Why and how to analyse the potential of mixed crop-livestock farming systems for sustainable agricultural and rural development at landscape level

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Abstract: Mixed crop-livestock farming systems (MCLFSs) have been declining in France despite the special value they are granted for the sustainable development of both agriculture and rural areas. We assume that to promote MCLFSs, first, we need to understand long-term changes by looking at rural development in the past, and second, we need to assess their potential using an integrated framework to evaluate their role in landscape functions. Consequently, we used interdisciplinary case studies concerning agriculture and the environment in contrasted regions in France to build a multi-scale and spatially-explicit conceptual model of the relationships between agricultural land use and landscape functions from the parcel to the landscape level. The processes of change in these relationships are assumed to be embedded in a double hierarchy of organisation and dynamics, i.e. local agriculture and its restructuring process on the one hand, and local landscape mosaïcs and ecological dynamics on the other. The parcel is the entity shared by the two hierarchies which enables the study of multiscale interactions between ecosystem services and agricultural practices. At higher levels, parcel management is incorporated in the decision-making strategies of farmers (agricultural viewpoint) and in society-driven ecosystem and landscape management regulations and incentives (ecological viewpoint). The results of the case studies underline: i/ the major role of grasslands and the spatial allocation of crops in providing ecosystem services at the landscape level, and ii/ common trends of change in farm management across case-study areas: an aim to secure forage resources (to cope with periods of drought), an interest in the services that livestock farming can provide to crop production, and increased exchanges between farms. We conclude that a combination of testing innovative MCLFS and conducting participatory research with the actors of rural territories can support progress towards multifunctional land use.

1. Introduction

The negative external impacts of the development process of agriculture based on farm specialisation and the intensification of production systems in developed countries in the 20th century resulted in an interest in integrated crop-livestock farming systems as a way to improve agricultural sustainability (Hendrickson et al., 2008, Griffon, 2009, Russelle *et al.*, 2007; Wilkins, 2008). Farming systems which combine crop and livestock production are considered to allow more efficient and environmental-friendly use of natural resources, mainly due to improved nutrient cycling. Crop-livestock integration at the farm level is viewed as the archetype of coordination between crops and livestock resulting in both environmental and economic benefits (Schiere et al., 2002). If farm specialisation has long been valued for its capacity to generate economies of scale, mixed crop-livestock farming has recently regained value as a source of economies of scope (Vermersch, 2007). Meantime, the number of mixed crop-livestock farms in Europe continues to decline. The 2010 Agricultural Census in France reported that the number of farms continued to decrease (-26 %) in the last decade, the decrease in livestock and mixed farms being particularly high.

The decrease in the number of crop-livestock farms also appears to fly in the face of the increasing awareness of the potential of crop-livestock integration for landscape management for the provision of varied ecosystem services. There is ever-increasing evidence for the major impact of change in agricultural land use on the depletion of ecosystem services, which are vital for sustainability from the local to the global scale (MA, 2005). The maintenance of agricultural land-use mosaics has contributed to support the multifunctionality of rural landscapes in various places in Europe, whereas, since the

mid-20th century, the modernisation of agriculture has resulted in the overall simplification and banalisation of its cultural landscapes (Antrop 2005). Management of landscape for multifunctionality is increasingly regarded both within the research community and by European policy-makers as an important function of agriculture for sustainable rural development (Pinto-Corriea et al., 2006) and the role grasslands can play in that respect is acknowledged (Gibon 2005).

The real possibility to maintain or enhance crop-livestock integration in agricultural systems is therefore a topical issue for both the future of agriculture and for rural development in general. In this paper, we use the results of case studies of changes in local agriculture and in farmers' land management to contribute to the discussion of current trends for change in crop-livestock integration in different regions of France. These case studies were undertaken in the framework of environmental research projects addressing the relationships between agriculture, landscape and biodiversity. Finally, we discuss the challenges that landscape management for the provision of a complex array of ecosystem services involve in agricultural sciences, especially in farming system research.

