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The emergence of agroecological practices on agropastoral dairy farms in the face of changing demand from dairies

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Description of the subject. Today, the dairy sector is facing economic, social and environmental challenges. Agroecology seems to be one way of meeting those challenges. However, dairy market demand in terms of volume and supply periods may not be in line with an agroecological transition. Breeders must respond to the production conditions fixed by dairies.
Objectives. We analyzed to what extent dairy farming practices are changing in two agropastoral territories after a change in the dairy process or supply period, and whether changes in practices induce a stronger uptake of agroecological practices or, on the contrary, a shift towards more conventional intensification of those practices. We were thus able to see if and how these livestock farming system dynamics contribute to and fashion agroecological transition in dairy production, in response to changes in local contexts.
Method. To highlight the evolution of breeders' practices, we interviewed 41 dairy ewe farmers in the South of France and dairy cattle farmers in Western Burkina Faso. We then proposed a normative approach to evaluate to what extent changes in practices corresponded to an agroecological transition. For that purpose, we proposed a grid to analyze local practices in combination with agroecological principles. We evaluated practices before and after changes to the supply period or the dairy market.
Results. In each of the territories studied, four trajectories emerged, some of which were part of an agroecological transition. The results showed that the market plays an important role as a driver of transition, in particular in situations of organic production, or limited access to inputs. Other drivers, such as resource management schemes, lead to changes in practices on rangelands towards a reduced use of pastoral resources.
Conclusions. In these highly contrasting contexts with different issues, such as food security and land accessibility, farmers bring into play practices according to agroecological principles that appear to respond to the local situation.
Keywords. Agroecology, ruminants, farming system, agropastoral system, milk, Mediterranean, West Africa.

L'évolution des pratiques vers une transition agroécologique : un défi pour les producteurs laitiers mobilisant des systèmes agro-pastoraux
Description du sujet. Aujourd'hui, le secteur laitier est confronté à des défis économiques, sociaux et environnementaux. L'agroécologie semble être une voie pour répondre à ces défis. Cependant, les injonctions du marché laitier en matière de volume et de période d'approvisionnement peuvent ne pas aller dans le sens d'une transition agroécologique. Les éleveurs doivent répondre aux conditions de production fixées par les laiteries.
Objectifs. Nous avons analysé dans quelle mesure les pratiques de production laitière évoluent dans deux territoires agropastoraux après un changement de laiterie ou de période d'approvisionnement et si les changements de pratiques sont en phase avec les principes qui sous-tendent l'agroécologie ou, au contraire, avec une intensification plus conventionnelle de ces pratiques. Nous avons ainsi pu voir si et comment ces dynamiques d'élevage contribuent et façonnent la transition agroécologique dans ces territoires, en réponse aux changements des contextes locaux.
Méthode. Pour mettre en lumière les trajectoires de pratiques des éleveurs, nous avons réalisé des entretiens auprès de 41 producteurs de lait de brebis dans le Sud de la France et de lait de vache dans l'Ouest du Burkina Faso. Ensuite, nous proposons une approche normative pour évaluer dans quelle mesure les trajectoires de pratiques correspondent à une transition agroécologique. Pour cela, nous proposons une grille d'analyse des pratiques locales en lien avec les principes de l'agroécologie. Nous évaluons les pratiques avant et après les changements de période d'approvisionnement ou de laiterie.
Résultats. Dans chacun des territoires d'étude ont émergé quatre trajectoires dont certaines sont en phase avec les principes de l'agroécologie. Les résultats montrent que le marché joue un rôle important en tant que moteur de la transition dans

les situations de production en agriculture biologique ou de faible accès aux intrants. D'autres facteurs conduisent à des changements de pratiques de pâturages et à une réduction de l'utilisation des parcours.
Conclusions. Dans ces contextes très contrastés, des questions telles que la sécurité alimentaire et l'accessibilité des terres conduisent à mobiliser des pratiques en lien avec les principes agroécologiques qui semblent répondre à la situation locale.
Mots-clés. Agroécologie, ruminant, système d'élevage, agropastoralisme, lait, Méditerranée, Ouest de l'Afrique.

1. INTRODUCTION

On a global scale, dairy farming displays a wide diversity of systems. The dairy sector is facing numerous challenges. It is involved in world food security: production is increasing to satisfy rising consumption. It provides income for dairy farmers and maintains economic activities in rural zones, but livestock farming is criticized for its adverse environmental effects (FAO, 2006; Gerber et al., 2013). These challenges take various forms in different regions of the world. In developed countries, intensive livestock farming also raises consumer health issues, notably through the development of resistance to antibiotics (Stanton, 2013). In developing countries, such as some African countries, consumption is outstripping production. To guarantee national food security, it is necessary to increase the quantity of food by relying on local resources in order to preserve the environment and the health of populations (Touzard & Temple, 2012; Temple et al., 2015).

Nevertheless, livestock offers the potential to contribute to agroecological transition. Dumont et al. (2013), adapted from Altieri (2002), proposed the following five principles to characterize the agroecological dimension of livestock farming systems:
– integrated healthcare management;
– reduced inputs for production requirements;
– reduced pollutants through optimized metabolic functions;
– greater diversity to strengthen resilience;
– preservation of biodiversity.

Hence, the question of whether the dynamics of change in those agropastoral dairy systems driven by the dairy process reinforce agroecological practices, or lead to conventional intensification, remains pending. Work on livestock agroecology mostly focuses on mixed crop–livestock farming systems (Bonaudo et al., 2014). These five principles of adapted livestock practices seem to be applied, at least in part, by pastoral livestock farmers. In particular, in the case of pastoralism, interactions between animals and their environment are strong. Breeders rely on diverse species and locally adapted breeds, and on multiple forms of mobility (seasonal, commercial, labor) (Gliessman & Engles, 2015; Soussana et al., 2018). In tropical areas and in the Mediterranean, a large share of milk production still comes from small farms using rangelands, in agropastoral systems. Agropastoral farming uses a range of feed resources, derived from spontaneous vegetation or recycled crop residues, and from local ecological knowledge (Gobindram et al., 2018). However, as highlighted by Jouven (2016), the reality is more complex, as grazing practices are only one component of livestock and cropping practices.

Looking beyond the status of a system at a given time, we need to consider how the whole system evolves. This evolution can be qualified in terms of implementing practices seen from an agroecological perspective, *i.e.* to what extent those practices make use, or not, of ecological levers to support production. Indeed, in both Europe and Africa, farmers are changing their farms, notably by implementing innovations having different origins, such as farmers, professional groups, technical support systems, policies (Ingrand et al., 2014). Vall et al. (2014) described changes and innovations in Burkinese livestock systems receiving technical support (government dairies, milk powder taxation) that encouraged breeders to use cross-breeding and artificial insemination, and to produce forage and purchase feed in the dry season. The socio-technical regime in which agriculture finds itself makes alternative innovations difficult, although they do exist (Stassart et al., 2012). Emerging of innovant practices (Meynard, 2017; Lacombe et al., 2018) permit to rethink of farming systems towards agroecological transition (Tittonell, 2014).

We analysed to what extent dairy farming practices were changing in two agropastoral territories after a change in the dairy process or supply period, and whether changes in practices induced a stronger uptake of agroecological practices or, on the contrary, a shift towards more conventional intensification of those practices. We were thus able to see if and how these livestock farming system dynamics contributed to and fashioned agroecological transition in those territories, in response to changes in local contexts.

2. MATERIALS AND METHODS

2.1. Description of the chosen territories

Ewe breeding in the Grands Causses area of France. In the Grands Causses area of France (GCF) (**Figure 1**), the production of ewe's milk and its

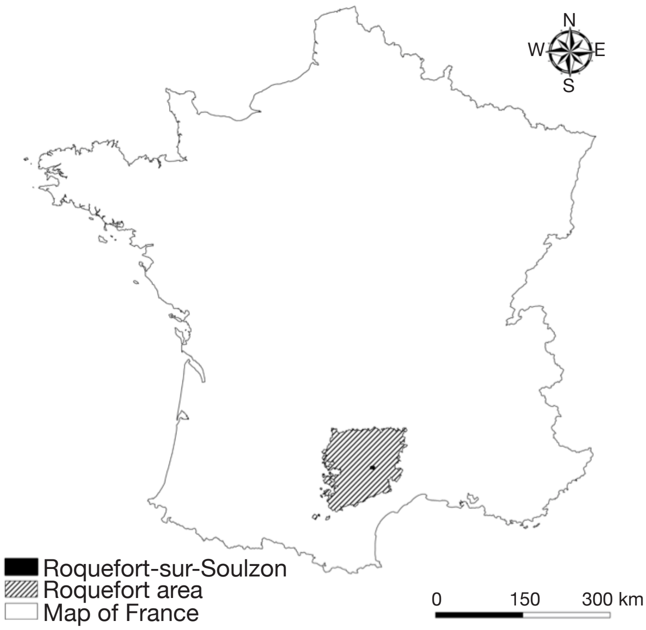

Figure 1. Geographical location of the roquefort cheese area in France (produced by Imad Shaqura) — *Situation géographique du bassin de production de roquefort en France (réalisé par Imad Shaqura).*

processing into Roquefort cheese have a long, shared history. Since 1925, roquefort cheese has benefited from protected designation of origin status. In 2014, technical organizations in the roquefort area were accompanying around 80% of dairy farmers, and 56% of the territory's dairy sheep farming systems were self-sufficient in fodder. Improving the genetic potential of ewes, coupled with appropriate feeding, increased milk production from an average of 210 litres per ewe in 2000 to an average of 239 litres per ewe in 2014. These extension services assisted dairy farmers by offering technical support (feed), technical/economic advice and genetic monitoring (Morin et al., 2016).

