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Agri-environment schemes - what have they achieved and where do we go from here?

Evaluating the performance of the Swiss agri-environmental measures for biodiversity: methods, results and questions

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Summary

In the early 1990s an agri-environmental programme was launched in Switzerland. To preserve and promote farmland biodiversity and threatened species, at least 7% of a farm's utilised agricultural area has to be managed as ecological compensation areas (ECA). After about 7 years of investigations, we concluded that ECAs have moderately positive effects on biodiversity in the lowlands. Comparisons showed, as a rule, more plant and arthropod species on ECAs than on intensively managed control areas. However, quality (based on plant species) compared with quality standards (ordinance) was particularly inadequate for meadows. There were large regional differences between lowlands and mountain regions. Threatened species were hardly promoted. Policy goals of the programme for biodiversity have been found to be somewhat vague and hence difficult to assess. For a consistent evaluation, multiple spatial and temporal scales need to be accounted for, and the response of farmland biodiversity to ECA should be considered at several diversity levels.

Key words: Agri-environmental scheme, Switzerland, plants, spiders, butterflies, hare, birds, evaluation

Introduction

Since 1993, Swiss farmers have been encouraged to establish ecological compensation areas (ECA). In 1999, direct payments were made conditional on farms producing Proof of Ecological Performance, including the requirement that farmers should manage 7% or more of their land as ECA, in order to preserve and promote farmland biodiversity. The objectives of ECA are to "enhance natural biodiversity" and to "preserve agro-biodiversity (no further extinctions but stabilisation and spread of threatened species)" (Bötsch, 1998; Forni *et al*., 1999). Today, more than 12% of Swiss farmland is managed as ECA, with higher shares in mountain regions than in the lowlands. The most prominent types are ECA meadows (subject to late cut, restricted fertilisation; 9% of farmland) and wildflower strip ECA (fallows sown with seed mixtures), which are less important in area (0.3% of farmland) but typical for arable regions.

After about 7 years of investigations, Herzog *et al*. (2005) and Aviron *et al*. (2009) concluded that the evaluation proved moderately positive. Lessons to be learned from this evaluation project are:

- biodiversity objectives are often not clearly defined by the policy maker. As a consequence, it may be problematic to evaluate (potential) biodiversity benefits against measurable objectives

- evaluating biodiversity is challenging because meaningful indicators need to be defined (ecological, environmental, policy driven, etc.)
- in biodiversity evaluations, multiple spatial and temporal scales need to be accounted for
- benefits for biodiversity can be measured and analysed in different ways that can each provide a different response (common and rare species, species number, species composition, etc.)
- targets have to be set by differentiating between regions and thus evaluations have to include differentiation

In this paper, we aim to highlight some results of the evaluation in Switzerland with a focus on the methods which were applied. Evaluation overview and results have been published by Herzog *et al*. (2005) and Aviron *et al*. (2009). We will discuss the challenges for landscape ecological research resulting from such a policy-driven task and the methodological lessons learned from this mid-term project, e.g. the spatial and temporal resolution of the evaluation, the selection of appropriate approaches and techniques for assessing environmental effects in a non-experimental setting. We will show that agri-environmental schemes may succeed or fail, depending on regions of implementation, on biodiversity indicators and diversity components investigated, and that short-term studies may fail in capturing the processes involved.

Materials and Methods

Lowland monitoring

Vascular plants and birds

Throughout the Swiss plateau, 56 study regions (municipalities) were examined between 1998 and 2003. Detailed methods of vegetation surveys and bird mapping are explained by Herzog *et al* . (2005). Botanical surveys were conducted in 1306 ECA meadows. The share of meadows with high botanical quality (with at least six plant species or taxa of the minimum standard list) was compared among biogeographical regions and differences tested with χ^2 statistics. Twice in the period 1998 – 2003, birds were observed three times per year between mid-April and mid-June. The centre of gravity of the three observations was considered as an approximation of the centre of the territory of a particular pair of breeding birds (Birrer *et al*., 2007). We examined whether the centres of territories were more frequent in or near ECA, by comparing their actual distribution with a hypothetical random distribution. The species were grouped according to their ecological requirements. Significance was tested with χ^2 statistics.

