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Analyzing farming systems diversity: a case study in south-western France

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Abstract

The huge changes in agricultural activities, which may be amplified by the forthcoming Common Agriculture Policy reform, call the future of crop-livestock systems into question and hence the impact of these changes on landscapes and biodiversity. We analyzed relationships between agriculture, landscape and biodiversity in south-western France. The study area covered about 4,000 ha and included four villages. We conducted a survey of 56 farms. Multivariate analysis (multiple factor analysis and cluster analysis) were used to analyze relationships between 25 variables and to build a typology. The type of farming (beef and/or dairy cattle, cash crops), size (area and workforce) and cultivation practices, among others, were revealed as differentiating factors of farms. Six farming types were identified (1) hillside mixed crop-livestock farms, (2) large 'corporate' farms, (3) extensive cattle farms, (4) large intensive farms on the valley sides, (5) small multiple-job holdings, and (6) 'hobby' farms. The diversity of farming systems revealed the variable impact of the main drivers of change affecting agricultural development, particularly the enlargement and modernization of farms along with the demography of agricultural holdings.

Additional key words: farming systems; farm typology; Hills of Gascony; mixed crop-livestock systems; multivariate analysis.

Resumen

Análisis de la diversidad de los sistemas de producción agrícolas: un caso de estudio en el suroeste de Francia

Los enormes cambios experimentados en las actividades agrícolas en Europa, que podrían ser amplificados por la próxima reforma de la política agrícola común de Europa, cuestionan el futuro de los sistemas agropecuarios y, por tanto, el impacto de estos cambios en el paisaje y en la biodiversidad. Para ello, se estudiaron las relaciones entre la agricultura, el paisaje y la biodiversidad en el suroeste de Francia (Cerros de Gascuña). El área de estudio cubre aproximadamente 4.000 ha e incluye cuatro municipios. Los datos relacionados con las actividades agrícolas provienen de encuestas realizadas en 56 explotaciones. Para estudiar las relaciones entre 25 variables, se utilizaron análisis multivariados (análisis factorial múltiple y análisis de conglomerados) y se elaboró una tipología. Los factores de diferenciación identificados, entre otros, son: el tipo de producción (ganado de carne y/o lechero, cultivos herbáceos), tamaño (superficie y mano de obra) y prácticas de cultivo. Se distinguieron seis tipos de explotaciones: (1) explotaciones de ladera que combinan agricultura y ganadería, (2) grandes explotaciones corporativas, (3) explotaciones ganaderas extensivas, (4) grandes explotaciones intensivas en valles, (5) pequeñas fincas explotadas a tiempo parcial, y (6) explotaciones para ocio. La diversidad de los sistemas de producción reveló el impacto variable de las principales fuerzas de cambio que afectan al desarrollo de la agricultura, en particular a la ampliación y modernización de las explotaciones, junto con la demografía de la población agrícola.

Palabras clave adicionales: análisis multivariados; Cerros de Gascuña; sistemas agropecuarios; sistemas de producción; tipología de explotaciones.

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Abbreviations used: AHC (agglomerative hierarchical clustering); AU (approximately unbiased); AWU (annual work units); CAP (common agricultural policy); FA (forage area); LU (livestock unit); MCA (multiple correspondence analysis); MFA (multiple factor analysis); PCA (principal component analysis); UAA (utilized agricultural area).

Introduction

Current agricultural development in developed countries is characterized by a decrease in the number of farms, along with the enlargement of individual farms, specialization, and an increase in labor productivity. In France, in the last ten years, the number of farms decreased by 3% per year (Agreste, 2011). Four farms out of five have disappeared between 1955 and 2010, resulting in an increase in the average size of farms from 15 ha to 55 ha. At the same time, farming systems became specialized both at farm and regional levels. There was a reduction in the most complex systems, such as mixed livestock-crop systems, making way for more specialized systems (cash crops, beef or dairy cattle) (De Ravignan & Roux, 1990). These changes have had a significant impact on the landscape, with the disappearance of hedges, which were considered to be an obstacle to mechanization as well as on yields (*ibid*.). The resulting simplification of rural landscapes linked with the intensification of agricultural practices is the main cause of change and loss of biodiversity in Western Europe (Gaston & Fuller, 2007).

In the last 15 years, recurrent common agriculture policy reforms and the drop in the prices of agricultural products has reduced farmers' incomes (Lobley & Potter, 2004). In this context, the complete decoupling of aid planned in 2013 will probably be unfavorable for ruminant livestock. In mountainous disadvantaged areas, where there is no viable alternative to livestock, agro-environmental measures will be needed to reduce loss of income (Acs *et al.*, 2010). Conversely, in mixed livestock-cropping areas there is a high risk of a move from cattle farming to crop farming (Chatellier & Guyomard, 2008), despite renewed interest in combining crops and livestock raising for reasons of sustainability (Russelle *et al.*, 2007).

Thus the future of these systems is being called into question and changes in production will very likely lead to further homogenization of agricultural ecosystems, continuing enlargement of farm parcels and, with the disappearance of meadows, a particular land-use mosaic.

In Europe the reduction in support linked to production is accompanied by a rural development policy based on the concept of multifunctionality to foster the development of alternative sources of income while preserving the environment (Simoncini *et al*., 2009). Multifunctionality has been the subject of many studies in recent years but nevertheless requires significant advances in terms of operationalization and the application of the concept (Renting *et al*., 2009). One serious difficulty is the mismatch between the scale of management and the scale(s) of the ecological processes being managed (Cumming *et al*., 2006). How can farmers be paid for services, such as conserving landscape or biodiversity, that operate at a larger scale? (Pelosi *et al*., 2010).

Agronomists need to design methods to enable a coherent negotiated compromise between individual management of farms and concerted management of small territories under environmental constraints (Deffontaines, 1998). In the opinion of this author, only developing models that link typologies of territories with typologies of farms will make it possible to foresee the effects of a change in cropping systems on the territory, and to predict the consequences of a transformation of the territory on the cropping systems.