The dairies now collect milk all year round, seeking to stagger production on dairy farms. In the past, the soil and climatic conditions, in particular, fashioned the local livestock farming systems, with highly seasonal milk production (December to July). The milking period plays a role in structuring livestock systems, leading farmers to vary their feeding practices and use of pastoral resources (Quetier et al., 2005), depending on the production period. This change has led farmers to adopt different feeding strategies. Depending on the production period, the strategies differ, which has had an impact on feeding and grazing practices, particularly on the development and use made of pastoral resources. Livestock producers have adopted two main feeding strategies, based on fodder stocks and grazing (Quetier et al., 2005).

Some farmers have implemented different practices aimed at encouraging forage production adapted to drought and increasing the value of rangelands (Allézard et al., 2014; Magne et al., 2019). Other farmers have labelled their farms "organic", and then changed their dairy process to sell organic milk (Magne et al., 2019). Magne et al. (2019) characterized four types of livestock systems from these practices:

- economical systems producing over a short period of time by exploiting available local resources, limiting fodder and concentrates;
- breeders, whose objective is to produce milk on grass by exploiting undiversified productive fodder resources. These farmers buy protein concentrates to optimize the genetic potential of Lacaune ewes, but they are self-sufficient in fodder;
- farmers who produce organic sheep milk by making the best use of the diversity between animal and plant biological resources. They purchase concentrates and fodder;
- farmers who produce milk over a long period in winter and summer. They seek to optimize the use of available harvested fodder resources and to use pastoral areas in summer.

High milk production levels offset the purchase of protein concentrates. However, not all farmers have followed this movement.

Cow breeding in Western Burkina Faso. In the Western Burkina Faso (WBF) area (**Figure 2**), the authorities have been implementing programs to support milk production since the 1990s (Hamadou et al., 2008), by backing "public" dairies, which were subsequently privatized. At the same time, some private dairies also developed, and that model appeared to be more resilient (Duteurtre, 2007). These small dairies have an average processing capacity of 200 to 300 litres per day (Sib et al., 2017). Four producers supply 100 litres of milk per day on average. Including producers and collectors, the dairies that use local milk hire twice as many people as dairies that exclusively process powdered milk (Orasmaa, 2017).

Some initiatives to improve milk production, supported by state extension services, focused on fodder production, use of feed inputs, and crossing local animal populations with European breeds, by artificial insemination. With the depletion of available grazing areas, initially transhumant livestock farmers tended to become sedentary, but the uptake of techniques recommended by supervisors remained limited (Dongmo et al., 2012), with only one percent of breeders adopting intensification schemes (Hamadou et al., 2008). Intensified farms require high investments in buildings and equipment. They are generally managed by farmers who invest while maintaining

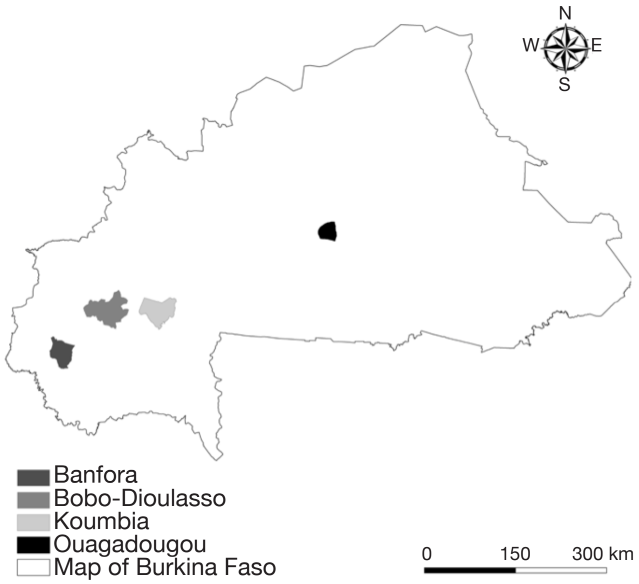

Figure 2. Geographical location of the farms studied in the areas around Bobo-Dioulasso, Koumbia and Banfora (produced by Imad Shaqura) — *Situation géographique des élevages laitiers étudiés autour des communes de Bobo-Dioulasso, Koumbia et Banfora (réalisé par Imad Shaqura).*

another professional activity (tradesman, civil servant, vet). Agropastoral farming systems of 5–11 ha account for 7% of the production units, while pastoral farming systems, with less than 1 ha, remain in the majority (92% of the production units) (Hamadou et al., 2008). Recently, Sib et al. (2017) described five types of dairy farming systems based on structural, functional and performance variables. Types 1 and 2 are low-input with suckler-cow farms, with high (T1) and medium (T2) pastoral inputs. T1 and T2 farms are characterized by a diet mostly based on grazed resources in all seasons, with a production level of less than 2 litres per cow per day, mainly for family consumption. Type 3 consists of suckler farms with an agropastoral orientation. These farmers make greater use of dry fodder and feed, which allows them to sell about 2 litres of milk per cow per day. Types 4 and 5 are specialized in milk production. The proportion of distributed fodder and concentrates in the ration is high all year round. Some have low use of green fodder (T4) and others have high use (T5). These farmers crossbreed dairy cows with improved genetic dairy potential, allowing them to sell 5–13 litres of milk per cow per day to dairies.

2.2. Sampling

The aim of the sampling process was to interview dairy farmers who had changed their practices to meet the demands of the dairies. We used a snowball sampling method, conventionally used in qualitative research in the social sciences (Goodman, 1961), turning to dairy farmer knowledge networks to identify people having made changes. Thus, sampling was not representative of the "population" of dairy farms in the two study areas, but maximized the diversity of changes in practices linked to demands from the dairies.

For the GCF area, through various professional networks, we identified a few dairy farmers who had changed their milking period, or their sales channel. Those farmers then informed us of other farmers who had made the same type of change. In order to make up the sample, we also sought to recruit farmers with a diversity of production (conventional or organic) and/or marketing schemes (milk sold to companies for Roquefort production or other manufacturing, or on-farm processing and short sales channels). In all, 21 dairy farmers were interviewed (**Table 1**).

For WBF, in the small agricultural regions of Bobo-Dioulasso, Koumbia and Banfora, the producer groups identified three dairy farmers. The initial three farmers informed us of other farmers who had made changes in their sales channel and who now regularly sold milk to a dairy. Here too, we sought to recruit a sample of dairy farmers with diverse types of production and marketing schemes, according to the typology of Sib et al. (2017). At some point in their lives, all the farmers had sold milk to dairies and cultivated cereals for the family. A sample population of 20 farmers was established (**Table 2**).

2.3. Data collection

We carried out semi-directive interviews lasting from 1.5 to 3.5 h per farm. In Burkina Faso, an interpreter translated the interviews with the farmers. The first

Table 1. Structural description of the 21 farms surveyed in the Grands Causses territory (France) in 2017 — *Description de la structure des 21 exploitations agricoles enquêtées dans le territoire des Grands Causses (France).*

	Minimum	Maximum	Average
Breeding dairy sheep (head)	200	750	415
Annual volume produced (hl)	350	2,200	860
Milk per ewe (l)	125	325	214
Arable areas (ha)	40	195	95
Pastoral areas (ha)	60	638	240
Labour of associates (FTE)	1	5	2.5
Hired labour (FTE)	0.0	0.6	0.6

FTE — *ETP*: full-time equivalent — *équivalent temps plein*.

Table 2. Structural description of the 20 farms surveyed in the Western Burkina Faso territory in 2017 — *Description de la structure des 20 exploitations agricoles enquêtées dans l'ouest du Burkina Faso*.

