How access and dynamics in the use of territorial resources shape agroecological transitions in crop-livestock systems: Learnings and perspectives

Vincent Thenard, Gilles Martel, Jean-Philippe Choisis, Timothée Petit, Sebastien Couvreur, Olivia Fontaine, Marc Moraine

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1. How territorial resources and local dynamics support agroecological transitions

1.1 Resources involved in agroecological transitions

The multi-level perspective (Geels, 2004) is widely used to define sociotechnical transitions through the sociotechnical landscape's pressures. This perspective raises existing problems in the dominant regime, and innovations in niches (Geels and Kemps, 2007). Agriculture here is conceptualized as a patchwork of sociotechnical systems embedded in various trajectories of evolution. Among them, agroecological transitions correspond to multiple processes starting from niches supporting "radical, systemic changes" in social, technological, political or institutional areas, but it is also the result of collective action for building and sharing knowledge (Elzen et al., 2017). These changes are based on individual and collective strategies supported by various resources: access to land, infrastructures, and institutional or informal networks (Wezel et al., 2009).

According to Buclet and Cerceau (2019), a territories' sustainable development depends on optimization and distribution in the use of material, immaterial and financial resources. We consider four types of resources:

(i) Natural resources supporting ecological processes in production systems: land, water, animal and vegetal biodiversity;
(ii) Technical and cognitive resources influencing ecological processes through adequate practices: specific equipment, adapted breed or crop varieties, specific know-how, farmers' ability to manage complexity, and trade-offs between short *vs.* long term benefits;
(iii) Social resources sustaining agroecological systems' legitimacy and recognition: social networks, local support from diverse stakeholders;
(iv) Economic resources enhancing the viability in agroecological systems: marketing channels, public subsidies.

Local, territorial and even global contexts can provide these resources. Natural ones are related to local conditions, while technical ones can be generic but must be locally adapted. Social and economic resources can be structured on national or supranational scale (NGOs, trade rules, policies), but depend on local networks and implementations. The role of local stakeholders and coordinated actions appears essential in the activation of territorial resources (Colletis and Pecqueur, 2005). Along with agroecological transitions, resources support the establishment and resilience of agroecological livestock farming systems (LFS) in the adaptation to hazards (Milestadt et al., 2012). Madelrieux et al. (2017a, b) identify the possible synergies between production systems, for example, when LFS use local biomass and semi-natural spaces, and provide effluent used by other activities. According to Rigolot et al. (2019), LFS' adaptation ability is a key element for the struggle with climatic and sanitary risks affecting the growth and quality of feed resources; market fluctuations in products and inputs; institutional risks related to regulation or policy changes; financial risks; and human-related risks (diseases, accidents, disabilities). We describe varied combinations of resources supporting LFS, and stakeholders' influence in resources mobilization.

1.2 How agroecological LFS combine biodiversity and territory embeddedness

Let us consider LFS's agroecological features according to Therond's two-dimensional approach (Therond et al., 2017): on one hand the mobilization of biodiversity in the productive process; and on the other hand LFS's territorial embeddedness regarding supply and commercialization chains. We identify dynamics of change within LFS moving towards agroecology, considering resources combination in different LFS.

Biodiversity mobilization's intensity can be estimated according to four criteria:

- Diversity of land uses;
- Diversity of reared species;
- Type of animal bred (breed and mode of selection);
- Management contribution to natural areas or specific ecosystems.

The intensity of local food chain anchorage is also measured according to four criteria:

- Activities' diversification: the nature of farms' activities, pluriactivity occurrence;
- Local production processing and marketing: farm shops or local distribution chains;
- Local purchase of inputs: inputs' origins and nature, purchase frequency;
- Collective dynamics on a local level, governance and shared values: stakeholders from the same local networks co/managing their own governance structures; according to share representations of common values and objectives in relation with land.

2. Looking at agroecological transitions in contrasting French territories

Let us consider transition in LFS through four contrasted cases from four different French areas. The differences of climate, ecosystems, and socioeconomic dynamics, determines some of territorial resources' various aspects. Two archetypal LFS define each of the four different territories: a "baseline", often a conventional system broadly spread, and an "agroecological niche" which represents an advanced and promising archetype of agroecological transition.

2.1 Territories description regarding territorial embeddedness and biodiversity mobilization

Mediterranean area in Languedoc

Languedoc is a patchwork of plains, scrublands and middle height mountains. It is a dry and windy area with Mediterranean climatic conditions. Rainfalls (600–1200 mm) are concentrated on heavy rain episodes and mostly shallow, rocky and poor soils.

Wine industry is located in the lowlands while specialized livestock farms are in mountain areas. Pastures, arable lands and vineyards represent the Usable Agricultural Area (UAA). On average in the region, farms are rather small (29 hectares of UAA), mainly due to small vineyards, fruit and vegetable farms. The main breeding system is agropastoralism, based on extensive grazing and feed inputs; and consequently these farms are larger. This territory has to deal with a dangerous exposure to climate change. Indeed, recent years' frequent and severe droughts have affected fodder resources availability threatening LFS's sustainability. We focus on mixed LFS as different in context as plains ones and hills-based ones, with various combinations of species including ruminants and monogastrics (Fuselier, 2019).

The baseline "Pig-Goat system – PGS" (UAA 70–400 ha, Organic farming and/or products with PDO label) relies on a network of mixed livestock farms combining goats for cheese production and pigs raised outside with by-products of cheese processing, and diversified crops.

The agroecological niche "Mixed Rangeland system – MRS" (UAA 90–1000 ha, Organic farming; robust breeds) defined by mixed livestock farms combines various herbivores and monogastrics. This niche only uses local resources and performs a high level of self-sufficiency. Both LFS types are engaged in agroecological transition, but the niche is above the baseline.

