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Biodiversity provides ecosystem services: scientific results *vs* stakeholders' knowledge

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Abstract. Maximizing the ecosystem services (ES) provided by biodiversity is presented as a solution to increase food production and decrease environmental problems. Science has produced significant results supporting this strategy. But what do stakeholders know about the ES provided by plant biodiversity? And does this knowledge agree with scientific results? We address these questions by combining a literature review and interviews with farmers and farm advisors in France. Scientific results and stakeholders' knowledge both indicate that plant biodiversity has a positive effect on the provision of ES. However our work revealed two gaps in our scientific knowledge. Only 3 scientific articles connected ES with plant biodiversity at the farm scale or between fields while stakeholders did so for 43% of the ES they mentioned. Similarly, management services concerned about one third of the services mentioned by stakeholders but were addressed in only 3 scientific articles.

Keywords. Biodiversity – Agroecology – Farming systems– Expertise – Innovation systems.

Biodiversité et services écosystémiques : résultats scientifiques* vs *connaissances d'acteurs

Résumé. *Maximiser les services écosystémiques (SE) fournis par la biodiversité est présenté comme une solution pour augmenter la production alimentaire et diminuer les problèmes environnementaux. La science a produit des résultats significatifs en ce sens. Mais que connaissent les acteurs des SE fournis par la biodiversité végétale ? Et leurs connaissances concordent-elles avec les résultats scientifiques ? Nous abordons ces questions en combinant une revue de la littérature et des entretiens avec des éleveurs et des conseillers agricoles en France. Les résultats scientifiques et les connaissances des acteurs indiquent que la biodiversité végétale a un effet positif sur la fourniture de SE. Cependant, notre travail révèle également des lacunes dans les connaissances scientifiques. Seuls 3 articles scientifiques associent SE et biodiversité végétale à l'échelle de la ferme ou entre parcelle alors que les acteurs le font pour 43% des SE qu'ils mentionnent. De même, les SE de gestion représentent 1/3 des SE mentionnés par les acteurs mais ne sont abordés que dans 3 articles scientifiques.*

Mots-clés. *Biodiversité – Agroécologie – Systèmes agricoles – Expertise – Systèmes d'innovation.*

I – Introduction

The challenge to increase and secure food production while decreasing environmental problems is increasingly associated with a new agricultural production often called agroecology (Wezel *et al*., 2009). Crop, livestock and landscape diversification is one pillar of agroecology. Diversification is expected to enhance the likelihood of biological complementarities and synergisms enabling reduced reliance on external input use. Such management policies and practices may enable the ecosystem services (ES), i.e. the benefits human obtain from ecosystems, provided by biodiversity to be maximised at the expense of the disservices. In recent years science has produced a number of significant results confirming that efficient use of biodiversity may maximize ESs (e.g. Hector and Bagchi, 2007). Yet application of these results in the field is dependent on stakeholders' knowledge and especially farmers' and farm advisors' knowledge. This article therefore addresses the following questions: 1) What do stakeholders know about the services and disservices provided by biodiversity? 2) Does stakeholders' knowledge agree with scientific results? We address these questions by combining a literature review and interviews with farmers and farm advisors in a French region characterized by a diversity of livestock production systems. This article is focused on the plant component of livestock production systems. Indeed, livestock production systems are known to contain a diversity of interacting plant components. The article is also focused on planned biodiversity (Altieri, 1999) at the field and farm scales, as this type of biodiversity and these scales correspond to what farmers manage in their daily activity.

II – Materials and methods

1. Literature review

The literature in the fields of ecology, agronomy and agricultural science was analysed to establish the state of the art about the services and disservices provided by plant biodiversity in livestock production systems. Search requests were used on ISI Web of KnowledgeSM with topics such as "biodiversity AND agricultural system AND service" and "biodiversity AND grassland AND production". Selected articles had to satisfy three criteria regarding the validity domain of the results, the type of research setup and the research protocol. In the end, the analysis was not exhaustive but considered 41 articles (see Lugnot and Martin, 2013 for an extended list).