Hare

In Switzerland, hare populations have been monitored since 1993 in 57 case study regions. We used this long term monitoring to analyse the development of hare density in lowland regions and the correlation to the share of ECA (all types together), as well as the effect of main land uses, i.e. grassland versus crop field regions by means of mixed models (Holzgang *et al*., 2005).

Case study regions

Hare and birds

Hare and bird populations have been recorded since 1991 in three case study regions. In each of the regions, zones with a special support programme were compared with zones of standard implementation of semi-natural habitats (in 1991 implemented habitats were not considered ECA). In particular, wildflower strip ECAs were regularly introduced and reached 2.9% of the farmland in 2003.

Spiders and butterflies

In three other case study regions of about 8 km^2, the diversity of spiders, vascular plants, butterflies and ground beetles was investigated between 1997 and 2004, in both ECA and conventionally managed fields (total fields = 681). In this paper, we focus on spiders and butterflies.

The alpha-diversity (average number of species) and beta-diversity (variation in species composition) of spiders was investigated bi-annually between 1997 and 2003, in both ECA and conventionally managed fields (total number of fields = 478). In a complex study design, pairs of habitat types were formed to represent the farmers' choice when deciding about the implementation of ECA. ECA habitats were compared with a corresponding conventionally managed field category on a pairwise basis. In this paper we focus on ECA meadows versus conventional meadows (three regions, bi-annually from 1999 to 2003, n = 163 *vs* 71). The differences in alpha-diversity and beta-diversity were tested with multifactorial mixed-model ANOVA with permutation (Anderson & Ter Braak, 2003) and distance-based multivariate ANOVA (Anderson, 2001), respectively. Tests were performed with DISTML (Anderson, 2004). Furthermore, the effect of meadow age since management changed was tested against spider assemblages in one case study region, with two sets of fields (each with n = 26), i.e. with meadows averaging 6 years (median = 7 years, range: 0.5–10 years) and 3 years (median = 3 years, range: 0.5–8 years) after ECA management has been introduced, respectively.

In one of the three investigated case study regions, the effect of the percentage cover in the surrounding landscape (200 m radius) and the network of wildflower strip ECA (WFS) on butterfly species richness was investigated (Aviron *et al*., 2010). The network in the surroundings of each sampled field was described by the amount, the spatial proximity and the connectivity of WFS using GIS. The amount or percent cover was calculated within a circle radius of 200 m around each field. The spatial proximity of other WFS was described by the Euclidian distance to the nearest WFS in the surroundings. Connectivity to other WFS was quantified as a function of area of neighbouring WFS and their distance to the sampled field (from Steffan-Dewenter, 2003).

