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The Swiss agri-environmental programme and its effects on selected biodiversity indicators

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Abstract

In Switzerland, parallel to agri-environmental measures which apply directly to the field management, farmers had to convert at least 7% of their land to ecological compensation areas – ECA. Major ECA are extensified grassland, traditional orchards, hedges, and wild flower strips. In 2000, the situation shows that farmers practise the agri-environmental scheme all over Switzerland with a total of 120,000 hectares of different types of ECA. The introduction of ECA throughout the country's agricultural area can be seen as a large scale landscape restoration experiment. Its biological effects are evaluated in a monitoring programme. In a case study area of about 6 km^2, in 1997, biodiversity indicators (spiders, carabid beetle and butterflies) were recorded following a stratified sampling design. Every field in the area was categorised and digitised. Habitat and landscape features that influence the indicators are analysed as well as the role of the ECA in this context. Hypothetical influencing factors are tested with the Canonical Correspondence Analysis (CCA) and partial CCA, and are categorised as follows: (1) habitat (habitat type, plant species richness); (2) landscape (habitat heterogeneity, variability, diversity, proportion of land use types in classes); and (3) space (geographical coordinates). The correlative models developed for spider and carabid beetle assemblages revealed that the most important factor is the habitat type (directly influenced by management practices). However, for spiders, land use types like ECA and natural areas in the surrounding landscape are significant factors too. The model developed for butterflies shows that species assemblages are sensitive to the habitat type and plant species richness but not to landscape features.

Key words: Agricultural landscape, arthropod diversity, canonical correspondence analysis, evaluation, restoration scheme.

Introduction

General context

In the early 1990s the growing costs for the regulation of agricultural markets and increased awareness of environmental damage caused by agriculture led to the introduction of agri-environmental programmes in Europe. In Switzerland, from 1993 onwards, farmers had to increasingly provide ecological services in order to qualify for direct payments and additional incentives were given for specific measures. Basically, the Swiss agri-environmental policy has particular features:

- the Swiss agri-environmental policy was repeatedly sanctioned by public referenda,
- the utilised agricultural area (UAA) of the entire country has been interspersed with ecological compensation areas (ECA).

The pillars of the Swiss agri-environmental programme consist of strong incentives for environment friendly production systems as integrated and organic farming (aiming mainly at a reduction of nutrients and pesticides in soils and waterbodies), of incentives for animal husbandry (aiming at increased animal health and wellbeing) and on the introduction of ECA. The main purpose of ECA is to stabilise and enhance populations of wild animals and plant species in agriculture.

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Ecological compensation areas (ECA)

The goal of the ECA scheme in Switzerland is (Forni et al. 1999):

- to enhance natural biodiversity,
- to preserve agro-biodiversity (no further extinctions but stabilisation and spreading of endangered species).

This can only be achieved by an approach aimed at the entire UAA. The Swiss agri-environmental programme therefore requires that each participating farmer has to convert 7% of his or her farmland to ECA. The catalogue of ECA encompasses traditional landscape elements as well as new types of biotopes which were designed for the purpose of enriching the agricultural landscape. The management of ECA is regulated in order to achieve environmental goals (restrictions in fertilisation, pesticide use, prescribed dates for mowing of meadows, etc.). Agricultural management must be continued (no abandonment). For most types of ECA farmers have to commit themselves for at least six years.

In this paper, we summarise the present situation of ECA in the Swiss agricultural landscape and analyse the impact of ECA on arthropods in one case study area during the first year of investigation. The research will continue until 2005 and a concluding evaluation will then be possible.

Method of evaluation

An evaluation programme was launched in 1996 in order to assess the effect of the agri-environmental policy. This programme is divided in three parts, according to three scales of investigation: (1) development of the participation to the scheme by measuring ECA surface for the whole Switzerland; (2) monitoring of a restricted set of biodiversity indicators at the Swiss plateau scale; (3) monitoring of a large set of biodiversity indicators in three case study areas of about 6 km^2 each. In this paper, we will consider the points (1), looking at the situation in 2000; and (3), showing results of the first year of investigation in one study area.