2. Stakeholder interviews

Stakeholder selection was comparable to the case-study research approach (Eisenhardt, 1989). With this approach, qualitative surveys do not rely on statistically significant samples but rather on samples corresponding to the diversity of studied objects in order to grasp the diversity of situations and representations. Following this approach, 8 farmers and 3 farm advisors located in the French region of Aveyron were selected based on several factors describing their situations, e.g. land use, support receive (Table 1). They were interviewed for the survey and this sample was not extended as no new fact or information emerged in the last interviews we conducted. The interview guide was designed to provide latitude to the interviewee in constructing an answer reflecting his ideas and opinions. A list of themes and open-ended questions was established and dealt with the provision of definitions by the interviewee, the main characteristics of her/his livestock production systems, the ESs and disservices she/he associated with plant biodiversity, her/his social networks.

Table 1. Main characteristics of the studied farmers

	Farmer	FM	LM	JYB	AS	IC	BV	XP	JMA
Climate	Moderate oceanic				x	x	x	x	x
	Semi-montane	x	x	x					
Animal production	Beef				x				
	Dairy	x	x	x	x	x		x	x
Forage production (% of the farm area)	Forage crop	0	0	15	21	30	31	37	46
	incl. maize	0	0	0	10	20	9	14	30
	Sown grassland	35	27	17	49	26	51	22	22
	Permanent grassland	65	73	68	30	44	18	41	32
Support received	Advisor chambre of agr.	x		x	x	x	x	x	x
	Advisor dairy coop.		x	x					
	Group of conv. farmers				x	x	x	x	x
	Group of organic farmers				x				

3. Data analysis

A deductive content analysis (Elo and Kyngäs, 2008) of interview recordings was made. A deductive content analysis is a combination of two approaches, content analysis and deduction. Content analysis consists in organizing words and discourses into a few content-related categories. Deduction is based on previous knowledge such as literature reviews. Then, in a deductive content analysis, the analysis moves from previous knowledge condensed into a few content-related categories to the specific material being studied and distributed in these categories. Starting with the classification of ESs and disservices proposed by Zhang *et al*. (2007) and refined by Lamarque *et al*. (2011), analysis of the literature enabled us to further subdivide the suggested classification. After this categorization matrix had been developed, stakeholders' discourses were reviewed and coded for correspondence with or exemplification of the identified content-related categories.

III – Results

1. Literature-based classification

In many reviewed articles, plant biodiversity has often been used as a synonym for species richness (SR). In the remaining cases, plant biodiversity referred to functional diversity (FD), i.e. the diversity of functional traits or functional groups within or between plant communities. Grassland ecosystems are overrepresented in this literature. These grasslands are either permanent or sown. In the latter case, studies deal with a limited number of species (typically 2-3). Hence, the reviewed biodiversity levels match any farming context. Indeed, in addition to permanent grasslands, farmers may manage low diverse plant communities such as pure stands, possibly included in a crop rotation. Because different species and functional groups favour different functions (Hector and Bagchi, 2007), there is an overall positive effect of within- and between-field plant biodiversity on the provision of ESs. Still, the reviewed articles seldom discussed the site-dependence of the results.

We distinguish five types of input services and disservices corresponding to supporting and regulating services (Zhang *et al*., 2007). These are: (i) biological control, e.g. resistance to weeds and pest control; (ii) soil structure, e.g. soil organic matter content improvement and erosion control; (iii) soil water status, e.g. soil water retention; (iv) soil fertility, e.g. conversion of inorganic into organic nitrogen; (v) pollination. Our production services are similar to Zhang *et al*. (2007) provisioning services and Lamarque *et al*. (2011) marketed services. We distinguish three types of such services and disservices: (i) crop and forage production, e.g. increase of biomass production; (ii) crop and forage nutritive value, e.g. higher forage crude protein content; (iii) stability of crop and forage production and nutritive value in response to external disturbances. We identified a third type of ESs and disservices that had never been reported in previous classifications, i.e. management (dis)service. They refer to services and disservices enabling farmers to improve or worsen their management and working conditions. We distinguish two such services and disservices: (i) management flexibility, e.g. timing flexibility in grassland use, i.e. the extent to which the use of a given grassland may be brought forward or deferred at various times of year depending on biomass availability, digestibility and herd feeding objectives; (ii) work, e.g. improvement in labour productivity.

