Validation of a method for biodiversity assessment in LCA (SALCA-Biodiversity) using indicator species groups

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ABSTRACT
The SALCA-Biodiversity (SALCA-BD) method developed by ART with the aim to integrate biodiversity as an impact category for agricultural production in LCA was validated for two of the eleven indicators: grassland flora and grasshoppers.
On the basis of management practices of ten farms grassland plots directly recorded by the farmers, biodiversity scores were calculated with SALCA-BD. Grassland flora and grasshopper field data recorded *in situ* were compared to the calculated scores at the plot as well as at the farm level. Significant correlations at the plot level were found between calculated scores and field data for both grassland flora and grasshoppers. At farm level significant correlations were found for the grassland flora only.
The results show that SALCA-BD method is appropriate for estimating the impact of management practices on indicator species groups and shows the wished sensitiveness with regard to different intensities of agricultural land use.

Keywords: LCA, biodiversity, flora, grasshoppers, agriculture

1. Introduction

In the context of Life Cycle Assessment for agriculture, we developed a method for the integration of biodiversity (species diversity) as an impact category, SALCA-Biodiversity (Swiss Agricultural Life Cycle Assessment for Biodiversity) (Jeanneret *et al.*, 2006; Jeanneret *et al.*, 2008). This method aims at assessing along a midpoint approach the impact of farming operations, management systems and farms on biodiversity in a predictive manner.

Biodiversity in the broadest sense of the Rio Convention cannot be totally measured and a single indicator is unlikely to be devised even in agro-ecosystems (e.g. Büchs, 2003). Instead, groups of indicators should be selected that are sensitive to the environmental conditions resulting from land use and agricultural practices, and give as representative a picture as possible of biodiversity as a whole. We selected indicator species groups (ISGs) according to their linking to agricultural activities, their association to specific habitats and their place in the food chain (Jeanneret *et al.*, 2006): flowering plants, birds, small mammals, amphibians, snails, spiders, carabid beetles, butterflies, wild bees, and grasshoppers. The impact assessment distinguishes between the overall species diversity (OSD) of each ISG, and the diversity of the ecologically demanding species or/and stenotopic species (EDS). To assess the impact of agricultural practices on the selected indicator species groups, inventory data reflecting detailed management options were specified (e.g. quantity of fertilizers, number of cuts). Based on information from literature and expert knowledge, a scoring system was de-

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veloped that estimates the response of every ISG to the management options taking into account the habitat where they take place (e.g. grasslands, cereals, semi-natural habitats). Scores of management options were then aggregated at the field level (e.g. fertilization and cutting regime) in order to compare agricultural systems. The impact of land use on biodiversity at farm level was calculated by further aggregating the biodiversity scores obtained at field level under consideration of the ecological relevance of the habitats concerned.

The aim of this study is to compare outputs (scores) from SALCA-BD calculated with management data with field data recorded *in situ* for grassland at the plot and farm level. Two of the ISGs, vascular plants and grasshoppers, were chosen for this comparison for following reasons: Vascular plants correlate well to the overall biodiversity of a region (Duelli *et al.*, 1998) and grasshoppers are typical grassland insects, 80% of the species in Switzerland being able to grow on meadows and pastures (Schneider *et al.*, 2001). Both indicator groups are relatively easy to record and identify, and react sensitively to management practices (e.g. Marini *et al.*, 2008).

Following question was addressed: Does the SALCA-BD scores for vascular plants and grasshoppers correlate with the respective data recorded in the field at both plot and farm levels?

2. Methods

In 2008, ten grassland dominated farms were chosen along a management intensity gradient at the southern margins of the Swiss Jura Mountains (Canton of Aargau) at altitudes between 350 and 750 m a.s.l. Vascular plants and grasshoppers were recorded in the field on every grassland plot of ten (n=198) resp. six (n=77) farms. Data on agricultural practices regarding fertilisation, mowing, grazing and weed or mice control that have taken place in 2008 at every single plot were directly obtained from the farmers.