Evaluation by the participation

The participation is calculated on a year based measurement of the ECA inserted on each farm in Switzerland. Farmers have to announce their participation and give the exact surface devoted to each type of ECA on their farm. Data are then gathered by the Swiss Federal Office of Agriculture. Data analysis allows the Swiss Federal Office of Agriculture to detail ECA shares in the different agricultural zones of Switzerland.

Evaluation in case study areas

Measures of biodiversity

The status of biodiversity is assessed by means of indicator groups: vascular plants, spiders, carabid beetles, butterflies, grasshoppers, breeding birds. The organisms are supposed to react specifically to the landscape change imposed by the ECA scheme. They meet general criteria for biodiversity indicators (e.g. Hammond 1995) such as stable taxonomy, occurrence in a breadth of habitats, a broad geographical range, etc.; represent all major functional guilds and take into account several spatial and temporal scales. Because an eventual observation of a change in biodiversity cannot be assigned to the agri-environmental scheme (other factors interfere such as modifications of agricultural practices caused by market forces, nature protection policies, climate change, etc.), in three case study areas of about 6 km^2 each, the correlative relationships between ECA and biodiversity indicators are investigated. Results are presented for three organism groups, namely spiders, carabid beetles and butterflies in one case study area, i.e. Rafzerfeld (northern Switzerland).

The case study area comprised a total surface of 567 hectares, consisting of arable land (70%), special crops (nursery and vegetables: 17%), grassland (8%), has a flat relief and is situated at a mean altitude of 450 m.

Sampling methods

Spiders, carabid beetles and butterflies were recorded according to a stratified sampling method. ECA, cultivated areas and forest edges were defined as strata. The number of samples per ECA type was determined in proportion to the number of elements in each type occurring in the study area. Samples were distributed as follows: three extensively used meadows (no fertilisation, late mowing), nine low intensity meadows (restricted fertilisation, late mowing), two hedgerows, 11 wild flower strips. In addition, twenty winter wheat fields were chosen to serve as references for the cultivated area, because they are predominant of the landscape in the region and six observation sites were set up along the forest edge.

Spiders and carabid beetles were collected in 1997 and butterflies observed in 1998 on the 51 sites. Spiders and carabid beetles were collected with three pitfall traps per site, during five weeks (during the first three weeks of May and last two weeks of June). The three pitfall traps and five weeks of sampling per site are pooled for the analysis. Between May and August, butterflies were observed five times during 10 minutes each, across an area of 0.25 ha per site. At forest edges, butterflies were recorded along the edge. The five censuses per site are pooled for the analysis. At each of the observation sites, the vegetation was assessed over a single area of 100 m^2 according to the Braun-Blanquet method.

Measures of environmental influence

The environmental explanatory variables are divided in three sets of descriptors (Table 1): (1) the habitat (habitat type, plant species richness); (2) the landscape (habitat heterogeneity, variability, diversity, proportion of land use types in classes); and (3) the coordinates of the sites to detect eventual biogeographic or climatic shifts, or the effects of other environmental factors. The habitats were assigned to the six types listed in Table 1. As habitat descriptor, plant species richness was introduced as the number of plant species in 100 m^2.

To calculate the values of the landscape descriptors, each agricultural field in the case study area was visited, categorised according to its use and digitised by means of a geographical information system (GIS, ArcInfo software). Landscape descriptors were calculated in a 200 meters radius circle around the observation points. In addition to the surrounding habitat variability and heterogeneity (Table 1), D1 index of landscape pattern was used (O'Neil et al. 1988). $D1 = \ln(n) + \Sigma\, Pi \ln(Pi)$, where n is the total number of land use types and Pi the proportion of patches in land use type i. Furthermore, land use types were grouped into four classes to give the surrounding land use, namely ECA (extensively used and low intensity meadow, hedgerow, wild flower strip), cultivated land (cereal fields, root crops, corn, rape, vegetables, pasture, natural and artificial meadow, nursery), natural area (forest, grove, slope, brook) and built up area. The goal is to test a qualitative measure of the landscape diversity. D1 and surrounding land use were calculated with the percentage of area in each land use type.