Territorial embeddedness is strongly guaranteed by a short supply chain and local economic empowerment. Diversified products are sold through direct sales or short supply chains (farm or local shops) which improves production added value and forges the bond with local consumers/citizens. Some farmers sell part of their products through long supply chains but always with a PDO label or niche markets such as luxury groceries or restaurants. Farmers often organize local supply for their feed inputs (hay from the area, or further like *Crau* hay about 200 km away). MRS use mainly local or regional by-products (*Camargue*'s rice straw, unsold fruits and vegetables from local shops). Whereas PGS can buy more standard feed (rapeseed cake) in remote areas, especially to ensure milk production for dairy ewes or goats. Pigs play an important role because they use local feed resources: whey from cheese production, acorn from wooded areas. Many of the farmers develop complementary activities, like hosting tourists or school classes, and provide their territory with services such as contracts for grazing against forest fires.

Biodiversity mobilization is higher for MRS than for PGS. MRS utilizes grazing on semi-natural pastures and rangelands of high nature value (Natural Parks, Natura 2000). The multiple livestock species allow to manage grazing in heterogeneous rangelands. Farmers often contract with biodiversity protection actors (Conservatories for natural areas, BirdLife NGO, etc.) to preserve patrimonial species (e.g. *Griffon vulture*, peat bogs' *Drosera*) or control invasive species (e.g. seagrass, *Russian olive* tree). Such cooperation can be rewarded directly or can be a commercial advantage. The choice of animal breed and the management of reproduction is carefully adapted to local constraints. While traditional sheep breeds (*Caussenarde des Garrigues, Raïole*) are still raised, *Highland* or *Galloway* cattle have been imported from United Kingdom for their rustic features well adapted to the harsh conditions of grazing in wetlands. In PGS, grazing areas and fodder sources are more frequent (permanent or temporary grasslands). Animal selection is often a combination of common and hardly breeds (e.g. crossbreeding *Duroc* pig with *Porc Noir Gascon*).

Oceanic area in Brittany

Brittany's livestock density is high. Climatic conditions and soil fertility, combined with land flatness guarantee a good growth of grass but also good yields on crops. Since the 1960s, the city of Rennes is the most densely populated area specialized in dairy production. Several international firms are implanted and trade on international markets. Strong supply chains and advisory services support high productivity livestock development with confined animals fed with maize and purchased concentrates. Environmental issues such as nitrate pollution and land degradation led to the development of alternative systems based on grasslands. Meanwhile the proximity of the city offers opportunities to develop organic production and local food network. Local policies aim to keep agriculture on the area and set up ecological networks (Couvreur et al., 2019; Petit et al., 2019a, b).

The baseline is "Maize dairy cow system – MDS" (UAA 40–180 ha, 7000–10500 kg milk per cow, mainly *Holstein* breed). Farmers look for higher work productivity, they develop cereal production and aim at increasing milk quantity per cow and stocking rate (above 1.7 $LU.ha^{-1}$).

The agroecological niche is "Grassland dairy cow system – GDS" (UAA 50–110ha, 3500–8500 kg milk per cow, mainly Holstein breed). Producers look for feed self-sufficient farms based on grass management (1.4 $LU.ha^{-1}$).

Territorial embeddedness is higher with GDS than MDS. The latter being the legacy of decades of structuring industrial dairy sector: genetic selection (*Holstein* breed), animal feed companies, product packaging, slaughterhouses, agronomic research (INRA experimental station located 8 km from Rennes), advisory structures and technical institutes. Maize and soybean meal have been introduced since the 1960s, along with *Holstein* breed, requiring high feed inputs. Feed production companies value cereals produced by dairy farmers and integrate imported soybean to produce cheap feed. MDS products are processed in the industrial sector, and exported outside Brittany (the rest of France and world markets). Like elsewhere, farm size increases and new areas are mainly devoted to increasing crop production.

GDS grew out of the Sustainable Agriculture Network in the mid-1990s. Alternative Farmers' Federation has given rise to grass-based farms that limit inputs and aim to achieve feed self-sufficiency and/or organic farming. A part of the advisory sector specializes in grassland seed (especially diversified grass and legume associations) and cover crop management methods. The inhabitants of Rennes are a good clientele for products from these farms, either through direct sales or by purchasing local organic products.

Biodiversity mobilization is medium in GDS and low in MDS. This latter ensures forage production with chemical inputs providing high milk yield, and concentrates purchase compensates the energy/protein imbalance. Environment is seen as a factor to be controlled. Nevertheless, crop rotation is diversified with winter and spring crops and temporary grasslands (mainly ryegrass and white clover). Crops are organized in 5-year rotations with pasture around the farm head, while distant plots can be dedicated to crop production as wheat, barley, rapeseed.

Holstein breed is the most common, embryo sexing occurs regularly, the main selection criterion being milk quantity of milk.

GDS also raises *Holstein* but here, selection criteria are multiple (longevity, milk quality, fertility, etc.), even sometimes carrying out crossbreeding. Meadows are the main cover and farmers adapt the sowing to soil characteristics. There are grasslands with fescue, others with orchard grass and also multi-species grasslands commonly grown in association with legumes, including clovers. Preserving grasslands as long as possible and developing patches of permanent meadow providing a heterogeneous landscape is a constant concern.

Semi-continental area in Aveyron

Aveyron is a southern Central Mountain region. The most original animal production being sheep milk, traditionally meant for "Roquefort" cheese production, especially famous for having been the first to obtain Protected Denomination of Origin (PDO) certification in 1925. For a long time milk production was limited to low-productivity limestone uplands called *Causses*. Traditional dairy sheep breeding has been modernized since the 1970s. Today's sustainability challenge is feed self-sufficiency improvement, targeted through intensification of meadows, native grassland use, milk production cuts, and milk price boost (Thénard et al., 2014; 2016, 2018).

