Estimation of grassland management impact on biodiversity

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Abstract

Agroscope Reckenholz-Tänikon Research Station ART developed a method for the integration of biodiversity (organismal diversity) as an impact category of Life Cycle Assessment (LCA) for agricultural production (SALCA-Biodiversity). This method is applied to grasslands and arable crops to estimate the impact of management systems on biodiversity. First, a list of indicator species groups (flora, birds, mammals, amphibians, snails, spiders, carabids, butterflies, wild bees, and grasshoppers) was established considering ecological and life cycle assessment criteria. Second, inventory data about agricultural practices with detailed management options were specified. Third, a scoring system estimated the reaction of every indicator species group regarding management options, followed by an aggregation step. In a case study, biodiversity scores for grassland management systems were calculated. Results show the dominant influence of management intensity on most indicators and the inflection point of management from which large impacts on biodiversity are to be expected.

Keywords: biodiversity, grassland management, impact estimation, life cycle assessment

Introduction

Grassland management operations may greatly affect biodiversity and furthermore, influence basic ecological functions, i.e. organic matter decomposition, herbivory, predation and pollination at global scale. Therefore, assessing impacts of grassland management on biodiversity is an important issue.
Agroscope Reckenholz-Tänikon Research Station ART developed a method for the integration of biodiversity as an impact category into the Life Cycle Assessment (LCA) of farms (SALCA-Biodiversity, Jeanneret *et al.*, 2006). Two approaches for evaluating the effects of agricultural activities (in a broad sense) on biodiversity are found in the literature: (1) biodiversity is included as an impact category in LCA like other categories, e.g. the greenhouse effect. This approach is essentially based on the species diversity of vascular plants and includes the impact of industry, agriculture and transport on a continent scale (e.g. Lindeijer *et al.*, 1998). (2) An environmental diagnosis based on a biotope evaluation with indicators is done ("ecological value" of farms, e.g. Brosson, 1999). Our method is based on the first approach but is more detailed and is designed for use in Switzerland and adjoining regions. The method aims at estimating and comparing the impact of agricultural management systems on biodiversity. As part of this project, impact assessment of grassland management practices on biodiversity is presented.

Materials and methods

Since the whole biodiversity can neither be measured nor can the impact of management practices on biodiversity be entirely estimated, indicators have to be used. In the present method the choice of indicator species groups was made using a criteria table based on the linking of the species to agricultural activity, and general criteria such as the species distribution in the cultivated landscapes, their habitats and their place in the food chain (Jeanneret *et al.*, 2006). The set of indicators must also give as representative a picture as possible of organismal diversity as a whole. The following species groups were selected: flowering plants, birds, small mammals, amphibians, snails, spiders, carabid beetles, butterflies, wild bees and grasshoppers. Soil organisms were not considered in this study. Furthermore, we distinguished between the overall species diversity of each species group and the ecologically demanding species (stenotopic species, red list species) in the impact estimation.
The effect of the management activities on each indicator species group were estimated based on information from the literature and expert knowledge. All the typical grassland management activities such as manuring and mowing were specified with options, e.g. the type of fertiliser or the mowing period (restricted to the Swiss farming). The impact of each management option was rated on a scale of 0 to 5 (rating R, Table 1).

Table 1. Rating R of management option impact on the selected indicator species groups.

0:	The species group is unaffected because it does not occur in grasslands.
1:	The option leads to a severe impoverishment of species diversity within the species group considered and renders impossible the occurrence of stenotopic species and red list species.
2:	The option leads to a slight impoverishment of species diversity within the species group considered and renders impossible the occurrence of stenotopic species and red list species.
3:	The option has no direct effect on the species group considered.
4:	The option leads to a slight increase in species diversity within the species group considered and makes possible the occurrence of stenotopic species and red list species.
5:	The option promotes species diversity within the species group considered and makes possible the occurrence of stenotopic species and red list species.

Since grasslands and other habitats of the agricultural landscape represent various habitat suitabilities, a coefficient ranging from 1 to 10 ($C_{habitat}$) was attributed to weight the rating of the management options, for each indicator species group specifically. Similarly, a second coefficient from 0 to 10 ($C_{management}$) quantified the relative importance of management activities for a given habitat, e.g. grazing and mowing in grasslands, for each indicator species group. The final score S of a management option was the product of the mean value of the two weighting coefficients $C_{habitat}$ and $C_{management}$, and the rating of the management option R. In case of management activities repeated during the year (e.g. mowing) an annual average was calculated when the indicator species group can recover from one period to another, or the most negative period was considered in case of a permanent damage. The final score S_f (= biodiversity score) of a given grassland was calculated as the sum of the scores of the management activities divided by the number of activities. Comparison of management scenarios can then be made at field level first but as ratings and coefficients were also defined for crops and semi-natural habitats, biodiversity scores can also be calculated at farm level.
Realistic scenarios of grassland management systems for the Swiss lowlands were defined to test the impact on the indicator species groups (Table 2, Nemecek *et al.*, 2005). Scenarios showed a large intensity gradient ranging from one utilization and no fertilization (extensive grassland, net yield: 2.7 t DM/ha and year) to five utilizations and fertilizer applications (intensive grassland, net yield: 11.1 t DM/ha and year). Slurry and solid manure were integrated as two different

fertilization forms. Scenarios for intensive, fairly intensive, low intensive and extensive grasslands did not include grazing. The extensive pasture scenario consisted of grazing only.