Data analysis

To conserve the whole information on the observed organisms, we defined species diversity as composed of species variety and relative abundance of the species. Species-environment relationship was then analysed with the help of multivariate statistics.

To identify the main environmental variables having an effect on species diversity, canonical correspondence analysis (CCA) and partial CCA, were carried out by means of the CANOCO programme (Ter Braak & Smilauer 1998). In CCA, the significance of a particular environmental variable can be assessed by Monte Carlo testing (bootstrapping) of the axis associated with that variable, using the axis eigen value as the test statistic (Ter Braak 1987).

The detailed model describing the use of CCA with each separate environmental variable prior to a forward selection being carried out, to be followed by CCA involving all the variables, is described in Jeanneret (2000). The goal is to eliminate the explanatory variables which do not explain any variation significantly and to establish a hierarchy between them. This can be achieved as follows:

1) CCA with each environmental variable, separately; classes of nominal variables are selected following a forward selection within the CCA procedure. The environmental variables that do not explain any significant part of the variation are eliminated (Monte Carlo test).

Table 1. Characterisation of the habitats, landscape and spatial position of the sites acting as explanatory variables on biodiversity.

Scale	Environmental variables	Land use types
Habitat descriptors	Plant species richness	
	Habitat type	6 types: ECA = extensively used and low intensity meadow, hedgerow, wild flower strip + winter wheat and forest edge
Landscape descriptors	Surrounding habitat variability = number of surrounding habitat types	18 types: 4 ECA types + cereal field, root crop, corn, rape, vegetable, pasture, natural and artificial meadow, nursery, forest, grove, slope, brook, built up area
	Surrounding habitat heterogeneity = number of surrounding habitat patches	idem
	D1 index of landscape pattern	idem
	Surrounding land use	4 classes: ECA, cultivated land, natural area, built up area
Space descriptors	Coordinate X Coordinate Y	

2) CCA with the whole set of environmental variables that explain a significant part of the variation under 1); the correlations between the variables are examined. If collinearity is detected (in our case the decision level was placed at a Pearson r value of 0,7), the correlations coefficients between each of the environmental variables and the CCA axis (intraset correlations, Ter Braak 1987, pp. 63–70) are examined. The variable(s) with the higher intraset correlation value is (are) then selected for the partitioning of variation.

Partitioning of variation is then performed through partial CCA (e.g. Anderson & Gribble 1998; Borcard et al. 1992; Pozzi & Borcard 2001). The fraction of the variation explained (and its significance, obtained by means of a Monte Carlo permutation test) by each of the environmental descriptors is given separately, after eliminating the variation due to the other (partialed) variables, which are used as covariables.

In our analysis, CCA and partial CCA were carried out with the 51 sites, and the spider, carabid beetle and butterfly assemblages, respectively. The environmental variables introduced as explanatory variables in the analysis are listed in Table 1, namely plant species richness (continuous variable), habitat type (nominal variable, six classes), surrounding habitat variability and heterogeneity, D1 (continuous variables), surrounding land use (nominal variable, four classes) and the geographic coordinates (continuous variables).

Results

Development of the ECA

Almost 80% of the UAA in Switzerland is grassland (SAEFL & FOA 2000), this is reflected by the high share of grassland-type ECA (75% of total ECA area) (Table 2). In comparison, the other types are far less important in area. Still, in regions where arable crops dominate, linear landscape elements (strips with annual or perennial vegetation) are important elements of the ecological infrastructure (Jedicke 1994; Herzog 2000).

