildflower strips on both the number of species and diversity of carabid insects (Feber, 1998; Thomas and Marshall, 1999). In agreement with them the highest species richness was found in the field margin with sown grass strip of the organic farm 3 (27 species in the field margin of plot 311 and 26 in the field margin of plot 316) (Tab. 3). The richness value (24) is high also in field margins with hedgerow and wild strip in the organic farm 4 (plot 3312) and in the farm 2 in conversion to organic (plot 341 and 342) (Tab. 3).

The lowest species richness was observed in the conventional farm 1 (plot 321 and 323) where field margins are cultivated margin strips (Tab. 3).

The highest value for Shannon’s index (2.9) was observed in the field margin with hedgerow and wildflower strip of farm 3 (plot 3112) (Tab. 3). The value of the diversity Shannon’s index is high also in the field margin in the farm 2 (2.6) for plot 341 and 342 (Tab. 2). The lowest diversity index was observed in field margins with cultivated strip of farms 1 and farm 4 (Tab. 3).

Table 3. Richness and diversity of Carabid insects found in field margins of the four studied farms (year 2004).

Farm	Plot number	Richness of species	Diversity (H)
1	321	20	2.4
1	323	18	2.3
2	341	24	2.6
2	342	24	2.6
2	343	23	2.6
3	312	27	2.5
3	316	26	2.5
4	331	23	2.5
4	337	19	2.1
4	3312	24	2.9

3.3 Statistic analysis

Plant species. Table 4 gives the eigenvalues and associated variances obtained using PCA for single species. The first two components explain around 86% of the total variance. The first eigenvector shows a positive correlation with

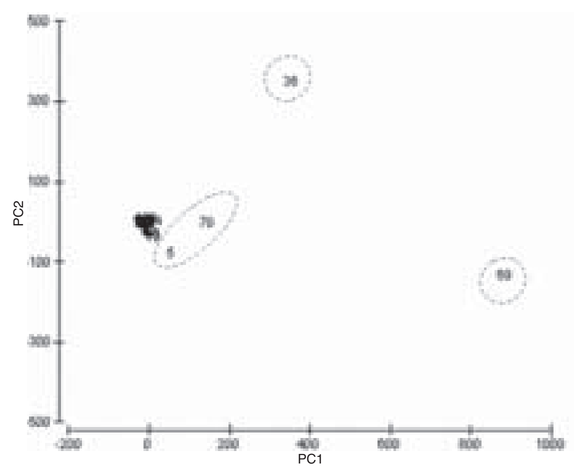

Figure 2. Principal Component Analysis (PCA) applied to single species of field margins of the four studied farms (year 2005). Numbers correspond to the following species: 5 = *Alopecurus myosuroides*; 70 = *Lolium perenne*; 36 = *Daucus carota*; 69 = *Lolium multiflorum* (Percentage Variance PC1 = 73.9%; PC2 = 11.6).

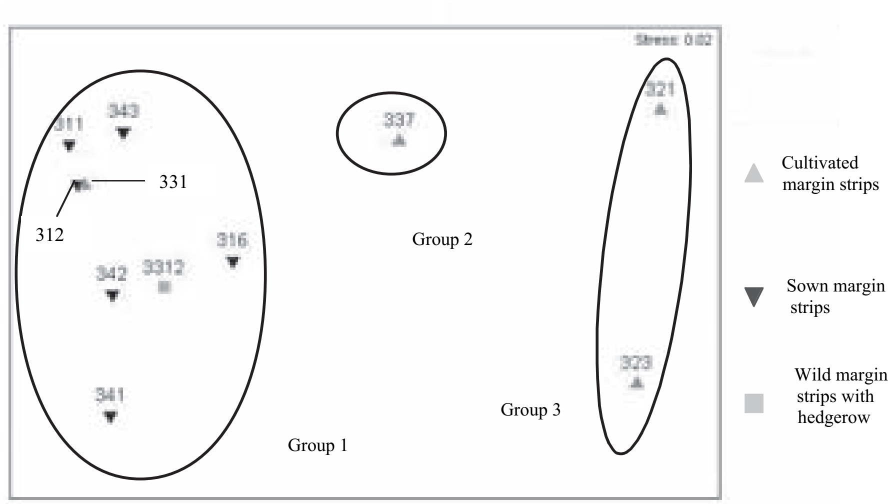

Figure 3. No-metric multi-dimensional scaling analysis (MDS) of herbaceous species classified into their biological group of field margins for the four studied farms (year 2004) based on the Bray-Curtis similarity coefficient (Stress 0.02).

variables 441, 442, 443 e 4312. The second eigenvector shows a positive correlation with variables 443. PCA shows a group of plants living in field margins with hedgerow and old sown strips (Fig. 2).