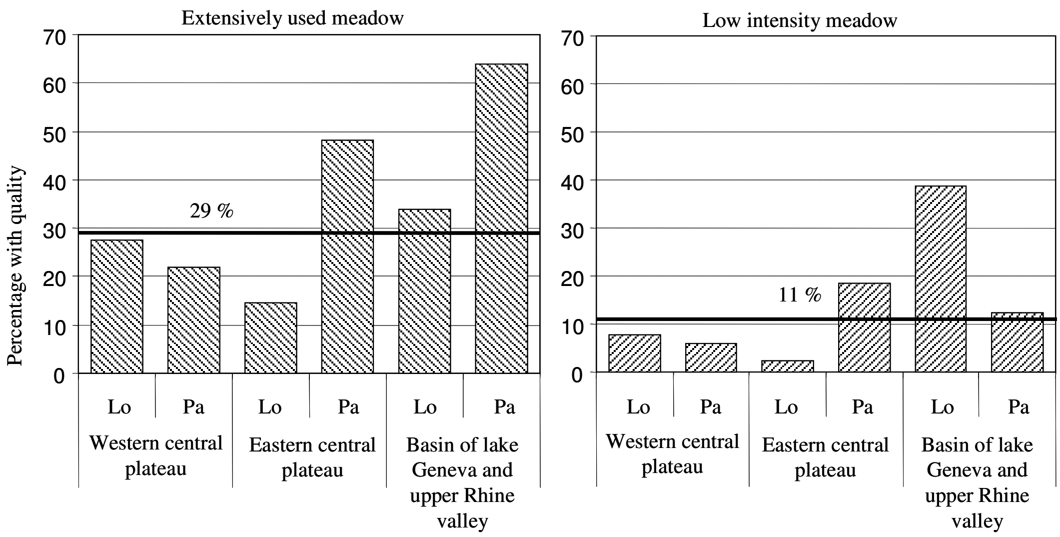

Fig. 1. Share of extensively used and low intensity meadows with at least six plant species or taxa of the minimum standard list (ecological quality) in the Swiss plateau (n=1306). Lo: lowland, Pa: pre-alpine.

Results

Ecological quality and rare species

Vascular plants – lowland monitoring

In the lowlands, 29 % of the extensively used meadows on average fulfilled ecological minimum standards as defined for the vegetation in the by-law on ecological quality (Bundesrat, 2001). However, large differences occurred among regions (Fig. 1). In the Basin of lake Geneva and Rhine valley, the share of ECA meadows with ecological quality was higher than in the other biogeographical regions Western central and Eastern central plateau (χ^2 =3.9, P < 0.05, and χ^2 =13.9, P < 0.0002, respectively).

Within regions, pre-alpine zones showed a significantly higher share of quality ECA meadows in both Basin of Lake Geneva and Rhine valley, and in the Eastern central plateau (χ^2 =11.4, P < 0.0007 and χ^2 =16.7, P < 0.0001, respectively).

Among 434 plant species recorded in total, eight endangered species and 17 vulnerable species were observed in relevés of ECA meadows. Endangered species (one or more) were found in 13.8% of the extensively used meadows of the pre-alpine zone of the Basin of Lake Geneva and upper Rhine valley. Vulnerable species were observed in 18% of ECA meadows.

Alpha-, beta-diversity

Spiders – case study regions

ECA meadows did not demonstrate a significantly higher α–diversity of spiders than conventionally managed fields (mixed-model ANOVA, F=3.2, df=1, P > 0.05, n=234, Fig. 2a). In contrast, significantly different species compositions were found (distance-based multivariate ANOVA with permutations, F=4.6, df=1, P < 0.001, n=234, Fig. 2b). However, the difference ECA vs. conventional meadows, was better explained by the region (F=7.8, df=2, P < 0.001). As the effect was dependent on regions and sampling years (third level interaction, F=1.4, df=4, P < 0.01), we further investigated the habitat type effect in regions and years separately. The species composition still differed significantly between regions (P < 0.005). This was confirmed by the non-metric MDS plots (Fig. 2b), which showed a more apparent grouping of ECA meadows according to the region than to the habitat type.