The Swiss agricultural sector mainly consists of relatively small family farms (average farm size 18.4 hectares in 1999; BLW 2000) and because the acceptance of the ECA-scheme is almost general (90.05% of farmers in 1999 farming 94.9% of UAA; BLW 2001), ECA are distributed throughout the UAA of the entire country. There is, however, an increased share of ECA in mountain regions, where 14.3% of the UAA is managed as ECA as compared to the intermediate hilly zone (7.1%) and the lowlands (6.7%).

ECA and landscape effects on faunistic biodiversity

Altogether, 15,500 spiders belonging to 127 species and 32,638 carabid beetles belonging to 96 species were collected from the 51 sites in Rafzerfeld in 1997. Altogether, 966 butterflies belonging to 22 species were observed on the 51 sites.

Within the scope of separate CCA and forward selection procedures, environmental variables and classes which explain a significant share of variation are recognised (Global and separate CCA section) and then introduced in partial CCA (Variation partitioning section).

Global and separate CCA

Habitat descriptors: Plant species richness explains a significant part of the variation of carabid beetle and butterfly assemblages but not of spider (Table 3). Habitat type significantly determines spider, carabid

Table 2. Major types and surface of ecological compensation areas in Switzerland. Surface is given in hectares. Source BLW, 2001.

ECA types	Surface in 2000 (hectares)
• Extensively used and low intensity meadows, litter areas: Grassland with minimum size of 0.05 ha, restrictions on fertilisation and mowing, commitment for 6 years.	88’201
• Traditional orchards: Standard fruit and nut trees, mostly on grassland.	26’339[1]
• Hedgerows, field and riverside woods: Hedgerows with grassland buffers of >3 m on both sides, total area ≥ 5 ares, commitment for 6 years or more.	3’110
• Others: Low intensity pastures, single trees and alleys, wooded pastures, water ditches and ponds, ruderal areas, stonewalls, naturally covered field tracks, species rich vineyards.	Not available
• Wild flower strips: Arable fallow sown with seed mixtures of wild plants, 3 m width or more, no fertilisers or pesticides. Short term rotational fallow is also possible.	1’315
• Low intensity cropping strips: Strips (3–12 m) of extensively managed cereals, rape, sunflowers, leguminoses; no fertilisation, restricted pesticide use, in two consecutive years at the lame location.	1’067

[1] Estimated from the number of trees, assuming 0.01 hectares/tree

beetle and butterfly assemblages. Among the habitat types, forest edge, wild flower strip and winter wheat have a strong influence. These habitats are differentiated by important factors which determine each of the species assemblages, e.g. habitat structure and microclimate for spiders and carabid beetles, and number of flowering plant species for butterflies. The influence of the habitat type is particularly high for the carabid beetles (37.8% of the variation explained).

Landscape descriptors: In general, the percentage of variation explained by the landscape descriptors are low compared with the percentages explained by the habitat descriptors (Table 3). Surrounding habitat variability and the D1 index of dominance do not explain a significant part of the epigeal arthropod and butterfly variation. Nevertheless, surrounding habitat heterogeneity (number of habitat patches) is an important factor for spiders and carabid beetles.

Surrounding land use, all classes put together, is a significant landscape explanatory variable for each organism. Nevertheless, the four classes were strongly correlated. Particularly, the percentage of natural area (mainly forest) and cultivated land were negatively correlated (more cultivated land implies less natural area). Therefore, the classes are selected according to separate CCA, forward selection of variables and examination of the intraset correlations (see Data analysis section). In this case, the percentage of natural area remains significant for spiders, carabid beetles and butterflies, as well as the percentage of ECA for spiders (Table 3).

Space descriptors (geographical coordinates): For each of the species assemblages, the spatial variation is significant. Nevertheless, the low percentage of variation explained shows that the spatial matrix acts partly as a synthetic descriptor of unmeasured underlying processes (external causes or biotic factors) and indicates that no fundamental spatial-structuring process has been missed.

