Integrating crop and livestock activities at territorial level in the watershed of Aveyron river: from current issues to collective innovative solutions

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Abstract: In developed countries, the development of interactions between crops and livestock could enhance sustainability of agriculture, as an alternative to the specialization trends. Strengthening integration of crop and livestock at farm and territory levels may improve metabolism efficiency of agricultural systems and enhance ecosystem services. It also allows diversifying income sources and creating activities locally. To design such Integrated Crop-Livestock Systems (ICLS), the socio-economic contexts must be taken into account to overcome sociotechnical lock-in, through situated co-design with stakeholders.

We present in this article a participatory approach to design ICLS at farm and territory levels in the Aveyron river watershed (South-West France). In this highly diversified area coexist irrigated or non-irrigated arable farming systems in lowlands and more or less intensive livestock systems in upper lands. With local stakeholders (farmers, land and water resources managers, environmental associations, collect and storage organisms, agricultural advisors) we built a diagnosis of local crop-livestock integration challenges and issues, identified the existing interactions and imagined promising options of integration. These options were articulated in two scenarios: a "territorial integration" scenario referring to large flows of products between lowlands and highlands, a "collective-level integration" scenario referring to small groups of farmers exchanging products and collaborating in a flexible way. These two scenarios have been discussed and assessed using a multicriteria assessment based on the participative diagnosis. Through our assessment and design participatory approach, stakeholders identified and described different ways for sustainable crop-livestock integration based on the local biophysical and social resources and the diversity of farming systems. At territorial level, integration would occur through collaboration between crop-specialized areas producing alfalfa for livestock areas. This collaboration would be driven by cooperatives and set on a large scale. At collective level, integration would occur through collective organisation and informal agreements between farmers, animated and organised by a farmers' association. The combination of both approaches is discussed as an opportunity for deep crop-livestock integration and transition in farming practices towards more agroecological practices.

Keywords: crop-livestock integration; participatory design; multicriteria assessment; territorial synergy

Introduction

The challenge of developing sustainable farming systems has led researchers to build holistic approaches based on interdisciplinary frameworks (Holling, 2001). Changes in technical practices, work or supply chain organization, require combining different sources of knowledge and imagining new production systems, suitable for farmers and supported by public policies. Several conceptual and methodological frameworks have been developed to design innovative farming systems with stakeholders, to initiate this forecasting of new production systems. Among others, agroecology (Wezel *et al*., 2009), social-ecological systems (Anderies *et al*., 2004 ; Ostrom, 2009), ecological modernization (Horlings and Marsden, 2011), socio-technical systems (Geels, 2004), complex adaptative systems (Hall and Clark, 2010), highlight the necessity of considering interactions within and between the social and ecological systems in which the farming systems take place and the dynamics of social and institutional innovations equally as biotechnical ones. Key properties have been identified to improve sustainability of the farming systems: resilience (Folke, 2006), adaptiveness (Darnhofer *et al*., 2010) and at the crossroad sustainagility (Jackson *et al*., 2010). The objective to ensure present and future human wellbeing and health put the light on the necessity to protect, restore and ensure resilience of ecosystem services (MEA, 2005). Recently, Biggs *et al*. (2012) have characterized principles for resilience of ecosystem services in which sustainability is seen as a process rather than a state, since the objective is to face together local and global, current and future social-ecological issues.

To design sustainable farming systems, a variety of methods and tools have been developed either to build new systems in a *de novo* design process or to improve the sustainability of existing farming systems in step-by-step design (Meynard *et al*., 2012, Martin et al., 2012). In the work presented hereafter the focus is made on building breaking innovations in *de novo* design. In transition approaches, Geels and Schot (2007), Lamine and Bellon (2009) or Lamine (2011) analyze the technical, organizational and social changes underpinning new configurations of the whole socio-ecological systems. Etienne (2010) proposed a participatory methodology called “companion modelling” to design solutions based on local and scientific knowledge and to propose collective management solutions. Following these authors, we try to develop multi-level and multi-domain options of change, articulated in “portfolio of promises” (Elzen and Spoelstra, 2010).

