

An overview of farming system typology methodologies and its use in the study of pasture-based farming system: a review

W. Mađry^{1*}, Y. Mena², B. Roszkowska-Mađra³, D. Gozdowski¹,
R. Hryniewski¹ and J. M. Castel²

¹ Department of Experimental Design and Bioinformatics. Warsaw University of Life Sciences - SGGW.
Nowoursynowska 159, 02-776 Warsaw, Poland

² Departamento de Ciencias Agroforestales. Escuela Técnica Superior de Ingeniería Agronómica.
Universidad de Sevilla. Ctra. de Utrera km 1. 41013 Sevilla, Spain

³ Unit of Business, Faculty of Economics and Management. Białystok University.
Warszawska 63, 15-062 Białystok, Poland

Abstract

The main objective of the paper is to do a critic study of the use of typology methodologies within pasture-based farming systems (PBFS), especially those situated in less favoured areas, showing in each case the more relevant variables or indicators determining the farming system classification. Another objective is to do an overview of the most used farming system typology methodologies in general. First some considerations about the concept of farming system and approaches to its study have been done. Next, the farming system typology methodologies have been showed in general to different farming systems, but addressed preferably to PBFS. The different tools integrated in these methodologies have been considered: sampling methods, sources of data, variables or indicators obtained from available data and techniques of analysis (statistical or not). Methods for farming system classification have been presented (expert methods, analytical methods or a combination of both types). Among the statistical methods, the multivariate analysis has been overall treated, including the principal component analysis and the cluster analysis. Finally, the use of farming system typology methodologies on different pasture-based farming systems has been presented. The most important aspects considered are following: the main objective of the typology, the main animal species, the employed methods of classification and the main variables involved in this classification.

Additional key words: livestock systems; grazing; multivariate analysis; expert methods; farming typologies; GIS.

Introduction

In animal production, the intensive concept is related to the maximisation of productivity of the scarcest factors as land, labour force or bought feed (Bernués *et al.*, 2011). The pasture-based farming systems (PBFS) are generically termed less intensive because of their link to natural resources and are more complex than the off-land livestock farming systems. These last are more intensive and traditionally studied and evaluated through technical-economic indicators while other kind of indicators should be additionally used in the PBFS study, which have great ecological,

landscape and cultural diversity, besides technical-economic aspects, both environmental and social aspects have also high relevance. On the other hand, these systems play a central role in the management and conservation of large High Nature Value (HNV) farmland in Europe, and are mostly located in less productive areas, *i.e.*, southern Europe and mountainous regions (Bernués *et al.*, 2011).

Bernués *et al.* (2011) state that PBFS are also called grazing, pastoral, agro-pastoral or agro-silvo pastoral systems. Different kinds of PBFS can be found including grazing in rangelands, grazing in cultivated pastures, grazing in stubbles and zero grazing. A high

* Corresponding author: w.madry@agrobiol.sggw.waw.pl; dariusz_gozdowski@sggw.pl

Received: 02-07-12. Accepted: 06-03-13

Abbreviations used: CA (cluster analysis); FADN (Farm Accountancy Data Network); FSS (farm structural survey); FST (farming system typification); GIS (geographical information systems); HNV (high nature value); LFA (less-favoured areas); PBFS (pasture-based farming systems); PC (principal components); PCA (principal component analysis).

proportion of PBFS are situated in the less-favoured areas (LFA), especially when animals graze in rangelands. To evaluate the relative marginality of LFA, an index is computed in a Geographic Information System (GIS). The index combines land use, demographic and socio-economic data (Bertaglia *et al.*, 2007).

Different authors have studied on the LFA sustainability. Bertaglia *et al.* (2007) have contributed to the delimitation and categorisation of LFA. Numerous authors have obtained results in order to promote and stimulate multifunctional and sustainable development of LFA (Meert *et al.*, 2005; Van der Ploeg *et al.*, 2009). The PBFS, which as stated are frequent in these areas, have higher diversity of characteristics and consequently a higher complexity and heterogeneity in relation to the off-land farming systems. This makes very necessary and interesting the farming system typification (FST) of this type of systems. This analysis can contribute to know these systems and increase the global improvement and promotion possibilities of these areas.

The main objective of the paper is to do a critic study of the use of typology methodologies within PBFS, especially those situated in LFA, showing in each case the more relevant variables or indicators determining the farming system classification. Another objective is to do an overview of the most used farming system typology methodologies in general.

Concept of farming system and approaches to its study

A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (Dixon *et al.*, 2001; Köbrich *et al.*, 2003). Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households. A farming system is seen as comprising the totality of production and consumption decisions taken by a farm-household, including the choice of crop, livestock and non-agricultural both on-farm and off-farm enterprises, and food consumed by the household and each farm has its own, unique farming system (Köbrich *et al.*, 2003).

