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Assessing ecosystem services provided by livestock farms in upland areas in the French Massif Central

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Abstract. The emergence of challenges linked to global change combined with new societal expectations has forced a reconsideration of the role of livestock farming systems in the provisioning of goods and services. The multifunctional approach makes it possible to find trade-offs between environmental benefits and production services, but it requires tools that are able to evaluate the farming system's potential to take up the challenge. DIAM is an innovative prospective diagnostic tool designed for dairy systems and co-developed through collaboration between extension services, research and cheese organizations in the Massif Central. Outputs allow a multi-criteria diagnosis that focuses on forage self-sufficiency, system coherence, and the services provided by grasslands: forage and environmental services, and those related to the nutritional and sensorial characteristics of cheeses. This paper details and analyzes the results obtained on a panel of 36 organic or conventional farms located in highland and upland areas of the Massif Central (France) raising cows, ewes or goats. The tool's assets are discussed.

Keywords. Grasslands – Typology – Forage systems – Animal products – Environment – Ecosystem services.

Evaluation des services écosystémiques rendus par les exploitations d'élevage : le diagnostic DIAM appliqué à des exploitations de montagne dans le Massif central

Resumé. *Les nouveaux défis liés au changement global associés aux attentes de la société conduisent à un réexamen du rôle des systèmes d'élevage et notamment à essayer de quantifier leurs contributions à la fourniture des services écosystémiques. DIAM est un outil de diagnostic prospectif et innovant qui répond à ce défi. Il a été conçu pour les systèmes laitiers et est issu d'un travail de co-construction entre le Développement, la Recherche et les filières fromagères AOP du Massif central. Il permet de réaliser un diagnostic multicritère qui porte sur l'autonomie fourragère, la cohérence du système fourrager et sur les services rendus par les surfaces herbagères de l'exploitation : services fourragers, environnementaux et ceux liés à la qualité nutritionnelle et sensorielle des fromages. Cet article détaille et analyse les résultats obtenus sur 36 exploitations de montagne du Massif Central (France) appartenant à une large gamme de systèmes d'élevage. L'intérêt de cet outil est discuté.*

Mots-clés. *Prairies – Typologie – Système fourrager – Produits animaux – Environnement – Services écosystémiques.*

I – Introduction

DIAM has been developed at farm-scale as a tool for running multifunctional diagnosis on forage-system livestock farms. It is the outcome of a co-development effort led by Research, extension services and PDO (Protected Designation of Origin) cheese organizations (Hulin *et al.*, 2012). As an agricultural analysis tool, it gives a diagnosis on forage system management and self-sufficiency that highlights the importance of the grass resource and the grassland diversity. As an agricultural extension tool, it educates livestock farmers and farm-sector advisors on the ecosystem services that the farm's grassland provides (Farruggia *et al*., 2012). Originally designed for farms producing cow's milk AOP cheeses, DIAM has since been tested on a broad gradient of Massif Central-based farms encompassing cattle, sheep and goats farmed for meat and dairy. This paper shows the results obtained by using DIAM on a panel of farms and summarizes the lessons learned for the Auvergne-region livestock sector.