In intensive agriculture area, the development of new interactions between crop and livestock enterprises is often seen as way to enhance sustainability of farming systems. Integrated Crop-Livestock Systems (ICLS) have been studied in several contexts for their interest regarding nutrient cycling and eco-efficiency (Wilkins, 2008 ; Russelle *et al*., 2007) and the provision of ecosystem services through the enhancement of agroecological processes (Dumont *et al*., 2013 ; Lemaire *et al*., 2013). Bell *et al*. (2013) show their benefits for productivity, soil fertility, and risk management regarding both market and climate fluctuations. De Moraes *et al*. (2013) show that, in Brazil, spatial crop-livestock integration within farms gives the opportunity for sustainable, well-balanced soil-plant-animal systems and a greatest profitability and stability of economic results. In face of standardization, labor force and drudgery constraints, mixed farming systems rapidly disappear. While it is often considered that livestock will not return into farms where they disappeared (Lapierre, 2004; Wilkins, 2008), several authors propose to analyze the potential and possibilities of crop-livestock integrations at the local (territory) level (Hendrickson *et al*., 2008; Lemaire, 2007; Wilkins, 2008). Such a territorial organization makes strongly arising actors’ coordination, agro-chain organization and governance issues (Moraine et al., 2013).

Our participatory design approach aims at developing ICLS coping with the local resources and constraints of socio-ecological systems. Considering Biggs *et al*. (2012) and Bonaudo *et al.* (2013) principles, we pay attention to the following objectives: increase of diversity of land use and connectivity of biodiversity habitats, and the parallel coordination between actors of the social system; development and sharing of local knowledge and its hybridation with scientific knowledge; flexibility and adaptability to climatic and market uncertainties. Stirling (2011) highlights the interest of “pluralizing progress” by targeting “transformative diversity” rather than unidirectional or normative transitions. Our interpretation of these principles brings us to consider a diversity of crop-livestock integration pathways in our case study, in order to initiate multiple transformations coping with different socio-technical contexts.

This paper presents our methodology and first results of participatory design of crop-livestock systems in Aveyron river basin in South-Western France. The first step is presented in section 2. It consists in a participatory diagnosis of current challenges of agriculture and the potential for crop-livestock integration. After this diagnosis, we identified two pathways for crop-livestock integration: one at territorial level on a rather large scale, the other at the level of farmers’ groups. The methodologies and first results of these two approaches are presented respectively in sections 3 and 4, and their complementarity and consistency is discussed in section 5.

Participatory diagnosis of the farming systems and challenges on the Aveyron river basin

Method of participatory diagnosis

The first step of our approach is to carry out a diagnosis of the agricultural systems of the studied area and the associated issues. For this, three participatory workshops have been organized. The stakeholders participating in the three workshops were representing four poles of interest:

- public goods management: rural development and natural resources management agents;
- economic feasibility: collect and storage organisms;
- landscape, environment and life quality: representatives of water management institutions, nature conservation institutions and environmental association;
- technical and organizational consistency: farmers and technical advisors.

They were from five to ten participants present at each workshop, each during half a day. A researcher played the role of facilitator to animate the discussion, distribute the speech and reformulate questions and ideas, using maps of the territory to localize the information.

The first workshop was focused on the description of current farming systems and their main issues (about resources management, conservation of biodiversity, economics, work, etc.). The second aimed at identification of potentially interesting options of change, and the third was the building of scenarios of implementation of the options in farming systems at territory level (Moraine *et al*., 2013). The whole participatory diagnosis is presented in Fig. 1.

Farming systems and challenges of the territory

During the first workshop through a structured brainstorming stakeholders described main farming systems of the studied area and the associated challenges for their sustainability.

The uplands of the Aveyron watershed are specialized in ruminant’s livestock production. In our study, we focus on the region of “Ségala”, a region of valleys with grasslands and forage crops. As in other French regions, the increase of farm size, economy of scope, specialization and intensification are the main dynamics of farming systems. Farmers, technical experts and references show that this region is non autonomous mostly because of high animal pressure inherited from the maize-based intensification of production. Less productive areas of farms or even part of the agricultural region are threatened by abandonment or being abandoned. The liberalization of milk quotas is encouraging an additional intensification of the milk production and an increase of the herd sizes. Maize surfaces grow at the expense of grasslands. The feed (straw, protein, forage) importations strongly expose farmers to the world agricultural markets fluctuations and represent an important environmental cost. Climate fluctuations, especially frequent droughts, threaten the forage production and make it dependent to irrigation. The low availability of forage during these periods raises their price. These economic difficulties and workload in livestock production impact the attractiveness of farming activities.