2. Methods

Data on crop-livestock farming systems (CLFSs) and their management used in this study were collated in the course of interdisciplinary environmental research addressing the relationships between agricultural land use and landscape change in four case-study areas (CSAs) in France (Figure 1). Local CLFSs were all based on ruminants. Environmental and ecological assessments stressed the significant role in the conservation of biodiversity played by grasslands and other semi-natural components of the landscape mosaics (hedges, woodlands, etc.), which tend to be cleared when livestock production decreases (Balent et Courtiade, 1992; Thenail *et al.*, 2009; Bretagnolle et al. 2011) and other important ecosystem services for rural development (run-off and erosion prevention, landscape visual quality, etc.) in the CSAs. Current rural development objectives call for maintaining, or even reinforcing them in areas where crop production has become dominant in local agriculture.

Field studies of the land management practices of local farmers in each of the CSAs included spatially-explicit assessments of land use and land management practices at the parcel level. However, research was carried out using designs that differed depending on the CSA, and were related to the specificities of each area and to the objectives of the study concerned. We thus searched for a common conceptual framework to take stock of all these results. In the present study, we also used data on the design of innovative low-input and sustainable organic farming systems based on crop and dairy production which are currently under assessment at the Mirecourt experimental farm (UR ASTER).

2.1. Case-study areas

The CSAs present a range of local agricultural conditions and topical issues regarding sustainable land management, at the interface of agriculture and rural development objectives.

Pays de Caux (Normandy)

In this region in north-western France, agricultural specialisation in crop production has resulted in erosive runoff, a process which has become a recurring problem and a source of serious damage for both the farmers and local inhabitants due to (sometimes deadly) muddy floods and water pollution. Grassland is regarded as a tool for mitigating these phenomena. To assess the possibility of developing dairy production systems including the increased use of grass, the SADAPT UMR (joint research unit) surveyed eight dairy farms and undertook an economic assessment of farm management options (Havet *et al.*, 2010a).

Plaine de Niort (Poitou-Charentes)

In the « Plaine de Niort », in western France, the conversion of grasslands into intensively managed annual crops led to a huge decline of the number of little bustards (Tetrax Tetrax, an emblematic bird species), a trend that was successfully reversed in 2004 thanks to targeted agri-environment schemes (AES) for the reintroduction of grasslands in the landscape mosaics. The UMR SADAPT researchers studied farmer management choices with respect to crop rotation and herd feeding to assess the role assigned to grasslands in the production systems following droughts in 2003 and 2005 on a sample of 24 dairy farms, and assessed their economic results (Havet *et al.*, 2010a). Surveys were carried out in 2009-2010 on five specialised crop farms and seven crop-livestock farms (dairy or beef cattle, or goats) to study farmers' decisions regarding crop choices, crop successions and crop allocation to land (Schaller et al., 2011).

Brittany

In Brittany, an area of western France with intensive crop-livestock production, dairy farmers developed a variety of livestock farming systems, ranging from grassland-based systems to maize-based systems. The SAD-Paysage research unit in Rennes carried out a study of the variety of grassland management practices and the relationship between grassland and biodiversity. Roche *et al.* (2010) made a survey of 21 farms to assess their livestock farming system (types of feed used for herds and products sold) and the use and management of the grassland parcels. Botanical surveys were carried out in 94 of these parcels to assess their biodiversity.

Coteaux de Gascogne (south western France)

The Coteaux de Gascogne is an upland area of steep hills characterised by frequent summer droughts. Local agriculture, which is less intensive than in the other CSAs, is based on crop and cattle production (mainly suckling cows). Many farms (47%) have continued mixed crop-livestock farming up to now, and agricultural landscapes still have a relatively well preserved cultural character and rich biodiversity (e.g. bird populations, which decreased by an average of 40% in France between 1980 and 2000, remained relatively unchanged locally; Balent, personal communication). The DYNAFOR UMR carried out a spatially-explicit survey of all farms located in the territory of four municipalities (60 farms, 4000 ha utilized agricultural area) to assess the local variety of farm characteristics and farmers' land management strategies (Choisis *et al.*, 2010), and the historical changes to farms since 1950 (Ryschawy *et al.*, 2011; 2012).