The baseline "Foddering dairy sheep system – FSS" (UAA 35–235 ha, 215–375 kg milk per ewe) has a high level of animal productivity. Usually, milk is produced in winter and spring. Plant resources diversity is wide and farmers cultivate sown pastures for grazing and harvesting. This baseline with smaller farms and higher animal productivity is located in the western zone. Farmers frequently harvest grass silage.

The agroecological niche "Grazing dairy sheep system – GSS" (UAA 65–538 ha, 170–300 kg milk per ewe) is located in the southern zone with harsher agronomic conditions: drought in summer and a light soil. Farmers use more grazing and match milking period with grass growth. In summer, farmers use rangelands or wooded pastures to limit forage consumption. Many farmers are leaving the "Roquefort" PDO organization to free themselves from production constraints, developing alternative production systems and commercialization chains.

Territorial embeddedness is medium due to local "Roquefort" cheese production, but now partly standardized and industrialized. The notion of *terroir* determines PDO label and mobilizes both local biological resources (*Lacaune* sheep breed), natural caves for the maturing of cheeses and human know-how. Today, a high level of rural employment still depends on sheep's milk production. FSS has spread to the rich lands of the *Segala* in western *Aveyron* with high productivity based on feeding with grass silage, soybean meal and dehydrated alfalfa produced in *Champagne* region. Multinational companies collect the main part of milk production. Some of it is used for "Roquefort" cheese (45%), with most of it is processed into industrial products without quality signs, sold in globalized supply chains. Farmers' organizations have initiated a process of reflective thinking on technical and commercial alternatives to deal with this situation. GSS on the *Causses* produces milk mainly in summer and autumn, which is processed into yoghurts or local cheeses through a local cooperative. Agricultural development is very active in this region; livestock farmers are mobilized in the challenges of enhancing their territory's value, searching for local resources autonomy and added value.

Biodiversity mobilization is variable. Animal genetic resources are limited as only the *Lacaune* breed is authorized in accordance with "Roquefort" specification. The challenge is to renew the selection criteria to better adapt to the agroecological transition and increase genetic diversity. Plant resources diversity is lower in FSS than in GSS. All arable land had been ploughed for many years and forage crops are abundant. Intensification using nitrogen fertilizer has led to short-term monospecific and intensive sown meadows (Italian and hybrid ryegrass, red clover). Forage crops such as alfalfa are also very common, sometimes combined with grasses. Forage production objectives are mainly a higher degree of intensification for FSS and longer-term grasslands for GSS. Recently, repeated summer droughts have impacted grassland sustainability especially in GSS, pushing farmers to increase diversity of meadows and crops (multi-species mixture, selection of local seeds, cereal-legumes associations). In various areas where tillage is impossible (rugged areas, wetlands near the rivers, calcareous rangelands) GSS maintains natural grasslands, rich in biodiversity. Sloped woodlands are also sources of grazing, especially in summer or winter. Some of these natural resources are included in the UNESCO World Heritage area and as Natura 2000 areas for the wealth of their fauna and flora. The resurgence of wolves on the C*ausses* can be a source of concern.

Tropical area in Reunion Island

In *Reunion Island*, animal production serves to employ people and to contribute to food autonomy. Animal farming has developed in organized cooperative sectors that cover 24% (beef meat) to 94% (eggs) of local consumption. An important part of subsidies is dedicated to help farmers, cooperative and agro-industries increase productivity and compensate huge production costs due to the island remoteness. Because of agricultural area scarcity, LFS have been set up according to intensive models and many inputs. These models are hardly compatible with organic farming and the elevated price of animal products is not an incentive to change. However, cow, calf and goat breeding are important users of local forage resources (grazing and mowing). Goat production is mostly a complementary activity, representing 10–50% of the total income. There are different systems, from multi-active or backyard farmers with few animals to large herds (30–100 goats) (Fontaine et al., 2010). Most of professional farms mix crop culture (sugarcane, market gardening, and arboriculture) with animal breeding (bovine meat, pig, poultry).

The baseline "Tropical Mixed livestock system – TMS" (UAA 5–60 ha, 20–100 goats-*Boer* breed), is based on a mixed indoor x grazing system. This is conventional farming with diversified production: meat (goat, cattle, pig, poultry) and crops (sugarcane, meadows, etc.).

The agroecological niche "Tropical Garden livestock system – TGS" (UAA 1–8 ha, 10–30 goats *Creole x Boer* breed) is based on small farms gardening and rearing goats for income diversification and manure availability. TGS intents improving its self-sufficiency.

Territorial embeddedness: Goat breeding is a diffuse animal husbandry rooted in the local society. Goat animals or meat (including cull goats) is a highly sought-after production sold through local food networks (direct sale and traditional butcheries). It is the basis of the island's traditional dish (*cabri massalé*), and a product for ceremonial slaughter (e.g. for the Tamil community needing well-conformed goats) (Fontaine et al., 2008).

Favorable valorization of animals allows feed purchase (hay and concentrate). There is a great diversity of practices and systems, from self-sufficient with low use of concentrate and veterinary products, to high dependency. Breeders having small agricultural areas use natural forage resources from outside of the farm (mowing grass on roadside, grazing wasteland and savannah) or buy hay (to lowlands' producers). Some systems are, however, highly dependent of imported concentrates (especially for fattening male goats). Breeding sector is mainly organized in the cooperative model with slaughtering and manufacturing facilities to ensure mass retailing. In this system, goat meat is not profitable enough because imported frozen meat is cheaper; recently a goat cooperative was forced to close. Farmers are weakly organized for marketing products with high demand.