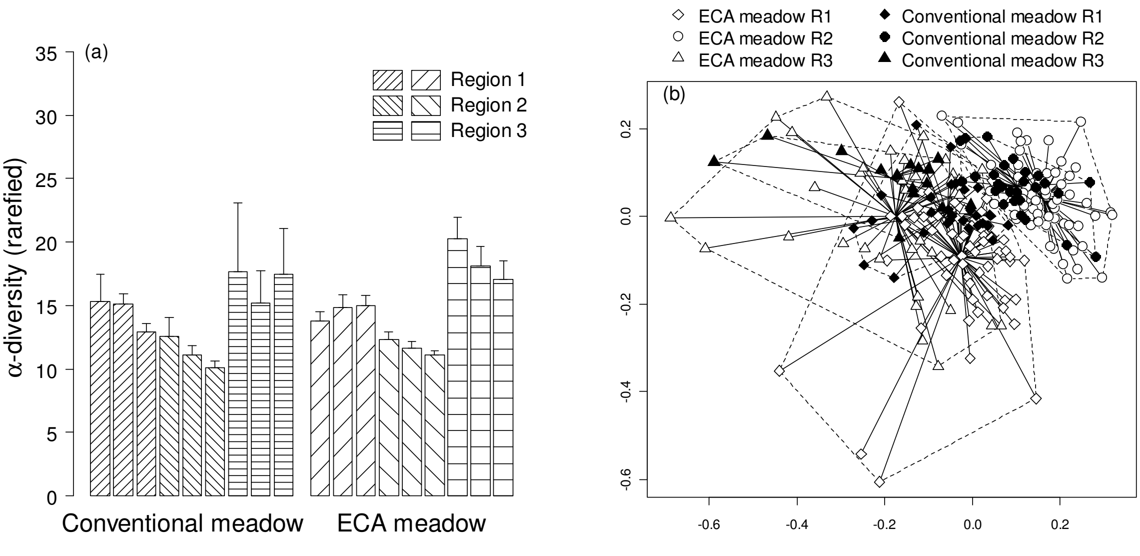

Fig. 2. (a) α–diversity (mean number of species +SE) of spider species (rarefied at 100 individuals) in ECA *vs* conventional meadow in three regions (n=234). Each bar represents α-diversity per year, i.e. 1999, 2001, 2003 from the left to the right. (b) Non-metric MDS plots of ECA vs. conventional meadow. R1 = region 1, R2 = region 2, R3 = region 3. Centroids, hull envelope and multivariate dispersion (distance between each site and the centroid to which it belongs) are shown for groups combining each habitat type per region.

Effect at landscape scale

Birds – lowland monitoring

The number of territories of open land birds in the surrounding of ECA was lower than expected from modelled random distribution (151 *vs* 68, χ^2-statistics = 45.6, P < 0.001). In particular, the dominant species, Skylark (*Alauda arvensis*) was significantly less frequent than expected in or near ECA (χ^2-statistics = 53.4, P < 0.001). On the other hand, the centres of the territories of hedgerow birds, as for example Yellowhammer (*Emberiza citrinella*) (293 *vs* 143,

χ^2-statistics = 157.3, $P < 0.001$) and Red-backed Shrike (*Lanius collurio*) (225 *vs* 102, χ^2-statistics = 148.3, $P < 0.001$), were significantly more frequent in or near ECA. Wetland birds, namely Reed Warbler (*Acrocephalus scirpaceus*) (52 *vs* 31, χ^2-statistics = 14.2, $P < 0.001$) and Marsh Warbler (*Acrocephalus palustris*) (27 *vs* 12, χ^2-statistics = 18.8, $P < 0.001$), were also more frequent on or near ECA, especially on unfertilized wet meadows used for straw which are generally also of high floristic quality. Amongst the orchard birds, only the Green Woodpecker (*Picus viridis*) was slightly more frequent in ECA orchards (11 *vs* 6, χ^2-statistics = 4.2, $P < 0.05$).

Butterflies- case study regions

Species richness and abundance were on average higher on wildflower strips ECA (WFS) than on grasslands and crop fields (Bonferroni pairwise comparison tests, $P < 0.05$, Aviron *et al*., 2010). Total species richness of butterflies in sampled fields was positively related to the percent cover of WFS in the surrounding landscape (200 m radius) (Fig. 3). The proximity and connectivity of WFS did not have any significant impact. Except for butterfly abundance, which increased with percent cover of grasslands (200 m radius), no site and landscape characteristics linked to grasslands, woody elements, crop fields and land use diversity significantly affected species richness and abundance of all butterflies.

None of the descriptors of WFS networks and other landscape characteristics related to grasslands, woody elements, crop fields and land use diversity significantly affected species richness and abundance of specialists.