2.2. A multi-scale conceptual model of agricultural land-use and landscape interactions as a guide for assessing local change in land management

The scale mismatch between ecological processes and land management is an acknowledged source of difficulty in assessing their inter-relationships at the landscape scale (Pelosi et al., 2010). We postulated that we needed to replace the different field assessments with a general framework to account for agricultural land management and the changes it has undergone in relation with landscape management issues. To this end, we used a conceptual multi-scale model coined by Gibon et al. (2010) to model changes in mountain agricultural landscapes, after verifying its applicability to the various CSAs. In this model, which was based on recent theoretical advances regarding the interactions between natural and social systems and their sustainability, landscape and agricultural land-use system are regarded as a complex self-organised system. This social-ecological system is structured in a nested dual hierarchy each comprising three main spatial levels of organisation: (i) the ecosystem, the landscape unit and the whole landscape in the ecological realm; (ii) the parcel, the individual farm holding, and the farmland of the whole farm population for the agricultural land-use system.

The parcel appears as an important basic level of organisation for the integrated assessment of a land-use/landscape system, since it is the only level at which a direct connection can be established between ecological processes and land management. In the research works considered in our analysis, land management practices at the parcel level were analysed according to a variety of issues: the choice of the crops allocated to the parcel in a given year and over a period of years (crop succession), the decisions regarding the technical management of the crop in a given year and over a period of years (fertilisation practices, ploughing or reduced tillage, sowing, etc.) in relation to the biotic and abiotic components of the agro-ecosystem, and also the management of the semi-natural ecosystems associated with the parcel, such as hedges and isolated trees, and field margins. We consider that together, farm management practices and decisions in this respect constitute '*parcel management modes'* whose integrated assessment is required when addressing the sustainability of agricultural land-use.

At higher organisational levels, land-use assessment calls for the analysis of the spatial arrangement of the parcels and their management modes within the landscape units and as part of the whole landscape with respect to ecological processes on the one hand, and, on the other hand, individual farm territory and total farmland at the farm population level with respect to local agriculture sustainability. An integrated assessment of agricultural land use also requires accounting for between-scale linkages within and between the two hierarchies.

In this paper, we focus on the land-use system, and consider land-use change at the landscape level to result from the individual farmer's choices and decisions, made according to his/her own particular technical and other objectives, the specificities of the farm territory, and the local dynamics of the agricultural system in relation to the production chains and markets, the spatial arrangement of farm territories within the landscape, and local rural change in general. Using this framework requires that

the assessment of change considers not only different spatial but also different temporal scales, as illustrated in the results section.

3. Results

3.1. The role of the local variety of individual farmer strategies in the long-term development of the farm

Changes in landscape mosaics can be considered as an emerging process resulting from changes in land use on individual farms driven by a variety of individual land-management behaviours of farmers. Here we explain this process, which has rarely been documented, in the Coteaux de Gascogne.

Before the modernisation of agriculture following World War 2, agricultural systems in the CSA were mainly based on a diversified CLFS. Farms progressively decreased in number after the 1960s, while the average farm size progressively increased from about 25 ha in the 1950s to 41 ha in 2000 and to 48 ha in 2011 (RA 2010). The majority of farms continue with CLFSs today. Livestock production specialised in cattle, mainly suckling cows. Dairy production expanded at the end of the 1970s but four out of five dairy herds disappeared between 1979 and 2005. Overall change in land use between 1970 and 2000 was relatively limited (Choisis et al., 2010). Total UAA in the CSA underwent a 12.5% decrease due to land conversion to other uses and abandonment of some of the most constrained parcels. Agricultural land occupation was subject to limited change, about two out of three ha being devoted to grassland and fodder crops, and the remaining hectare to cereal production, and, since the end of the 1970s, also to protein-rich and oilseed crops. The enlargement of the land-management units was moderate, the average parcel size being about 2.5 ha in 2006.