Variation partitioning

Explanatory variables which did not have significant effects on the communities (see Global and separate CCA section) were eliminated before performing a partial CCA. The significant habitat and landscape variables (plant species richness and habitat type; surrounding habitat heterogeneity and the significant surrounding land use classes) were introduced in partial CCA in order to rank them according to explained variation. The fraction of variation explained and its significance (Monte Carlo permutation test) by each of the environmental variables is given separately, after eliminating variation due to the other (partialed) variables, which are used as covariables. In this context, it must be emphasised that the very low percentages of variation explained by landscape descriptors and geographical coordinates will further be reduced by the variation partitioning, in which the part explained by the other factors is extracted.

For the three groups of organisms, the share of variation attributed to the habitat remains greater than any other explained variation after partitioning (Figures 1–3). The correlative model developed for the spider

Table 3. Summary of the percentage of variation explained and *p*-values (Monte Carlo permutation test) by environmental variables for spiders, carabid beetles, and butterflies. n.s. : $p \geq 0.05$.

Scale	Environmental variables	Spiders		Carabid beetles		Butterflies	
		%	*p*	%	*p*	%	*p*
Habitat descriptors	Plant species richness	2.2	n.s.	6.1	< 0.05	6.6	< 0.05
	Habitat type	22.6	< 0.05	37.8	< 0.05	10.8	< 0.05
Landscape descriptors	Surrounding habitat variability	1.5	n.s.	1.7	n.s.	2.2	n.s.
	D1 index of landscape pattern	2.2	n.s.	1.9	n.s.	1.5	n.s.
	Surrounding habitat heterogeneity	4.1	< 0.05	4.4	< 0.05	3.0	n.s.
	Surrounding land use classes:						
	Cultivated land	–	n.s.	–	n.s.	–	n.s.
	Natural area	9.2	< 0.05	12.5	< 0.05	7.7	< 0.05
	Ecological compensation area	3.1	< 0.05	–	n.s.	–	n.s.
	Built up area	–	n.s.	–	n.s.	–	n.s.
Space descriptors	Coordinate X Coordinate Y	6.9	< 0.05	6.7	< 0.05	6.3	< 0.05

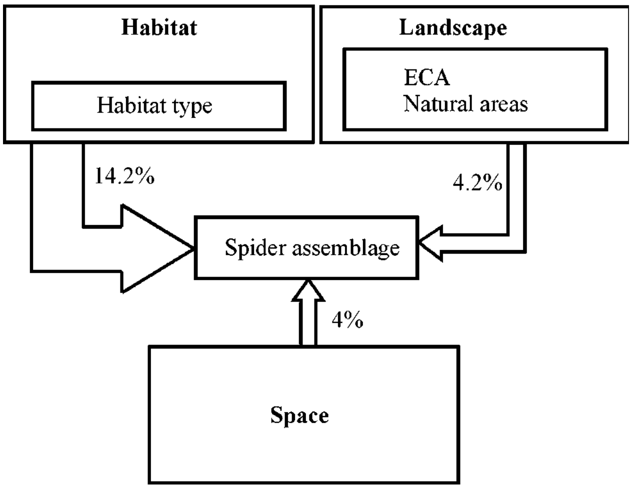

Figure 1. Synthetic model of correlative relations between environmental variables and spider assemblages, based on partial CCA. Habitat, landscape and space descriptors explain a significant part of the variance (p = 0.05, Monte Carlo procedure). The arrows are proportional to the percentage of the explained variance and can be compared with the percentages stated for carabid beetle and butterfly assemblages in Figures 2 and 3.