	Minimum	Maximum	Average
Number of cattle (head)	11	125	46
Number of milking cows (head)	3	29	10
Annual volume produced (l)	367	12,012	4,505
Milk per cow (l)	87	2,085	490
Number of arable hectares (ha)	0	20	4.7
Family labour (FTE)	1	8	4
Family help, number of people	0	13	4
Hired labour, number of people	0	6	1

FTE — *ETP*: full-time equivalent — *équivalent temps plein*.

part of the survey traced the history of the farm from the arrival of the current manager, with a particular focus on changes in practices. We collected data on herd management practices (reproduction, genetics, feeding), crop management (tillage, choice of varieties) and work schedules. The second part described the annual management of the livestock farm over the 2015-2016 (GCF) or 2016-2017 (WBF) period. We used an interview grid sheet to ensure topics were effectively covered with the farmer. We recorded the interviews with farmers in GCF, and took written notes during the interview, particularly in WBF.

2.4. Analysis of changes in livestock practices

Our objective was to highlight the change in farming practices over time after a change in demands from the dairies. To do this, we used a linear and a normative analysis of the trajectories (Capillon & Tagaux al., 1984; Perrot et al., 1995). According to Moulin et al. (2008), two types of changes can be distinguished. Gradual changes, over several years, can occur without affecting the coherence of livestock management. In that case, we considered the farm to be in a period of stability. Other changes, mostly affecting practices and occurring over a short time span, affected the coherence of the livestock system. In this case, we considered the farm to be in a period of transformation. From this stability/transformation breakdown, we considered two periods for each farm (**Figure 3**). Between these two periods, the farmer made at least one change in sales channel and/or milking period. The first period (P1) corresponded to the period of stability before the changes. This period P1 was spread between 2000 and 2015, depending on the farm. The second period (P2) corresponded to farm functioning over the year preceding the survey: 2015-2016 for GCF, or 2016-2017 for WBF. In P2, the farm could therefore be in a period of stability or, conversely, in a period of transformation. Depending on the farm, the duration between P1 and P2 varied from 2 to 15 years.

Secondly, we analyzed changes in practices between those two periods covering the 2000-2017 period. We did this by constructing variables (**Tables 3** and **4**) to characterize livestock farmer practices. The variables chosen were not uniform from one territory to the other, in order to take into account the livestock rearing context. We did not take into account practices that did not vary from one farmer to another in the sample. For instance, in GCF all farmers used the Lacaune breed. We qualified these types of practices based on the five agroecological principles. For GCF, we considered seven types of practices (Magne et al., 2010): health,

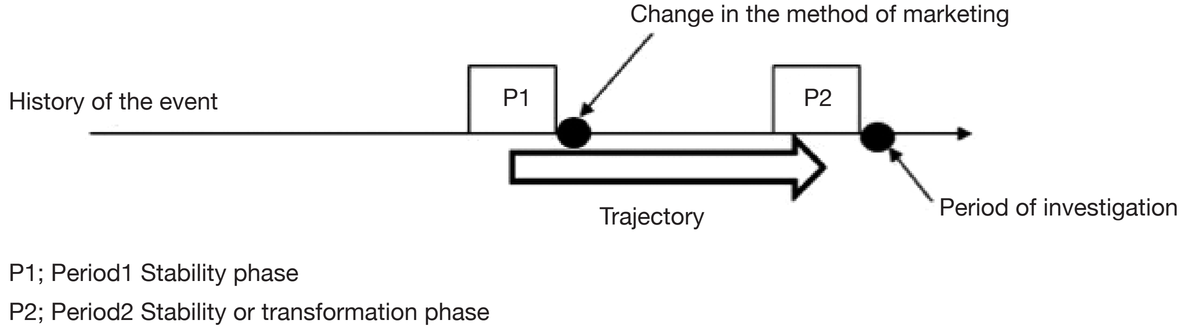

Figure 3. Schematic representation of the division between two periods — *Représentation schématique du découpage effectué entre deux périodes*.

Table 3. Presentation of the different domains of practices in the Grands Causses region (GCF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques dans les Grands Causses (GCF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel : C, Intermédiaire : I, Agroécologique : A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie*.

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological characterization
Healthcare practices	Ecopathological healthcare management	13.7	2.6	A	Ecopathological health management takes into account the interrelated factors, in the biological, physical, human and economic environment of animals, that are likely to induce a disease (Ganière et al., 1991). Breeders carry out preventive actions by identifying the sources of disease. This approach limits the use of antibiotics (Dumont et al., 2013; Wezel & Peeters, 2014)
	Targeted healthcare management	0.8	0.8	I	Targeted health management aims to use allopathic medicine while targeting ewes presenting pathological signs to avoid systematic treatment of the entire flock
	Allopathic healthcare management	3.2	1.4	C	Breeders provide systematic antibiotic treatment to the entire flock at key times of production, such as drying up
Reproductive practices	Natural mating without synthetic hormones	7.7	0.2	A	Natural mating has the advantage of limiting inputs (seeding and hormonal treatments) (Dumont et al., 2013)
	Hormonal synchronization and artificial insemination	9.3	0.7	C	Breeders are required to combine artificial synchronization with synthetic hormones to inseminate the ewes. Hormone use represents a potential risk to public health and the environment. The development of artificial insemination has facilitated the reduction of genetic diversity (Dumont et al., 2013)
Cereal – legume complementarity	Cereal–pulse mix	7.4	1.2	A	Combining protein crops with grain in the same crop increases nitrogen fixation, which improves protein and grain yield. This combination will store carbon, limit erosion, limit pest and disease pressures and contribute to diversity (Bonaudo et al., 2014) which will, in turn, increase yield, resilience, and improve feeding quality (Wezel & Peeters, 2014)
	Cereal crop	2.3	0.4	C	Cultivation of a single variety of cereal, on a field scale, depletes the soil and creates less resilience to diseases (Bonaudo et al., 2014; Wezel & Peeters, 2014)
Start of milking period	Spring	6.6	6.3	A	When milk production starts in spring, it makes it possible to enhance the value of the fodder resource through grazing, at a time when the animals have the greatest need for production. That contributes to a decrease in the use of feed inputs (Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)
	Winter	0.7	2.3	I	When milk production starts in winter, breeders give grazing ewes a share of the production that contributes to a decrease in feed inputs (Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)

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Table 3 (continued 1). Presentation of the different domains of practices in the Grands Causses region (GCF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques dans les Grands Causses (GCF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel : C, Intermédiaire : I, Agroécologique : A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie*.

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological characterization
	Autumn	3.5	9.7	C	When milk production starts in autumn, grazing is practically excluded from the production system, with breeders distributing most feed inside
Rangeland use linked to the dairy season	Rangeland use at the start of milking	7.2	1.4	A	The grazing of natural rangeland ensures a share of needs during lactation, while also limiting forest fires and the loss of biodiversity through the maintenance of semi-natural habitats (Lepart et al., 2011; Dumont et al., 2013; Wezel & Peeters 2014)
	Rangeland use at the end of milking	0.1	0.1	A	
	Rangeland consumption by dry ewes	1.4	2.7	I	The grazing of natural rangeland ensures a share of needs during the drying up period while also limiting forest fires and the loss of biodiversity through the maintenance of semi-natural habitats (Lepart et al., 2011; Dumont et al., 2013; Wezel & Peeters, 2014)
	No rangeland consumption by dairy ewes	2.2	0.1	C	The grazing of natural rangeland is not used as a feed source for dairy sheep herds; hence it does not contribute to the preservation of these areas and their biodiversity (Lepart et al., 2011)
Diversity of varieties in forage crops	Complex mixes of forage grass with legumes	4	9.95	A	Legumes help to fix nitrogen in the soil, which is then used by grass. The diversity of crop varieties contributes to feed quality and improves resilience. Tannin plants reduce parasite infestations in ruminants. These crops help to stock carbon, limit erosion and contribute to diversity (Bonaudo et al., 2014; Wezel & Peeters, 2014)
	Association of forage grass with legumes	0.6	0.0	I	Legumes help to fix nitrogen in the soil, which is then used by grass (Bonaudo et al., 2014; Wezel & Peeters, 2014)
	Grass crop from the cereal family	1.8	2.5	C	Without legumes, grass crops deplete the soil of its nitrogen and do not improve the quality of feed
Cereal origin	Home produced cereals	1.2	1.6	A	Home produced cereals help to limit inputs on a farmer scale (Dumont et al., 2013). The French territory is self-sufficient in grain with 50% of its production being exported (FranceAgriMer). Feed-food competition may be considered as low
	Purchased cereals	3.4	0.2	C	Purchasing cereals from outside the farm risks increasing feed-food competition in other territories (Dumont et al., 2013)
Use of chemical inputs for crops	No chemical inputs on crops	3.1	8.0	A	Reducing chemical inputs on crops limits inputs and pollution. This leads to the adoption of other practices, such as manure application, choice of resistant varieties and mixes of varieties (legumes–grasses) to strengthen crop–livestock interactions (Altieri, 2002; Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)