The study of the past development of contemporary farms since the 1950s revealed that individual farm households followed six main contrasted paths for maintenance within a same social-economical environment (Ryschawy et al., 2011; 2012). Twenty percent adopted farm-development models in line with agricultural policy, i.e. strategies based on farm enlargement and specialisation (either beef cattle or crop production) or the dairy production intensification. All the others maintained “traditional” CLFSs, a large proportion of them prioritizing the maintenance of farm autonomy among their objectives.

Local agriculture and rural development stakeholders currently agree about the interest of CLFSs both for meeting landscape-management expectations and farm-sustainability objectives, but their future involves difficult challenges. A significant proportion of farmers will retire shortly without a potential successor and, when farms become very large, farmers tend to abandon livestock production due to its high labour requirements. Since the number of dairy farms is already low, any abandonment of dairy farming threatens the future of the local production chain and hence the sustainability of the remaining dairy farms. Another challenge follows from the strategy adopted by the cattle sector to face changes in the livestock market at the regional scale which relies on partial fattening of store calves. This strategy appears to contradict the wide-spread adaptive strategy used by local farmers, for whom managing a LCFS for autonomy is the keystone of the economic viability and perenniality of the farm front to uncertainties linked to climate change, policy reforms, and markets (Belland 2011). Analysis of exploratory scenarios for the future is currently underway in a local participatory research group including both agriculture and rural development stakeholders to examine possible combinations of policies and farm-development strategies that could simultaneously help match objectives related to farm perenniality, the future of the livestock sector, and landscape management.

3.2. Current changes in land management at farm level

Ensuring the functional integrity of the farm in a continuously changing environment can be regarded as a primary objective of land use and management practice at the farm level. We analyzed these issues using the results of three of the CSAs.

In the Pays de Caux, the farm management priority of livestock farmers was to be able to fulfil dairy cows feeding requirements all year round using maize silage and grassland grazed at a high stocking rate during periods of different lengths in spring. Some farmers currently limit purchased inputs and aim to ensure farm autonomy by including more grassland in their crop successions (80% grassland in the fodder area instead of 60% in conventional systems): they rely on grass and almost manage without maize. Their decisions regarding the spatial allocation of grassland to parcels concern not only grazing but also reflect their stated objective of reducing erosive runoff, grasslands being established in parcels located in the path the water takes when there are heavy rains (Faure *et al.*, 2010).

In the Plaine de Niort, a succession of droughts in the 2000s increased farmers' concern about their inability to produce the quantity of maize-silage they need to feed their high producing dairy cows. They consequently increased their grasslands at the expense of their maize cropping area, this process being more noticeable on farms where maize requires irrigation. The extension of grassland was also spurred by the AES aimed at conservation of the little bustard. Farmers accepted the reduction in milk yield per cow, which was accompanied by a decrease in purchased concentrates; grazing was included in the herd feeding management (Havet *et al.*, 2010a). On the other hand, during the course of the agricultural year, farmers may decide to increase their stocks of forage for the following year in anticipation of possible shortages. At the end of the second hay-cutting period, if the quantity stored forage is not the desired minimum, the farmer may decide to sow grass in the autumn or in the following spring (after a wheat or a winter-barley crop) instead of sunflower or pea as originally planned. Such a decision may also be made after the third and last hay harvest, once the final quantity of forage available for the next winter is known. In the case of a severe shortage, the farmer will sow grassland in autumn in order to cut hay as soon as the following spring (Havet *et al.*, 2010b).

Improving farm autonomy as regards herd feeding is another way of reacting to the increased drought which affects current management choices by farmers in the Plaine de Niort (Havet et al., 2010a). Farmers explicitly mentioned it when explaining their decisions to change their farming systems: in fact, in their opinion, including more grass in herbivore diets goes hand in hand with a decrease in per capita yield that can only be offset by a decrease in the amount of protein-rich compounds fed to the herd. In the Coteaux de Gascogne, where the organisation of forage systems used to be a major source of operational flexibility to face climatic uncertainty in mixed cattle-crop farms, farmers, who maintained permanent grassland in the steepest parcels, are currently increasing the share of seeded grasslands in their crop successions. This allows them to make the adjustments to achieve farm autonomy in livestock feeding made necessary by climate change. They store large quantities of hay in years with suitable climate conditions in anticipation of possible shortages in grassland production in dry years. Any surplus can also be sold, providing them with supplementary income. Management practices for securing forage resources are also incorporated in production logics based on diversification and in reducing external inputs for livestock feed (Ryschawy et al., 2012).