Biodiversity mobilization: In comparison to other productions developing on a "technological package" pattern, goats are using the greatest diversity of forage resources with (i) natural resources, (ii) cultivated resources mowed (elephant grass, temporary meadows for hay) or grazed (pasture), (iii) forage crops (maize) and (iv) by-products (sugarcane tops and straw). Farms with several species of livestock are common as sheep and goats are a diversification form for the rearing of cattle or monogastrics (pigs or poultry). The local goat breed *Pei* is hardy (good mothering abilities, prolificacy, etc.), and is well suited to the environment. However, this breed with small size does not correspond to current expectations (well-conformed goats for ceremonial slaughter). *Boer* breed was imported from South Africa and produce better conformed goat. Finally, goat population is mainly crossbreeding *Pei x Boer.*

Goats are mostly bred in housing, with trough fed with green fodder or hay supply. The small size of the herds, diversification and multiactivity complicate grazing practices all the more because of the constant monitoring required by stray dogs or animal thefts issue. However, grazing is applied for large herds, on cultivated meadows or on natural resources. A research project is underway to find an opportunity to manage savannah with cattle and goat grazing.

2.2 Agroecological LFS multi-criteria assessment

Assessing LFS agroecological performances requires surveying complex ecosystem functions. For this, normative methods such as Life Cycle Assessment (de Vries and Boer, 2010) are less relevant than multicriteria approaches studying jointly natural resources, ecosystem services, health management, socioecological resilience, etc. (Affholder et al., 2019). We focus on the agroecological functioning dimensions that are directly connected to farmers' practices (Thénard et al., 2016; Magne et al., 2019). We thus assess LFS through four dimensions and nineteen corresponding indicators (Fig. 1). This set of indicators determines the extent to which LFS implement the principles of agroecology by mobilizing biodiversity-based processes, recycling energy and nutrients, improving diversity and connectivity on the farm and on local territory (Dumont et al., 2013; Bonaudo et al., 2014; Thénard et al., 2014). Best scored are LFS which boost agroecological management principles: soil fertility increase, chemical inputs restriction, farm autonomy improvement, integrated crop management and animal diversity promotion.

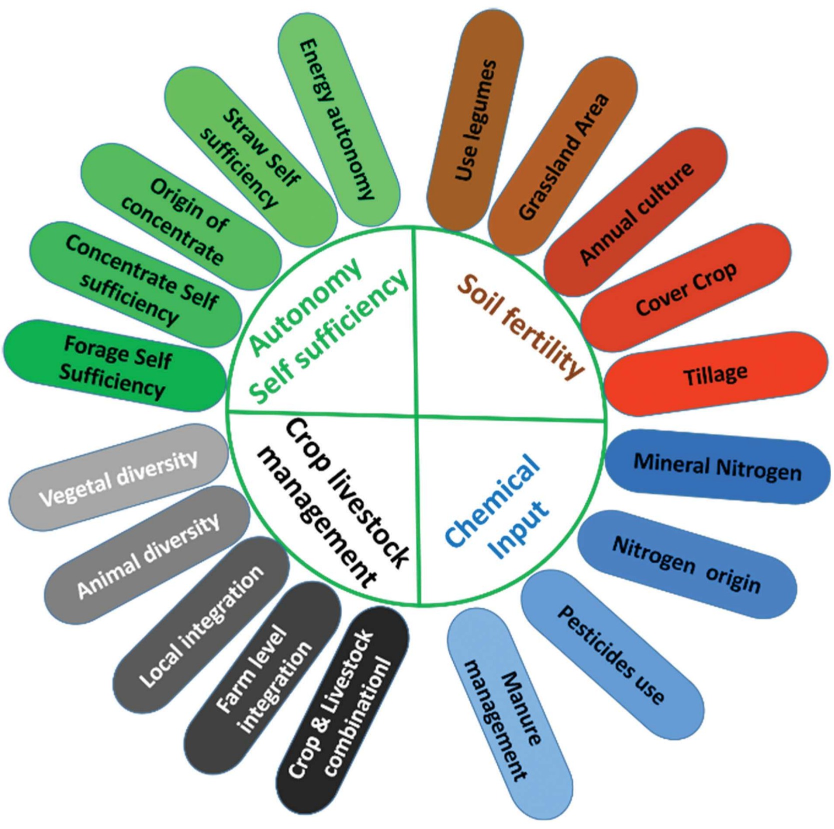

Fig. 1: Indicators used to evaluate the LFS according to the four agroecological performances. Adapted from Magne et al. 2019.

3. From mobilized resources to LFS agroecological performances

3.1 LFS archetypes in case studies

Inspired by Therond et al. (2017), we have placed the eight LFS archetypes on a factorial map (Fig. 2) according to the four types of resources (cf. §1.1) mobilized by each one. The horizontal axis represents the system's territorial embeddedness and the vertical axis shows biodiversity integration level. Archetypes draw a diagonal from less (MDS) to more (MRS) anchorage in the territory and biodiversity-based. Despite differences of resources used between regions and systems, this representation allows positioning the production systems in an agroecological gradient. For each territory, niche systems – all located in the right and top quarter- logically turn out more advanced in terms of biodiversity integration and territorial embeddedness than the baseline, but significant differences