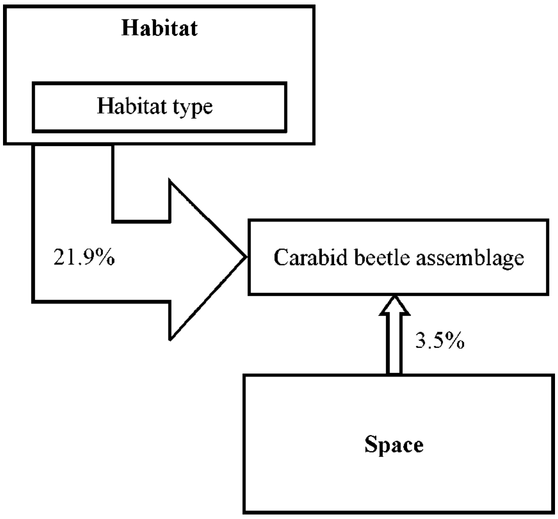

Figure 2. Synthetic model of correlative relations between environmental variables and carabid beetle assemblages, based on partial CCA. Both habitat and space descriptors explain a significant part of the variance (p = 0.05, Monte Carlo procedure). The arrows are proportional to the percentage of the explained variance and can be compared with the percentages stated for spider and butterfly assemblages in Figures 1 and 3.

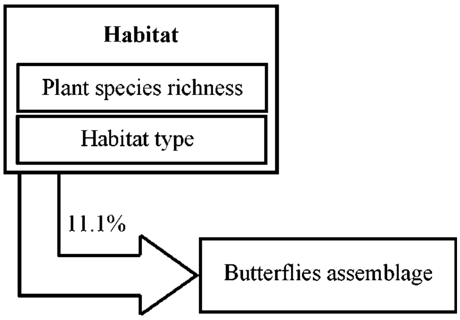

Figure 3. Synthetic model of correlative relations between environmental variables and butterfly assemblages, based on partial CCA. Habitat descriptors only explain a significant part of the variance (p = 0.05, Monte Carlo procedure). The arrows are proportional to the percentage of the explained variance and can be compared with the percentages stated for spider and carabid beetle assemblages in Figures 1 and 2.

assemblages revealed that local habitat variables (habitat type: 14.2%, Figure 1) that affect the site directly are the most important ones. Still the effect of landscape variables represented by the land use classes ECA and natural area in the surrounding are significant too (4.2%, Figure 1). The geographical variation remains significant but explained only a low percentage of variation.

Compared with spiders, habitat type (21.9%) has a stronger impact on carabid beetles (Figure 2). Winter wheat, hedgerows and wild flower strips are occupied by clearly differentiated carabid beetle assemblages. Landscape represented by the heterogeneity of the surroundings and the surrounding land use class “natural area” do not significantly influence carabid beetle assemblages any more after partitioning. Like for spiders, the variation explained by space is low and emphasises that the geographical position of the sites do not play an important role.

The model developed for butterflies showed that species assemblages are sensitive to habitat features only (habitat type + plant species richness: 11.1%). Landscape features and geographical coordinates do not explain a significant part of the variation (Figure 3).

Discussion and conclusion

The success of the restoration programme is demonstrated by the participation of farmers. Nevertheless, it must also be evaluated by its real impact on biodiversity.

On the basis of our results, habitat and landscape parameters have varying impacts, depending on the organism. This is also true of the particular case of ECA.

On one hand, spider, carabid beetle and butterfly assemblages are influenced by the habitat type, which is a result of the extensification at local scale because ECA contain characteristic species assemblages. The characterisation of habitats with arthropods has been demonstrated for spiders (e.g. Alderweireldt 1989;

Clausen 1986; Duffey 1974; Martin 1991), carabid beetles (e.g. Kramer 1996; Luff et al. 1989; Turin et al. 1991) and butterfly assemblages (e.g. Debinski & Brussard 1994; Dennis 1992; Kremen 1992). In the context of this study, wild flower strips introduced in an agricultural landscape dominated by cereal crops represent important and valuable habitats for species assemblages as demonstrated by the habitat type effect.