In this context, the micro-regional scale, (*i.e.* a scale of several thousand hectares), is a key scale to address water pollution or conservation species issues (Thenail, 2002) or other local development issues. This is the scale we used to study the dynamics of changes in farms and in the landscape of a small agriculture region (Gascony) that has been characterized by mixed crop-livestock systems since 1950; systems which are threatened by European agriculture development (Ryschawy *et al.,* 2012). The aim was to build scenarios of agriculture change to support discussion with local rural stakeholders to identify sustainable development paths (Choisis *et al*., 2010). To this end, we developed an investigation method based on an exhaustive survey of all the farmers in the area. As in any prospective research it is necessary to analyze first the current situation and the past changes (Sheate *et al.,* 2008). The first step of our approach was then to analyze the farming systems of the area. This article describes the diversity of farms in the area and the resulting farm typology.

Material and methods

Study area and data collection

The study area is part of the '*Long-Term Ecological Research*' site «*Vallées et Côteaux de Gascogne*» (LTER-Europe). It comprises Aurignac county, located at the foot of the Pyrenees 75 km south-west of Toulouse (Fig. 1). The region is characterized by a hillside and hedgerow landscape with a lot of private woods. The 'Côteaux' is still a mixed crop-livestock region but has undergone specialization towards beef cattle and

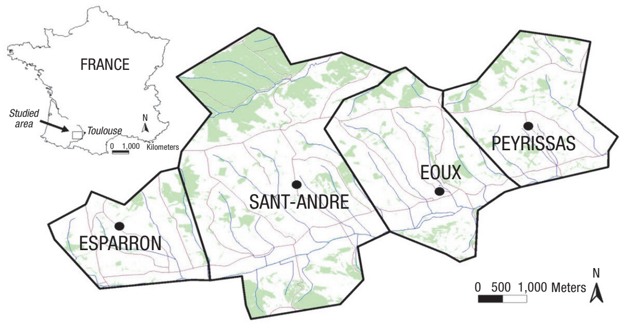

Figure 1. Study site.

cash crops (Table 1). The coexistence of tradition and modernization make it a relevant study site to analyze the effects of the main drivers of change faced by European agriculture and the conditions of maintaining crop-livestock systems.

The data collection method was developed by Gibon (1999) and has already been used at another Pyrenean site (Mottet *et al.*, 2006). The method was applied in collaboration with local stakeholders (Choisis *et al.*, 2010). The first step was to choose a sample of villages to be surveyed. Four adjacent agro-ecologically homogeneous villages located on the northern slope of the Nere basin were selected (Fig. 1). This sample provided data on hillside agriculture, characteristics of the area, and irrigable land on the valley. This territory covers an area of 4,121 ha, of which 72% is agricultural land and 16% woodland. The second step was to identify and conduct an exhaustive survey of farmers who cultivated land in the study area, regardless of the location of the farmstead and the size of the area cultivated. However, the survey did not include farmers whose homestead was located in other villages and who cultivated only a few parcels in the study area. Consequently, we surveyed 56 farms out a total of 61 farms identified in the area with the help of the chamber of agriculture advisor and of the farmers themselves. These farms covered an area of 2,779 ha, representing 94% of the agricultural area of the territory. Apart from one refusal, the farms that were not surveyed were hobby farms covering only a few hectares.

Table 1. General agricultural characteristics in Aurignac County

Number of farms	277
Agricultural area (ha)	11,415
Cereals (ha)	3,022
Forage area (ha)	6,991
Industrial crops (ha)	908
Fallows and other crops (ha)	479
Woods (ha)	3,351
Suckler cows	4,769
Dairy cows	1,183
Sheep	3,944

Source: Agreste — Recensement Agricole 2000 — La fiche comparative Midi-Pyrénées.

Data was collected in two consecutive interviews with farmers. The first survey concerned the history of the farm since 1950, and its structure and functioning. The parcel register map indicating the cultivated ‘blocks’ of land was recovered, at the end of the first visit, in preparation for the second interview. The second survey was based on a graphic support and addressed land tenure and past and present land-use systems. Later, the data collected was entered in an Access® database and an ArcGIS® geographical information system. Surveys were carried out between October 2006 and March 2007.

In this article, historical data were used to understand the general trends of the production systems. The trajectories of change of the farms will be in a second stage subjected to a detailed analysis.

Farm model

The methodology relies on the analysis of the family farm system (Osty, 1978). At the level of the agents of the system, it takes into account (i) decision making (the farm manager is characterized by age and level of agricultural education), (ii) the agricultural workforce and (iii) the family project. The analysis of the elements of the system is based on the livestock farming systems approach (Gibon, 1999) that differentiates (i) the forage system (here extended to include the cropping system), (ii) the herd management system and (iii) the value-added system.

The analysis of these different sub-systems leads to the identification of differentiated strategies resulting in coherent organizations of the productive processes. Fig. 2 shows the broad categories of information collected to inform this systemic model of the farm.

Data analysis

K-table analysis

To build a typology, the diversity of a sample of farms is generally analyzed by principal component analysis

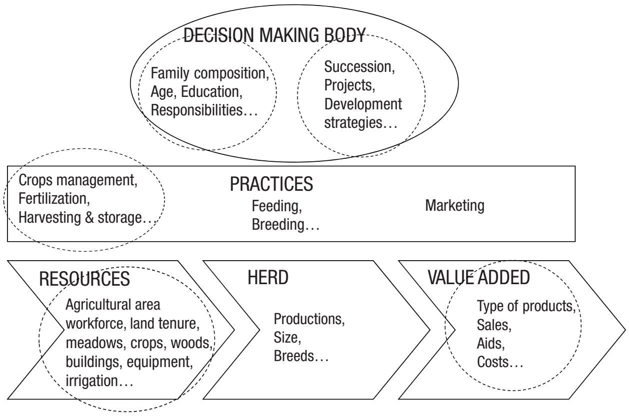

Figure 2. The broad categories of information collected on the farms (adapted from Choisis & Vallerand, 1994). The themes retained for analysis are indicated by dotted lines. Variables related to herd management were not taken into account as some farms did not have livestock.