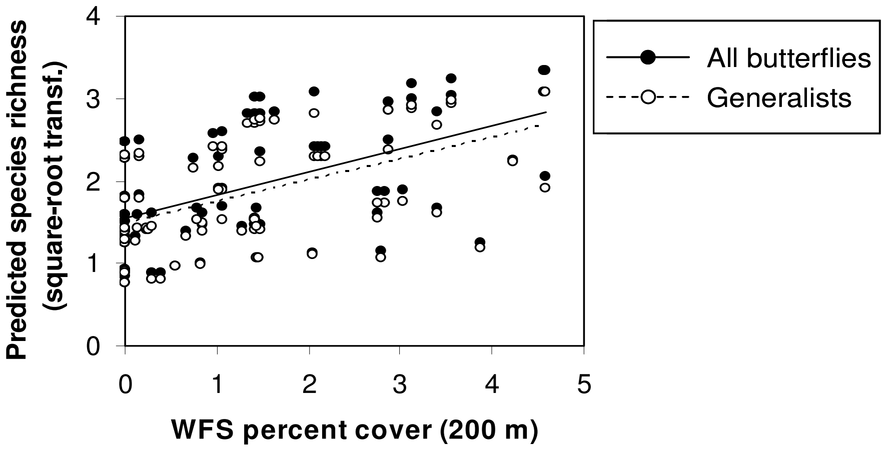

Fig. 3. Relationships between species numbers of all butterflies (solid line) and of generalists (dotted line) predicted by general regression models, and percent cover of wild flower strip ECA in the landscape context (200 m radius) of sampled fields (n=114) (Aviron *et al*., 2010).

Effect over time

Hare populations – lowland monitoring and case study regions

The evolution of hare density in lowland regions was significantly correlated with the share of ECA (all types together). However, there was a significant interaction between ECA proportion and land use (grassland versus arable land), both affecting hare populations (χ^2-statistics = 8.2, $P = 0.004$). In fact, the share of ECA had a positive effect on hare populations in regions dominated by arable land, but not in grassland regions (Holzgang *et al*., 2005).

Monitored since 1991 in two case study regions, hare populations have increased in zones with special programmes compared with zones with a standard implementation of ECA. From less than 1% ECA in both case study regions in 1991, and eight and four hare individuals/100 ha, populations increased to 16 and 13 individuals/100 ha, with 9% and 8% ECA in 2004, respectively. In contrast, populations increased only slightly in zones with standard implementation of ECA (up to 4%) from eight and three to 10 and five individuals/100 ha.

Birds – case study regions

In regions with special ECA support, typical bird species for agricultural regions were monitored since 1991. Bird populations of Melodious Warbler (*Hippolais polyglotta*), Eurasian Stonechat (*Saxicola torquatus*) and Common Whitethroat (*Sylvia communis*) increased in line with the amount of wildflower strip ECA (WFS). From less than 0.5% WFS in 1991, the number of territories km^{-2} increased from two for the three species to about seven, eight and 12 in 2003 (3% WFS), respectively. In contrast, populations only increased slightly in zones with standard implementation of ECA, reaching four territories km^{-2} for all three species together with 0.4% ECA in 2003.

Spiders – case study region

The age of ECA meadows had a significant effect on spider assemblages by the mid-term (RDA, F = 1.9, P = 0.03, n = 26), with ECA meadows averaging 6 years (median = 7 years, range: 0.5–10 years) since ECA management has been applied, while spider assemblages sampled in ECA meadows averaging 3 years (median = 3 years, range: 0.5–8 years) were not affected (RDA, F = 1.5, *P* = 0.06, n = 26).

Discussion

The political objectives of the policy in Switzerland were formulated as follows (Bötsch, 1998; Forni *et al*., 1999):

- Natural biodiversity should be enhanced,
- Agro-biodiversity should be preserved (no further extinctions but stabilisation and spread of threatened species).

These goals should be reached by 2005, with the years 1990/1992 – before the introduction of ecological direct payments – acting as a reference period. Achievement of such objectives is difficult to assess because "enhanced" as well as "stabilisation and spread of threatened species" clearly need baseline data to compare with.

Such objectives are difficult to translate into scientific hypotheses that can be tested with measurable "variables" and "factors". In this, we agree with Kleijn & Sutherland (2003), who pointed out the methodological difficulties of assessing the effects of agri-environment measures and providing statistically valid conclusions. Evaluations should follow BACI designs (Before After Control Impact, e.g. Kleijn *et al*., 2006), with situations observed before and after the scheme is applied, and control situations without scheme, both being then monitored in parallel. However, this is rarely applicable because initial situations (before the scheme is applied) are often not assessed. In our case, the evaluation programme started in 1996 (first biodiversity indicators observed in 1997) for political reasons, three years after the scheme had been implemented. We tried to overcome the problem in three ways.