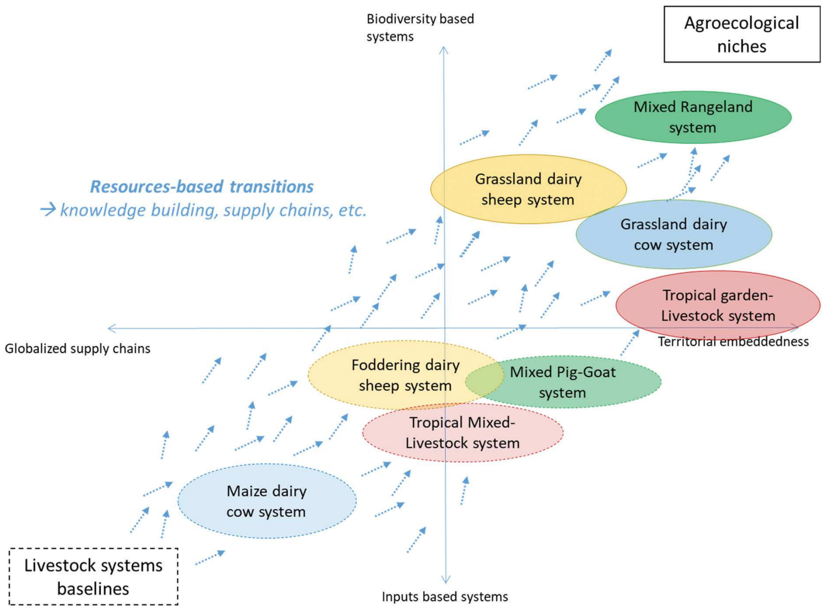

Fig. 2: Position of the eight LFS archetypes on a factorial map. The dotted arrows show possible pathways for transitions towards agroecological systems, independently from any unique roadmap. Adapted from Therond et al. 2017.

also appear within and between regions, underlying that trajectories and targets are context dependant. In order to understand how the systems have been placed on the map, we will study resources used in each case study and by each archetype in the next paragraph.

3.2 Mobilized resources in the case studies

LFS always rely on a combination of natural (ecosystems), technical (animal breed and management skills), economic (markets) and social (networks, support from local stakeholders) resources (Figs. 3, 4, 5, and 6).

Languedoc's mixed farming systems combine nature-oriented ecosystems, strong products valorisation and knowledge-sharing networks.

In *Languedoc*, both types of LFS use of rangelands, scrublands and more (MRS) or less (PGS) natural grasslands (Fig. 3). They rely on different social networks to access grazing areas, technical advice or local support: farmers' associations, local stakeholders such as forest managers

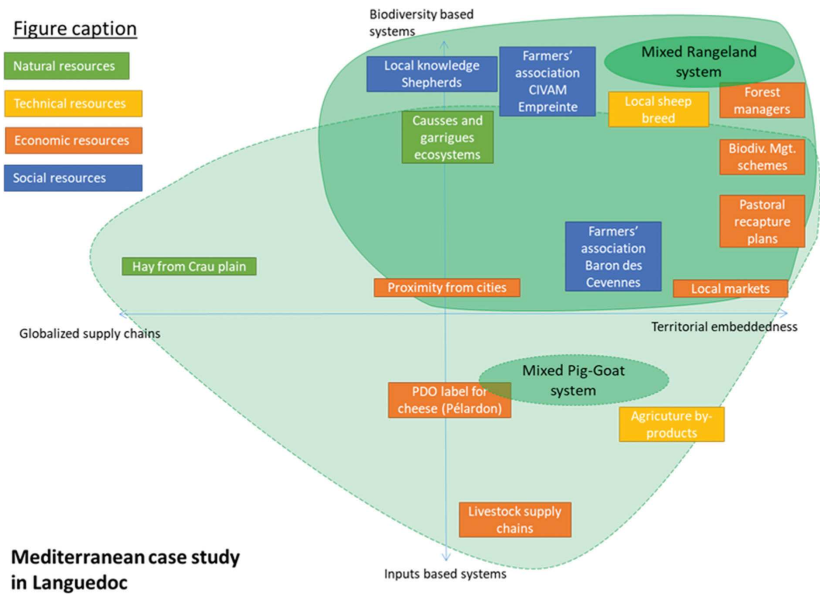

Fig. 3: Resources mobilized in the Languedoc case study.

or nature conservation societies. Farmers partly or fully sell their products through direct sales or local food networks, thus increasing benefits (Fuselier, 2019). Besides, subsidies from the European Common Agricultural Policy (CAP) largely contribute to their income, together with additional supports from territory stakeholders including indirect economic gain such as free access to grazing areas, or rewarded environmental services. Local stakeholders legitimize their LFS communicating on their importance to manage ecosystems and to preserve biodiversity.

The social networks linked with these two LFS permits the exchange of experience and knowledge, and increase collective support and share objectives.

The *Baron des Cévennes* society helps marketing pig products (ham and sausages) of PGS which is more oriented on commercial purposes. The center of rural initiatives (CIVAM) "*Empreinte*" promotes the defense of common values and a specific vision of the profession. Both groups also exchange resources such as breeding animals, equipment, work for organizing transhumance, etc. PGS sells "*Pélardon*" PDO cheese in long supply chain and need to use resources less embedded in local territory, like hay from the *Crau* plain (150 km away), feed from suppliers, but also a part of external inputs, like by-products, supplied by territory (e.g. unsold fruits or vegetables fed to the pigs).

Brittany's dairy systems promote intensive LFS products to local consumers with labels.

In *Brittany*, oceanic climate and good soil fertility are favorable to all kinds of resources for both systems (Fig. 4). On one hand, MDS produces maize needing water, on the other hand GDS promotes grass growth in spring and autumn. However, MDS has also a high use of feed from local companies with imported concentrate and by-products of the local agro-food sector. Both systems integrate genetic *Holstein* breed selection, but with different selection criteria. MDS targets milk high quantity and fertility whereas GDS looks for milk quality, robustness of cows and fertility. Both systems can use the "*Bleu Blanc Coeur*" label as an economic resource based on milk composition without specification of practices. For that, MDS uses inputs such as extruded flaxseed, while GDS achieves milk composition thanks to grass use.