(PCA) or multiple correspondence analysis (MCA) depending on the quantitative or qualitative nature of the variables. These well-established methods have been widely used for the study of livestock farming systems (Cervantes *et al.*, 1986; Milan *et al.*, 2006; Pardos *et al*, 2008). Nevertheless, they have two drawbacks: (i) they include heterogeneous variables in the same analysis, and (ii) they can process only either quantitative or qualitative variables. Complementary multi-table methods that allow variables to be organized in themes should thus also be used. One example of such a use is described in Escofier & Pages (1994) with a sample of wines judged using visual, olfactory and gustative criteria. Beyond judging each wine, the aim was to search for common dimensions in the three criteria.

The same objective could apply to the analysis of farms using components of the farming system as themes. Alary *et al.* (2002) used multiple factor analysis (MFA) for the study of dairy farms. This method allowed the authors to carry out an inter-structure analysis (relations between themes) and an intra-structure analysis (relations between farms with respect to each theme).

This method allows the weighting of variables by the inverse of the first eigenvalue of the separate analysis of each table (Escofier & Pages, 1994). This enables the influence of each variable and theme in the global analysis to be balanced. It takes into account the components of the farming system that are considered to be important and reduces the weight of the more discriminating variables.

In our study, data were processed using the *FactomineR* package (Lê *et al.*, 2007) of R software (R Development Core Team, 2008). This package allows quantitative and qualitative data to be taken into account on the basis of the PCA and MCA respectively. However, data must be of the same type in each table. This combination avoids having to convert quantitative data into classes and having threshold effects.

Typology of farms

In the first step, we performed agglomerative hierarchical clustering (AHC), using Ward's criterion, on the component scores of individuals on the seven first axes of the MFA. In the second step, we consolidated the resulting typology using k-means clustering on the centroids of the selected clusters, to increase the interclass inertia of the partition.

To assess the quality of clustering, we calculated approximately unbiased (AU) *p*-values for hierarchical clustering via multiscale bootstrap resampling (Suzuki & Shimodaira, 2006). For a cluster with AU *p*-value >0.95, the hypothesis that "the cluster does not exist" is rejected with a significance level of 0.05. Data were processed with the *pvclust* package of R software.

Selection and organization of data

Among the 56 farms surveyed, three were very small units from which the data we collected could not be processed using these multivariate methods, so the analyses were based on the remaining 53 farms.

We extracted a first dataset of 48 variables from the database to inform the different components of our farm model. We classified these variables in five themes: family decision making, orientation and objectives, operational management, productive assets, and economics (Table 2). We then reduced the number of variables taking into account the variability and non-redundancy of parameters, and the absence of unbalanced classes. This process led us to retain 25 variables for the analysis of which 12 were qualitative and 13 quantitative (Table 2). In Fig. 2 these variables are plotted in relation to the components of the farming system. Variables related to herd management were not taken into account as some farms did not have livestock. The two first themes comprised qualitative variables apart from 'age' that we converted in qualitative data by codifying it in three

Table 2. Variables selected for the analysis

Theme	Variable	Heading[1]	Type[2]	Number of classes	Modalities
Family – Decision making	Family composition	FAM	Qual.	3	Single man (A), couple without children (B), couple with children (C)
	Sources of income	INC	Qual.	4	Farm only (A), pluriactivity(B), spouse work (C), both (D)
	Responsibilities of the farmer	RES	Qual.	3	Absence (A), municipal (B), professional (C)
	Level of agricultural education	EDU	Qual.	3	Absence (A), medium level (B), higher level (C)
	Age of farmer	AGE	Qual.	3	< 45 (A), 45-55 (B), > 55 (C)
Orientation & objectives	Mutual aid	AID	Qual.	2	Absence (A), presence (B)
	Succession	SUC	Qual.	3	Absence (A), presence (B), not concerned (C)
	Projects	PRO	Qual.	4	Cessation (A), no change (B), enlargement (C), diversification (D)
	Orientation of the farming system	TYP	Qual.	4	Beef (A), beef & crops (B), milk (C), crops (D)
	Marketing of products	MAR	Qual.	4	Standard (A), partial finishing (B), quality label (C), complementary unit/ direct sale (D)
Operational management	Tillage	TIL	Qual.	3	Ploughing, both, simplified
	Forage area/Agricultural area	FA	Quant.		
	Livestock units / Forage area	LU/ha	Quant.		
	Small grain cereals/ cultivated area	CER	Quant.		
	Nitrogen fertilization of wheat	FER	Quant.		
	Number of fungicidal treatments	FUN	Quant.		
Productive assets	Agricultural work units	AWU	Quant.		
	Utilized agricultural area	UAA	Quant.		
	Level of assets	CAP	Qual.	3	Low, medium, high
	Use of land in distant villages	FAR	Quant.		
	Irrigation	IRR	Quant.		
	% ownership of land	OWN	Quant.		
Economics	Turnover / Agricultural work unit	TUR	Quant.		
	% of agricultural premiums in the turnover	SUB	Quant.		
	Farm debt	DEB	Quant.		

[1] See Figures 3 and 4. [2] Qualitative and quantitative - AGE was initially a quantitative variable that we converted in qualitative data by codifying it in three classes. TIL and CAP were treated as quantitative variables since they were ordinal variables.

classes (with limits at 45 and 55 years). The other three themes comprised quantitative variables, except 'tillage' and 'assets level'. These later were nevertheless retained since they were ordinal variables. They were divided into three classes.