Finally, increasing farm autonomy in livestock feed and securing forage resources to face climate change appear to be the major drivers of a common trend to increase the area of grassland on the farm observed in the different CSAs, despite differences in agroecological conditions and types of farming systems.

3.3 Expansion of between-farm interactions in land management

The exchange of manure and straw between farms with and without livestock are the most common between-farm interactions in the CSAs. However, their importance varies with the region. Opportunities for exchange currently appear to partially determine farmers' decisions regarding crop and crop-succession choices in Plaine de Niort, whilst they are limited in Coteaux de Gascogne, where surplus of organic fertilizer at the farm level is uncommon. In the Plaine de Niort, manure provided by livestock farmers allows farmers specialized in crop production to grow spring crops on a large area, where they spread organic fertilizer at the end of winter. The possibility for crop-livestock farmers to benefit from straw without growing cereal crops allows them to devote a larger area to forage crops and seed oil crops, and to increase the range of crops they grow (Schaller et al., 2011). In contrast, most livestock farmers in Coteaux de Gascogne are obliged to become self sufficient in straw. Because of pressure on organic matter, farms specialized in crops are indeed faced with a decline in soil organic matter which they try to lessen by making the appropriate crop-succession choices and ploughing the straw into the soil after harvest.

Other types of between-farm exchange frequently observed in both the Plaine de Niort and the Coteaux de Gascogne concern fodder. Some livestock farmers benefit from fodder-crop areas cultivated by other farmers. Mostly, exchanges concern cultivated grassland (alfalfa or grass species) cropped for hay. But they sometimes also concern maize crops: when they work parcels with deep soil where maize can be grown without irrigation, some crop farmers choose to grow maize and benefit by selling it to a neighbouring livestock farmer for silage. In addition, particularly in the Coteaux de Gascogne, farmers specialised in crop production are forced to maintain permanent grassland on a few parcels with high constraints. They usually allow livestock farmers to use their grassland in to avoid their encroachment by woody species (Ryschawy et al., 2011).

Both in the Plaine de Niort and Coteaux de Gascogne, farmers with livestock consider fodder exchanges between farms as a way to enhance and secure fodder production to face the increasing

risk of drought. Such exchanges result in a spatial dispersion of fodder crops within the landscape that can be considered as a strategy for minimizing risks linked to a water deficit. Conversely, the presence of crop-livestock farms in the Plaine de Niort provides specialised crop farmers with the opportunity to diversify crop rotations.

3.4. Land management at the parcel level

We illustrate issues regarding land management at the parcel level from results of the Brittany CSA and the design of innovative farming systems currently under assessment at the Mirecourt experimental farm.

In Brittany, the major increase in production per farmland-area and livestock unit capita resulting from the intensification of farming systems in recent decades has been accompanied by the simplification of land use, a reduction in *bocage* and farm specialisation and enlargement. Nevertheless, even when only grassland covers are considered, a mosaic of parcels can still be observed within an individual farm territory. Roche et al. (2010) reported that no farmer in their farm sample managed all his/her grassland parcels in a homogeneous way (the types of animals using them, the duration of the grassland in the crop succession, etc.). Moreover, management of grassland parcels varied considerably even among farms with a similar production system. It is consequently impossible to assess the way a grassland parcel is managed based only on knowledge of the type of dairy farming system:the layout of the farm land and the role of the parcels in the system also need to be taken into account. This variety of parcel management also reflects influences other than that of direct productive factors (agricultural advice, farmers' perception of their job, soil-climate conditions, etc.). There is also a parallel to be drawn between the grassland-use mosaic and the observed biodiversity gradient. Indeed, even if biodiversity remains lower than in territories which are managed extensively, the study pinpointed drivers of species diversification, the most important of which concerns the duration of grassland in crop rotations.