Figure 3 displays the results of ordination by MDS based on similarity matrix of 9 sites. The generated stress value is 0.02. According to Clarke and Warwick (1994) a stress < 0.05 gives an excellent representation with no prospect of misinterpretation. MDS applied to species classified into biological groups shows, particularly in 2004, a group of plant species found in plots with field margins with sown grass strips of farms 2, 3 and 4 (group 1). This group involves Therophyte -Th and Hemicriptophyte -Hr species. These are species at higher level in the scale of evolution and their presence means a higher degree of stability of agroecosystem (Fig. 3). Groups 2 and 3 are related to plots with field margins with cultivated strips of farms 4 and 1 (Fig. 3).

Table 4. Eigenvectors and percentage explained variance PCA of plant species (year 2005).

Plot number	Eigenvectors I	Eigenvectors II
421	0.002	- 0.003
423	0.013	- 0.012
412	0.036	- 0.055
416	0.030	- 0.161
431	0.015	- 0.056
434	0.036	- 0.081
4312	0.201	- 0.223
441	0.659	- 0.507
442	0.320	- 0.302
443	0.647	0.751
Percentage Variance (%)	73.9	11.6

Cluster analysis applied to plant species richness and diversity shows a diagram of similarity where plots are distributed according to the different type of field margins (Fig. 4). The first cluster involves plots with field margins represented by sown grass strips and wild strips of farms 2, 3 and 4; the second cluster involves plots with field margins represented by cultivated strips of farm 4.

Table 5 shows the R statistic of the analysis of similarity (Cluster analysis) for species diversity and richness. All the three groups (1, 2: R = 0.025; 1, 3: R = 0.333; 2, 3 R: = 0.32) have a R statistic value that is higher than zero and this confirms that the difference between field margins is verified. The comparison between group 1and 3 has a higher R (0.333) and this confirms the different ecological value of wild margin strips with hedgerow and cultivated margin strips.

Carabid insects. As regard to carabid insects, the most indicative analysis was the CA applied to richness and diversity which distributed plots in three clusters: the first cluster includes plots

Table 5. R statistic Anosim test of plant species (year 2005).

Group	R statistic	Level
1, 2	0.025	36.5
1, 3	0.333	40.0
2, 3	0.320	16.7

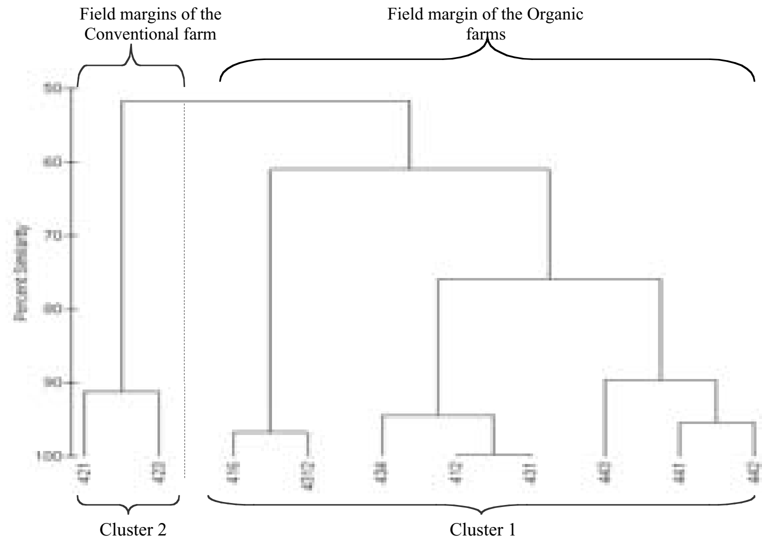

Figure 4. Cluster analysis (CA) of plant richness and diversity species in field margins of the four studied farms (year 2005) based on the Bray-Curtis similarity coefficient (MDS = 0.01).