First, we used data of long term monitoring of hare and bird populations. The examples showed that data collected in particular restored sites may inform the success of the scheme (i.e. the ECA implementation) (Birrer *et al*., 2005; Holzgang *et al*., 2005). However, such studies usually do not show proper experimental design, because factors acting on biodiversity and measured in the particular monitoring programmes do not correspond with the factors designed by the agri-environment scheme a couple a years after, e.g. biotopes integrated within the restoration programme may not correspond to ECA biotopes. In addition, true replications are often missing. Nevertheless, results suggest that the agri-environment scheme in Switzerland acts positively on hare and bird populations if particular biotopes, then declared as ECA, are integrated in the landscape within special restoration programmes.

Second, we replaced true temporal evaluation with space evaluation, by comparing biodiversity on sites with and without agri-environment schemes (i.e. ECA and production fields), and monitored the trends in the mid term 1997 to 2004 in case studies. Differences in species richness (alpha-diversity) of plants, spiders, carabid beetles and butterflies between ECA and production fields were observed in general, demonstrating positive effect of the ECA programme (Aviron *et al*., 2009). An exception to that was species richness of spiders in ECA vs. conventional meadows. Detailed analysis revealed that species composition (beta-diversity) of ECA meadows was significantly different from the conventional ones. This shows that depending on the diversity level analysed (alpha- *vs* beta-diversity), response and conclusion about the effectiveness of agri-environment programme can be controversial. Species composition was not affected over this time span, but was by the age of meadows since ECA management has been implemented. This revealed the difficulty of interpreting snapshot records. However, these investigations did not take into account possible initial differences between the sites. In this context, a major problem encountered with non-experimental evaluation at landscape scale is the land use dynamic. As participating farmers are contracted for managing specific ECA plots for 6 years, ECAs may return to production fields after this period. This will profoundly disturb the evaluation. In addition, production fields selected to compare may also show large changes of management (e.g. crop rotation). Thus, the complex spatial-temporal structure of land use in agricultural landscapes strongly limits proper evaluation design to take place. Last but not least, observations of biodiversity made in sites with and without agri-environment scheme may be influenced by landscape features, such as the share of particular habitats (habitat diversity in the surroundings, e.g. Jeanneret *et al*., 2003; wildflower strip ECA for butterflies, Aviron *et al*., 2010).

Third, we operated with standards, i.e. the share of ECA, which fulfil ecological minimum standards as defined for the vegetation in the by-law on ecological quality; these standards are based on a historical perception of traditional agriculture as it was practised until the middle of the 20th century before intensification accelerated and agricultural biodiversity was strongly reduced (indicator species lists; Dietl, 1995). Results showed that the standards for vegetation were achieved for a low percentage of ECAs. Result-oriented schemes are efficient and relatively easy to evaluate for very well documented species groups in the agricultural landscape (e.g. plants, birds, mammals), for which standards or target species can be derived. It is more complicated for species groups for which standards are more difficult to establish (e.g. what is a spider community of good quality?) and more time-consuming to record, e.g. for arthropods. Furthermore, presence of red list species provides proof of success, but is challenging to assess because such species are rare. Only large monitoring programmes can provide distribution pattern of such species. In this case, baseline data are necessary, i.e. data collected before measures are introduced.

Evaluation of schemes aiming to increase biodiversity in general (like "Natural biodiversity should be enhanced") needs indicators because "biodiversity" cannot be entirely measured as such. Search for indicators is a recurrent topic in biodiversity assessment (e.g. Noss, 1990; Duelli & Obrist, 2003; UNEP, 2003). The choice of indicators for biodiversity depends primarily on the objects of the study. In the case of agri-environment schemes, not all species groups react the same way to a given scheme. Particular measures will be successful with particular species groups, species will react at different temporal and spatial scale to the measures, etc. Indicators should be selected that react specifically to the measures of particular management of fields or the integration of semi-natural biotopes in the cultivated landscape.

Evaluation should be made with respect to the goals of the agri-environment scheme. Indicators should be selected that potentially react to the scheme or to particular measures of the scheme. Searches for correlates and surrogates may help in reducing time-consuming monitoring of indicator groups. Evaluations have also to be performed within the spatial and temporal scales defined by the agri-environment scheme.

References

Anderson M J. 2001. A new method for non-parametric multivariate analysis of variance.