The lowlands of the Aveyron watershed are dominated by irrigated maize on alluvial soils and short cereal rotations (sunflower / wheat) dry or irrigated on more and less deep clay-calcareous soils. Much of these cropping systems use fertilizers and pesticides intensively. Erosion is locally strong and soil fertility is often considered as declining. Although these farming systems are very productive and profitable on the short run, their sustainability is discussed because of inputs consumption, risks of pollution and intensive use of natural resources, water in first place.

Water management is indeed a major stake of the region. The water demand by different activities, mainly agriculture, is structurally larger than its availability. Consequently, the Aveyron watershed shows very recurrent and important water shortages due to irrigation. The water deficit is evaluated, at the watershed level, around 5 million m^3 (Mm^3) on a watershed of 1560 km^2. 85 % of the irrigation is concentrated on the lowlands, where irrigation restrictions occur frequently, implying tensions and harsh negotiations (Debril and Therond, 2012).

From challenges to scenarios of crop-livestock integration

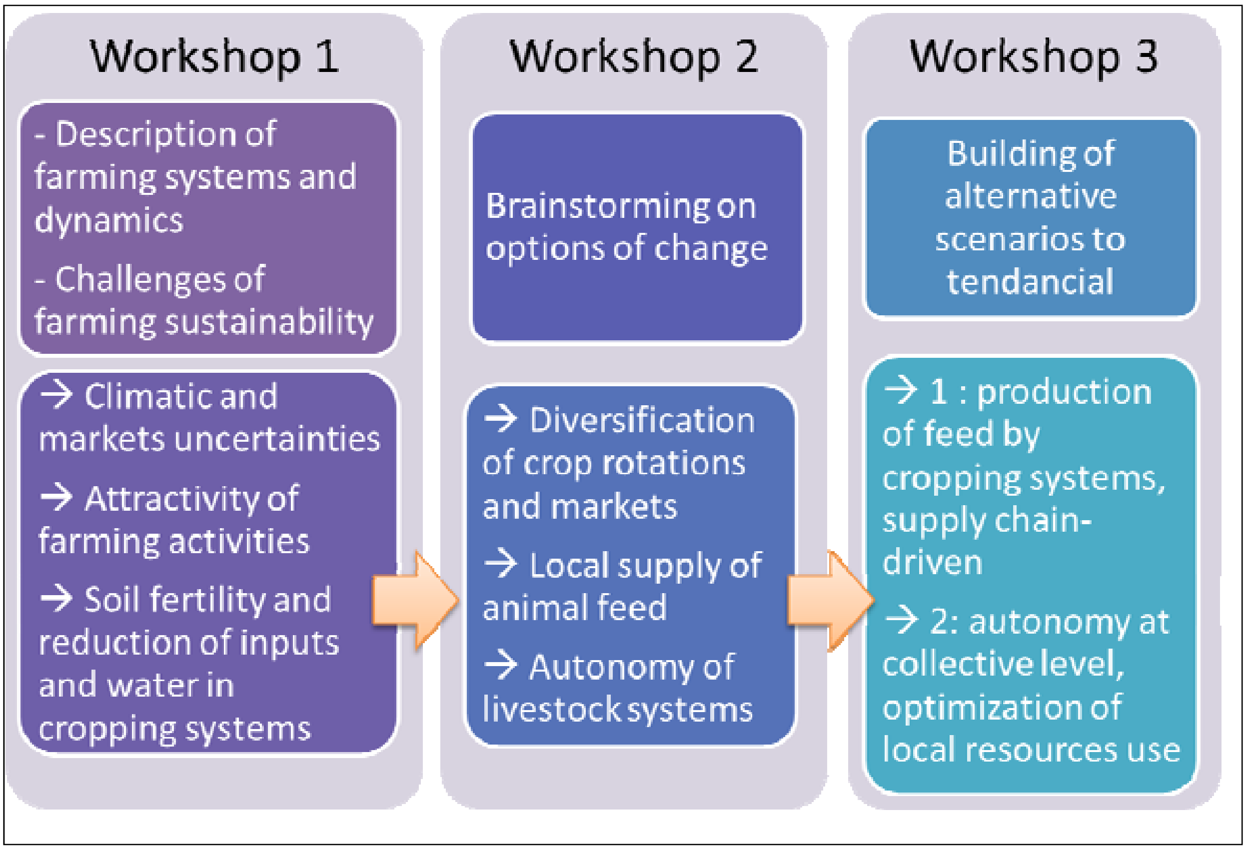
During the second workshop through a card sorting method stakeholders proposed explorative change options to deal with challenges for farming sustainability identified in the first workshop. These options are either in technical or organizational domains. In the third workshop we led stakeholders to build two contrasting scenarios that describe alternative future pathways of the local agriculture integrating a set of change options identified in the workshop 2.