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Table 3 (continued 2). Presentation of the different domains of practices in the Grands Causses region (GCF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques dans les Grands Causses (GCF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel : C, Intermédiaire : I, Agroécologique : A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie.*

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological characterization
	Chemical inputs on crops	3.1	4.7	C	The use of chemicals could lead to increased pollution (Altieri, 2002; Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)
Fodder conservation method	Hay in bales	0.5	0.0	A	Bale storage and hay in barns require later haymaking, which is beneficial for pollinators and birds (Dumont et al., 2014). However, hay in barns consumes the most energy for drying
	Hay in barns	0.0	0.8	I	
	Silage	1.3	1.6	C	Silage requires early haymaking, which is a problem for biodiversity (Dumont et al., 2014)
Fodder origin	Home produced fodder	1.5	1.4	A	Home produced fodder makes it possible to combine temporary pasture and cereals, to set up a more complex crop succession scheme. Rotations help to reduce mineral inputs. (Bonaudo et al., 2014; Wezel & Peeters, 2014)
	Purchased inside the Roquefort area, 100 km from the historic village of Roquefort	1.6	4.4	I	Purchasing fodder within the delimited area helps reduce the CO_2 impacts of transport. It fosters exchanges between farmers in the territory (Bonaudo et al., 2014)
	Purchased outside the Roquefort area, 100 km from the historic village of Roquefort	2.3	1.2	C	Purchasing fodder outside the delimited area increases the CO_2 impacts of transport
Type of protein supplement	No protein supplement purchase	1.5	0.1	A	Limiting the consumption of protein feed, such as soybean, dehydrated alfalfa, or industrial whole feeds, helps to reduce irrigation and chemical inputs (Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)
	Meal cake (without GMO)	0.4	0.0	I	It is preferable to purchase the by-products of industrially made feed to maximise their use
	Dehydrated alfalfa	0.4	3.4	C	Alfalfa is probably included in the crop succession scheme that fixes nitrogen in the soil, but the drying process has a high cost in energy, even though the tendency is balanced with process improvement (Thiébeau et al., 2011)

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Table 3 (continued 3). Presentation of the different domains of practices in the Grands Causses region (GCF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques dans les Grands Causses (GCF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel : C, Intermédiaire : I, Agroécologique : A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie.*

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological characterization
Duration of supplemental feed distribution	Months of concentrate distribution between 7 and 12 months	0.1	0.2	A	The supplements distributed are based on cereals and/or protein feeds. Limiting the distribution of supplements to 7 or 8 months per year decreases inputs and gives priority to forage resources in the diet (Bonaudo et al., 2014; Wezel & Peeters, 2014)
				I	Limiting the distribution of supplements to 9 or 11 months per year decreases inputs and gives priority to forage resources in the diet (Bonaudo et al., 2014; Wezel & Peeters, 2014)
				C	The distribution of supplements all year round did not lead to a decrease in the dependence of feed inputs
Duration of milking period	150 and 300 days of ewe milking	0.04	0.12	A	Short milking periods of less than 150 days limit the distribution of feed supplements
				I	Medium milking periods of 150 to 214 days limit the distribution of feed supplements
				C	High milking periods of more than 214 days encourage the distribution of feed supplements

reproductive, feeding, rangeland, milking, cropping, input. For WBF, the practices were: feeding, grazing, reproductive, breeding, forage, input, infrastructure. We qualified these types of practices based on the five agroecological principles. The modalities of practices, which differed from one trajectory to another, led us to characterize within-group homogeneity and between-group variability. We used multiple factorial analyses (MFA) to obtain a summary of changes in practices for all farmers. Thus, we established a typology of trajectories grouping the farms according to size, orientation, and the proximity of the segments. All calculations were performed with R software, using FactoMineR for WBF and the additional library PCAmixdata for GCF (allowing us to analyze both qualitative and quantitative data). In the MFA, an individual corresponded to a farm at a given period. In order to give the same weight to each type of practice, we weighted the variables describing it by $1/n_i$, with n_i being the number of variables defining type *i*. When a group of practices (*e.g.* feed) was described by two variables, we assigned a weight of 0.5 to each of the variables. In the factorial plane (dimensions 1 and 2), we traced line segments between the two individuals representing a farm at period P1 and period P2. A segment represented the trajectory of changes in practices for a given farm. The segment length between P1 and P2 for one farm depended on the practice changes and on their relative contribution to axis construction. If several livestock farmers had made the same types of changes, the segments aligned in the same direction in the factorial plane. The modalities of variables that contributed most in the construction of the axes (contribution higher than the averaged contribution) were noted on the axes of the figures to explain modifications in practices between the start (P1) and the end points (P2). We then constructed a Bertin grid to describe each type of trajectory (Bertin, 1983). We assessed the tendency to move towards more conventional practices, or towards more agroecological practices, while comparing their position in P1 and P2. For each variable, we classified the modalities from the most conventional, corresponding to the dominant practices in the territories, or which followed conventional intensification, to the most

Table 4. Presentation of the different domains of practices in Western Burkina Faso (WBF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques à l'ouest du Burkina Faso (WBF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel : C, Intermédiaire : I, Agroécologique : A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie*.

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological qualification
Fodder storage infrastructure	Barn	9.0	0.7	A	Storing fodder under optimum conditions guarantees its quality
	No barn	3.0	0.7	C	When stored outside, often on roofs, fodder is exposed to sun and rain
Livestock housing	Corral	1.8	1.7	A	Night corrals are mobile and enable direct soil fertility transfers (Bonaudo et al., 2014; Blanchard et al., 2017)
	Stalling	8.6	8.2	C	The use of permanent sheds requires labour to remove and spread manure to increase soil fertility (Bonaudo et al., 2014; Blanchard et al., 2017)
Fodder purchase	Fodder purchase	8.5	0.6	A	Forage bought locally reduces greenhouse gas emissions and enables exchanges and complementarity between crop farmers and livestock farmers (Bonaudo et al., 2014)
	No forage purchase	5.0	0.4	C	In this context, space is very limited, so it is important to limit food-feed competition. For example, buying fodder or residues from the maize crop is better than growing fodder to feed the family (Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)
Fodder harvesting and storage	Fodder storage	5.0	5.8	A	Fodder storage helps to manage resources throughout the year. Stocks help to maintain the condition and production of milking cows in the dry season
	No fodder storage	5.5	6.4	C	When farmers do not stock fodder, it is complicated to maintain the production of milking cows in the dry season, with grazing only
Cotton meal cake origin	Local cotton meal cake	2.3	0.0	A	The purchase of cotton meal cake, produced locally by small-scale and industrial manufacturers, has the advantage of using a resource that is not for human consumption and fostering exchanges between actors in the territory (Bonaudo et al., 2014; Wezel & Peeters, 2014)
	No meal cake	5.3	5.7	I	Farmers are not taking advantage of a local resource to improve milk productivity
	Imported cotton meal cake from Côte d'Ivoire	2.1	8.4	C	Using cotton meal cake imported from Côte d'Ivoire increases the CO_2 impact from transport (Bonaudo et al., 2014; Wezel & Peeters, 2014)
Reproduction method	Natural mating without synthetic hormones	1.7	0.1	A	Natural mating has the advantage of limiting inputs (seeding and hormonal treatments) (Dumont et al., 2013)

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Table 4 (continued 1). Presentation of the different domains of practices in Western Burkina Faso (WBF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques à l'Ouest du Burkina Faso (WBF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel ; C, Intermédiaire ; I ; Agroécologique ; A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie.*

