An approach for assessing the ecological intensification of livestock systems

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Abstract

Promoting the development of farming systems towards more sustainable forms, in particular maintaining production without harming the environment, means being able to analyse these systems in their complexity and dynamic, at the same time providing the means to assess their ecological intensification. The approaches to these livestock systems have to be adapted to this aim. This is what we have done as part of a study on the diversity of goat farming systems (GFS) in Livradois-Forez, a small region of fairly low mountains in France. Semi-structured interviews were conducted with 18 farmers, a sample selected to cover the diversity of livestock forms in this territory. We analysed the operation of livestock systems, looking at the system configurations (dimensions, buildings and equipment, labour force, combinations of farming activities, production project) and the combination of management practices (crops, herds and valorisation of products). We also analysed the place of the goat system within the family farm's long term trajectory. To assess the ecological intensification in GFS, we mobilized the five agroecology principles for the design of sustainable livestock systems proposed by Dumont et al. (2013): (i) adopting management practices aimed at improving animal health, (ii) decreasing inputs for production, (iii) decreasing pollution by optimizing the metabolic functioning of the farming system, (iv) enhancing diversity within animal production systems to strengthen their resilience and (v) preserving biological diversity in agro-ecosystems by adapting management practices. We present this approach and illustrate its application to our case study. We show the interest of understanding the diversity of livestock forms and identify what promotes or limits the development of these systems into more ecologically-intensive forms.

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1. Introduction

Nowadays the ecological intensification (EI) concept is being highlighted to suggest possible answers to the dual challenge of improving environmental impacts and increasing livestock production at global level, whilst at the same time incorporating the local dimension (Griffon, 2006 ; Steinfeld et al., 2010). Ecological intensification is an evolution of agriculture that aims to produce without harming the environment and to make better use of ecosystem functions (Bonny, 2011 ; Griffon, 2013). Although this movement is widely documented in field crops (Griffon, 2010), it is less well-documented in animal production. The development of these new forms of farming systems needs to improve the integration of ecological processes into the operation of livestock systems. To foster such a development, we must be able to analyse these systems in their complexity and their dynamic, at the same time giving ourselves the means to assess their ecological intensification. Analytical frameworks of farming systems, designed in the 1980s must be adapted for this purpose. There are several proposals in literature to qualify cropping systems with reference to ecological intensification (Cassman, 1999 ; Zhang et al., 2007 ; Doré et al., 2011 ; Rusinamhodzi et al., 2012 ; Hochman et al., 2013), however, for livestock systems there are fewer equivalent studies.

We propose an approach for analysing the ecological intensification (EI) of livestock systems. This approach should make it possible to describe and understand the diversity of livestock forms and identify what promotes or limits the development of these systems into more ecologically-intensive forms. This paper presents an approach and its application to assess the diversity and pathways of evolution of goat systems in Livradois-Forez, a small agricultural region in central France.

2. Theoretical basis for the construction of the approach

Our approach is constructed on three concepts: the farming system (Gibon et al., 1999), the framework of the farming activity (Terrier, 2013) and agroecology for animal production (Dumont et al., 2013). These three concepts were structured in an approach that allows two frameworks to be applied consecutively: the first to characterise the operation of livestock systems, and the other to assess their ecological intensification.

2.1 Approach to livestock farming systems

Farming systems come from a human project that defines the extension, linking its constituent elements (Landais, 1987). It can be defined as "« a collection of elements in dynamic interaction, organised by man according to his objectives,, to produce milk, meat, hides, skins, manure, etc., from domesticated animals which reproduce themselves, by using and renewing a variety of resources » (Dedieu et al., 2008). For Moulin et al. (2001), the farming system is the linkage between a production project and the dimensioning and management of surface areas and herds. The analysis of how a livestock system functions consists i) in identifying their 'underlying motivations' (Landais et al., 1988) from the observation of practices and combinations of practices, or of the farmer's production project, and ii) in revealing the farmer's management strategy (Landais et al., 1988).