II – Materials and methods

Five agricultural advisors belonging to Auvergne agricultural development services performed a total of 36 diagnostics in 2012 and 2013 with farmers ready and motivated to test the tool. DIAM was thus implemented in farms equally split between the highland (altitude > 900 m asl) and upland (altitude < 900 m) located in granitic or volcanic areas. Two thirds of the surveyed farms are specialized dairy cattle farms, with the remainder oriented towards sheep, goats or cattle. A quarter of the farms are organic and half is engaged in local food supply chains, with farm-gate sales direct-to-consumer. A prerequisite to running DIAM on-farm is to collect global and easily-accessible data on the farm's forage system and animal performances. The brunt of the effort involves working with the farmer to establish a 'plot-by-plot profile' of his farm that maps each grassland plot to its management and grassland type, as defined in the Massif Central grassland typology (Carrère *et al*., 2012). This typology counts 60 types of permanent and temporary grassland. The 23 most common types found in the DPO area are described in detail in a typology document (www.prairies-aop.net). To determine the type match for each plot, the advisor has a series of 4 ID keys rank-ordered based on altitude, management, fertilization and soil hydromorphism criteria. Plots may be visited with or without the farmer to verify that they have been assigned to the right type. Types 1 to 23 come with a factsheet listing their characteristic plant species, species rarity index, vegetation productivity and early maturity and potential annual productivity. Agricultural services are evaluated by indexes scored on a scale of 1 (low) to 5 (high) and captured through a set of 5 indicators: production, productive seasonality, forage nutritive value, management flexibility, and potential dairy production (Carrère *et al*., 2012). Environmental services are also described through indicators on the soil carbon storage, botanical patrimonial asset, diversity of flower colors, and capacity as a habitat for pollinators and for fauna. Services linked to cheese quality are captured through indicators on carotenoids content, sensorial characteristic, potential antioxidant content and potential nutritionally valuable fatty acids content. Once this baseline data has been collected, the DIAM package algorithms calculate and give the results as four modules. The forage module gives the range of grassland types found on-farm and the functional distribution of the grassland area: proportion of area offering high productive potential and proportion allowing late-season management. It also estimates potential mean annual production of the all-farm grassland area, calculates effective and potential (deduced via potential productivity) stocking rates, and provides a forage budget and forage system management indicators, and finally the annual animal intake expressed in tons of concentrate intake and of quantities available as stored or grazed forage per LU. The environmental module and the cheese module are split into 6 and 4 indicators, respectively, that give a score at system scale of the environmental services. Lastly, the on-farm resources valorization module aggregates three indicators: proportion of milk produced during the grazing season, forage autonomy, and proportion of milk produced by on-farm resources.

III – Results

3600 ha spread across 1600 plots were analyzed counting 41 different grassland types. Two-third of farms required at least two ID keys to be used, which underline that plots are stretched between highland and upland zones within farms. Only 9% of total grasslands are temporary grassland. The remaining 91% permanent grassland is distributed over a wide fertility gradient: 9% are poor grasslands, 49% are moderately fertile and 33% are fertile-to-highly fertile. Only 11% of total grasslands are qualified as wet meadows. Grasslands in the all-farm population are dominated by 11 types, with a good symmetry of the types found in the two altitude zones: moderately fertile to fertile hayfield types and moderately fertile to highly fertile pasture types found in both zones and, temporary grassland type in the uplands coped with highly fertile pasture type associated to poor pasture type in the highland zones. Some types are relatively common on the farms but amount to little area, such as pasture on poor and dry soil type. Herbage area on the farms varies in the range 15-250 ha, with a mean of 94 ha, spread across an average 45 plots, with a mean plot size of 2 ha. Three farms produce corn and 11 grow cereal crops as self-feed. Eleven farms –9 organic and two conventional– do not use any mineral fertilizer inputs. The other farms make only modest use of mineral nitrogen fertilizer, with a mean 29 U mineral N/ha on the forage area. Grasslands diversity well-characterizes the grass systems independently of animal stocking rate, livestock systems and altitude since the average farm counts 10 different grassland types, 8 of which belong to the 23 most common types. The all-farm mean potential grass production is 5.4 t DM/ha which among other factors, varies according to mineral nitrogen input per ha (r^2 = 0.50). In all the farms, herbage area that offers assets in terms of productivity coexists alongside herbage area that offers greater management flexibility within the forage system. Calculated potential stocking rates are higher on average (0.97 LU/ha) than effective stocking rates and suggests that the farms have opted for a strategy based on securing their forage budget. Herbage, whether grazed or stored, constitutes the essential of the annual feed intake of livestock. Available herbage grazed averages 52% of intake profile and its part tends to increase with the decrease of the animal stocking rate (r^2 = 0.52). This finding suggests that in the less intensive systems, a fraction of the biomass produced on pasture is not used by the animals. In the more intensive farms, grazed resource balances out with stored fodder. Where fodder is bought, it accounts for only a minor fraction of the food intake profile (0.3 t DM/LU). Amount of cereal crops consumed on-farm and bought concentrate account for a mean 900 kg/LU, but varies strongly in a range from 100-2000 kg/LU.

A principal component analysis (PCA) was carried out to study the relationships between the different services provided by the farms (Fig. 1). The principal component axis (45% of variance) shows close relations between biodiversity indicators, aromatic density, antioxidant content of the dairy products and the management flexibility factor which are opposed to grassland productivity, stocking rate, and carotenoids content. This principal axis allows discriminating the farms according to the altitude.