All plant species present on a 25 m^2 circle representative for the plot were recorded in the field. In case of a heterogeneous plot presenting a mosaic of patches of different vegetation types, a plant list and the percentage of area covered by every patch were also recorded. Grasshopper species were recorded visually and acoustically on sunny days with little or no wind during one hour walk through the plot. From the field data species richness and high nature value scores based on species composition were derived. High nature value scores for the vascular plant group were obtained with a point system for valuable species to the Swiss Ecological Quality Ordinance (EQO) (BLW, 2008b; 2008a) and the UZL plant lists (BAFU & BLW, 2008). Species not mentioned in the list received zero points. To calculate the total plant species richness and the high nature value scores of heterogeneous plots a weighted average was performed taking into consideration the percentage of area covered by each vegetation patch. High nature values for the grasshopper group were derived from the Swiss Red List (RL) for grasshoppers (Monnerat *et al.*, 2007) and the UZL grasshopper list (BAFU & BLW, 2008). To calculate high nature value scores points were assigned depending to the level of high nature value and endangerment of the species. Because of the restricted number of grasshopper species with high nature value mentioned in the RL and UZL lists, the majority of plots resulted in a score of zero points. Therefore a minimum of one point was attributed to every grasshopper species and RL scores were summed to UZL scores resulting in a single high nature value (RL+UZL score) for the grasshopper group.

SALCA-BD outputs, OSD and EDS (grasshoppers only) scores, calculated on the basis of agricultural practices, were compared to the species richness and high nature values for both plant and grasshopper groups (Tab. 1). With the statistical program R (R Development Core

Team, 2008) significant correlations at the plot level were tested with the Spearman's rank correlation test and at the farm level with the Pearson's product-moment correlation test.

Table 1: SALCA-BD scores and field data pairs compared. OSD = Overall species diversity; EDS = Ecologically demanding species.

Grassland flora			Grasshoppers		
SALCA-BD scores		Field data	SALCA-BD scores		Field data
Grassland flora OSD	↔	Species richness	Grasshopper OSD	↔	Species richness
Grassland flora OSD	↔	UZL score	Grasshopper EDS	↔	Species richness
Grassland flora OSD	↔	EQO score	Grasshopper OSD	↔	RL+UZL score
			Grasshopper EDS	↔	RL+UZL score

3. Results

Overall 294 plant and 17 grasshopper species were recorded with an average per plot of 29 plant resp. 6 grasshopper species.

Table 2 summarizes the results of the correlations between SALCA-BD scores (OSD and EDS) and field data recorded *in situ* (species richness, UZL score, EQO score and RL+UZL score) for grassland flora and grasshopper groups at the plot and farm level.

Table 2: Results of the correlation tests. P-value: * = < 0.05; ** = < 0.01; *** = < 0.001.

		SALCA-BD score – field data	Correlation value
Grassland flora	Plot level (N=198)	OSD - Species richness	0.578***
		OSD - UZL score	0.624***
		OSD - EQO score	0.609***
	Farm level (N=10)	OSD - Species richness	0.735*
		OSD - UZL score	0.734*
		OSD - EQO score	0.755**
Grasshoppers	Plot level (N=77)	OSD – Species richness	0.389***
		EDS – Species richness	0.361**
		OSD – RL+UZL score	0.338**
		EDS – RL+UZL score	0.323**
	Farm level (N=6)	OSD – Species richness	0.658
		EDS – Species richness	0.696
		OSD – RL+UZL score	0.583
		EDS – RL+UZL score	0.628

Correlations between SALCA-BD scores and species richness or high nature values for grassland flora and grasshopper at the plot level were overall positively correlated. The correlation values were higher for the grassland flora than for grasshoppers. For grassland flora the highest correlations between SALCA-BD score and field data were found for the UZL score, one of the two scores suggesting high nature value of species composition. For grasshoppers, in contrast, the highest correlation values with SALCA-BD scores, OSD and EDS, were found for species richness. Correlations of field data with the OSD scores resulted to be higher than with the EDS scores (only grasshoppers).

At the farm level, correlations between the SALCA-BD scores and field data recorded *in situ* resulted to be significant only for grassland flora. The highest correlation value was found between the farm OSD and the farm EQO scores. Despite the relatively high correlation values at the farm level for grasshoppers, both OSD and EDS scores resulted to be non significantly correlated with the species richness and the RL+UZL score.