Our framework for analysing how the livestock system functions takes its inspiration from that of Terrier (2013) which takes account of the family dimension of the farm and the plurality of forms of agriculture today (multi-active or not, managed by a couple, by just one permanent worker,- the partner working outside the farm etc…). We thus define the operation of a livestock system as an association among family and farm system configurations (available dimensions and structures, labour force), the chosen production project (animal production type, investment for processing and marketing the products, and combination of economic activities) and the combination of management practices (crops, herds and valorisation of products). The trajectory of the farmer

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(who manages the goat herd) and of the farm has been introduced to take into account the dynamic aspect of this operation (see Figure 1).

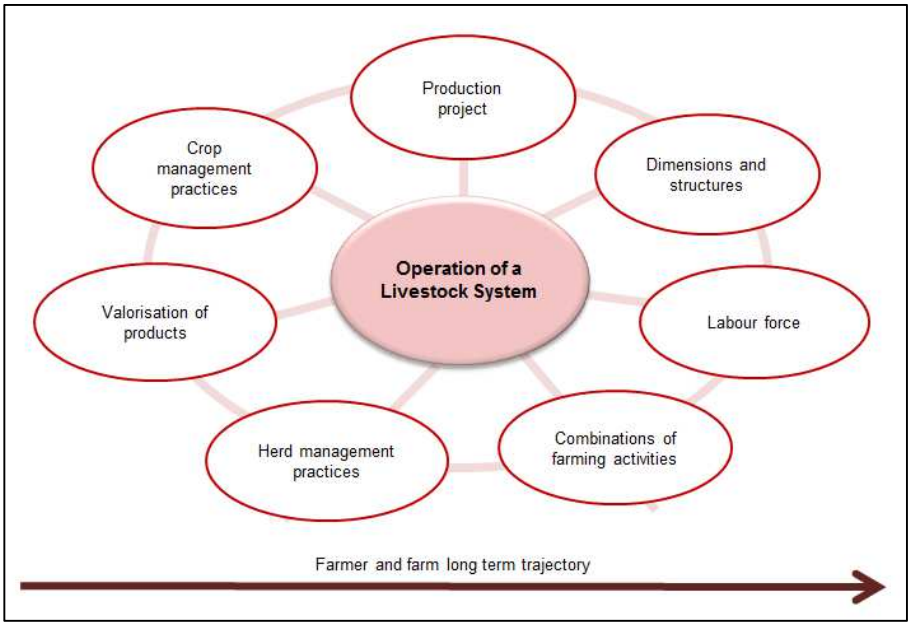

Figure 1. The framework for analysing the operation of a livestock system

2.2 Approach to ecological intensification

Ecologically-intensive agriculture, unlike organic farming, does not have a set of specifications that provides a framework for production practices; it is a progressive approach which brings many practices into play (Griffon, 2013). To assess the ecological intensification of the operation of livestock systems, we rely on the framework proposed by Dumont et al. (2013) to characterize ecology-based alternatives for animal production systems. These authors identified the processes to be optimized for sustaining yields, while minimizing the negative environmental impact of animal production systems, which corresponds to the objectives of ecological intensification. These processes need to be optimized according to the five major agroecology principles in reference to those set out by (Altieri, 2002) : (i - Health) adopting management practices aimed at improving animal health, (ii - Inputs) reducing the inputs needed for production, (iii - Pollution:) decreasing pollution by optimizing the metabolic functioning of farming systems, (iv - Diversity) enhancing diversity within animal production systems to strengthen their resilience and (v - Biodiversity) preserving biological diversity in agro-ecosystems by adapting management practices. We used these five principles to describe the practices implemented on the farms and build an "ecological intensification" profile for each of them (cf below in Methodology for more details).