Australian Ecology **26**:32–46.
Anderson M J. 2004. *DISTLM v.5: a FORTRAN computer program to calculate a distance-based multivariate analysis for a linear model*. New Zealand: Department of Statistics, University of Auckland.
Anderson M J, Ter Braak C J F. 2003. Permutation tests for multi-factorial analysis of variance. *Journal of Statistical Computation and Simulation* **73**:85–113.
Aviron S, Herzog F, Schättin I, Schüpbach B, Jeanneret P. 2010. Effects of wild flower strip quality, quantity, and connectivity on butterfly diversity in a Swiss arable landscape. *Restoration Ecology* (In press).
Aviron S, Nitsch H, Jeanneret P, Buholzer S, Luka H, Pfiffner L, Pozzi S, Schupbach B, Walter T, Herzog F. 2009. Ecological cross compliance promotes farmland biodiversity in Switzerland. *Frontiers in Ecology and the Environment* **7**:247–252.
Birrer S, Kohli L, Spiess M, Herzog F. 2005. Evaluation de l'efficacité des surfaces de compensation écologique pour les oiseaux nicheurs. In *Evaluation des mesures écologiques - Domaine biodiversité,* pp. 139–148. Eds F Herzog and T Walter. *Schriftenreihe der FAL* 56. Zürich: Agroscope FAL Reckenholz.
Birrer S, Spiess M, Herzog F, Kohli L, Lugrin B. 2007. The Swiss agri-environment scheme promotes farmland birds – but only moderately. *Journal of Ornithology* **148**:295–303.
Bötsch M. 1998. Das Agrar-Umweltprogramm der Schweiz. *Schriftenreihe Landesanstalt für Pflanzenbau und Pflanzenschutz* **6**:25–43.
Bundesrat. 2001. *Öko-Qualitätsverordnung, Ordinance SR 910.14*. Swiss legislation.
Dietl W. 1995. Wandel der Wiesen-Vegetation im Schweizer Mittelland. *Zeitschrift für Ökologie und Naturschutz* **4**:239–249.
Duelli P, Obrist M K. 2003. Biodiversity indicators: the choice of values and measures. *Agriculture, Ecosystems & Environment* **98**:87–98.
Forni D, Gujer H U, Nyffenegger L, Vogel S, Gantner U. 1999. Evaluation der Ökomassnahmen und Tierhaltungsprogramme. *Agrarforschung* **6**:107–110.
Herzog F, Dreier S, Hofer G, Marfurt C, Schüpbach B, Spiess M, Walter T. 2005. Effect of ecological compensation areas on floristic and breeding bird diversity in Swiss agricultural landscapes. *Agriculture Ecosystems & Environment* **108**:189–204.
Holzgang O, Heynen D, Kéry M. 2005. Retour du lièvre commun grâce à la compensation écologique? In *Evaluation des mesures écologiques - Domaine biodiversité*, pp. 150–160. Eds F Herzog and T Walter. *Schriftenreihe der FAL* 56. Zürich: Agroscope FAL Reckenholz.
Jeanneret P, Schüpbach B, Pfiffner L, Walter T. 2003. Arthropod reaction to landscape and habitat features in agricultural landscapes. *Landscape Ecology* **18**:253–263.
Kleijn D, Baquero R A, Clough Y, Dıaz M, De Esteban J, Fernandez F, Gabriel D, Herzog F, Holzschuh A, Jöhl R, Knop E, Kruess A, Marshall E J P, Steffan-Dewenter I, Tscharntke T, Verhulst J, West T M, Yela J L. 2006. Mixed biodiversity benefits of agri-environment schemes in five European countries. *Ecology Letters* **9**:243–254.
Kleijn D, Sutherland W J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology* **40**:947–969.
Noss R F. 1990. Indicators for Monitoring Biodiversity: A Hierarchical Approach. *Conservation Biology* **4**:355–364.
Steffan-Dewenter I. 2003. Importance of habitat area and landscape context for species richness of bees and wasps in fragmented orchard meadows. *Conservation Biology* **17**:1036–1044.
UNEP. 2003. Monitoring and indicators : designing national-level monitoring programmes and indicators. In *UNEP/CBD/SBSTTA/9/10* (Ed.).