2. Stakeholders' knowledge

Farmers and farm advisors cited input services 16 and 6 times respectively in the interviews. No disservices were mentioned by either. In 8 cases, services were connected to within-field plant biodiversity. Fourteen other references to services referred to plant biodiversity at the farm scale or between fields due to crop rotations. The most cited input service was soil fertility (10 times). Both farmers and farm advisors mentioned the benefits provided by the integration of legumes, lucerne in particular, in the crop rotation. Soil structure was the second most cited input service (6 times). Plant biodiversity was also seen as a means of biological control by farmers and farm advisors (4 mentions). For instance, the organic farmer (AS) practices undersowing. He sows each new grass/legume ley under oats. In this way, the weeds are restricted by the emerging grass and legume species and by the shading by the oats. The last input service mentioned was pollination (2 mentions).

Production services were the ones most cited by farmers and farm advisors, i.e. 75 and 18 times respectively. Farmers also mentioned disservices 6 times. In 61 cases, services were related to plant biodiversity at the field scale. Another 32 references to services related to plant biodiversity at the farm scale or between-fields through crop rotations. The most cited production service was crop and forage nutritive value (39 times). For instance, one farmer (AS) combined legume species by adding 10% trefoil to lucerne seed mixes in order to improve forage palatability. Increased yields of crops and forage (mentioned 22 times) and their stability (32 times) due to plant biodiversity were also frequently mentioned and often interconnected. For instance, farmers AS and FM incorporated a small proportion of Italian ryegrass in their perennial ryegrass seed mix in order to compensate for the lower yield of the perennial ryegrass in the year following sowing. One farmer (IC) explained that she included maize and lucerne in addition to grasslands in her crop rotations to ensure forage stocks despite year-to-year weather variability.

Farmers and farm advisors mentioned management services 24 and 8 times respectively in the interviews. They also referred to management disservices 12 and 4 times respectively. Fifteen references to services related to plant biodiversity at the field scale against 17 at the farm scale or between fields through crop rotations. Disservices were related to plant biodiversity at the field scale and at the farm scale or between fields through crop rotations in 6 and 10 farm cases respectively. The most cited management service provided by plant biodiversity was management flexibility (16 times). Several farmers and one farm advisor (BD) explained that within a field, it is possible to benefit from the differences in timing of production between species as it enlarges the time window for grassland use. Plant biodiversity was also considered to provide labour services (8 times). Multi-species sown grasslands last longer than pure stands or two-species mixtures traditionally used in the region thereby requiring less frequent resowing. However, one farmer considered managing within- and between-fields plant biodiversity may be a hard task (BD). A third type of management service was mentioned by farmers and farm advisors, namely risk reduction. Indeed, one farm advisor (CM) explained that mixing species is a kind of insurance against weather variation.

IV – Discussion and conclusion

According to scientific results, there is scope for implementation of a new agricultural production paradigm often called agroecology. Stakeholders' knowledge confirms opportunities for implementation of this new paradigm. Indeed, stakeholders consider that plant biodiversity has an overall positive effect on the provision of ESs yielding among other things input reductions, higher and more stable plant production and even improvement of farmers' management conditions. Still, our work revealed two scientific gaps susceptible to slow down this implementation process. Compared with stakeholders' knowledge, science insufficiently addresses (i) ESs provided by plant biodiversity at the farm scale or between fields; (ii) management services and diservices provided by plant biodiversity. Stakeholders' expertise can thus help us to prioritize research options in order to simultaneously fill scientific gaps and produce knowledge relevant for practice.

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