MDS milk is mainly produced for the world market (milk powder, cheese, conditioned milk). GDS milk can be sold through cooperatives

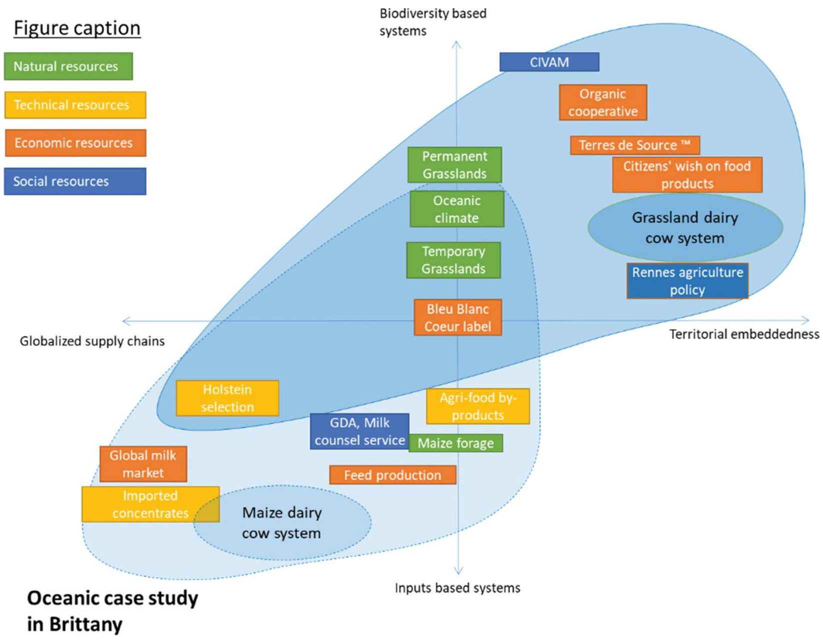

Fig. 4: Resources mobilized in the Brittany case study.

specialized in organic agriculture or through local food network thanks to Rennes' inhabitants demand. The city recently launched a new specification called "*Terres de sources*." The brand is based on a sustainability score which must be greater than a minimum threshold, and the commitment to improve its value over a period of 5 years. This new possibility of promotion can be seized by both systems but the expected score is better achieved by GDS than MDS.

Finally, the two systems mobilize different consulting networks. CIVAMs support GDS' farmers by providing advice on grass management and low-input dairy production, while mainstream advisory bodies provide advice on milk productivity, fertilizer use or legumes integration to complement maize silage.

Aveyron's dairy sheep systems combine intensification of milk production and feed self-sufficiency thanks to a wide variety of plant resources and a strong network for farmers' advice.

In *Aveyron*, vegetal diversity is important and "*Roquefort*" PDO label encourages local resources use (Fig. 5). The intensification of milk production has led to an increase in inputs purchased mainly on the world market (nitrogen fertilizers, seeds, soybean meal, and dehydrated alfalfa) which are used by both systems. However, GSS farmers are trying to improve feed self-sufficiency and therefore use more local resources produced from diversified grasslands and native grasslands.

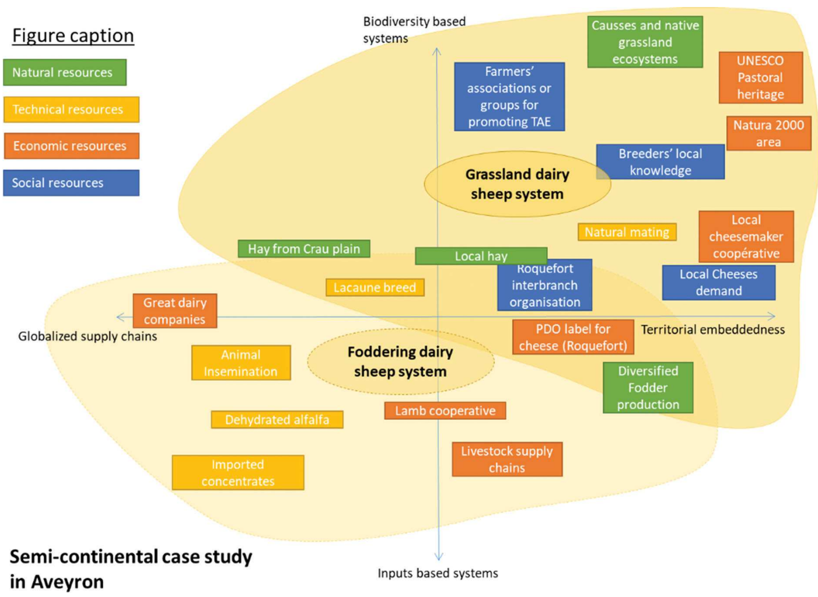

Fig. 5: Resources mobilized in the Aveyron case study.

The *Lacaune* breed is common to both systems. All farmers who participate in breed's genetic selection use animal insemination. GSS looks for other features like the robustness of animal well adapted to "extensive" breeding and grazing. In organic production, farmers use natural mating and look for compatible rams. All the farmers involved in Roquefort cheese production deliver their milk to manufacturers operating on the world market. Paradoxically, cheese production is strongly embedded in its territory, but the major actors of dairy industry sell it worldwide. Some GSS farmers have also set up a cheese cooperative in order to enhance the value of summer and autumn milk production from animals grazing on local native grasslands.

Strong farmers' organizations and a wide range of technical support focus mainly on milk production (quality, quantity, animal feed). Farmers' groups supported by technicians design and test new agronomic practices based on local knowledge of grazing, forage cultivation or conservation agriculture. In the southern area, different actors (farmers, technicians, advisors, researchers) have recently created an "AgroEcolab"network to support local agroecological transition.

Reunion' goats are a diversification source of income with a good added value combined with a high cultural embeddedness.