Results

Interpretation of the K-table analysis

The bar plot of eigenvalues from the MFA global analysis shows the major contribution of the two first axes, which represent 16% and 11.2% of the inertia. This led us to focus our analysis on the factorial map built on these two axes. The bar plot of eigenvalues from the separate analyses shows the significant role of productive assets and management in differentiating farms. However, there was also an effect of the nature of the variables because eigenvalues were higher for quantitative than for qualitative variables.

The representation of themes in the first factorial map of the MFA shows that 'economics' and 'productive assets' were close and structured the first axis. Likewise, 'family' and 'management' were close but linked to the second axis. The 'objectives' theme was between the two and was linked to both axes.

The combination of quantitative and qualitative variables in the MFA allowed the correlation circle of quantitative variables (Fig. 3) and the modalities of

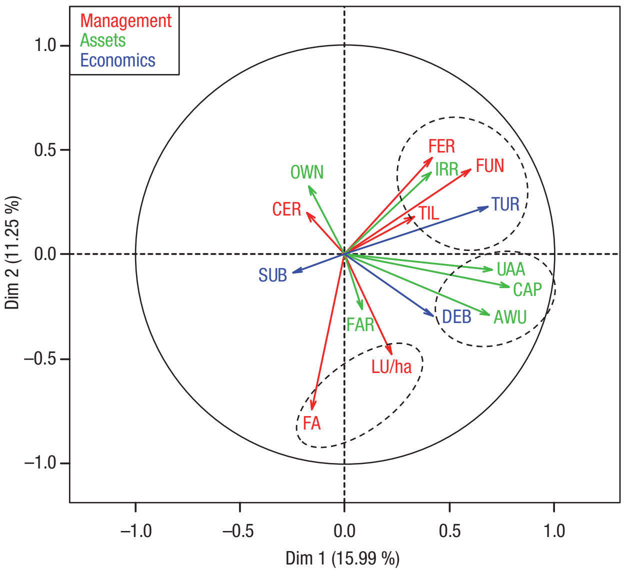

Figure 3. Representation of the quantitative variables on the first factorial map of the multiple factor analysis (MFA): AWU, agricultural work units; CAP, level of assets; CER, small grain cereals/cultivated area; DEB, farm debt; FA, forage area/agricultural area; FAR, use of land in distant villages; FER, nitrogen fertilization of wheat; FUN, number of fungicidal treatments; IRR, irrigation; LU/ha, livestock units/forage area; OWN, % ownership of land; SUB, % of agricultural premiums in the turnover; TIL, tillage; TUR, turnover/agricultural work unit; UAA, utilized agricultural area.

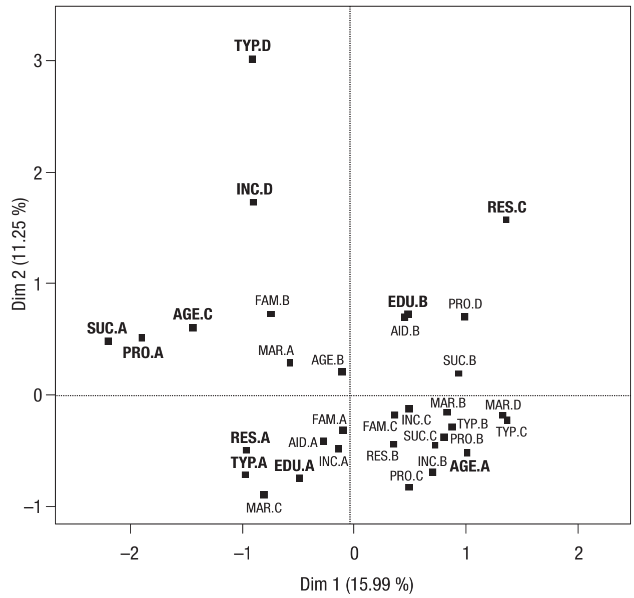

Figure 4. Representation of modalities of the qualitative variables on the first factorial map of the MFA (the modalities contributing most to the axes are shown in bold): AGE, age of farmer; AID, mutual aid; EDU, level of agricultural education; FAM, family composition; INC, sources of income; MAR, marketing of products; PRO, projects; RES, responsibilities of the farmer; SUC, succession; TYP, orientation of the farming system (see Table 2 for the meaning of the modalities A to D).

qualitative variables (Fig. 4) to be represented on the same factorial map.

Regarding quantitative variables, Fig. 3 shows three groups of correlated variables:

— The three most correlated variables were agricultural area (UAA), work units (AWU) and level of investment (CAP). They were associated with the productive assets theme and were indicators of farm size. They greatly contributed to the first axis. The level of indebtedness (DEB) was projected close to these variables, in particular because of the low indebtedness of small farms.

— The second group of variables was closely linked to cultivation practices. Fertilization level (FER), use of fungicides (FUN) as percentage of irrigated land (IRR) reflected the level of intensification of the farm. Tillage (TIL) was also linked to this group but to a lesser extent. Thus, low tillage, which is part of an enlargement process of farms, may be related to intensification of production. In contrast, most small 'traditional' farmers continued to plow their land. Turnover per work unit (TUR) was also linked to the level of intensification. These variables contributed to both axes.

— Forage area (FA) and stocking density (LU/ha) were linked to the presence of livestock and greatly contributed to the second axis.

The correlation circle also revealed opposition between (i) the contribution of owned land (OWN) and that of distant land (FAR) implying farm enlargement and recourse to rented land (ii) diversification of arable crops (CER) and livestock (LU/ha and FA) — all the variables that contributed to the second axis — (iii) the contribution of subsidies to turnover (SUB) and turnover per work unit (TUR) that contributed to the first axis.

Representing the modalities of the qualitative variables on the factorial map of the MFA completed the interpretation (Fig. 4).

