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An indicator-based tool to assess environmental impacts of multi-specific swards

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Abstract

We developed a set of indicators to assess the impacts of grassland plant diversity and management on the abundance and diversity of six animal taxa (biodiversity indicators), on soil, water and air quality, and energy consumption (abiotic indicators). The methodology combines multi-criteria decision trees with fuzzy partitioning, allowing to deal with different types of information (qualitative or quantitative, more or less accurate knowledge). Biodiversity indicators were calculated from simple and easily accessible input variables (main management features and botanical composition), according to an analysis of the literature, and could be partly validated at plot scale. Abiotic indicators were calculated as model outputs at farm scale. Combining these two types of indicators allows assessment of the overall environmental footprint of grassland management practices and discussion of the benefits provided by multi-species swards. Here, we report major advances and obstacles closely linked to the available scientific and technical knowledge.

Keywords: grassland, diversity, management, indicator

Introduction

For several decades grasslands have been gradually decreasing across Europe, and many remaining grasslands have become simplified to grass monocultures or simple grass-clover mixtures. On the other hand, research in ecology has shown the benefits of plant diversity for the functioning of grassland ecosystems. This stresses the need for increasing knowledge of the positive economic and environmental values of multi-species swards in agricultural systems. In agriculturally used grasslands, plant species richness varies from simple grass-clover mixtures to semi-natural grasslands that may contain up to 50 species per plot. A key objective of the European research project FP7 'MultiSward' was to conceive, evaluate and promote sustainable ruminant production systems based on multi-species grasslands. One step to reach this objective was the elaboration and the validation of an operational evaluation tool (OET) based on a set of indicators sensitive to plant diversity and grassland management.

Materials and methods

The development of the OET was based on three sources: 1) expert consultation to decide key environmental impacts and the structure of the OET, 2) analysis of scientific literature to determine how plant diversity impacts on environmental outputs, and 3) real datasets used to either calibrate or validate the OET. Fifteen experts from five countries (CH, F, IRL, N, NL) were involved in the procedure. The OET consists in a decision tree where leaves reflect individual environmental impacts (e.g. nitrate in soil water or web-spider abundance) and branches or nodes reflect aggregated impacts (e.g. soil water quality or spider diversity). The calculation of basic (at leaf level) or aggregated (at node level) indicators results in a score between 0 and 10, (10 corresponds to an extremely favourable environmental impact as compared with other types of grassland management). Elaboration of the tree was performed with a qualitative multi-criteria decision modelling and support system called FisPro (Suárez

and Lutsko, 1999). It implements a decision tree with fuzzy partitioning model, which makes it possible to account for uncertainty in the decision boundaries between alternatives. Therefore, the nodes can present different kind of data-sources and data uncertainty.

Results and discussion

The complete evaluation tool is presented in Figure 1.