Alternative scenario 1: Crop diversification appears crucial to enhance sustainability of cropping systems. Introducing fodder crops, temporary grasslands, in crop rotations could reduce the need of pesticides and fertilizers. The economic risk due to climate and market uncertainties could be reduced by diversification also. Local production of animal feed in diversified cropping systems could limit the replacement of grasslands by forage crops (maize) in Ségala, where maize is still more cultivated in poorly adapted soils. The main logic of this scenario is to develop production of forage crops and protein crops in Aveyron' lowlands, where diversification and reducing water withdrawals are the main issues, to meet requirements of livestock systems of Aveyron' uplands. In this scenario, the supply chains, mostly cooperatives, play a key role of intermediary and organize the technical changes. Information and governance is mainly "vertical": from farmers to supply chain and back.

Alternative scenario 2: This scenario is based on the concept of territorial autonomy and sovereignty, which aims at collective actions in local groups of farmers to exchange products and organize land use in order to strongly increase their autonomy. In this scenario, the objectives of farmers are not focused on production levels but on the autonomy at collective level. This implies redesign of practices and objectives of farming, e.g. the reduction of stocking rate. Knowledge exchange is particularly important in this scenario: collective learning and experimentation are core issues. Information and governance is mainly "horizontal": between farmers, with the help of animators of the farmers' association.

In the following sections we present characteristics of the two approaches. Our underlying hypothesis is that multiple pathways toward sustainability could be an answer to the diversity of expectations, needs and farmers' identity and values.

Figure 1: Summary of procedures and main results of the participative diagnosis



The territory integration approach: development of a local production of legume-based fodder and concentrates under the supply chain leadership

The territory integration approach is based on an explorative study conducted by Grimaldi (2013) relying on three major steps: the identification of livestock feed requirements (inputs) in the uplands, the design of options of change in lowlands cropping systems answering to these inputs needs, and the assessment of the options of change.

Identification of uplands livestock systems inputs

Quantification of inputs of uplands livestock systems has been performed on the "Ségala" region. Data on purchased annual forage, concentrates and straw of the farms of the area have been estimated trough extrapolation of information on 96 reference farms representing the diversity of local farming systems to the 2455 farms of the Ségala. Results of this data analysis of feed purchased and their fluctuations have been discussed and consolidated during a meeting with technical experts and through nine interviews with managers of cooperatives and commercial firms specialized in animal feed business.

Our results show that structurally, the small region of Ségala is not autonomous neither for fodder or straw or concentrate. The imported volumes are constituted by:

- 17 000 tons of dry matter (tDM) of fodder, coming mostly from north-eastern France or Spain. During dry years, the quantity of forage purchased in this area can be multiplied by five.
- 46 000 tDM of straw, coming from the cereal plains of the surrounding districts.
- 110 000 tDM of concentrates feed, including oilcakes coming from international channels (South America, China or India).

These data show a large potential for locally-produced fodders and above all, concentrates. The autonomy in protein is of particularly concern for Ségala' livestock systems and accordingly was the central entry of the lowland cropping systems design step.

Cropping systems design in lowlands

The design workshop gathered one technical advisor and six farmers during one whole day, animated by a researcher playing the role of facilitator. Upland farmers did not participate because this workshop focused on the technical practices in lowland farming systems. The method of this design workshop has been developed by Murgue *et al*. (2014). It is constructed to open up and then narrow the space of possibilities, by a preliminary introductive sequence on the expectations and stakes of participants. This sequence allowed us to pass from our question, which came from a scientific viewpoint that was not necessarily shared by the participants, to a question accepted by the entire researcher-actor group. The validated question was "On the territory, what crop rotations and technical practices could be envisaged to answer to the upland livestock systems' requirements?".

Then a phase of directed brainstorming led the group to freely express individual ideas for change compared to the current situation. We then organized collective selection of the ideas that seemed the most interesting, and asked the group to detail the implicit objectives and characteristics of each idea. Finally, we asked participants to describe the territory entities (field/farm type, soil unit…) that would be touched by the change and factors limiting the change. The latter corresponds to thresholds of technical, economic, and organizational acceptability for farms (resulting in the definition of the part of the area in the concerned farms).