3. Application of the approach in goat farms in Livradois-Forez

The study was conducted with goat farmers in Livradois-Forez, a rural territory in an area of low mountains, to the east of the Massif Central in France. The goat farms are scattered and form a minority in the territory, but they are of interest for this territory and the ecological intensification of its livestock activity. In fact this type of livestock farming often makes good use of marginal areas with limited potential, of little interest to the cattle farms that form the majority in this region. These systems do not require much land and offer opportunities for low-volume production with high

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added value because of processing on the farm and sales on local markets. Young farmers find this type of system easier to set up outside the family framework, and many more of them work under this system than in the other sectors. Surveys were conducted with eighteen of the 34 goat farms identified in the Puy-de-Dôme region in this territory. These goat farms were selected to cover as large a diversity of systems as possible in terms of dimension (surface area and herd), goat grazing, production orientation (milk or cheese) and association with other animal units. Semi-structured interviews addressed the trajectory of farmers and farms, the management practices of herds and lands and their justification, the forms of marketing and valorisation of products, and farmer perspectives.

These data were used to build variables which enable us i) to characterise the operation of each livestock system according to the first framework (cf 2.1) ii) assess its ecological intensification according to the second framework (cf 2.2).

30 variables were used to characterise the operation of each system (see Table 1). Among the possible variables we included only those which had different values among farms. A typology was carried out on these active variables. Bertin's graphical method (Bertin, 1977) was used for bringing similar farms closer together visually by successive permutation of rows (active variables) and columns (the farms studied). The types of systems identified correspond to specific combinations of these variables, reflecting specific logics of operation that are characterized as prototypes (Girard, 2006). We used other information gathered during the interviews relating to the way in which the system had been constructed over time, to complement our description of the types of operation.

To characterize the ecological intensification profile of each system, five variables were built, one for each principle (Health, Inputs, Pollution, Diversity and Biodiversity). Each variable allowed the system to be positioned on an EI gradient, according to its level of response to the corresponding principle. This gradient was summarized in 3 synthetic modalities: low, medium and high. Each farm was rated as low, medium or high mode for each of the 5 variables (principles) depending on whether it was implementing less than 33%, between 33 and 66% or more than 66% of the practices listed for the corresponding principle. We defined the ecological intensification profile of each farm type as the combination of five variables (five principles).

The system typology was then cross-referenced with the characterisation of the EI profile. Thus for each type of system we built an EI profile, retaining for each variable (principle) the modality which was the most represented among the farms of the type.

Our sample has a wide variety of dimensions of the utilized agricultural area (UAA) with an average of 62 hectares, but it varies from 1 ha to 254 ha, and the number of goats from 12 to 195 with an average of 65 goats. The installations outside the family framework are numerous (50%), and the working groups are diverse, with single farmers and couples as well as associations of 2 to 3 people. The majority of farms chose to process goat's milk to make cheese, sometimes mixed with cow's milk. Only four farms deliver all of their goat's milk to a dairy. The majority of farms (89%) associate the goat unit with another livestock unit (beef cattle, dairy cows, sheep, horses, poultry or pigs). There is a high diversity in terms of resources used, with systems entirely on feedlot which purchase all food for their goats, and others based on significant use of pasture with varying degrees of food self-sufficiency.

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4. Results

We begin by presenting the typology of the goat farming systems, then the ecological intensification profiles of these different types and finally we identify what promotes or limits the development of these goat systems into more ecologically-intensive forms.

4.1 Four types of goat operation systems …

The typology in 18 goat farms identified four types of operation systems that are described as: 1) Resource-centred; 2) Goat-centred; 3) Cow-centred; and 4) Limited land area, which are discriminated by the importance of the goat activity in the farms and the mobilization of available resources (see Table 1).

In the first type called ***"resource-centred"*** the farmers settled on the family farm when a parent took retirement. They aim for production quantity and deliver all of their goat's milk to a dairy. Farms that have expanded since the farmer's installation are relatively large for the sample and in addition to the goat unit, include another activity of beef cattle or sheep of the same importance in terms of income and labour. The interaction between these herds is thought to be the best way to manage the territory of the farm (nearby fields for the goats). The logic of the operation is centred on plant resource management and the assignment of the best feed to the goats. Diversity of surface area (temporary meadows, permanent meadows and cereals) achieves forage self-sufficiency and covers part of the production of concentrates for the animals.