In *Reunion* LFS rely on two main resources: goats ability to promote natural resources and their strong profitability on local market (Fig. 6).

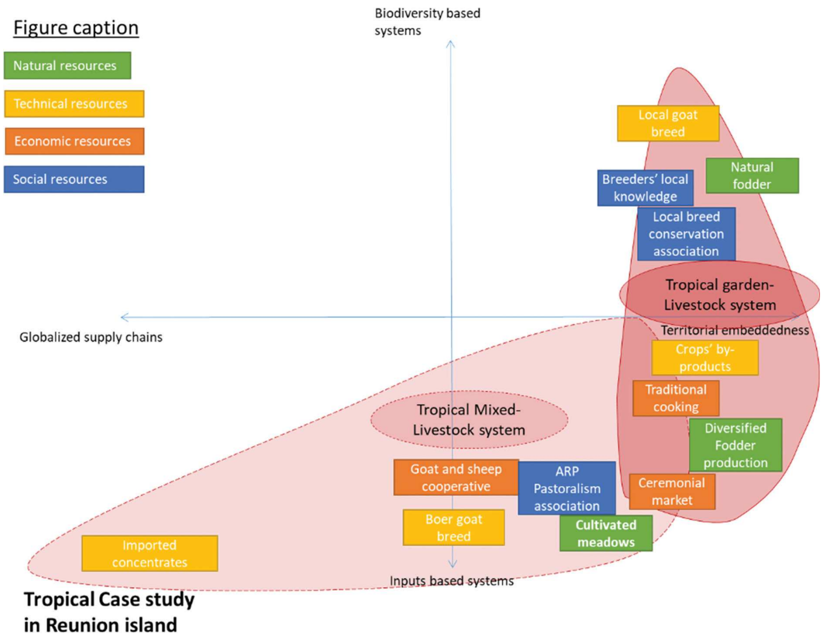

Fig. 6: Resources mobilized in the Reunion case study.

Fodder and by-products are the basis of animal feeding, but while TMS is developing a productive strategy to valorize long-term temporary grasslands; TGS opts for a multifunctional strategy of crops by-products and natural grass. Nevertheless, most farms use a large amount of concentrates from imported resources for lactating and fattening goats. The products' high profitability is due to direct sales for ritual slaughtering (for males) or short supply chains (butchers) for culling. The high costs of concentrate should not be considered only through its economic angle, but as a mean to obtain an expected conformation of animals. Moreover, cooperative market is weakly developed because of lower selling price.

There is a lack of a farmer's association which could create a real social dynamic, and this leads to a lack of technical advice. However, TMS benefits from access to services related to organized and conventional sector (Pastoralism Corporation, agriculture chamber, feed provider, financial companies, etc.). TGS relies more on a neighborhood network to access to resources like natural or cultivated fodder. Unlike cattle or sheep farming, goat farming often does not seek CAP subsidies or environmental services because the ratio between the small monetary amount and additional regulatory constraints is not attractive.

For both systems, goat genetic resources are crucial. TMS should be more oriented on imported *Boer* breed with high-quality carcasses. TGS would need a more robust breed with mother abilities and hardiness (as such *Pei*, *local breed*). In fact, crossbreeding has largely been used threatening the local breed. From this perspective, agroecological transition is limited by local breed's lack of a breeding scheme and the weak involvement of farmers in breeders' associations.

3.3 LFS agroecological performances in contrasted territories

LFS agroecological performances (Fig. 7) appear to be correlated with the level of biodiversity-based practices, first of all in most extensive systems based on natural grasslands (GDS, MRS, PGS). These systems reduce chemical inputs levels and improve soil fertility management at the same time, but trade-offs between the two criteria must often be sought, like FSS using herbicides to reduce soil tillage. Farms' autonomy is stronger for GSS, based on an intensification of forage production and optimal use of grass resources. Besides, farm's autonomy is hampered by limited productivity (in

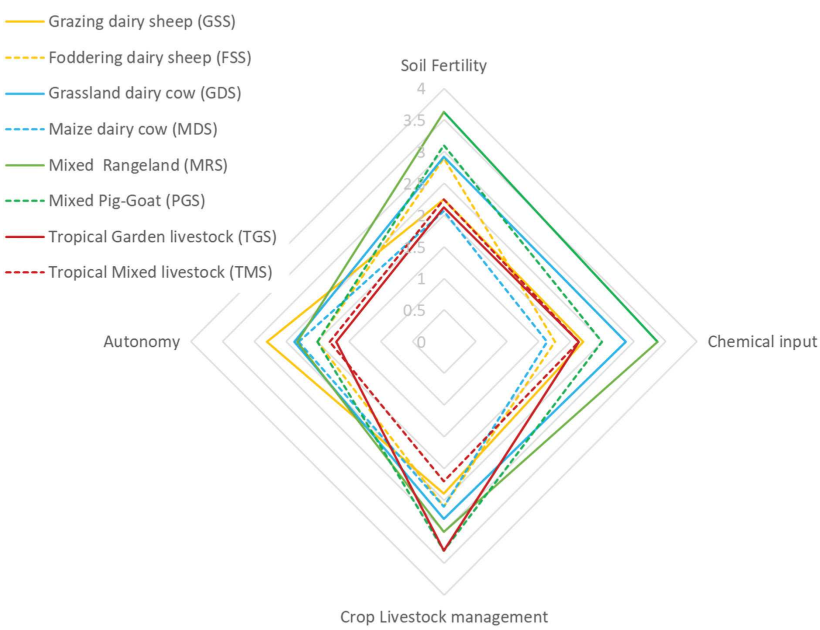

Fig. 7: Assessment of four agroecological performances for different systems.

extensive native grassland) or limited availability of land (in Reunion Island), which require to import feed and concentrates.