We call "options of change" ideas collectively described in a form that is stable and accepted by the group. Farmers of the lowlands participating in the workshop agreed that supplying livestock farms with fodder crops could represent an opportunity for them to diversify their crop rotations, thus reducing some inputs of which irrigation water. The main acceptable and realistic option of change for them is to insert alfalfa in their cereal crop rotations and maize monoculture. Alfalfa is an interesting crop as it may improve soil fertility by symbiotic fixation of nitrogen. As a semi-perennial crop, alfalfa would ensure soil cover that may reduce both erosion and the stocks of weeds. Farmers consider alfalfa would be cropped with irrigation when water is available, or without irrigation in dry years. During the years of water shortage, this strategy should allow using available water to secure the yields of maize whereas alfalfa, due to its profound root system, is able to grow and ensure at least low yields in dry conditions.

Alfalfa cultivation constraints were discussed. The technical knowledge is a crucial point and could be the source of failures in cultivation resulting in crop abandonment. Moreover, the questions of specific material, workload and conditions for the harvest of alfalfa and the security of outlets were extensively discussed. To overcome these problems, different levels of development of alfalfa have been envisaged by workshop participants.

The first level is the development of alfalfa in farms where small livestock enterprises remain, or where livestock has been recently stopped. As these farmers are often used to alfalfa cultivation, they could value this knowledge by developing alfalfa in their cropping systems and maintain their grasslands surfaces, and relay this knowledge to neighbor farmers.

The second level is the development of alfalfa in a large range of farms. The cooperative would be in charge of providing technical advices and would fully take in charge the harvest organization and achievement. This would ensure quality of harvested alfalfa and management of logistic constraints such as adapted and regular flow to the drying oven.

The cooperative plays a role of intermediary between lowland and upland farmers and ensure a regular and adapted production quality and contracting aspects to guaranty an adequacy between offer and demand on the long run.

Other options of change were imagined, notably the diversification with other crops like pea and faba, but farmers rejected totally the possibility to implement it in their cropping systems due its high variability of yield.

Assessment of options of change

We assessed impacts of main option of changes compared to the current situation, at the farm and lowland landscape levels, using a geographic information systems (Murgue et al., this conference) and dedicated indicator calculators. Four variables were used to estimate area and farms concerned by the different options of change: soil type, crop rotation, irrigation and technical practices.

Three options of changes were assessed, from a "low-adoption" option, in which development of alfalfa is restricted to farms where livestock remain or has recently disappeared, to a "maximum-potential" option in which alfalfa is cropped widely and irrigated as far as possible. These options concern from around 1900 to 4800 ha of alfalfa introduced in the area (on 40 000 ha of field crop).

The simulated performances regarding yields, production costs, semi-net margins, irrigation water and working time were estimated on the basis of data collected from farmers and technical advisory services. These performance criteria were calculated at the cropping system level, per ha per year for the whole crop rotation, and then aggregated for the whole lowlands area. All the values have been presented, discussed and consolidated with the participants in a specific second meeting.

In all scenarios, switching from maize monoculture to alfalfa / maize rotations (3 years alfalfa then 3 years maize) or from sunflower / wheat to alfalfa (x3) / [wheat/ sunflower] (x2) have been estimated as economically interesting. Production costs are strongly decreased, resulting in an average better economic margin.

Water withdrawn for irrigation is also evaluated as lower with alfalfa introduction. In a "water economy" scenario, 1.6 Mm^3 are saved, that is around 10 % of the global water demand of lowlands and 30 % of the mean water deficit. The work criteria would be improved as alfalfa requires few technical interventions compared to maize monoculture. Scientific literature outlines agronomic benefit of alfalfa introduction, evaluated as one herbicide spreading saved on the following crop and a reduction of the global pest and diseases pressure. Nitrogen supply is evaluated as 50 kg N/ha the first year after alfalfa and 20 kg N/ha the second year (Thiebeau *et al.,* 2001).

Regarding the covering of the uplands (Ségala) requirements, the production of alfalfa in the different scenarios could supply 90 to 200 % of the current inputs of fodder. Alfalfa is an interesting fodder as it is very rich in protein while good for rumination and animal health. The substitution of a part of maize by alfalfa could reduce up to 17% of the current needs of concentrates.