Table 2. Management intensity and production features of grasslands used to test the impact on indicator species groups. Underlined are management activities entering the estimation of impact on indicator species groups.

Grassland management	Net yield[1]	NEL-content[2]	N. util.[3]	kg N[4]	N. fertil.[5]	Fertilization form (% N available)		Herbicide[6]
						Slurry	Solid manure	
Intensive	11.1	5.8	5	146	5	100		0.5
Fairly intensive	9.0	5.2	4	99	4	100		0.5
Low intensive	5.6	4.8	3	33	1		100	0
Extensive	2.7	4.2	1	0				0
Extensive pasture	2.3	5.3	2	0				0

[1]t DM/ha and year, [2]MJ/kg DM, [3]number of utilization/year, [4] kg N available/ha and year, [5]number of fertilizer application/year, [6] kg active ingredient/year

Results and discussion

Calculated for the range of grassland types and indicator species groups, biodiversity scores definitely increase with decreasing management intensity for the overall species diversity (aggregated), for most of the indicator species groups and the ecologically demanding species (Table 3). Scores for ecologically demanding species are slightly lower than those of overall species diversity. An obvious inflection point occurs between fairly intensive and low intensive grasslands, i.e. between 4 to 3 cuts/year, a decreasing amount of quickly available N and a change of the manure form. Indeed, aggregated biodiversity scores increase by 0.2 from intensive to fairly intensive, by 7.4 from fairly intensive to low intensive. Nevertheless, scores increase by an additional 7.5 from low intensive to extensive grasslands showing the importance of extensive grasslands for biodiversity. Snails are an exception to this pattern, the largest difference taking place between low intensive and extensive grassland (93.9% increase). No fertilization at all is then more important than the fertilizer form for snails. Extensive grasslands obtain higher biodiversity scores than low intensive grasslands except for mammals which do not take advantage of one of both types. The largest difference in percentage between fairly intensive and low intensive grasslands occurs for the amphibian special life phase (aquatic life phase, 0.8 to 2.9, 257.8%). The reason is that fertilization with slurry may cause damages during the amphibian aquatic phase by streaming in water bodies. The highest scores are obtained by butterflies in extensive grasslands (36.0 for both features), followed by grasshoppers and wild bees. These high scores are mainly due to the high habitat coefficients attributed to grassland habitats reflecting their importance for all three indicator species groups in the agricultural landscape. In contrast, plants obtain slightly lower scores because non-grassland habitats in the cultivated landscapes may show higher plant diversity than grasslands, e.g. hedges. Overall, extensive pastures and extensive grasslands have similar scores. Nevertheless, while snails, spiders and carabid beetles show the same pattern as the other indicators regarding comparison of extensive and intensive grasslands, they are less positively influenced by the extensive pasture scenario. This suggests that these indicator species groups are more disturbed by cattle grazing than by mowing activities.

Table 3. Biodiversity scores S_f of indicator species groups obtained with the SALCA-Biodiversity method for five grassland management systems. Theoretical minimum score is 1 and maximum 50.

Grassland management	Intensive	Fairly intensive	Low intensive	Extensive	Extensive pasture
Overall species diversity					
Aggregated[1]	6.2	6.4	13.8	21.3	20.1
Plants	3.7	3.9	11.4	18.5	21.0
Birds	6.4	6.7	13.8	22.0	25.3
Mammals	7.3	7.3	11.1	11.1	10.8
Amphibians	2.1	2.1	5.2	9.5	11.8
Snails	5.4	5.6	5.8	11.3	6.4
Spiders	9.1	9.3	15.8	22.4	19.3
Carabid Beetles	7.0	7.4	13.6	21.0	14.8
Butterflies	6.8	7.0	20.0	36.0	35.8
Wild Bees	7.4	7.6	18.6	23.0	20.6
Grasshoppers	6.9	6.9	19.4	33.1	31.6
Ecologically demanding species and special life phase					
Amphibians	0.8	0.8	2.9	4.8	5.8
Spiders	8.9	9.0	15.3	21.6	17.8
Carabid Beetles	7.0	7.3	13.4	20.6	14.0
Butterflies	6.7	6.8	19.4	36.0	35.8
Grasshoppers	6.8	6.8	19.3	32.9	30.0

[1]Scores are aggregated taking into account rules of trophic relations between indicator species groups.

Conclusion

For biodiversity at farm level, extensive grasslands all over the farm would be the best. Nevertheless, results suggest that a combination of intensive and extensive grasslands (e.g. 2/3-1/3, 3/4-1/4) to associate advantages for biodiversity with agricultural production would be more beneficial for biodiversity than fairly intensive grasslands all over the farm because the biodiversity potential of the extensive part in this combination model is much higher than the one of fairly intensive grasslands.

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