Crop farming (TYP.D) was located in the upper part of the second axis, which was also explained by (i) sources of household income by combining the farmer's multiple jobs with the paid employment of the spouse (INC.D) and (ii) the fact that the farmer held responsibilities in professional organizations (RES.C). This modality appeared to be linked to the level of intensification of the farm (Fig. 3) by the fact that elected professionals are holders of a technical model. It also revealed that these farmers have been trained in the agricultural education system (EDU.B).

In contrast, we found modalities linked to the absence of agricultural education (EDU.A) and lack of institutional responsibilities (municipal or professional) (RES.A). They were projected close to beef cattle farming (TYP.A). The left part of the first axis was driven by elderly farmers (AGE.C) in cessation of their activities (PRO.A) and with no designated successor (SUC.A). Younger farmers were projected on the opposite part of the axis (AGE.A).

Farming type appeared as a differentiation factor (Fig. 5). Specialized arable farming was located on the upper part of the second axis, whereas specialized beef cattle farming was located in the south-east quarter. However, there was significant dispersion of each of these four major orientations.

Interpretation of clustering

The bar plot of eigenvalues shows slight discontinuity between axis 7 and axis 8. This limit appeared to be satisfactory given that it provided more than 50% of inertia. The coordinates of individuals on the first seven axes of the MFA, which represented 58.5% of inertia, were therefore used to perform the AHC.

To define the number of clusters, a subjective partition of the dendrogram from the AHC can be performed to find a compromise between the number and the homogeneity of the clusters retained (Kobrich *et al*., 2003). Actually, this partition relies on observed 'jumps' in the inertia inter-clusters: a high loss of inertia means that two associated clusters are quite far apart. This principle led us to retain a partition into five clusters.

The *p*-value calculated for each cluster underlined the fact that the clusters were not equally homogeneous (Table 3). The homogeneity of cluster 1, which had the most individuals, was lower. The partition of this cluster at a lower and more relevant level isolated one individual and two more homogeneous clusters (*p*-values of 0.78 and 0.65). However, applying this cutting line to the whole sample led to ten clusters. We therefore retained the more aggregated level with five clusters but used infra-cutting to improve the description of the types.

The *k*-means calculated on the centroid of the five clusters, to consolidate the typology, reclassified only three individuals in the nearest cluster.

The five groups obtained appeared to be relatively well separated on the global map of the MFA (Fig. 6).

The superimposition of Figs. 5 and 6 shows that the type of farming was an important element for the constitution of the groups but it could not be reduced to it. A cursory look at the typology with regard to the correlation circle of the PCA (Fig. 3) suggests that intensification and size of the farms decrease from type 4 to type 5 turning clockwise. In the next paragraph we describe each type.

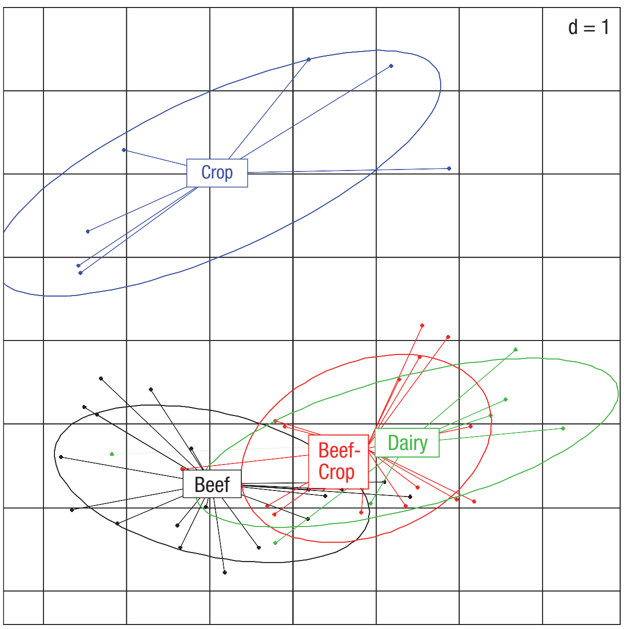

Figure 5. Positioning of the farms, grouped according to their farming system, on the first factorial map of the MFA.

Description of the farm typology

Size and descriptive parameters of each type are presented in Table 4. Analysis of variance indicated

Table 3. Calculated *p*-value for the five clusters

Clusters	1	2	3	4	5
n	17	12	13	6	4
AU *p*-value	0.44	0.72	0.91	0.91	0.80

AU: approximately unbiased.

Table 4. Main characteristics of the farm types (mean ± standard-deviation)

Farm types	1	2	3	4	5	6	p<
Number of farms	17	12	13	6	4	4	–
Age (years)	42 ± 6[a]	51 ± 9[ab]	56 ± 8[b]	49 ± 8[ab]	52 ± 2[ab]	51 ± 8[ab]	0.00
AWU	1.4 ± 0.5[b]	2.8 ± 1.1[a]	1.2 ± 0.5[b]	1.1 ± 0.5[b]	0.5 ± 0.5[b]	–	0.00
UAA (ha)	83 ± 33[bc]	179 ± 86[a]	65 ± 46[bc]	134 ± 26[ab]	19 ± 5[c]	7 ± 3[c]	0.00
FA/UAA (%)	68 ± 23[a]	47 ± 25[ab]	73 ± 21[a]	27 ± 25[b]	16 ± 19[b]	–	0.00
LU/FA	0.8 ± 0.4[a]	0.9 ± 0.5[a]	0.8 ± 0.5[a]	0.4 ± 0.4[ab]	0[b]	–	0.00
Number of cows	41 ± 19[ab]	67 ± 51[a]	35 ± 31[ab]	29 ± 26[ab]	0[b]	–	0.00
Turnover/AWU (k€)	53 ± 30[ab]	68 ± 29[ab]	34 ± 16[a]	94 ± 55[b]	38 ± 45[ab]	–	0.00

AWU: agricultural work units, UAA: utilized agricultural area, FA: forage area, LU: livestock units.

highly significant effects of the different types for all variables.