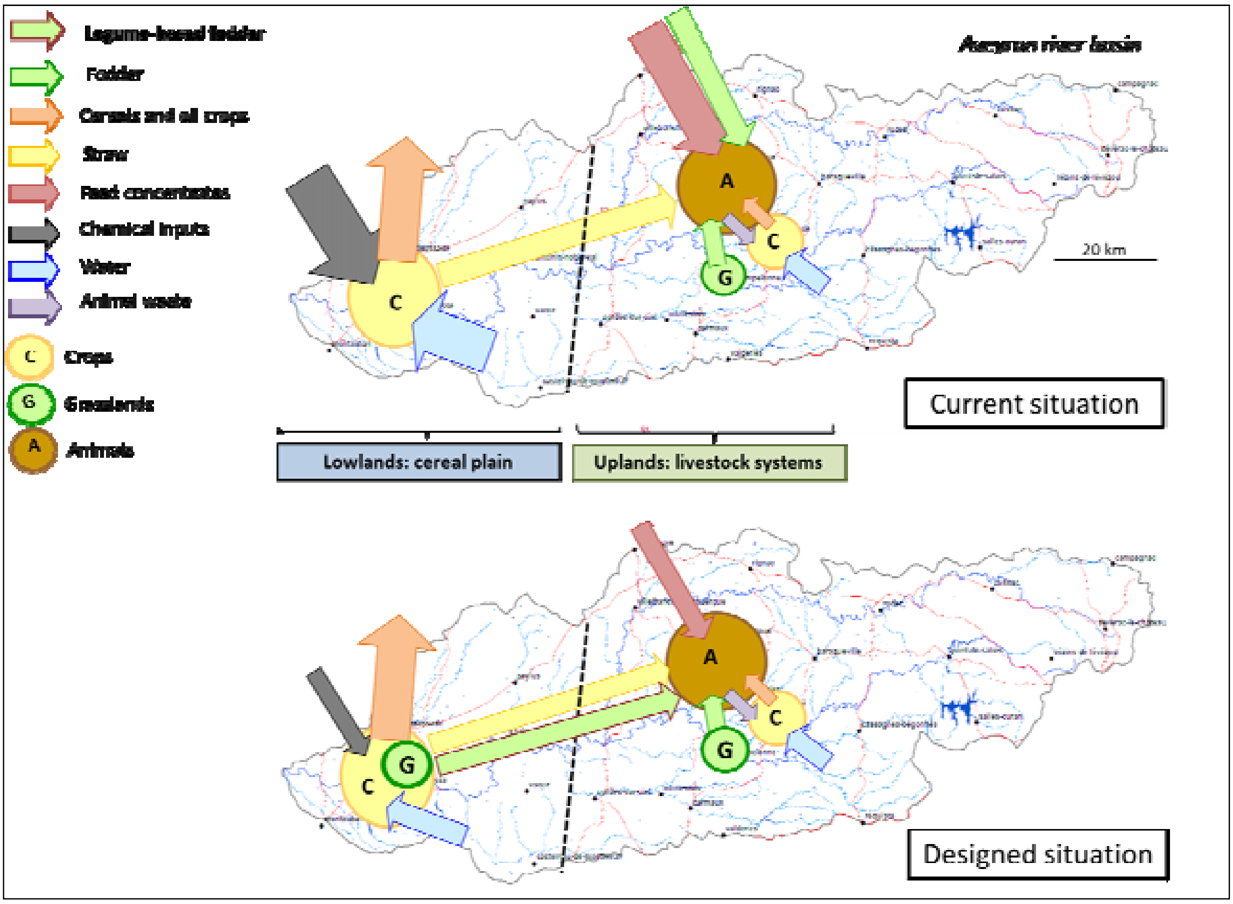
Main outcomes of a territory integration approach

In the territory approach, the design phase is important as it is the time when local stakeholders consider new practices and conditions of their development. Assessment outputs have been considered, both by farmers and representative of cooperatives, as interesting and encouraging for further reflections and tests. This territory approach allow identifying changes considered as acceptable in farms by farmer themselves and estimating potential impacts at the upper level.

The territory approach is also an attempt to generate a kind of "common goods" vision of the complementarity between uplands and lowlands, through the development of synergetic interactions between the two areas: the production of alfalfa in lowlands is a manner to diversify crop rotations and manage agronomic sustainability of the cropping systems, with a guaranteed outlet represented by uplands. For uplands, the local supply of protein-rich fodder could reduce their dependency towards international markets and imply better animal performances (health, reproduction, milk quality) (see synthesis of the territory integration in figure 2).

Further investigations would be necessary to concretely assess the consequences and potential benefits of the envisaged changes. The relations between farmers, cooperatives and other stakeholders are also considered as non-disturbing, whereas matter of power, independency and many other social processes could occur during the development of new practices and agro-chains.