The ***"goat-centred"*** type occurs in smaller farms managed by couples who became established outside the family framework more than 15 years ago because of their passion for the work. The system was built around the goat herd and the processing and marketing of goat's cheese; it has gradually changed, without expanding, to include other activities (educational farm, farm accommodation, bed and breakfast, cottages) and other animal units. It has gradually improved the management of forage resources. In these systems, the diversity of resources, whether animal, vegetable or labour force, is thought to foster system flexibility and efficiency.

The ***"cow-centred"*** type of farming is found in large family-based systems managed by a collective formed progressively by the arrival of new members (family members and employees). The system is designed around the main herd composed of dairy cows, following logic consistent with the dominant model in Livradois-Forez, i.e. intensified production with a forage system based on corn silage and with high use of feed concentrates and chemical fertilizers. The ambition of these farmers is to continue to extend their farms. The goats are secondary, providing added value for the cow's milk via the processing of mixed cheeses. In the 1950s, the majority of farms in the Livradois-Forez had dairy cows and a few goats to make "Brique du Forez", a mixed cheese typical of this territory.

In the last type called ***"limited land area"***, the farmers set up their business outside the family framework, because it was their passion, challenge and desire to change their lifestyle. The project revolves around the processing and marketing of cheeses. The farmers have only recently set up their business; their land area is limited, and their fields do not allow them to produce enough forage to feed their animals, so they resort to purchasing forage and concentrates in varying proportions. They are still building up systems that have not yet found a balance between livestock production and the management of farm plant resources: at this stage the farmers focus more on the development of cheese processing and marketing.

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Table 1. Description of the type of operation of goat livestock systems in Livradois-Forez

		Resource-centred	Goat-centred	Cow-centred	Limited land area
Number of Farmers		*5*	*6*	*2*	*4*
A. System configurations					
A.1. Trajectory of the farmer and the farm					
1.	Motivation to be a farmer	Take over the place	Passion, challenge	Find a place	Passion, challenge and change of life
2.	Date of installation	Between 5 and 20 years	More than 20 years	More than 20 years	Less than 5 years
3.	Installation mode	Family framework	Outside family framework	Family framework	Outside family framework
4.	Dynamic evolution of surface area	Without enlargement	Without enlargement	Enlargement	Developing
5.	Technical knowledge	Parent to child	Training and dialogue with other farmers	Parent to child	
A.2. Dimensions and structures					
6.	Utilized agricultural area (UAA)	87 ha	21 ha	197 ha	13 ha
7.	Labour force	2 people (couples or associations)	Pair	Association of 3 people	Pair
8.	Use of hired labour	No employee	Employee	Employee	No employee
9.	Number of goats	84	59	31	75
A.3. Production project					
10.	Main orientation of goats	Milk delivery	Processing of milk	Processing of milk	Processing of milk
11.	Main herds	Goat and beef cattle	Goat	Dairy cows	Goat
12.	Different animal units	Beef cattle, Sheep or Poultry	Pigs, Horses, Sheep, or Dairy cows	Dairy cows	Horses, Sheep, Dairy cows, Poultry or Specialized
13.	Complementarity between species*	Resources and Territory	Resources and Territory	Resources and Product	Product
14.	Other non-agricultural activities	No other activities	Other activities	No other activities	No other activities
15.	Annual milk production per goat	800 litres	610 litres	775 litres	690 litres
B. Management practices					
B.1. Land management practices					
16.	Main forage area (MFA)	90%	98%	92%	100%
17.	Permanent grassland	58% of MFA	88 % of MFA	42% of MFA	100% of MFA
18.	Presence of temporary grassland	Temporary grassland	Temporary grassland in half of the cases	Temporary grassland	No temporary grassland
19.	Presence of cereals	Farm consumption	No cereals	Farm consumption	No cereals
20.	Fertilization	Manure	Manure	Manure and Fertilizer	Manure
B.2. Goat feeding system					
21.	Food self-sufficiency	Forage	Forage	Forage	No self-sufficiency
22.	Grazing	60% of the farms	100% of the farms	50% of the farms	50% of the farms
23.	Grazing goats area	23% of the MFA	59% of the MFA	14% of the MFA	58% of the MFA
24.	Grazing goats stocking rate	2.4 goats.ha^{-1}	3.5 goats.ha^{-1}	2.4 goats.ha^{-1}	2.4 goats.ha^{-1}
25.	Kg of concentrate per goat per year	304	201	310	180
B.3. Goat management practices					
26.	Milking frequency	twice daily	temporarily once daily	2 times daily	temporarily once daily
27.	Practice of drying off	Sudden drying off	act on the milking and feeding	act on the milking and feeding	act on the milking and feeding
28.	Number of batches for reproduction	1 batch	2 to 3 batches	1 batch	1 batch
B.3. Valorisation of products					
29.	Channels of trade	Indirect	Direct and indirect	Direct and indirect	Direct
30.	Cheese diversity	No cheese	Pure goat cheese lactic and rennet	Lactic cheeses mixed with goat's and cow's milk	Pure goat cheese