Type 1: Hillside mixed crop-livestock farms

This was the largest group, which was also the most heterogeneous, corresponding to crop-livestock farming, with beef cattle predominating, typical of dry hillsides. Farmers were significantly younger than the other types (average of 42 years) for whom the problem of succession had not arisen. Despite their age, half of them had no agricultural education, because they had a different job before taking over the family farm. Farms were medium size (83 ha of UAA and 41 cows) managed by a single farmer or in association with a parent. The practices did not determine the type apart from the fact that no farms were irrigated.

The partition of this group, on the basis indicated previously, distinguished two groups of different ages with an average of 39 years (n = 6) versus 45 years (n = 10). In the first group, farmers were single men and in the second they lived as a couple with children (the majority of spouses had an off farm job).

Thus, these two groups can be interpreted as the same type but at two different stages of their evolution. This was also apparent in the average values of the variables linked with farm structure: 28 *vs.* 50 cows, 65 *vs.* 98 ha of UAA, 39% *vs.* 51% of land ownership, respectively for these two groups.

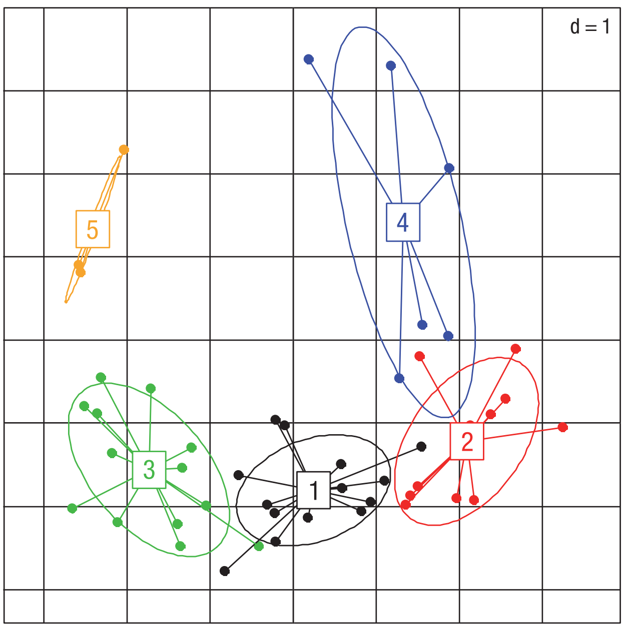

Figure 6. Representation of the five groups of farms on the first factorial map of the MFA.

Type 2: Large corporate farms

This type grouped large corporate farms with a higher number of workers: 179 ha, close to 90 cows for those with livestock, and an average of 2.8 AWU. Their enlargement partially resulted from the purchase of parcels located far away from the farmstead. These were crop-livestock farms that combined arable crops with beef cattle or with more intensive animal production: dairy cattle and/or indoor production (pigs, poultry). The aim of combining different production units in the farm was to provide an income for all the members of the family. These farms used somewhat more intensive practices (average fertilization 130 units of nitrogen per hectare for wheat, two fungicide applications, etc.) and low tillage practices combined (or not) with plowing. Half had access to irrigation and all invested in equipment. The majority of farm managers had an agricultural degree and some farm members held professional or municipal responsibilities. The farms were fully operational or were seeking to diversify their activities. Succession was not an issue due to the age of farmers, or was already ensured.

Type 3: Extensive cattle farms

This type was composed of extensive livestock farms (11 beef cattle farms, one farm that raised sheep for meat and one dairy farm), located on dry hillsides. An average of 73% of the UAA was forage. In comparison with the other types, this type made fewer investments in the farm and used, on average, the lowest level of inputs (fertilization: 60 to 100 units of nitrogen per hectare for wheat, zero or one fungicide application, etc.). The farmers were significantly older and had a lower turnover per work unit. 75% had no agricultural degree and none held professional responsibilities (only two held municipal responsibilities). The partition of this group on the dendrogram distinguished two groups. One accounted for farmers in cessation (n = 8). These farmers were older (average 59 years) with no successor. They worked alone on the farm which was their only source of income. The farm was small (average of 43 ha of UAA) and mainly in ownership. They had no particular strategy for marketing their products. They continued to use more 'classical' practices like plowing and cultivated a small range of arable crops.

The other group (n = 5) had a strong livestock orientation: forage area represented 86% of the UAA. Farms were less likely to disappear than those in the previous group. Farmers were on average younger (52 years old), and succession was not an issue for the younger farmers and was ensured for the others. They had bigger farms (102 ha — 1.6 AWU — 60 cows). While making moderate use of inputs, they combined this practice with less classical ones such as low tillage. Unlike farmers in the previous group, who sold standard products, they had a strategy of valorization which aimed at increasing added value (finishing cattle, suckling calves) and had complementary off-farm income (agricultural services, spouse's salary).

Type 4: Large intensive farms on valley sides

This group included six farms that were more oriented towards arable crops. The group included the three arable crop farms located in the north-east part of the MFA map (Figs. 5 and 6). The agricultural area, which comprised more than 100 ha of valley sides, was relatively compact and suitable for cereal production. Farmers used relatively intensive practices together with high quantities of inputs and low tillage. This farm type used the highest level of wheat fertilization (125 to 190 units of nitrogen per ha) and also a lower number of AWU in proportion to the area (average of 1.1 AWU). Low workforce availability was a reason for decreasing or abandoning livestock. The turnover per AWU, which was by far the highest, was due to higher productivity and fewer workers. These farms invested in equipment: they all joined a 'cooperative for the use of agricultural equipment' and four out of the six irrigated their land. They were all bound to a modern agricultural model, which is linked to the fact they had all received an agricultural education and held professional responsibilities. Farm succession was not an issue or was already ensured.