On the other hand, ECA in the surrounding landscape have a significant influence on spider assemblages observed on a given site, which is a result of the extensification programme at landscape level. These results do not confirm precedent studies carried out by Asselin & Baudry (1989), Burel & Baudry (1995) showing no effect of the landscape structure on spiders. Our results show that particular habitats like ECA and natural areas in the surroundings may control the attainability of the habitat for spiders.

It is astonishing that landscape descriptors and the surrounding habitat type in particular has no major influence on butterfly assemblages as it might be at least for some groups according to Dower (1992) and considering results for particular species (Thomas & Hanski 1997; Thomas & Harrison 1992). Most butterfly species fly over the landscape, visiting small or large areas. They need structures to move and often require several habitats to complete their life-cycles. Therefore, butterflies should be influenced by the habitat arrangement arround a visited point. In the landscape studied, however, the lack of vertical structures like hedgerows, forest edges, ditches, etc. leads to an uniform attainability of a given habitat for butterflies. Furthermore, it will be interesting to test formally other landscape features like the attainability, the connectivity and the permeability, as well as the landscape influence at different scales and not only at the one used in this study, namely 200 meters radius circle around the observation points.

Because of the differentiated response, it is important to approach the role of the extensification programme by examining different species assemblages (species composition and relative abundances). Biodiversity response to the extensification programme cannot be summarised by one single indicator. Monitoring species assemblages allows for the most direct assessment of fundamental management goals, such as the maintenance of viable communities.

Examining species assemblages allows for a comprehensive appreciation of the impact of habitat and landscape parameters on biodiversity. We use this approach instead of summarising the biotic information in one single value such as species richness or a diversity index where interpretation would be difficult and the loss of information too substantial. In another case study area, the species richness of spiders, e.g., did not allow to differentiate sufficiently between extensively used meadows and intensively used meadows (Jeanneret et al. 2000). Species assemblages, however, made a very significant distinction possible. In the particular case of ECA, differences between ECA and non-ECA species assemblages induce a biodiversity increase at regional level.

In conclusion, there are indications that the introduction of ECA into the agricultural landscape has positive effects on the biodiversity indicators which are examined and – as a consequence – positive effects on biodiversity as a whole can be expected. Nevertheless, data gathering over a long time span is necessary to confirm or disprove this conclusion.

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References

Alderweireldt M (1989) An ecological analysis of the spider fauna (Aranae) occurring in maize fields, Italian ryegrass fields and their edge zones, by means of different multivariate techniques. Agriculture, Ecosystems and Environment 27: 293–306.

Anderson MJ & Gribble NA (1998) Partitioning the variation among spatial, temporal and environmental components in a multivariate data set. Australian Journal of Ecology 23: 158–167.

Asselin A & Baudry J (1989) Les araneides dans un espace agricole en mutation. Acta Oecologica 4: 143–156.

BLW (2000) Agrarbericht. Bundesamt für Landwirtschaft, Bern.

BLW (2001) Evaluation der Ökomassnahmen und Tierhaltungsprogramme – Bereich Akzeptanz und Effizienz. Vierter Zwischenbericht. Bundesamt für Landwirtschaft, Bern.

Borcard D, Legendre P & Drapeau P (1992) Partialling out the spatial component of ecological variation. Ecology 73: 1045–1055.

Burel F & Baudry J (1995) Species biodiversity in changing agriculture landscapes: A case study in the Pays d'Auge, France. Agriculture, Ecosystems and Environment 55: 193–200.

Clausen IHS (1986) The use of spiders (Aranae) as ecological indicators. Bulletin of the Brithish Arachnological Society 7: 83–86.

Debinski DM & Brussard PF (1994) Using biodiversity data to assess species-habitat relationships in Glacier National Park, Montana. Ecological Applications 4: 833–843.

Dennis RLH ed. (1992) The ecology of butterflies in Britain. Oxford University Press, Oxford.