Figure 2: Synthesis of the territory integration approach



The territory of Aveyron river basin is divided in two areas: lowlands dominated by field-crop systems, uplands dominated by livestock systems. The upper part of the figure presents the current situation, the lower part presents the designed situation after the territory integration approach. Archetypal farming systems are represented through spheres for Crops, Animals and Grasslands production systems. The inputs and outputs of these systems are represented by arrows. The size of spheres and arrows represents the importance of each system and flows. In the designed situation, the introduction of grasslands (alfalfa) in crop rotations reduces chemical and water inputs and produces legume-based fodder that can be sold to livestock systems of uplands.

The collective integration approach: development of networks of farmers exchanging in multiple ways

The collective integration approach has been developed in parallel to the territory integration approach to emphasize the diversity of opportunities for management of land and resources obtained from direct coordination between farmers.

Method
The collective integration approach has been developed within an existing group of farmers of the intermediary area between lowlands and uplands of the Aveyron river watershed. They all belong to a formal association with an animator. In comparison with the general challenges and constraints of farming systems presented in section 2.2 they present the specificity of a wide diversity of crop and animal productions at the collective level, and a large share of organic farming systems.

One design workshop has been conducted with twelve farmers, almost as crop specialized as livestock farmers, and the association animator. The design workshop has been conducted using the same method as in territory approach (see 3.2) except that options of change are expected in broader domains than cropping systems. Around twenty other farmers participated in the reflection through sending descriptions of their farms, the products they want to exchange and some ideas of coordination.

Design of coordination options for improving autonomy at collective level
In this section we present the options of change imagined by farmers of the group in cropping systems to provide feed to livestock systems, in these later to meet needs of the first ones and the necessary organizational changes to support the two types of change.

Options of change in cropping systems for livestock feeding. Multi-crop mixtures ("meslins") including legumes are proposed as principal option. It is practiced by several organic farmers to reduce the occurrence and incidence of crop diseases and support yield despite low or no fertilization. Furthermore because of the often high density of cover they allow a good control of weeds. For crop specialized farmers, this practice raises some problems: even if it is possible to segregate grains from different species, many species are dedicated to animal consumption and not accepted by collect organisms for being too rare, or badly paid. However, the use of meslins in animal diet is interesting as it has often good protein content, allowing reducing the share of soybean cake or other protein-rich concentrates distributed to balance low-protein forage and feed concentrates. The management of crop mixtures, in particular the proportion of the different species when sowing, depends on the required grain composition at the end. Livestock farmers who know how to associate the different crops could help arable farmers to calibrate their mixtures and livestock systems could be outlets for these meslins. The introduction of alfalfa in crop rotations is also an option to provide livestock systems with high quality fodder. The interests for cropping systems are the same as exposed in the territory-approach section. In this case, the harvest would be done by livestock farmers who get the material and technical know-how to carry it.

Other crops such as linen and hemp have also been envisaged for their complementary interests in livestock feeding. Engrain (*Triticum monococcum*) is currently cropped by arable farmers for its low rate of gluten, very sought by organic and pro-health shops. Besides, it has long straw and so good straw yield that is interesting for livestock farmers. The cost of shelling the grain is high but the organization of an intern market could justify and initiate a collective investment to equip with shelling machine.

Options of change in livestock systems for returns to cropping systems. Organic farmers without animals are often struggling to find organic fertilizers, essentials for maintaining soil fertility. Agreements between crop and livestock farmers of the group are envisaged to provide the first ones with livestock manure. The spreading material would come from livestock farmers. This option is of particular importance as it really argues for the implication of the field crop farmers in the general partnership. The implication of farmers with confined animals (e.g. poultry) could be interesting as they often don't have enough agricultural area for spreading their nitrogen-rich animal waste.

The circulation of animals is also an option envisaged for some animal types (heifers, beef). These animals could use land like non-mechanized permanent grasslands or temporary grasslands in crop rotations, and maybe crop residues or cover crop if adapted. Circulation of animals between farms requires installing fences on plots, and a good coordination for the watching and care to animals.

The introduction of livestock enterprises in crop farms has also been envisaged. As farms often have unused buildings, confined animals in these buildings could generate organic manure locally. This option would be supported by partnerships between livestock and field crop farmers for knowledge exchange, technical and organizational support.