*Complementarity between species: Territory: for the use of land (e.g. field proximity for goats and less close for lactating cows); Resources: for the use of resources (e.g. the best hay for goats); Product: for making mixed cheese and commercialization.

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4.2. …corresponding to different ecological intensification profiles

The analysis of farm ecological intensification profiles shows that there are specificities according to the type of operation (see Figure 2).

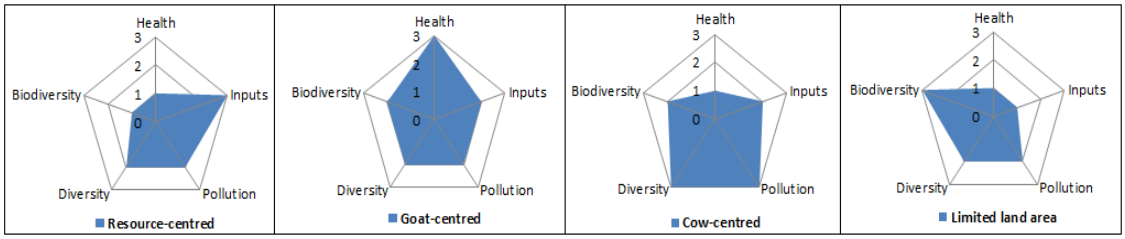

Figure 2. Ecological intensification profile of each operation of goat livestock systems
Degree of ecological intensification: high = 3, medium = 2, low = 1.

The ecological intensification profile of ***"resource-centred"*** farms is out of balance. It is characterized by the importance of "ecologically-intensive" practices linked to the management of surface areas including those that can reduce inputs (rotations, choice of plant species, grass-legume integration, organic fertilization, organization of fields to reduce movement of stock). On the other hand, animal management favours quantity of milk production over the integrated management of goat health; there is no diet transition, drying-off is sudden, pesticides are used systematically, and animal housing is poorly adapted.

The ***"goat-centred"*** farms are those which have the most balanced ecological intensification profile. Practices that can be described as "dense" from the EI point of view concern the whole system. Particular attention is given to the integrated management of animal health: the females do not suckle their kids, so as to prevent the transmission from goat to kid of the Caprine Arthritis Encephalitis Virus (CAEV); goats are returned to the building during rainy days to prevent lung problems; feed transitions are reflected, grazing is organized to reduce parasitism, trees in pasture and buildings provide goats with thermal comfort. Farmers have gradually changed their strategy for using animal and plant resources, minimizing inputs and playing on complementarities among animals (remote fields for sheep or horse grazing, whey used for pigs ...).

The ***"cow-centred"*** farms have an EI profile that reflects their ability to promote synergies and recycling via the interaction between plant crops and two different animal herds, dairy cows and goats. The processing of mixed milk cheese enhances the value of the two dairy productions. The possibility of processing cow's cheese when goats are dry also allows the farmers to keep their place on the market all year round. On the other hand, this type of farm is relatively intensive on land use and on animals, with the use of inputs (mineral fertilizers, phytosanitary, and health products).