Dower JW, Clarke SA, Rew L (1992) Habitats and movement pattern of satyrid butterflies (Lepidoptera:Satyridae) on arable farmland. Entomologist's Gazette 43: 29–44.

Duffey E (1974) Habitat selection by spiders in man-made environments. Proceedings of the 6th Intenational Arachnid Congress, Amsterdam IV: 53–67.

Forni D, Gujer HU, Nyffenegger L, Vogel S & Gantner U (1999) Evaluation der Ökomassnahmen und Tierhaltungsprogramme. Agrarforschung 6: 107–110.

Hammond PM (1995) Practical approaches to the estimation of the extent of biodiversity in speciose groups. In: Biodiversity, Measurement and Estimation (ed DL Hawksworth): 119(136. Chapman and Hall, London.

Herzog F (2000) The importance of perennial trees for the balance of northern European agricultural landscapes. Unasylva 200: 42–47.

Jeanneret P (2000) Interchanges of a common pest guild between orchards and the surrounding ecosystems: a multivariate analysis of landscape influence. In : Interchanges of Insects between agricultural and surrounding landscapes (eds B Ekbom, ME Irwin & Y Robert): 85–107. Kluwer Academic Publishers, Dordrecht.

Jeanneret P, Schüpbach B, Steiger J, Waldburger M & Bigler F (2000) Tagfalter und Spinnen. Agrarforschung 7: 112–116.

Jedicke E (1994) Biotopverbund, Grundlagen und Massnahmen einer neuen Naturschutzstrategie. Ulmer, Stuttgart.

Kramer I (1996) Biodiversität von Arthropoden in Wanderbrachen und ihre Bewertung durch Laufkäfer, Schwebefliegen und Stechimmen. Agrarökologie 17. Bern.

Kremen C (1992) Assessing the indicator properties of species assemblages for antrual areas monitoring. Ecological Applications 2: 203–217.

Luff ML, Eyre MD & Rushton SP (1989) Classification and ordination of habitats of ground beetles (Coleoptera: Carabidae) in north-east England. Journal of Biogeography 16: 121–130.

Martin D (1991) Zur Autökologie der Spinnen (Arachnida: Aranae) I. Charakteristik der Habitatausstattung und Präferenzverhalten epigäischer Spinnenarten. Arachnologische Mitteilungen 1: 5–26.

O'Neil RV, Krummel JR, Gardner RH, Sugihara G, Kackson B, Deangelis DL, Milne BT, Turner MG, Zygmunt B, Christensen SW, Dale VH & Graham RL (1988) Indices of landscape pattern. Landscape Ecology 1: 153–162.

Pozzi S & Borcard D (2001) Effects of dry grassland management on spider (Arachnida: Araneae) communities on the Swiss occidental plateau. Ecoscience 8: 32–44.

SAEFL & FOA (2000) Swiss agriculture on its way to sustainability. Swiss Agency for the Environment, Forests and Landscape/Swiss Federal Office of Agriculture, Bern.

Ter Braak CJF (1987) Unimodal models to relate species to environment. PhD thesis, Agricultural Mathematics Group-DLO, Wageningen, the Netherlands.

Ter Braak CJF & Smilauer P (1998) CANOCO Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power. Ithaca, New York.

Thomas CD & Hanski I (1997) Butterfly Metapopulations. In: Metapopulation Biology (eds I Hanski & ME Gilpin): 359–386. Academic Press, San Diego.

Thomas CD & Harrison S (1992) Spatial dynamics of a patchily distributed butterfly species. Journal of Animal Ecology 61: 437–446.

Turin H, Alders K, Boer PJ Den, Essen S Van, Heijerman T, Laane W & Peterman E (1991) Ecological Characterization of carabid species (Coleoptera, Carabidae) in the Netherlands from thirty years of pitfall sampling. Tijdschrift voor Entomologie 134: 279–304.

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