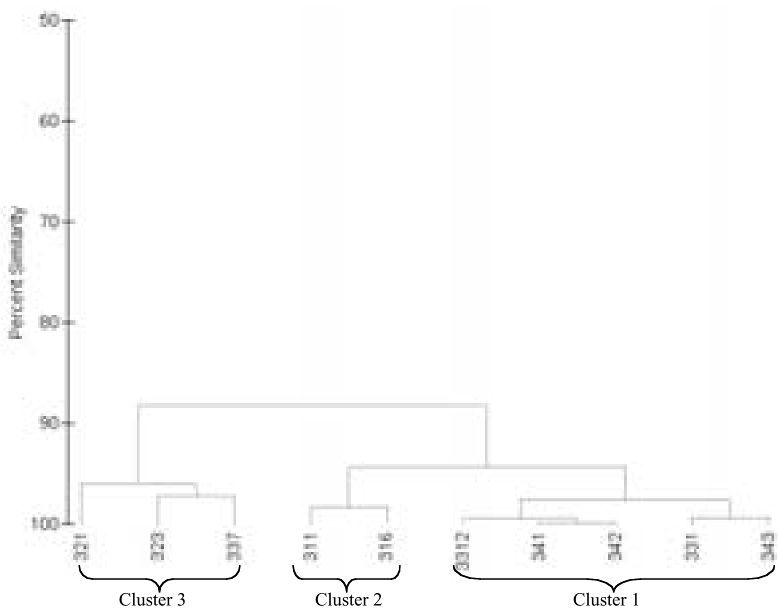

Figure 5. Claster analysis (CA) of Carabid beetles richness and diversity in field margins of the four studied farms (year 2004) based on the Bray-Curtis similarity coefficient (MDS = 0.01).

with field margins represented by old sown grass strips in farm 2 and field margins with hedgerow and wildflower strips in farm 4; the second cluster includes plots of field margins with sown grass strips in farm 3; the third cluster includes plots of field margins with cultivated strip of farm 1 and 4 (Fig. 5).

Table 6 shows the R statistic of the analysis of similarity (Cluster analysis) for the diversity and richness of carabid beetles. Two of the three groups (1,2 R = 0.669; 1,3 R = 0.583) have a R statistic value that is higher than zero and this confirms the different effects of the studied field margins. The comparison between 1 and 3 has a higher R (0.583) and this confirms the difference between wild margin strips with hedgerow and cultivated margin strips; at the contrary, the comparison between group 2 and 3 has a negative R (-0.16) confirming a similar effects of the two typologies of field margins: grass margin strips and wild margin strips with hedgerow.

PCA for single species does not show a clear difference between plots with sown grass or wild margin strips and those with cultivated strips.

Table 6. R statistic Anosim test of carabid beetles (year 2004).

Group	R statistic	Level
1, 2	0.669	0.8
1, 3	0.583	20.0
2, 3	- 0.160	66,7

4. Conclusions

The whole analysis carried out leads to the conclusion that the studied area, Val d'Orcia, is very poor in biodiversity and therefore, it is necessary to improve the planned biodiversity introducing new ecological infrastructures represented by complex or simple field margins. There is evidence that organic farming could play a significant role in implementing biodiversity, especially by increasing the quality and quantity of non cropped habitats and boundaries. The presence of sown grass or wild strips managed by the farmer has great importance in increasing biodiversity of flora and fauna (insects) species.

The more complex the field margins are, for example with tree, hedgerows or wildflower or sown grass strips, the more positive the effects are. The statistic analysis of biodiversity confirms a clear positive influence of plots with field margins with sown strips.

PCA shows a cluster of species living in complex field margins. Fields margins with sown or wild strip give the same benefits also for the indicators "carabid beetles", both for its richness and diversity.

These results confirm that there is a relationship between planned biodiversity, crops and even simple field margins with sown strips, and the increasing of associated biodiversity (Vandermeer and Perfecto, 1995; Altieri et al., 2003). The careful adoption of specific management practices is necessary to sustain optimal levels of such biodiversity.

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