The crop-livestock management score arises from many combinations linked with animal and plant diversities and their integration. Dairy systems (cows and sheep) have a low level of animal diversity offsets due to a diversity of crops and forage resources. Tropical systems embody both extremes values: TMS has a very low value of plants and crops diversity while TGS is very integrated and diversified. Despite the weakness of legumes use in forage, use of manure for gardening is a cornerstone of Crop-Livestock integration.

This analysis highlights generic patterns for adapting agroecological systems to local conditions, and resource availability or constraints, leading to performance trade-offs.

Extensive systems could improve most of criteria, but with lower agricultural production. Feed self-sufficient system limits feed purchases, but not chemical inputs for forages and crops production. A highly diversified system increases integration and combination of animal and plant species without improving soil fertility and reducing the use of chemical inputs.

4. Learnings and perspectives

4.1 What resources analysis tells us about transition dynamics?

Studied LFS are based on a broad gradient from inputs-based systems in a globalized market to biodiversity-based systems deeply embedded in the territory. The position of these systems in this gradient results from individual objectives and strategies of mobilization of resources, and stakeholders interacting strategies influencing LFS territorial integration and short or long supply chains organization (Nguyen and Purseigle, 2012).

Our work illustrates how natural, technical, economic and social resources determine biodiversity-based systems' implementation and territory embeddedness. Farmers and local stakeholders build alternative sociotechnical niches based on local resources, networks and new forms of legitimacy, which justify their local relevance (Geels and Kemp, 2007).

A first learning is that the localized power relationships between stakeholders led to specific agroecological transition trajectories. The social capital (Coleman, 1988) and actors' abilities to coordinate properly also influences the baseline and agroecological systems, due to actors defining their own technical standards based on common values and objectives (e.g. the use of improved vs. rustic animal breeds). The technical and managerial strategies are therefore oriented towards certain resources: some are shared between baseline and agroecological systems, but many are specific. In our examples, local breeds, adapted to climate and local fodder resources, could be "open" resources accessible to all farmers, but are currently linked with specific networks. These include access to breed associations to procure the animals, experienced breeders, technical advisors and/or researchers to gain adequate knowledge in order to adapt management practices, commercialization channels for specific products such as labeling and branding. Success has been achieved with public support for breed maintenance (i.e. *Raïole* sheep in *Languedoc*).

The second learning is that some sets of resources become mobilized in open-ended transitions, without a determined model to follow. For instance, *Aveyron*'s LFS can follow four pathways using natural resources in different ways (Thénard et al., 2018). *Languedoc* and *Reunion* LFS diversify technical options with several species and breeds combined differently at farm level. The use of *Crau Hay* can be an opportunity to secure feed supply in case of difficult years in LFS that are usually feed self-sufficient (e.g. GSS in *Aveyron*), or to structurally provide feed (e.g. PGS in *Languedoc*). In each LFS, each breeder builds his own system according to available resources in a relatively unique combination, but with common principles.

The third learning is that specific resources can lead to determinist transitions in the sense that they exclude some types of systems (e.g. incentives from Natura 2000 policies, local breeds in *Reunion* only for agroecological niches). Other specific resources stay out of some LFS scope (e.g. in *Brittany*, the baseline system does not consider permanent grassland as productive resource and therefore does not use it). Rules such as PDO specifications or local incentives as "*Terres de sources*" determine which LFS is in or out of agroecological transition pathways, as they structure the set of accessible resources.

The final learning is that even a determinist transition can induce a more general transition. In *Brittany*, for example, organic milk cooperative started advising on grassland management, providing knowledge to all farmers around. This type of knowledge has been built within agroecological niches, but it also has been made accessible to baseline systems, authorizing hybridizations and new pathways to be developed. Flexibility can be found in these "middle way" resources, For example, performance obligation in *Bleu-Blanc-Coeur* and *Terres de sources* certifications. Even organic farming, based on an obligation of means, will not mobilize the same mix of resources according to the territory.

In conclusion, each system in transition will try to mobilize different resources, moving towards greater use of diversity and stronger territorial anchorage. In a territorial perspective, maximizing socio-agroecosystem productivity can be achieved by combining different LFS, as each one only promotes a specific part of territorial resources. The degree of local-specificity, resource availability and the sociotechnical networks will influence agroecological transitions in a more determinist or open-ended way.

4.2 LFS agroecological transitions perspectives

Our approach to define sustainable LFS is based on agroecology main principles as applied to animal production (Dumont et al., 2013). To implement these principles in order to help farmers change their practices, a first methodological development was carried out in the *Aveyron* case study (Thénard et al., 2014, 2016, 2018). The present work is an attempt to widen the methodology by testing and adapting the indicators to a set of contrasting territories. The approach allowed assessing different LFS ranks of advance in agroecological transitions, and described the set of resources mobilized, possible changes considering available resources and those to be developed.

Comparing four contrasted case studies reveals similarities and specificities of the various territories, and allows identification of pathways and options to check adequate resources and unlock agroecological transitions. A further perspective is to assess robustness and vulnerability of key resources to the hazards and possible changes.

Today, agroecology implementation is mainly considered at farm level because it affects farmers' practices and personal willingness for change. However, farms partnership offers opportunities to access and manage equipment, labor and material resources, used in agroecological transitions (Lucas et al., 2019). Despite widespread use of agroecology concepts amongst professional and political bodies, a gap remains between rhetoric and practices of implementation on farms. To assess the possible changes and transitions in farms, territorial resources inquiry seems promising, to: (i) activate resources and to favor the emergence and diffusion of innovative practices, (ii) design adequate public policies to support adequate systems, and (iii) involve consumers and citizens. In these ways, societal expectations and controversies around animal husbandry practices and animal welfare could also play a part in LFS transformations towards agroecological perspectives.

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