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological qualification
	Hormonal synchronization with artificial insemination	5	0.3	C	Breeders are required to combine artificial synchronization with synthetic hormones to inseminate the ewes. Hormone use represents a potential risk to public health and the environment. The development of artificial insemination has led to a reduction in genetic diversity (Dumont et al., 2013)
Genetic type	Local/regional breed and selection based on milk quantity	0.2	0.6	A	The use of local and regional populations contributes to animals adapting to the environment (resistance to disease, heat, parasites, etc.). Populations selected on milk criteria improve productivity. (Dumont et al., 2013; Phocas et al., 2016; Phocas et al., 2018)
	Local breed	3.2	0.1	A	Difficult breeding conditions require animals to mobilize their reserves. In addition, the use of local breeds preserves genetic diversity, which tends to decrease when using high productivity breeds, disseminated by artificial insemination (Dumont et al., 2013; Phocas et al., 2016; Phocas et al., 2018)
	Local and regional cross	2.1	0.4	I	The use of local and regional populations contributes to animals adapting to the environment (resistance to disease, heat, parasites, etc.) (Dumont et al., 2013; Phocas et al., 2016; Phocas et al., 2018)
	Cross breeding with European cows	4.5	6	C	Cross breeding with European cows allows an increase in milk production, but these cows are not adapted to the context of Burkina Faso (Phocas et al., 2016; Phocas et al., 2018)
Feed distribution period	Distribution in dry season	1	3.3	A	The distribution of feed (fodder and concentrates) in the dry season is used in addition to the availability of pastoral resources in the rainy season. Milking cows maintain their milk production and body condition. This helps to maintain the immune system (Dumont et al., 2013). In such a case, production makes it possible to satisfy the local demand for milk (Wezel & Peeters, 2014)
	No distribution	4.5	1	I	In the dry season, the overgrazing risk is high, which represents a risk for biodiversity and resource renewal (Vall & Diallo, 2009; Dumont et al., 2013)
	Distribution all year long	3.3	3.6	C	Distribution all year long contributes to the improvement of inputs (Dumont et al., 2013; Sib et al., 2017)
Diversity of species in crops for human consumption	Grain and legumes	0	5.3	A	The diversity of crops for human consumption allows an increase in the nutritional value of food for humans and animals. Legumes help to fix nitrogen in the soil (Bonaudo et al., 2014)
	Grain (corn)	3	0.6	I	Unconsumed leaves and straw are recycled into animal feed (Bonaudo et al., 2014)
	No crop	0	9.4	C	The family depends on animal resources for food and income. Increasing the diversity of resources increases resilience (Dumont et al., 2013; Sib et al., 2017)

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Table 4 (continued 2). Presentation of the different domains of practices in Western Burkina Faso (WBF) with their variations in terms of modalities, the weight of modalities in the MFA, the grade of the modality in Bertin's grid (Conventional: C, Intermediate: I, Agroecological: A), and the qualification of each of the practices with regard to the principles of agroecology — *Présentations des différents domaines de pratiques à l'ouest du Burkina Faso (WBF) avec leurs déclinaisons en modalités, le poids des modalités dans le MFA, le grade de la modalité dans la grille de Bertin (Conventionnel : C, Intermédiaire : I, Agroécologique : A) et la qualification de chacune des pratiques au regard des principes de l'agroécologie*.

Practices	Modalities	Weight for Dim1	Weight for Dim2	Grade on the table	Agroecological qualification
Diversity of species in forage crops	Mix of grass and legume forage	0.1	1.5	A	Legumes help to fix nitrogen in the soil, which will then be used by grass or by the next crops, making it possible to combine fodder and cereal crops and to set up rotations. Together, this helps to stock carbon, limits erosion and contributes to diversity (Bonaudo et al., 2014)
	Single forage legume crop (*Mucuna* [L.] DC.)	1.9	3.1	A	Legumes help to fix nitrogen in the soil, which will then be used by grass or by the next crops, making it possible to combine fodder and cereal crops and to set up rotations (Bonaudo et al., 2014)
	No forage crop	1.1	1.0	A	The risk of competition for arable land between human food and animal feed does not exist (Dumont et al., 2013)
	Single forage grass crop (*Panicum maximum* Jacq.)	1.2	4.7	C	There is a risk of competition for arable land between human food and animal feed (Dumont et al., 2013)
Pasture management	Grazing	0.0	0.4	A	Grazing implies the direct use of forage resources and the inaccessibility of land for cropping. It limits mechanical and manual harvesting work. Grazing contributes to fertility transfer. In addition, grazing mostly takes place in pastoral zones, helping to increase the biodiversity and human activity within these areas (Dumont et al., 2013; Bonaudo et al., 2014; Wezel & Peeters, 2014)
	No grazing	1.2	17.0	C	All feed is distributed to cows, reared inside a stall with no grazing.

agroecological, and we assigned a score from C to A (**Tables 3** and **4**).

3. RESULTS

3.1. Trajectories of ewe dairy farms in Grands Causses, France

In the GCF sample, we identified four types of trajectories on the basis of farm position in period 1 and 2 (**Figure 4**), with the help of a Bertin grid (**Table 5**). Factorial axis 1 (**Table 5**) opposed the variable modalities corresponding to conventional practices in the types of health, reproduction, period of production, use of chemical inputs for crops and varieties of crops (variable modalities with negative coordinates along axis 1) to some more agroecological modalities (positive coordinates). Factorial axis 2 (**Table 5**) opposed the variable modalities corresponding to conventional practices in the types of milking organizations, use of chemical inputs for crops, and rangeland (positive coordinates) to some more agroecological modalities (negative coordinates).

Types T1_GCF and T2_GCF corresponded to farms that had converted to organic farming more than seven years earlier and had made many changes in their practices. The dairy farms belonging to these two types displayed long segments in the MFA factorial plane (**Figure 4**) and were positioned in period P2 on the right-hand side of the factorial plane. Health management was, in particular, what differentiated between T1_GCF and T2_GCF with the use of rangeland. Indeed, breeders in T1_GCF applied more preventive health practices based on hygiene and natural products to replace curative actions based on antibiotics. Thus, the ewes grazed the rangelands during the lactation or drying-up period. Type T3_GCF concerned farms that converted to organic farming in period P2, with few changes between P1 and P2 and, therefore, shorter segments in the factorial plane. In P2, type T3_GCF

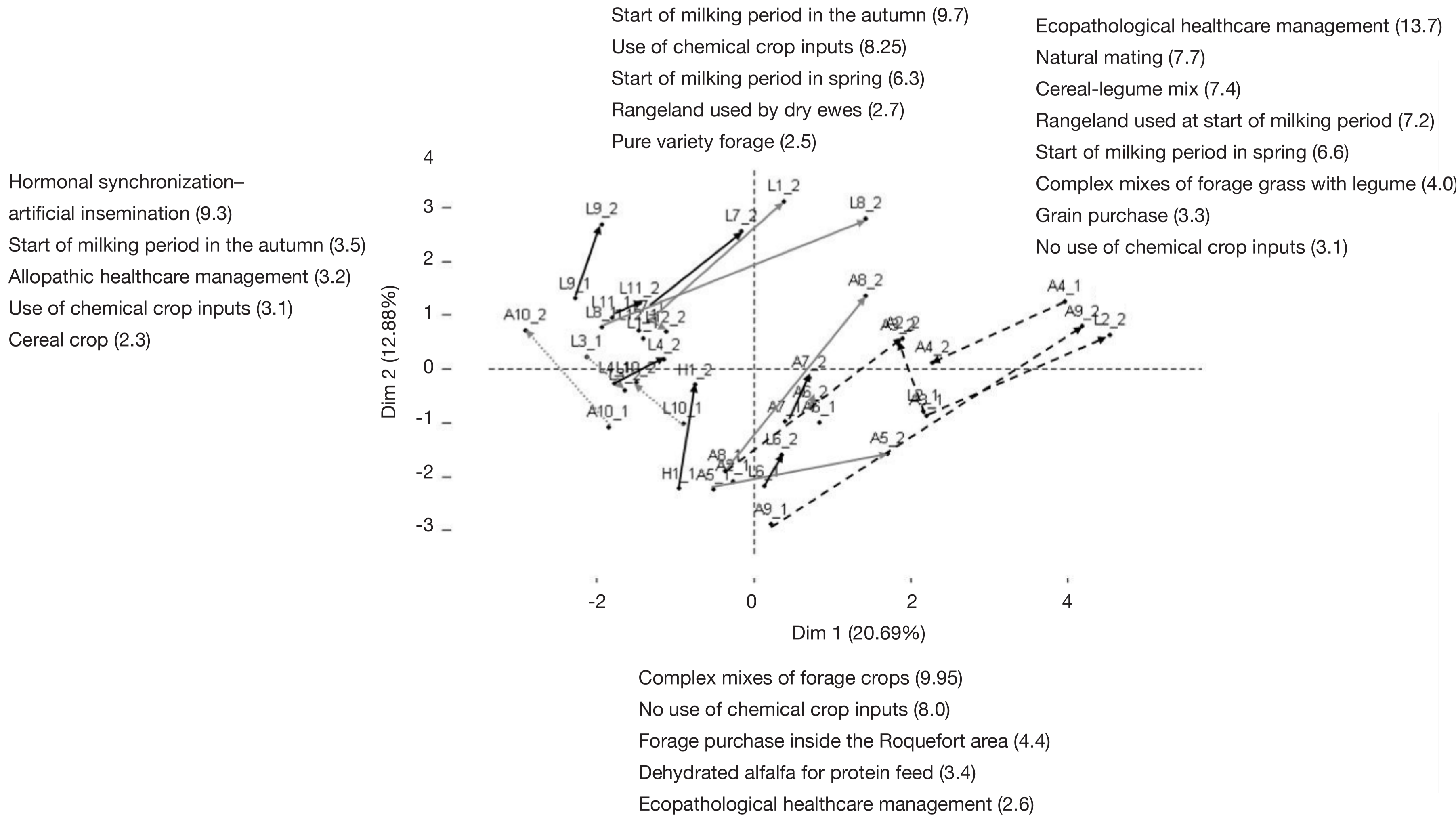

Figure 4. Projection of individual farms in the factorial plane (Dim 1 & Dim 2) for a sample of 21 ewe dairy farms in the Grands Causses France territory — *Projection des élevages sur les plans factoriels (Dim 1 & Dim 2) pour un échantillon de 21 élevages de brebis laitières sur le territoire des Grands Causses, France.*