For the **"limited land area"** farms, land management is not or poorly implemented by farmers and food purchases are considerable. The priority of farmers who are starting up their system is to process cheese and develop a marketing network. One hundred percent of the utilized agricultural area is composed of permanent grass grazed or harvested in late mowing to make some hay, but without seeking a high production, which promotes biodiversity (Dumont et al., 2007).

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4.3. What promotes or limits the development of goat systems into more ecologically intensive forms

This approach highlighted the links between goat farm operation and EI profile. These links make it possible to identify what promotes or limits the development of these systems into more ecologically-intensive forms.

Thus, the available land area and its features, and the possibility of obtaining more land, condition the possible configurations for interaction between production and resources. Large "resource-centred" family structures where the fields are well grouped together are certainly more likely to develop a strategy of food self-sufficiency than small "Limited land area" structures, whose evolution towards more ecologically-intensive forms depends on their ability to use the land adequately.

Depending on the conditions of his establishment (taking over the family dairy farm after the departure of a parent, installation outside the family framework...) the farmer will not have the same technical livestock farming models as a reference. Goat farming is not dominant in this territory and technical advice on this production does not exist at departmental level. There is no "goat farming model" recognised by the profession or by tradition, with the exception of dairy cows associated with a few goats to process mixed milk cheese, a system that persists in some dairy farms but which remains anecdotal. But even in this latter case, the model that dominates is the dairy cow, with production that is intensive but low according to agroecology principles. When farmers settled on the family farm, livestock already formed part of one of the two dominant models of the region: dairy cows with a system based on grass, cereals and corn silage, or beef cattle with a grass and crop system. These farms expand and adopt productivity logic. When farmers settle down outside the family, they are looking for a system that allows them to live their profession in accordance with their own values, and they have everything to build. But to do this, they cannot rely on what they learned from their parents. More than others, they have to build their technical knowledge through trial and error, and training and dialogue with other farmers. They will more easily be receptive to forms of livestock farming that do not aim at enlargement and intensification, and which turn to alternative techniques. This is notably the case of farmers of the "goat-centred" category.

The surveys also show that the establishment of an ecologically-intensive farming system takes time. The most favourable EI profile is found in the “goat-centred” system, where farmers who have been established for a long time, tell how they built their system progressively, playing on all the registers (making best use of animal and plant resources, recycling and synergies, diversity and biodiversity). In contrast, the poorly balanced EI profile of the “limited land area" systems can be explained by the lack of time farmers have to implement appropriate practices for the management of resources: they have focused on the processing and marketing of cheese. The system is under construction.

5. Discussion

5.1. A relevant framework…

The application of the approach has enabled us to describe the diversity of goat systems in Livradois-Forez. The absence of a specific goat technical model in this territory partly explains the high diversity of operations observed, within a framework of the livestock exercise: i) combining this activity with other herbivores, ii) managed by a couple or by wider forms of association. The approach showed that each type of livestock system operation was associated with a different ecological intensification profile. It also highlighted the impact of available land, the farm and

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farmer history, on the livestock system operation and the EI profile. This confirms the need to understand and analyse the farming system, taking into account the trajectory of these systems (Milestad & Darnhofer, 2003 ; Schiere et al., 2012): the systems with the most agro-ecological practices are those developed gradually within the trajectories of couples who were seeking self-sufficiency in food and reduction in inputs rather than the expansion of their farm.

But, this approach does not explain every connection between livestock system operations and ecological intensification profile. Other dimensions are involved in the farmers' reasoning to manage their system: work, economic aspects, wishes and farmers' values.

5.2. …with limits

Our approach to goat systems, their operation and their EI profile is a choice of departure, even though the reality observed emphasizes rare cases of goat specialization. Similarly, the construction of modalities for each variable depends on the diversity of situations and observed practices in the studied area. Our proposed typology has therefore a local and located character, while the proposed approach and framework have the ambition to have a more general scope. Factors identified in this analysis that can discriminate types, such as the size of the goat herds, the product added value (goat's or mixed cheese, market or milk delivery) and the history of the goat unit in the farm, are also candidates for generalization to other samples.