In the design of the organic crop-dairy production system currently under assessment at the Mirecourt experimental farm, emphasis was placed the real compatibility of objectives concerned with production and the preservation of ecosystem services. The main dimensions considered when designing their land-use system were nutrient cycle completion and a feeding system for the dairy herd based on resource diversity, as well as farm self-sufficiency with respect to both herd food resources and straw for bedding. The allocation of management modes to parcels (crop succession types and sequences of operational actions included) accounted for production suitability and environmental sensitivity of the different landscape components of the experimental farm territory. Hedges are scarce in the local context and parcel edges mainly consist in the space between fields, forest edges, and watercourses. When designing the parcel mosaics, the first step was to distinguish between permanent grasslands and arable lands. Then, among the latter, a distinction was made between the parcels best suited for cultivation of lucerne and the others. The last production factor considered in the process was the suitability of the land for spring-seeded crops and for including intercropping in the crop succession. The average size of the agricultural parcels was fixed to about 2 ha. Groups of parcels were also designed based on logistical considerations, the first aim being to facilitate the management of the various animal categories within a given herd, especially for grazing. The tuning of these low-input and organic crop-dairy production systems resulted in an increase in the interactions and functional interdependencies between crops and livestock: the capacity for resource production of the farm territory defines the herd size and reveals new possible controls of the balance between crop and livestock production (herd demography, the buffering role of heifer groups, etc.); services between the cropping system and the livestock system become more diverse and reciprocal, e.g. weed control (Coquil et al., 2011).

4. Discussion and conclusions

The need to preserve Europe's specific landscape from the perspective of both the natural and cultural heritage has been stressed since the beginning of the 1990s and the need to design policy and land-planning and –management instruments- which can solve contextual and place-based problems is increasingly acknowledged (Pinto-Correia et al. 2006). The assessment of the role that farming can play in the management of the landscape functions depending on the rural area concerned raises important conceptual and methodological challenges and calls for a new strategic approach to the agricultural sector on a territorial basis rather than a sectoral one (Pinto-Corriea and Breman 2009). Our study firstly exemplifies how considering change in farmers' management of crop-livestock farms in a variety of contextual conditions can improve our understanding of the dynamics involved in agricultural land-use change in the agricultural sector today and also help assess the way they affect landscape services. Our results confirm that mixed crop-livestock production at the farm level is currently regarded by CLFS farmers in the different CSAs as providing them with enhanced adaptive

capacities to face environmental uncertainties. They also point out that the increased frequency and intensity of droughts in the last decade in all the CSAs have been a major spur to farmers to undertake changes in the management of mixed crop-livestock systems. These changes involve an increase in grassland area and in crop diversity, which benefit different services at the landscape scale. It is noticeable that they result not only from internal changes in their own land-use practices at the farm level, but also from an increase in various types of exchanges with farms specialised in crop production.

Our results nevertheless suggest that such changes occur preferentially in rural areas where a limited number of farms maintained crop-livestock farming systems and where in fact the detrimental impacts of the intensification and specialisation of agriculture were concretely experienced, and local AES created to alleviate these impacts. Results obtained in the Coteaux de Gascogne suggest that conversly, in less favoured areas where intensification has been limited up to now and mixed crop-livestock farming systems are still frequent, their role in maintaining the landscape in a reasonably well preserved condition as well as in conserving biodiversity has not been given much consideration in agricultural and rural policies up to now and farmers encounter more difficulties in trying to maintain mixed systems.