4. Discussion

Cultivated land is used as habitat by numerous plant and animal species, and agricultural practices have a major impact on the biodiversity of this environment (e.g. Stoate *et al.*, 2001; Benton *et al.*, 2002; Robinson *et al.*, 2002). Appropriate monitoring methods to evaluate and reduce the impact of agricultural farms on biodiversity are needed. SALCA-BD is an indirect method which enables to assess biodiversity of a farm, plot or crop in a cheap, fast and simple way (Jeanneret *et al.*, 2006).

At the plot level, the significant correlations for both grassland flora and grasshopper indicator groups between calculated scores and field data shows that the SALCA-BD method is appropriate for estimating the impact of management practices on indicator species groups, at least the ones investigated in this study. These results suggest the validation of the scoring system, based on results presented in the scientific literature and expert knowledge, and in particular SALCA-BD aggregation steps at the plot level. Aggregated plot scores at farm level conducted to positive significant correlations with *in situ* observations for vascular plants but not for grasshoppers, although positive but not significant for the latest.

Correlation values for the grassland flora were overall higher than for the grasshopper indicator, which may be due to the smaller number of plots recorded, the fewer species of grasshoppers compared to that of grassland flora and/or plot heterogeneity which was taken into consideration only for the flora group, since it was assumed that grasshopper species were moving freely within the plot. In addition, an important feature observed in grasshoppers was the high impact of the surrounding land use, reported also for various other insect groups (Duelli *et al.*, 1999; Jeanneret *et al.*, 2003), and not taken into account in SALCA-BD. Surrounding areas indeed can positively or negatively affect biodiversity (e.g. De Snoo *et al.*, 1999; Tscharntke *et al.*, 2005). The history of the plot, non considered in SALCA-BD, can play an important role too (Smith *et al.*, 2003; Marriott *et al.*, 2004). The inexactness of the estimations due to both abovementioned limitations of the method affect the results, but for the plot level it was shown that even with such constraints, SALCA-BD sensitivity was high enough to lead to significant correlations between calculated scores and field data. At the farm level, good results were achieved only for the grassland flora. However, the relatively high correlation values between grasshopper SALCA-BD scores and field data at the farm level give evidence that not the data but the few farms recorded (N=6) is the probable reason for the undetected significance.

For the grassland flora, the highest correlation values with SALCA-BD scores were found for the high nature value scores: at the plot level with UZL score and at the farm level with EQO score. Plants mentioned in these two lists are species specific to cultivated land. In contrast, no distinction between cultivated land and forest plant species, these latter encountered in plots at the forest edge, was done for the record of the species richness. The focus of SALCA-BD on agricultural habitats could explain the higher correlations with the high nature value scores mentioning species growing on cultivated land only and the lower correlation values with the species richness often including also species unspecific for this habitat. For the grasshopper group, both SALCA-BD scores (OSD and EDS) were higher correlated with the species richness. Because of the limited number of grasshopper species with high nature value the RL score and UZL score were summed, which may have lead to an inadequate point system to represent the high nature value score leading to lower correlation values with SALCA-BD scores. Correlations between the OSD scores and both the species richness and the quality value for grasshoppers were higher than with the EDS scores, showing a higher sensitivity of the method when calculating OSD values.

The results obtained for grassland flora and grasshoppers cannot be directly transferred to the other indicators. However, the scoring system of the remaining groups was established with the same method, i.e. based on scientific literature and expert knowledge. There are therefore good prospects that SALCA-BD gives satisfying results also for the indicators not validated in this study.

The study presents the high sensitivity of the method concerning the impact of different agricultural management practices on biodiversity at the plot level. SALCA-BD resulted to be a suitable method to investigate the optimization of agricultural management activities as well as the comparison of farms or different land uses relative to biodiversity. At the farm level sensitivity with regard to agricultural practices was attained only for grassland flora; the outcome for grasshoppers possibly affected by the few replicates should be ascertained with more research.

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6. References

BAFU & BLW (2008). Umweltziele Landwirtschaft (UZL). Hergeleitet aus bestehenden rechtlichen Grundlagen. Umwelt-Wissen Nr. 0820. Swiss Federal Office for Environment, Bern.