Conditions of implementation of the options. To develop interactions between them, crops and livestock farmers would handle specific logistic and organizational issues usually taken in charge by cooperatives, storage and supply sectors. For example, manufacturing feed for animals on farm necessitate being able to conserve the harvests, through drying, storage, ventilation. Collective enterprises are envisaged to do this. Farmers see it as an opportunity of better valorization of crop products, development of new activities and contribution to local employment. Farmers wish to develop direct sales infrastructures to add value to their products and share together this added value, on the basis of the local provenance of the products.

The definition of prices for traded products within the group would also be performed in collective: by providing references, developing frameworks for multi-year and collective agreements: group demands, make projections of crop rotations, etc. It is necessary to consider the forms of multi-year contract to avoid opportunistic behavior: agree on a price favorable to both parties on the long run regardless of one year results.

Main outcomes of a collective integration approach

The collective integration approach emphasizes the optimization of local resources by solving individual constraints through collective organization. The objective is to find the best compromise between collective and individual use to every type of resource. The collective allows the development of new activities, transformation of products and direct sales, by introducing more flexibility. In the collective integration approach, quality of human relations and collective governance have a central place. The animation, ideas and knowledge sharing helps to structure new initiatives and maintain solidarity between farmers.

Transversal analysis, discussion and conclusion

A comparative analysis of the two approaches presented above leads us to several elements of discussion and key conclusions.

In terms of methodology, the partners involved in the two approaches are very different: cooperatives in the territory approach, organic farmers' association in the collective approach. Their interests and constraints are different and their criteria of performances also: scenarios in territory approach include the criteria of critical volumes of crops to guarantee the profitability of collect and storage, whereas in the collective approach the flexibility remains high. The assessment framework we proposed had to be wide enough to cover the different aspects of this contrasted scenario and question the envisaged scenarios.

Regarding the ecological system, the current and envisaged planned diversity is higher in collective approach than in territory approach. The ecosystem services and environmental benefits should then be higher in the systems designed by collective approach. However, it can be noticed that the area concerned by options of change envisaged through the collective approach remains very small, compared to the territory approach in which large areas are concerned by the changes.

Regarding the social system, option of changes envisaged by the territory approach are strongly dependent of the local cooperatives involvement; latters would have to organize and perform technical advices to farmers, alfalfa harvest, processing (e.g. drying) and transportation and organize and ensure stable market of alfalfa. In such an organization farmers would have not much decision room in the production and the distribution of the added value of alfalfa. The governance issue also arises in the collective approach: as in every human group, relations between farmers will determine the collective choices made and the nature and dynamics of changes.

The conditions of implementation of changes are also very different between the two approaches. In the territory approach, one important change must be done with the introduction of alfalfa, but it is the only one. We presume that the technical knowledge could be acquired with the support of cooperatives with rather top-down logic. In the collective approach, numerous changes of different nature would be implemented. A dynamic of collective continuous learning and change would have to be launched, that could be stimulating but is not exempt of risk and may be sometimes not obvious for farmers to manage and sustain (Pahl Wostl and Hare, 2004).

Finally, we do not anticipate the possible reluctance to changes: farmers who don't want to change their practices, those who feel excluded of the groups and other political or social obstacles.

There are no obvious conclusions about the most adapted of the two approaches to deal with sustainability challenges. Above all because, as Stirling (2011) shows, sustainability has no unique direction and finalized trajectory. Then because our approaches need to be reinforced by an integrated assessment of each options of changes envisaged through the collective approach, and the assessment of the ones produced by the territorial approach remain to be completed (for example on environmental issues). Our ambition here is to present and put in perspective the two types of design process for identification of potential ways to develop interactions between crop and livestock systems. The ecologization of agriculture through crop-livestock integration cannot be restricted to one or the other approach, but must be designed to fit with each territory or farming system characteristics and stakeholders' preferences. The collective approach may be interesting for the diversity of ideas and practices developed, whereas the territory approach proposes quite rapid changes on a large scale and appear interesting especially for water quantity challenge.

Moreover, the dynamics of change should be studied and accompanied by research on the long run, the present work being promises of new practices and organization more than a plan for action.

As a conclusion, this work proposes an example of "situated" participatory design, in which the way of working with farmers is different from one collective to another, taking into account their particularities, values and beliefs. In this way we target the diversity of the current socio-technical systems of the territory. Despite the lack of quantification of impacts and benefits of the designed systems at this stage of the research, we outline the complementarity of the two approaches to contribute to sustainable development of the studied territory. The development of the two approaches could allow "cross-fertilization" by inter-nourishing dedicated reflections, in which the researchers have an important role of transmission and translation of knowledge and ideas.

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