First type of trajectory (black dotted arrow) – organic farms with the use of pastoral resources and integrated animal health (T1_GCF), second type of trajectory (grey arrow) – organic farms (T2_GCF), third type of trajectory (black arrow) – farms under conversion to organic management (T3_GCF), and fourth type of trajectory (grey dotted arrow) – conventional farms (T4_GCF). The modalities of variables with a higher weight than the average are noted on the figure axes together with their weight, in brackets — *Premier type de trajectoire : (flèches pointillées noires) élevages en agriculture biologique avec un recours aux ressources pastorales et une gestion intégrée de la santé animale (T1_GCF) ; deuxième type de trajectoire (flèches grises) : élevages en agriculture biologique (T2_GCF) ; troisième type de trajectoire (flèches noires) : élevages en conversions à l'agriculture biologique (T3_GCF) et quatrième type de trajectoire (flèches pointillées grises) : élevages conventionnels (T4_GCF). Les modalités des variables ayant un poids supérieur à la moyenne sont notées sur les axes des figures ainsi que leur poids, entre parenthèses.*

Table 5. Changes in practices between period 1 (P1) and period 2 (P2) in the trajectories in Grands Causses, France (GCF) on a scale from conventional practices (score C), intermediate practices (score I), to agroecological practices (score A). Trajectory 1 – T1_GCF, trajectory 2 - T2_GCF, trajectory 3 - T3_GCF and trajectory 4 – T4_GCF — *Changement des pratiques entre la période 1 (P1) et la période 2 (P2) dans les trajectoires des exploitations enquêtées dans les Grands Causses, France (GCF) sur une échelle allant des pratiques conventionnelles (score C), des pratiques intermédiaires (score I), aux pratiques agroécologiques (score A) : trajectoire 1 - T1_GCF, trajectoire 2 - T2_GCF, trajectoire 3 - T3_GCF et trajectoire 4 - T4_GCF.*

	T1_GCF			**T2_GCF**			**T3_GCF**			**T4_GCF**		
	C	**I**	**A**	**C**	**I**	**A**	**C**	**I**	**A**	**C**	**I**	**A**
Healthcare practices		P1 →	P2		=			=		=		
Reproductive practices			=	P1 →		P2	=			=		
Cereal-legume	P1 →		P2	=			=			=		
Start of milking period		P1 →	P2		P1 →	P2		=		P2 ←	P1	
Rangeland consumption linked to the dairy season			=		P2 ←	P1		P2 ←	P1		P2 ←	P1
Diversity of varieties in forage crops	P1 →		P2		P1 →	P2	P1 →	P2		=		
Use of chemical inputs for crops	P1 →		P2	P1 →		P2	P1 →		P2	=		
Forage conservation method			=	P2 ←		P1	P2 ←		P1	P2 ←		P1
Forage origin		P2 ←	P1			=			=			=
Cereal origin		P2 ←	P1			=			=			=
Type of protein supplement		=			=			=			=	
Duration of supplemental feed distribution		P2 ←	P1	=			=			=		
Duration of milking period			=		=			=		=		

had positive coordinates along axis 1, towards the more agroecological modalities. Lastly, type T4_GCF corresponded to conventional farms. They had made a few changes in practices (short segments) in various directions. The length of the segments reflected the importance of the changes in practices that the farmer had made.

In trajectory type 1 (T1_GCF) (*n* = 5), during the already old conversion to organic farming, the farmers had adopted a set of agroecological modalities (**Table 5**) to sell organic milk. In period 1, before the conversion, some practices were already implemented according to agroecological modalities, such as natural mating without synthetic hormones, or the use of rangelands at different production periods (start and end of lactation, end of lactation). Between period 1 and period 2, the farmers adopted integrated healthcare practices. These practices limited allopathic interventions (antibiotics), preferring ecopathological practices designed to limit the occurrence of health problems by combining different means of prevention, from farm building hygiene to alternative medicines, such as essential oils, or grazing on tannin rich plants, such as sainfoin to limit parasitism. They had stopped using chemical inputs for crops. They had implemented greater diversity with complex legume-based mixes in fodder crops, and protein crops (vetch, peas, etc.) in cereals. These farmers were not self-sufficient in fodder and grain.

In type 2 (T2_GCF) (*n* = 5), all the farms had also converted to organic farming more than seven years previously to sell organic milk. However, T2_GCF had not adopted the same practices as T1_GCF (**Table 5**). They had made the changes to respect organic farming specifications. For instance, the dairy farmers had abandoned hormonal synchronization, artificial insemination and use of chemical inputs for crops and systematic allopathic treatments were limited. The farmers had adopted mixes of species for fodder crops. While some farmers only grew cereals, others had combined cereals with legumes. Rangeland use varied greatly, depending on the farmers in this type, with one of the five farmers having abandoned rangeland grazing. These farmers were self-sufficient in fodder and grain.

In type 3 (T3_GCF) (*n* = 7), all the farms had converted to organic farming in period 2 to sell organic milk. The conversion period was two years for crops, while it was only six months for livestock (**Table 5**). Thus, these farmers had stopped using chemical inputs on crops, but had maintained their reproduction practices, notably artificial insemination, leading to an incomplete conversion of their livestock farm. Regarding healthcare practices, the farmers had already adopted the targeted practices in P1. These farmers had tended to abandon fodder cropping of a single variety to grow combinations (legumes–grasses), or complex mixtures. Rangeland use had not changed between periods 1 and 2, but some farmers had already stopped using rangeland in period 1.

The farmers of the fourth type of trajectory (T4_GCF) ($n = 4$) remained with conventional agriculture. The organization of work, in particular to avoid competition between fieldwork and the herd, led farmers to change their milking period. The flexibility of dairy rules regarding the production period facilitated this change. However, they did use some agroecological practices, such as not abandoning rangelands (**Table 5**), but they used them at the end of the milking period, or their use was moved from the end of the milking period to the drying-up period, meaning that pastoral resources had limited value to feed the flock. Among these farmers, the tendency was to maintain the use of artificial insemination for reproduction. Healthcare practices remained allopathic with systematic treatments, or with targeted practices according to analysis results. Cropping practices continued to rely on chemical inputs. These farmers continued to grow single variety cereals, while grass–legume combinations or complex mixes were sometimes used to sow cultivated grasslands.

3.2. Trajectories of dairy cattle farmers in Western Burkina Faso

In the WBF sample, we identified four types of trajectories on the basis of farm position in period 1 and 2 (**Figure 5**), with the help of a Bertin grid (**Table 6**). In fact, factorial axis 1 opposed the variable modalities corresponding to traditional practices in the types of feed, structure, reproduction and genetics (negative coordinates) to some more specialized modalities in milk production (positive coordinates). Factorial axis 2 opposed the variable modalities corresponding to conventional practices in the types of grazing, crops, structure, genetics and feed (positive coordinates) to some practices of more agroecological modalities (negative coordinates).

Types T1_WBF and T2_WBF corresponded to very similar livestock farmers in period P1, with dairy farming relying on the grazing of highly diversified resources, including rangelands and cultivated fields in which crop residues remained in the dry season, with milking in the rainy season. These farmers had made some major changes (long segments, see **Figure 5**), leading to more agropastoral forms of livestock farming (crop residue storage, distribution of concentrates and fodder to sustain milk production in the dry season). Trajectory type T3_WBF corresponded to farmers who had also made some major changes. These dairy farms were quite diverse in P1, in pastoral or already more agropastoral situations. Now, they converged towards a similar operation in P2 (**Figure 5**). They had notably invested in infrastructure (cowsheds), used for cows with a higher milk potential, with feed distribution throughout the year to sustain milk production, in addition to grazing. Lastly, type T4_WBF4 corresponded to a type of intensified milk production, with livestock housing evolving towards a permanent indoor system.