Type 5: Small multiple-job holdings

This group comprised four farms located in the north-west part of the MFA map (Figs. 5 and 6). The farms were small (19 ha and 0.5 AWU on average) and were managed by farmers who had a full-time off-farm job. These farmers chose to maintain the small family farm they had inherited while continuing to work off the farm. The small farm size generated a very low turnover, but the objective of the farmer was more related to conserving the family patrimony than to generating an agricultural income. Low workforce availability led these farmers to abandon livestock. They used quite 'classical' practices similar to type 3 (low level of inputs, plowing, no irrigation). Like farmers in cessation, they had no successor.

Type 6: Hobby farms

We classified in this group very small farms that generated a very low or zero income from agricultural activity. It included four farms that were surveyed from which three could not be part of the multivariate analysis. Four other farms that were not surveyed were of this type. They were either agricultural pensioners who kept a few ha of land to remain in work or people who had purchased a house with the associated land. The average size of the surveyed 'hobby' farms was seven ha. It should be noted that this group included two neo-rural residents whose installation was motivated by a farm project. One had an agricultural activity based on organic market gardening. Although classified as a hobby farm, this farm could be considered as an alternative farming system, which had no other representative in the study area.

Discussion

A typology finalized by the territorial scope

Today, farm typologies are widely used to build knowledge on local agriculture (Caballero, 2001; Milan *et al.*, 2006; Pardos *et al.*, 2008) or to adapt advice and development policies to a diverse audience of farmers (Landais, 1998; Daskalopoulou & Petrou, 2002). However, purposes have diversified thanks to the development of modeling (Valbuena *et al.*, 2008; Vayssières *et al.*, 2011), sustainable development issues, land-use changes and land-use planning (Alvarez-López *et al.*, 2008; Valbuena *et al*, 2008) that correspond to our research framework. These typologies are often based on farm surveys that have to select a representative sample of the population to be surveyed.

Our approach was rather different because we aimed to survey all those who cultivated land in a given area so as to be able to study ecological dynamics and changes in agricultural activities jointly (Gibon, 1999; Choisis *et al.*, 2010). Such an approach reveals a wider range of situations as it accounts for all forms of agriculture including marginal forms (very small or very large farms for example) whose probability of being included in a stratified sample is very low. In return, the scope of our study was limited by its survey capacity and the resulting typology consequently cannot be generalized to a larger scale. However, our choice of a micro-regional scale was not determined by the need to be representative but by the relevance of the relations between farms and landscape analysis.

As a result, the UAA of the 56 farms we surveyed ranged from 2 ha, for a market-gardening farm, to nearly 400 ha, for a corporate mixed crop-livestock farm. Despite the small size of the study area, we observed a wide range of systems that revealed different farming practices and functions assigned to agriculture. We found traits in common with a typology elaborated in other French regions (Laurent *et al.,* 1998; Van der Ploeg *et al.,* 2009). The main ways of practicing agricultural activity identified by these authors (*i.e.* agriculture as structured profession — agriculture based on traditional farmer logic — non integrated multi-activity — retired farmers and small-scale recreational agriculture) are also present on our study site.

The main drivers of changes in production systems

Enlargement

The main change has been the decrease in the number of farms, which is representative of French agriculture. According to agricultural censuses in 1955 and 2000, the number of farms decreased threefold in the agricultural region 'Coteaux de Gascogne'. This reduction, which started in the 1950s, is still continuing, hand in hand with the enlargement of farms. The average size of the farms we surveyed was 96 ha in 2006 while in 1950 the farms that existed at that time had an average size of only 26 ha. However, strategies of enlargement differed between farms. At one end of the gradient were farmers who had multiple-job activities (type 5) who seized the opportunity to work off the farm and did not enlarge their farm and, at the other end, types 2 and 4 farms that became bigger and today are seven to nine times larger than in 1950 (Table 4). This enlargement was partly achieved by renting land, particularly since the beginning of the 1970s. From 10% in 1950, the proportion of rented land increased to 43% in 2006. But, paradoxically, the types of farms that enlarged most were not those that rented more land located farthest from the farm, but rather type 4 farmers who owned more land and whose land was located closer to the farmstead than smaller types 1 and 2 farms.

One reason for this situation is the "house-based" social system typical of this region. Traditionally, the aim was to transfer the property unchanged from one generation to the next. A historical study of these households revealed that little fragmentation of holdings occurred during the last century; on the contrary, owners contributed to their survival and consolidation (Sourdril & Ladet, 2008). We observed during our surveys that enlargement was often due to grouping farms through family alliances and opportunities (marriage, farms belonging to relatives, e.g. uncles and aunts with no successor). The differences we observed between farms were more due to opportunities families had to group their farms and in the availability of a family workforce than to farmers being determined to enlarge their farm by buying or renting land. Furthermore, corporate farms (type 2) which were mostly the largest farms were those that employed the most family labor. Their average agricultural area per work unit (64 ha) was equivalent to types 1 and 3 farms.

Modernization

Farms have been undergoing another process: modernization, which led to mechanization and to the specialization of farming systems with the aim of increasing labor productivity. Previously, farms had diversified agricultural activities with the aim of being self-sufficient. This process led to a simplification of farming systems. In Aurignac County, where the four surveyed villages are located, simplification resulted in a major decline in secondary animal production (sheep, pigs and poultry) and plants (family gardens, vines).

The expansion of milk production, which took place at the end of the 1970s, was in fact short lived: between 1979 and 2005, the number of dairy farms dropped from 137 to 25. The number of beef cattle heads is the only one that remained stable. Similar changes can be observed in less-favored areas in southern Europe under the effects of the European common agricultural policy (CAP) (Garcia-Martinez *et al.*, 2009) with the implementation of milk quotas and premiums for beef cattle. The combination of these measures favored the development of beef cattle at the expense of dairy cattle.