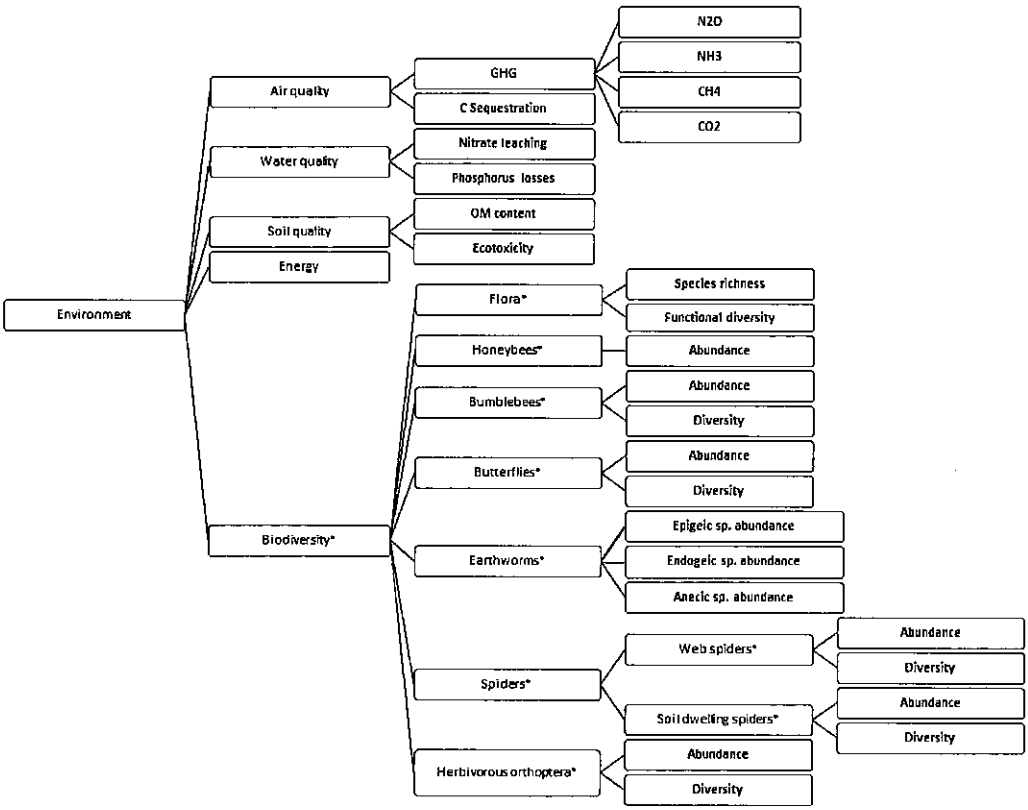

Figure 1. Structure of the indicator-based tool for environmental assessment in MultiSward. Basic indicators in bold, aggregated indicators followed by a star.

We initially aimed at calculating all indicators at plot and farm level, but literature analysis and expert consultation showed two major obstacles: 1) the lack of knowledge on the effects of sward plant diversity on 'abiotic impacts' (air, soil, water quality and energy) and 2) the lack of dataset to calibrate and validate biodiversity indicators at farm scale. Nevertheless, the OET in its current form calculates all biodiversity indicators at plot scale, taking account of the effects of sward diversity and management. Abiotic indicators can be calculated at farm scale, taking into account management factors but, very poorly, sward diversity. Indicator inputs are made of discrete or continuous management variables, soil features and botanical composition. Outputs (basic indicators) are then calculated either by models DairyWise (Schils *et al.*, 2007) and Melodie (Chardon *et al.*, 2012) for abiotic indicators, or by the newly developed decision tree for biodiversity indicators. As an example, Table 1 shows the impact of sward diversity and management on two biodiversity indicators calculated for 395 French grasslands across a wide range of pedoclimatic conditions, and housing between 1 and 69 plant species.

Table 1. Biodiversity indicator (0 low – 10 high richness and abundance) for two taxa calculated on a set of 395 French grasslands. Sp = species richness per plot . TG or PG= Temporary or Permanent Grassland

Management	Plant diversity	Spiders diversity and abundance	anecic earthworms abundance
continuous grazing with medium stocking rate	TG	3.40	6.56
	PG <20 sp	5.99	6.01
	PG 20-35 sp	6.30	3.99
	PG 36-50 sp	6.60	4.13
	PG >50 sp	6.15	3.83
Rotational grazing with low stocking rate and low or high grass height after grazing period	TG	5.88	5.35
	PG <20 sp	5.76	3.41
	PG 20-35 sp	6.15	4.29
	PG 36-50 sp	6.32	3.96
	PG >50 sp	6.82	4.85
One cut and rotational grazing, short duration of grazing periods	TG	2.76	5.35
	PG <20 sp	2.77	4.85
	PG 20-35 sp	2.88	4.62
	PG 36-50 sp	2.91	5.53
	PG >50 sp	N/A	N/A

A first run of validation with real data (indicator value *vs* biodiversity observations) and with expert opinions on outputs showed promising results. Nevertheless, the main restriction encountered during the development of the OET was the lack of knowledge, which in turns encourages further basic research on grassland functioning.

Conclusion

The OET developed in the MultiSward project is the first set of 'pressure indicators' (*sensu* DPSIR indicators typology of the European Environment Agency) sensitive to management and sward plant diversity. Indicators do not have to be compared to models outputs, as the main goal is not to predict a precise and real value but get a score which permits the right decision for the decision maker. The calculation of indicators is based on simple and easily accessible inputs, and its implementation in a free website (http://eflorasys.inpl-nancy.fr) is in progress. The current state of knowledge makes it difficult to fully calibrate and validate all abiotic and biodiversity indicators at plot and farm levels. First results obtained on fauna biodiversity at plot level reveal the usefulness of including plant diversity and simple management inputs to improve the environmental evaluation of grassland based systems.

Acknowledgments

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