Our results also provide new prospects for supporting landscape management for multifunctionality in crop-livestock agriculture areas. Such a landscape management objective is known to call for enhanced communication between rural stakeholders and action-oriented planning and management based on the place-specific requirements (Pinto-Correia et al., 2006). Our integrated modelling framework and assessment methods of the processes that underpin agricultural land use change offer an opportunity for participatory building and assessment -with local stakeholders- of prospective scenarios for changes in agricultural land use and of their impact on landscape and ecosystem services, which, in turn, lead to shared knowledge and finally to shared reflection about appropriate land management policies. Such approaches have been already successfully applied in agro-pastoral systems in which most of the land is grassland (Gibon et al., 2010; Havet et al., 2010c) and in silvo-pastoral systems (Etienne, et al. 2010). In the latter, a companion-modelling method was used as a support for the simulation of the interrelationships between forest and grassland management practices, considering labour-allocation constraints and farmers' priorities for forest production and feeding herds, respectively. The modelling of land management in mixed crop-livestock agricultural systems in developed countries involves its own challenges concerning the incorporation of knowledge and know-how, since, up to now, crop and livestock systems have been studied mostly separately by agricultural scientists either specialised in crop or in animal production. In-depth field research on crop allocation and crop successions in crop-livestock farming systems (Schaller et al., 2011) supported progress in that direction. .

Finally, our study illustrates the current renewal of methods that animal production researchers and other agricultural scientists use to support the development of agriculture in a way that allows production and landscape management functions to be combined. This renewal not only includes the reinforcement of interdisciplinary research by a wide array of disciplines, but also the implementation of research and action in collaboration with farmers, agricultural advisors and policy decision-makers and other rural stakeholders, and increased concern for the site specificities of rural areas and the real challenges to rural development they face.

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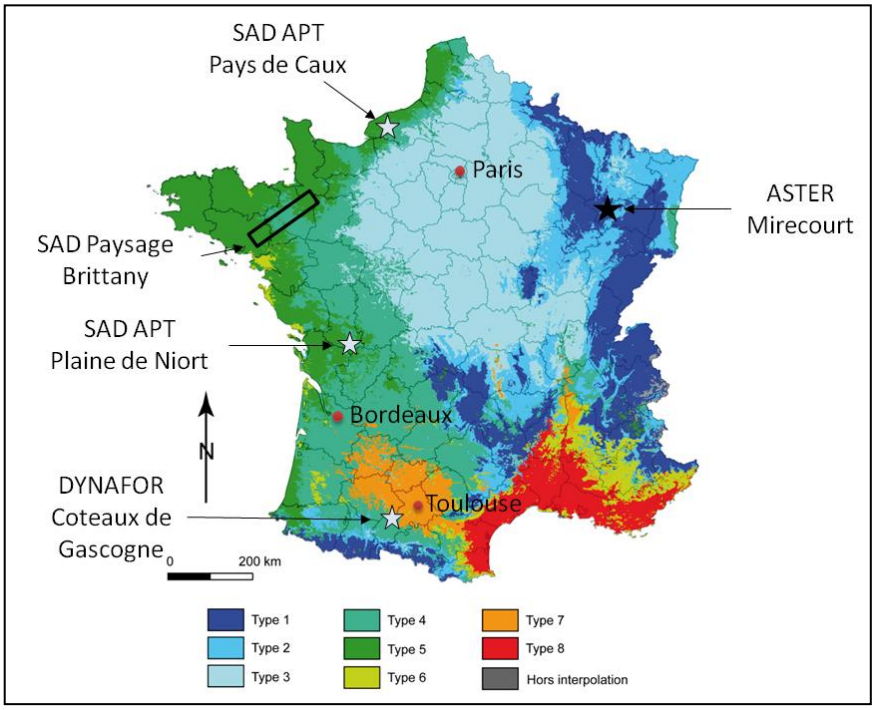
Figure 1:



Legend:

Base map: types of climate in France (source: Joly et al. 2010): Type 1: mountain; Type 2: semi-continental; Type 3: semi-oceanic –variant 1; Type 4: semi-oceanic – variant 2; Type 5: oceanic; Type 6: debased Mediterranean - variant 1; Type 7: debased Mediterranean -variant 2; Type 8: Mediterranean

The Plaine de Niort and the Coteaux de Gascogne case-study areas are part of national or European long-term environmental research networks, respectively.