Workforce availability

But the orientation of farming systems has also depended on the availability of a family workforce, which was a general constraint faced by farmers: 60% of surveyed farms had less than 1.3 AWU. In response to the regular increase in the UAA per AWU, farming systems were simplified. Concerning livestock, the increase in labor productivity has gone through the reduction in routine work per livestock unit. This process favored the development of suckler cows systems as dairy cattle and milk-fed veal systems are more labor intensive because of the daily milking or feeding (Dedieu & Serviere, 1997). That's why the 1970s and 1980s saw jointly the increase in herd size, the substitution of the local breed (Gasconne) by meat breeds (Limousine and Blonde d'Aquitaine) and the replacement of suckling calves and milk production by weanlings.

Following this trend, when the problem of workforce availability increased, some farmers abandoned livestock and specialized in cash crops. It was, in particular, the case of multiple-job farmers for whom the availability of farm labor was the lowest. But it also concerned other farms when, for instance, the father could no longer work on the farm. These were four farms, of which three were type 4, with more than 100 ha of UAA per AWU. This recent change is still marginal concerning the number of farms but is not negligible in terms of UAA (620 ha in total) because it concerns large farms.

These changes led to the dominance of beef cattle and cash crop systems alone or in combination (types 1, 3, 4 and 5). Type 1 represents a production system that is typical of the 'Coteaux de Gascogne' with a young farmer, living alone or as a couple, and who succeeded his/her father. He/she farmed an average of 66 ha per AWU and, to a greater or lesser extent, changed to raising beef cattle combined with growing cash crops. He/she produced mainly weanlings followed by suckling calves.

Corporate farms (type 2) were the only type that did not have to face problems of workforce availability. With two to four available AWU, unlike the others, their concern was to make better use of the available workforce by searching for more value added products with a more demanding work load, and/or diversifying their production. Along with cash crops and beef cattle, this farm type had the largest number of intensive livestock units (dairy cattle, pigs and poultry rearing). Two farmers processed their products on the farm. Similar intensification and diversification strategies were observed on livestock farms when the number of AWU was high in relation to the available UAA (Milan *et al.*, 2006).

Possible future changes in farming systems

From the typology elaborated here, it is possible to envisage some future changes in farming systems. Without including hobby farms, overall, the decrease in the number of farms and the increase in their size look set to continue, as one quarter of the farmers had no designated successor. Their farms were all type 3 (extensive cattle farms) or type 5 (multiple-job farmers) and concerned the three quarters of them. These types are therefore likely to disappear in the medium term. One major reason for the cessation of activities is the low income (the average UAA was 37 ha) which is not enough to maintain a young farmer. But cessation can also be due to the lack of a successor in the family because, locally, the transfer of the farm is traditionally based on a preferential inheritance system to a sole successor (Sourdril & Ladet, 2008). The survival of small farms can however depend on motives other than economic ones if there is another source of income. Multiple-job farmers may have technical motives, related to leisure or to access to a social status (Fiorelli *et al*., 2007).

In our study area, attachment to the heritage is a major justification for having double activities. The farm is kept because it is a family inheritance, although none of the type 5 (n = 4) or type 3 farmers with less than 70 ha (n = 9) were considering a transfer of the farm within the family.

Whereas cessation is planned for a fair number of farms, these farms represented less than 10% of the UAA because of their small size. Although their grip on the territory was low, it is to be feared that their disappearance will contribute to homogenization of the environment and to a reduction in habitat diversity.

One of the major issues for the future of these territories is the future of livestock. For large type 2 farms, as diversification of production allows better use of the available workforce and reduces the risks, livestock and arable crops should continue to be associated, unless the number of workers decreases. In which case, there could be a decrease in livestock raising as in the case of type 4.

For medium size farms (types 1 and 3), the future of livestock is very uncertain. Dairy cattle are currently in the minority and are likely to be discontinued in this category of farm because of the very low prices the farmers can obtain. Of the eight dairy farms surveyed, half were type 1 or 3, and the other half type 2. The low profitability of dairy farming is then reinforced by the small herd size (34 cows on average in types 1 and 3 versus 67 cows in type 2). Sheep raising, which was only carried out on two farms, is falling behind and has little future in the area. Raising beef cattle, favored by the CAP premiums, appears to be dominant (25/30 farms in types 1 and 3). The consequence is that cattle farmers' income has become very dependent on aids. The guidelines in the 2013 CAP reform will be decisive for the future of beef cattle farming and hence for mixed crop-livestock farming.

Finally, in the context of the continuous enlargement of farms, will the presence of hobby micro-holdings be an epiphenomenon or a perennial category of new rural actors?

If, like land and house prices, the landscape quality of these agricultural communities have been significant factors in attracting a neo-rural population, particularly from Northern Europe, it has also led to a high increase in the price of these goods, which appears to be a barrier to the continuation of the process.

As conclusions, Gascony is a mixed crop-livestock region. But, although cash crops and cattle are the main agricultural products, an exhaustive survey of 56 farms in four villages revealed a wide range of situations. K-table analysis revealed the effect of size, orientation of farming systems, farming practices, and the availability of family workforce on farm differentiation. Although overall, farms are increasing in size, this is happening in a very unequal way. Classification of farms led to the identification of six farm types. Although the majority of farms were mixed crop-livestock farms (types 1 and 2), some were moving towards extensive cattle farming (type 3) or, on the contrary, to cash-crop systems (type 4 and 5). These orientations are due to several different factors, including agronomical constraints, but the availability of a family workforce appeared to be a determining factor. Thus, for farm type 5, multiple activity, or for type 4, a low AWU linked to farm size, should lead to giving up livestock raising. Conversely, 'corporate' farms (type 2) diversified their activities to make better use of the available workforce. Beyond their productive dimension, the diversity of situations reflects the differences in the value attributed to agriculture by the farmers and expected income. At one extreme, the main objective of farming is to earn a living, while at the other, it is simply a hobby. In our small study area, the main short and medium term outcomes appear to be farms that continue to increase in size and farmers who stop farming because they have no successor.

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