Benton T. G., Bryant D. M., Cole L., Crick H. Q. P. (2002). Linking agricultural practice to insect and bird populations: a historical study over three decades. *Journal of Applied Ecology*, 39, pp. 673-687.

BLW (2008a). Weisungen für extensiv genutzte Weiden nach Art. 20 der Öko-Qualitätsverordnung (ÖKV). Swiss Federal Office for Agriculture, Bern.

BLW (2008b). Weisungen für extensiv genutzte Wiesen, wenig intensiv genutzte Wiesen, Streuflächen nach Art. 20 der Öko-Qualitätsverordnung (ÖKV). Swiss Federal Office for Agriculture, Bern.

Büchs W. (2003). Biotic indicators for biodiversity and sustainable agriculture. *Agriculture, Ecosystems and Environment*, 98, pp. 1-16.

De Snoo G. R., Van der Poll R. J. (1999). Effect of herbicide drift on adjacent boundary vegetation. *Agriculture, Ecosystems and Environment*, 73, pp. 1-6.

Duelli P., Obrist M. K. (1998). In search of the best correlates for local organismal biodiversity in cultivated areas. *Biodiversity and Conservation*, 7, pp. 297-309.

Duelli P., Obrist M. K., Schmatz D. R. (1999). Biodiversity evaluation in agricultural landscapes: Above-ground insects. *Agriculture, Ecosystems and Environment*, 74, pp. 33-64.

Jeanneret P., Baumgartner D., Freiermuth R., Gaillard G. (2006). Méthode d'évaluation de l'impact des activités agricoles sur la biodiversité dans le bilans écologiques. Agroscope Reckenholz-Tänikon Research Station ART. pp. 67.

Jeanneret P., Baumgartner D. U., Freiermuth Knuchel R., Gaillard G. (2008). A new LCIA method for assessing impacts of agricultural activities on biodiversity (SALCA-Biodiversity). 6th International Conference on Life Cycle Assessment in the Agri-Food Sector 2008, Proceedings. pp. 34-39.

Jeanneret P., Schüpbach B., Luka H. (2003). Quantifying the impact of landscape and habitat features on biodiversity in cultivated landscapes. *Agriculture, Ecosystems and Environment*, 98, pp. 311-320.

Marini L., Fontana P., Scotton M., Klimek S. (2008). Vascular plant and Orthoptera diversity in relation to grassland management and landscape composition in the European Alps. *Journal of Applied Ecology*, 45, pp. 361-370.

Marriott C. A., Fothergill M., Jeangros B., Scotton M., Louault F. (2004). Long-term impacts of extensification of grassland management on biodiversity and productivity in upland areas. A review. *Agronomie*, 24(8), pp. 447-462.

Monnerat C., Thorens P., Walter T., Gonseth Y. (2007). Rote Liste der Heuschrecken der Schweiz. Bundesamt für Umwelt, Bern, und Schweizer Zentrum für die Kartographie der Fauna, Neuenburg. Umwelt-Vollzug 0719, pp. 62.

R Development Core Team. (2008). R: A language and environment for statistical computing. http://www.R-project.org.

Robinson R. A., Sutherland W. J. (2002). Post-war changes in arable farming and biodiversity in Great Britain. *Journal of Applied Ecology*, 39, pp. 157-176.

Schneider K., Walter T. (2001). Fauna artenreicher Wiesen: Zielarten, Potenzial und Realität am Beispiel der Tagfalter und Heuschrecken. *Schriftenreihe der FAL*, 39, pp. 34-44.

Smith R. S., Shiel R. S., Bardgett R. D., Millward D., Corkhill P., Rolph G., Hobbs P. J., Peacock S. (2003). Soil microbial community, fertility, vegetation and diversity as targets in the restoration management of a meadow grassland. *Journal of Applied Ecology*, 40, pp. 51-64.

Stoate C., Boatman N. D., Borralho R. J., Rio Carvalho C., De Snoo G. R., Eden P. (2001). Ecological impacts of arable intensification in Europe. *Journal of Environmental Management*, 63, pp. 337-365.

Tscharntke T., Klein A. M., Kruess A., Steffan-Dewenter I., Thies C. (2005). Landscape perspectives on agricultural intensification and biodiversity - ecosystem service management. *Ecology Letters*, 8, pp. 857-874.