We limited ourselves to a consideration of ecological intensification at farm level when it could be carried out at larger scales. Several authors (Zhang et al., 2007 ; Power, 2010) show that ecosystem services and disservices are often expressed at a wider scale than the farm. We have not considered the exchange of resources (hay, manure, work) among farmers at local level, and have not identified a form of food self-sufficiency that would favour buying local food (e.g. hay from a neighbour) purchase outside the territory (e.g. Spanish alfalfa, hay from the Crau, soybean meal from Brazil).

5.3. Methodological choices to improve

To build the ecological intensification profile, we have chosen to count the number of management practices associated with each agroecology principle (Altieri, 2002) recalled by Dumont et al. (2013). In order to assess the performances of the livestock farming systems, Mena et al. (2012) also constructed variables on practices, but based on organic farming specifications and using weighting techniques to construct the variables. In (Guyomard et al., 2013), the performances of the livestock farming systems are also assessed through the link between the practices and 5 "meta-performances": economics, production, use of natural resources, environment and social. In our case, we were not able to rely on a set of specifications as in organic farming, and we did not seek to quantify the influence of each practice on a type of performance. We sought less to assess the proximity of the EI profile of each system to an ideal profile that would have high modalities for each principle, than to understand how the functioning of a system and the way it was constructed plays on the profile obtained. What is more, assessing performances is difficult and controversial because it often results from a contextualisation of bibliographical knowledge, or from a generalisation of local experiences (Bidaud, 2013). Other studies have sought to link intensification and ecologisation of practices, based on the reading of a diversity of livestock farming systems (Riedel et al. (2007), Vall et al (2011) and Ripoll-Bosch et al. (2012), for example). All of these studies mobilised indicators to quantify the intensification and ecologisation of practices, which led the authors to define the perimeter of what constituted ecologically-intensive systems to certain combinations of practices.

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We intend to continue this work by refining the inclusion of other management practices in the construction of the EI profile and applying it to other livestock situations.

5.4 Results to be repositioned in the agrifood system

This study is centred on the practices and strategies of livestock farmers. It has to be resituated in the territorial context of the agrifood system to understand how the individual strategies of farmers interact with those of other players (Lamine 2012). We have mentioned the link between the absence of technical advice and an organised sector in goat farming and the diversity of forms of livestock farming which, in addition, are very largely diversified. In this region there is no official label for goat's cheese. The « Brique du Forez » is a traditional product, but its composition fluctuates depending on the farmer and the season, and it does not in fact benefit from PDO (Protected Designation of Origin) certification. A small dairy in great economic difficulty collects the milk from the "resource-centred" types of farmers to make the Brique du Forez, but the prospects are rather uncertain. Developments in the systems rely hardly at all on collective dynamics or advice specific to the goat sector, but on networks associated with the farm's cattle productions when they exist, or on inter-individual relationships between farmers and consumers or between farmers. Some institutions such as the Chamber of Agriculture and the Parc Livradois-Forez, conscious both of the interest of these farms for the territory and of their isolation, are attempting with difficulty to relaunch collective dynamics.

6. Conclusion

We have shown the usefulness of this approach to understand and analyse the diversity of livestock systems and identify what promotes or limits the development of these systems to more ecologically-intensive forms. In a general context of goat farming combined with other herbivores, the systems are often only partially agro-ecological, if reference is made to practices associated with the five principles of Altieri (2002). The situations in which these principles are followed the most successfully refer back to situations characteristic of small grassland farms, engaged in cheese processing, aiming at self-sufficiency in forage, low-input use, and adaptation to the seasonal nature of goat herd production. These farms also demonstrate that mastery of the balances necessary for this type of system to function in an agro-ecological way, has been built up very progressively over time, confirming the importance of the time factor (Lamine 2011). We intend to continue this work by refining the inclusion of other management practices in the construction of the EI profile and applying it to other livestock situations.

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