Farms in highland zones are characterized by provisioning significant environmental services, more aroma-dense and antioxidant-rich animal products, and a greater proportion of farm area offering management flexibility without a significant loss in performances. Farms in upland zones are characterized by provisioning services linked to production and by products that present a yellower color due to the carotenoid-rich grass offered to the animal. In this spread, organic farms do not stand out from conventional farms. The second component axis (14% of variance) is negatively correlated to farm size, plot size and number, and high stocking rate on spring pasture. Interestingly, soil carbon storage, capacity as a habitat for pollinators, number of grassland types on the farm, nutritionally valuable fatty acids content, and the indicator on forage system coherency are not discriminant variables for farms (Fig. 1).

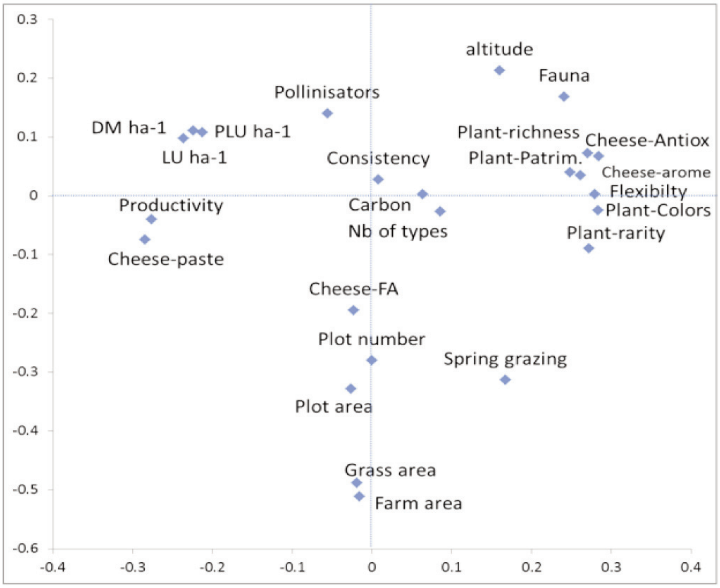

Fig. 1. Principal Component Analysis on environmental, provisioning, and animal products quality services, and characteristics of the forage systems.

IV – Discussion and conclusion

These results show that DIAM gives a broad global vision of the farm tying together agronomy, animal performances, environmental impacts and animal products qualities. It gives to the farmer a new vision on the environment previously experienced mostly by him as a source of constraints. DIAM reframes environmental impacts as positive services provisioned by grasslands –services that offer the livestock farmer a source of pride. Furthermore, this work creates starting references on the news issues of the ecosystem services provided by a wide range of livestock farming systems. These references have to be shared and extend further, with the overriding priority being to work with farmers groups, as many of the indicators given by DIAM are still too abstract for individual farmer. Results feedback sessions show that the livestock farmers are still relatively unreceptive to ecosystem services, despite farmers are engaged in PDO schemes with farm-gate sales direct-to-consumer. Advisors are also still uncomfortable with the process of reporting the DIAM results feedback and analyzing it to highlight hidden value. Nevertheless, through DIAM, advisors and farmers appropriate together the novelty of the concept of grasslands diversity. DIAM brings a new awareness that the crux of the issue is that there is not just one 'grassland' but a mosaic of many different grasslands, and that it is through this diversity that forage systems can be sustainable in herbage mountain areas. The DIAM diagnosis also prompts the protagonist to share and to begin understanding the finer-grained perception of grasslands held by botanists.

Nevertheless, the tool does involve a learning curve to gain the expertise needed to correctly allocate types to plots. Diagnosis accuracy relies on both the mastery of the tool and the accuracy of the typology use: a plot with several plants communities may be assigned to a single type or split into different-typed subplots. Finally, this study demonstrates that DIAM can be applied to livestock farms other than the dairy cattle targeted in its initial project brief, although the tool still needs work to re-adapt it to small ruminant and suckler-based systems. Although the overall result remains coherent, there is still room for improvement through various adjustments, particularly via more accurate descriptions of grasslands types commonly found in these systems and yet not featuring among the main 23 types of the typology document.

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