In the first type of trajectory (T1_WBF) ($n = 7$), the dairy farmers had changed their feeding practices in order to produce milk all year round to supply a dairy processor. In period 1, they mainly used grazing of rangelands, with high herd mobility. Between period 1 and 2, the farmers continued to grow cereal crops for human consumption and they recycled straw for the cows. In period 2, the farmers had started to store various types of fodder in bales. In order to maintain milk production during the dry season, milking cows were grouped together to receive supplemental fodder (cereal straw, legume haulms or dried bush straw) and concentrates (bran, cotton cakes, or brewers' grain), in addition to grazing. The rest of the herd was transhumant. In the rainy season, the resources removed from pastures remained the only feed for milking cows. In this type of trajectory, the farmers maintained some agroecological practices (**Table 6**).

In the second type of trajectory (T2_WBF) ($n = 8$), the dairy farmers had adopted the same changes in feeding practices as in the first type, but they had also adopted other reproduction practices in order to produce all year round for a dairy. To complete their fodder stocks, they had begun to buy additional fodder resources. They had also invested in sheds for better conservation of their stored fodder. The farmers recycled crop residues, such as corn straw or bean leaves, for distribution to cows. In period 2, some farmers ($n = 4$) cultivated forage such as *Panicum maximum* Jacq. or *Mucuna pruriens* (L.) DC. Apart from these feeding changes, the farmers had also changed their genetic practices to improve their cows' milk production potential. For example, they kept bulls whose mothers had quantitatively better milk production as reproducers, or used regional breeds (Goudali) reputed for their better milk production. Some also carried out crosses with exotic dairy breeds (*Holstein*, *Brune des Alpes*, *Tarentaise*). These numerous changes in practices (**Table 6**) involved either adopting more agroecological modalities or, conversely, abandoning certain agroecological modalities.

The third type of trajectory (T3_WBF) ($n = 4$) corresponded to dairy farmers who had invested in milk production, generally investing capital from another activity (trader, male nurse, civil servant, etc.). This type had long been selling milk to dairies, but was

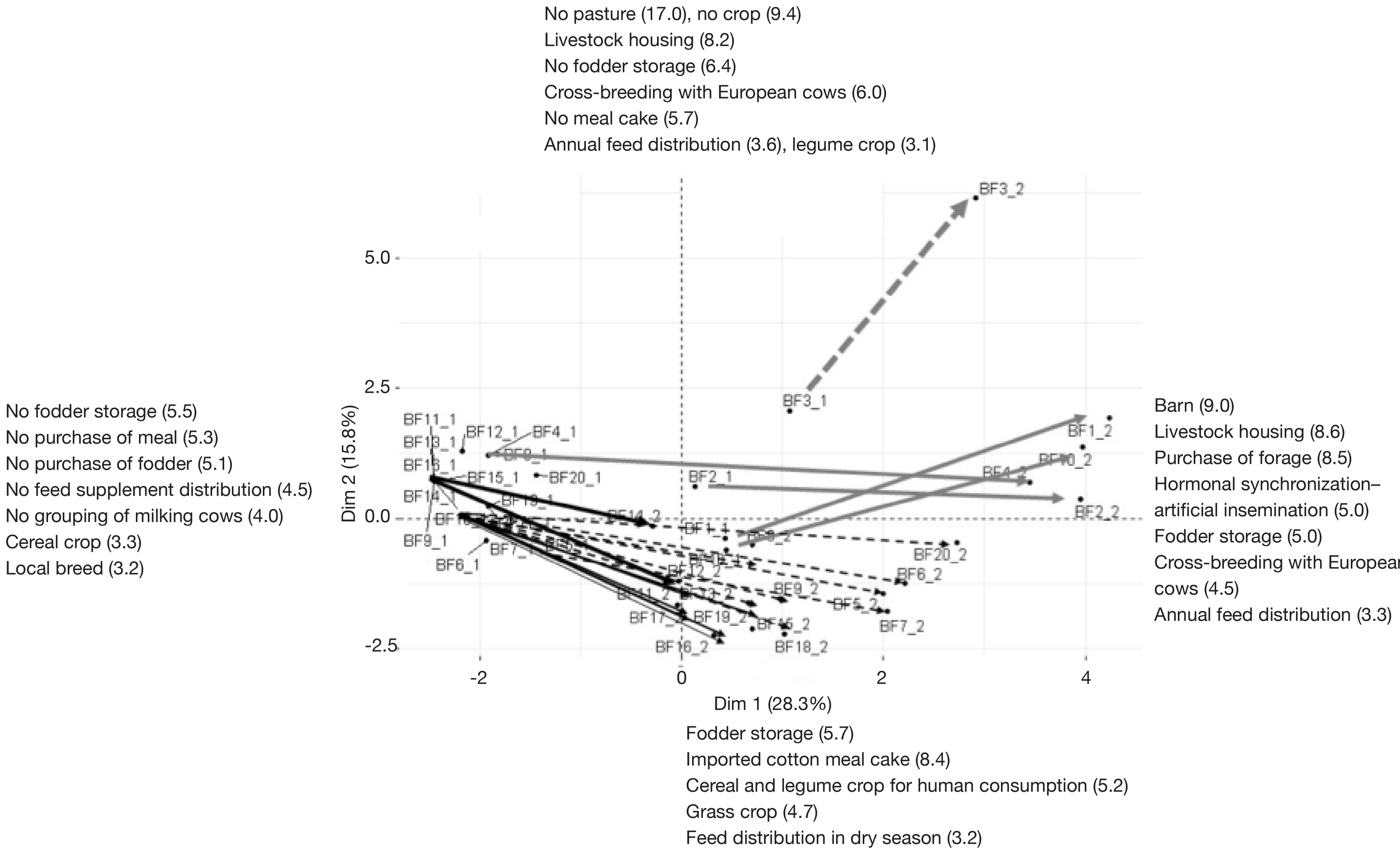

Figure 5. Projection of individuals in the factorial plane (Dim 1 & Dim 2) for a sample of 20 dairy cattle farms in the Western Burkina Faso territory. First type of trajectory (black arrow) (T1_WBF); second type of trajectory (black dotted arrow) (T2_WBF); third type of trajectory (grey arrow) (T3_WBF) and fourth type of trajectory (grey dotted arrow) (T4_WBF). The modalities of variables with a higher weight than the average are noted on the figure axes together with their weight, in brackets — *Projection des élevages sur les plans factoriels (Dim 1 & Dim 2) pour un échantillon de 20 exploitations de vaches laitières sur le territoire de l'ouest du Burkina Faso. Premier type de trajectoire (flèche noire) (T1_WBF) ; deuxième type de trajectoire (flèche pointillée noire) (T2_WBF) ; troisième type de trajectoire (flèche grise) (T3_WBF) et quatrième type de trajectoire (flèche grise pointillée) (T4_WBF). Les modalités des variables ayant un poids supérieur à la moyenne sont reprises sur les axes des figures ainsi que leur poids, entre parenthèses.*

Table 6. Changes in practices between period 1 (P1) and period 2 (P2) in the trajectories of the farms surveyed in Western Burkina Faso (WBF) on a scale from conventional practices (score C), intermediate practices (score I), to agroecological practices (score A). Trajectory 1 – T1_WBF, trajectory 2 – T2_WBF, trajectory 3 – T3_WBF and trajectory 4 – T4_WBF — *Évolution des pratiques entre la période 1 (P1) et la période 2 (P2) dans les trajectoires des fermes de l'ouest du Burkina Faso (WBF) sur une échelle allant des pratiques conventionnelles (score C), des pratiques intermédiaires (score I), aux pratiques agroécologiques (score A). Trajectoire 1 - T1_WBF, trajectoire 2 - T2_WBF, trajectoire 3 - T3_WBF et trajectoire 4 - T4_WBF.*

	T1_WBF			**T2_WBF**			**T3_WBF**			**T4_WBF**		
	C	**I**	**A**	**C**	**I**	**A**	**C**	**I**	**A**	**C**	**I**	**A**
Forage storage infrastructure	=			P1 →		P2			=			=
Livestock housing			=			=	P2 ←		P1	=		
Fodder purchase	=			P1 →		P2			=			=
Fodder harvesting and storage	P1 →		P2	P1 →		P2	P1 →		P2	=		
Cotton meal cake origin	P2 ←	P1		P2 ←	P1				=	=		
Reproduction method			=	P2 ←		P1	P2 ←		P1	=		
Genetic type			=		P2 ←	P1	P2 ←		P1	P2 ←	P1	
Feed distribution period		P1 →	P2		P1 →	P2	P2 ←		P1	P2 ←		P1
Diversity of species in crops for human consumption		P1 →	P2		P1 →	P2		P1 →	P2	=		
Diversity of species in forage crops		=		=				P1 →	P2		=	
Pasture management			=			=			=	=		

forced to find new markets after the closure of the public dairies. They had acquired the land on which the farms were established with part of their pasture. Then, they invested in infrastructures (livestock housing, storage shed, etc.) and in herd genetics. They started crossing their cattle with European dairy breeds, using hormonal synchronization and artificial insemination. Feeding practices shifted from seasonal fodder and concentrate supplementation during the dry season, in addition to pasture, towards supplemental feeding throughout the year. In period 2, the majority of farmers ($n = 3$) cultivated forage such as *P. maximum* or *M. Pruriens*. This type of trajectory was characterized by the abandonment of several agroecological modalities, but the adoption of others (**Table 6**).

The fourth type of trajectory (T4_WBF) ($n = 1$) traced the changes in practices in a very urbanized zone, where the farmers had been selling milk for a long time to a dairy. Accessibility to pasture gradually decreased with urbanization and the classification of forest as a protected zone. This led to a suppression of grazing. Farmers kept cows in a yard under shelter. Initially the herd contained cows of the Goudali breed with a view to supplying the nearby dairy throughout the year. The farmers inseminated their cows to produce crosses with European breeds. The feed of the half-breed cows was totally purchased and came from industrial by-products (cotton husks), food waste (cabbage leaves), or fresh grass sold in town. This type of trajectory corresponded to conventional intensification of milk production, based on inputs purchased to feed housed cows with good potential. The agroecological modalities used in period 1 were largely abandoned (**Table 6**).

4. DISCUSSION

Faced with biophysical and socio-economic changes in their environment, notably through the demands of dairies, farmers have adapted livestock management and cropping practices. While the two samples were limited in size, they did reveal a diversity of trajectories of changes in practices. However, the samples did not guarantee an exhaustive picture of the types of trajectories and did not bring out their relative importance within the population. Moreover, the link between the change in dairy or production season, and the change in practices, was difficult to establish because of the length of time between the two periods studied. Nonetheless, this study provided knowledge about eight current trajectories and showed how they are, or not, in line with agroecological practices.

The trajectories involved in agroecological transition in France appear to be structured around the organic farming label. However, we found two trajectories. In the T1_GCF trajectory, farmers applied a set of practices based on agroecological principles while making use of pastoral resources. However, these farming systems were not self sufficient in feed. In contrast, the livestock farming systems of the T2_GCF trajectory were self-sufficient in terms of animal feed. The latter did not make use of pastoral resources. The two trajectories T1_GCF and T2_GCF corresponded to a conversion to organic farming more than seven years earlier. In trajectory T1_GCF, the farmers adopted twelve agroecological practices. Trajectory T2_GCF showed that the application of organic farming specifications did not necessarily commit livestock farmers to completely redeveloping their system based on agroecology principles. Van Dam & Nizet (2012) spoke of the institutionalization, or conventionalization, of organic farming to standardize organic products on the grounds of market pressure. This process strengthened some industrialization and commodification principles, but they were combined with certain ecological references. The authors highlighted that this phenomenon was a second observed evolution of organic production that responds to trade-offs. As shown in trajectory T2_GCF, the farmers changed some practices for others corresponding to organic rules, but did not change all their practices like T1_GCF. Organic farming corresponds to a diversity of reality (Allaire, 2016). Conversion to organic farming suggests that trajectory T3_GCF was in a phase of ongoing transformation, suggesting a change in practices towards the adoption of agroecological practices, notably abandoning synthetic inputs in favor of cycle closing. On the other hand, trajectory T4_GCF showed that remaining with conventional farming was compatible with the adoption of two out of thirteen agroecological practices. According to Quetier et al. (2005), the specifications of the Roquefort Protected Designation of Origin (PDO) have played a role in committing the dairy farmers in the territory to continue using rangelands. Over the medium term, it could be imagined that the Roquefort PDO might strengthen its specifications to include more agroecology principles, as under certain winegrowing PDOs (Gautier, 2016). As with PDOs and organic farming labels, agroecological farming is subject to different visions (Cayre et al., 2018).

In Western Burkina Faso, our sample highlighted four trajectories for farms supplying milk to the local market. In Burkina Faso, we observed two agroecological transition trajectories (T1_WBF and T2_WBF). These two trajectories had livestock systems that had shifted from extensive production systems to production systems favoring crop-livestock integration. These new farming systems relied on locally produced resources from agriculture and industry that were not consumed by humans.

To enable more milk to be delivered in the dry season, the changes made remained well within an agroecological framework for trajectories T1_WBF et T2_WBF (Dumont et al., 2013). Farmers used feed inputs that were mostly produced locally (Sib et al., 2017), enhancing biomass flows at territorial level (Dumont et al., 2013) by crop–livestock integration (Bonaudo et al., 2014). In trajectories T1_WBF and T2_WBF, the farmers were traditional breeders who used low inputs (Hamadou et al., 2004; Sib et al., 2017). In trajectory T3_WBF and T4_WBF, the farmers specialized in milk (Hamadou et al., 2004; Sib et al., 2017). Before changing practices, T3_WBF farmers applied a set of agroecological practices, but breeding practices involved crosses with exotic breeds and reproduction by hormonal synchronization and insemination for an intensification of production. Such practices entailed uncertainties about the ability of animals to adapt to tropical conditions (Phocas et al., 2016). Crossing between local animal populations and exotic dairy breeds would need to be accompanied by genetic improvement programs, in order to produce animals adapted to local environmental conditions and to low-input production systems (Phocas et al., 2018). The second noteworthy fact is that trajectory T4_WBF farmers had abandoned grazing. This illustrates the problem of securing land and farmers' accessibility to pastoral areas to allow animals to graze in West Africa (Gonin & Tallet, 2012).

The comparative analysis of the trajectories in the two study areas showed that changes in agropastoral dairy systems took place under different constraints that did not always lead to an increase in agroecological practices in agropastoral dairy farming systems. Our normative approach was a social and scientific construction according to an agroecology analysis framework (Altieri, 2002; Dumont et al., 2013), which enabled us to identify trajectory types and qualitatively assess their engagement in agroecological transition. However, the context played a major role in understanding the trajectories. Land challenges do not take on the same meaning in West Africa and Europe. Human pressure (Dongmo et al., 2007) on agropastoral resources leads livestock farmers to adopt intensification practices in WBF (Vall et al., 2006). The development of fodder crops exclusively for animal feed is limited by access to land and competes with food crops (César et al., 2004). These constraints have led dairy farmers to buy feed inputs to produce milk and earn a higher income. Nevertheless, these livestock systems use local resources (Sib et al., 2017). Crop–livestock integration seems to be a sustainable pathway (Dugué et al., 2012). For European countries, with farms being abandoned, rangelands are gradually being deserted. There are stakes in reconquering these areas (Lepart et al., 2011). In the trajectories identified here, rangeland use varied from one farm to another, from maintaining pastoral practices and feed resources, right up to their abandonment. The abandonment or under-use of rangelands is a risk for the closure of pastoral areas, with the development of forest, and threatens a share of biodiversity (Lepart et al., 2011), even though they were originally man-made. The return of wolves to the territory casts doubts on these pastoral practices (Meuret et al., 2017).

The issue of food security is a major challenge that occurs differently in the two study areas. In Western Burkina Faso, food security challenges are reflected in the need to increase milk production, but also to diversify food commodities (Lourme-Ruiz et al., 2016). The dairy farmers introduce practices to support family consumption and to supply the local dairies throughout the year. In the Grands Causses territory in France, food security issues concern health quality, traceability, but also the practices introduced by dairy farmers through signs of quality and origin, and supplying food (cheeses, ultra-fresh) for local consumption (Allaire & Sylvander, 1997). In Europe, consumers contribute to changes in farming practices because they buy labelled or local products (Allaire, 2016). This comparison between the two territories shows that agroecological transition needs a strong structural support, such as market organization demanding high quality products that respect the environment. The WBF example shows that, without support, such as the organic referential in the GCF territory, or organization, the trend would be towards specialization in order to facilitate production and secure supplies to dairies.

5. CONCLUSIONS AND PERSPECTIVES

The emergence of novel trajectories provides food for thought for designing innovative systems. However, it would be worth making a quantitative assessment of how changes in practices affect farm performance and sustainability, depending on the technical and economic results achieved, and not only the means devoted by farmers *via* their practices. A comprehensive and understanding approach to transition would elucidate the issues raised by this study, especially how the process takes place and who the stakeholders involved in this agroecological transition are. Agroecological transition would benefit from being co-constructed, by taking into account the diversity of local contexts through research, in partnership with farmers, technical supervision, NGOs and policy makers.

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