There is a wide diversity of farming systems among a group of farms, not only on a large-scale in terms of geographic space but also within restricted rural areas or more oriented types of these systems (Castel *et al.*, 2003, 2010; Carmona *et al.*, 2010; Van de Steeg *et al.*, 2010). Then, a farming system includes the conjoint use of crops, grass and livestock (Engledow *et al.*, 1978) and in order to synthesize, it can be defined as an economic and agricultural concept holistically describing (as a whole, based on a set of many variables and indicators) a farm household in terms of agricultural land use, *i.e.*, the systems of crop and livestock production, non-agricultural economic activities of farm household members (on-farm and off-farm activities), the income generated and the structure. Moreover, the natural, social, economic, infrastructural and institutional resources and environments that determine all economic activities occurring in the farming system should be considered (Kostrowicki, 1977; Keating & McCown, 2001; Köbrich *et al.*, 2003; Bertaglia *et al.*, 2007). As a level of organization, farming systems mediate the relationship between farmers and the landscape by bringing together biophysical, economic, social, cultural, and political factors that constrain or promote the land use and land cover change (Carmona *et al.*, 2010; van de Steeg *et al.*, 2010).

Every farming system is different, if not unique, facing distinctive decision-making problems, whose solutions could also be unique. Consequently, it becomes necessary to classify or group farms in some way (typification) - (Lesschen *et al.*, 2005). Such groups (clusters) are constituted by roughly homogenous farmers with similar circumstances for whom we can make more or less the same recommendation (Köbrich *et al.*, 2003). The farming system typification (FST) helps to know the characteristics of different farming systems found on a farmland. The knowledge of the strengths and weaknesses of each system type (diagnosis) allows for some improvement strategies.

To carry out a FST, previously objectives of them should be established and elements or subsystems which integrate systems should be found. In this sense, Spedding & Brockington (1976) stated that the kind of information needed to construct a FST model could only be specified by examining their role or purpose. Each subsystem is related to farm structure, technology, social relations, interrelation between values and objectives of people integrated in the system and planning, organization and control of the system.

Keating & McCown (2001) recognized two key components of farming systems, namely the biophysical 'Production System' of crops, pastures, animals, soil and climate, together with certain physical inputs and outputs, and the 'Management System', made up of people, values, goals, knowledge, resources, monitoring opportunities, and decision making. These authors stated that six types of farming systems analysis and intervention had been reviewed, which have evolved over the last 40 years, namely: (1) economic decision analysis based on production functions, (2) dynamic simulation of production processes, (3) economic decision analysis linked to biophysical simulation, (4) decision support systems, (5) expert systems, and (6) simulation-aided discussions about management in an action research paradigm. These different modes of study and analysis of the systems are destined to better know them. After this analysis, if farm systems are sufficiently heterogeneous, a classification can be done, looking for weaknesses and strengths in order to obtain a diagnostic which allows establishing some system changes or improvements (Köbrich *et al.*, 2003).

Also, the principal components analysis can be added like a method for farming systems study (Lesschen *et al.*, 2005). This method which later is more detailed is a part of multivariate analysis, being a preliminary step before the farming systems classification (cluster analysis). Principal components include diverse variables or indicators that determine the more important differences between the different groups which go to be done through the cluster analysis.

Farming system typology methodologies

The farming system typology methodologies showed in this section in general could be addressed to particular more general (major) kinds of farming systems (Caballero, 2001; Castel *et al.*, 2003; 2010; Pardos *et al.*, 2008; Gaspar *et al.*, 2011). However, references have been addressed preferably to pasture-based farming systems, overall those situated in less favoured areas. Before the study of farming system typology the selection of the aim of such a study should be made. Next, different tools should be considered: sampling methods, sources of data, variables or

indicators obtained from available data and analysis techniques (statistical or not).

Size and characteristic of farm samples

The size and characteristics of the samples of farms must be related to the number of farms and characteristics of a study area. Samples should include a number of farms of each geographical area (Caballero, 2001; Usai *et al.*, 2006; Castel *et al.*, 2010; Marey-Pérez & Rodríguez-Vicente, 2011) and/or each economic activity structure, in the case where the farms are multifunctional (Gaspar *et al.*, 2008), and each type of farm, in relation to aspects considered important in the classification (size, productive aptitude, gender of workers, etc.) should be proportionally represented (Ruiz *et al.*, 2008). Regarding the size of the sample, this should be greater when studying large areas, regions or countries (Riveiro-Valiño *et al.*, 2009; Acosta-Alba *et al.*, 2012) that when studying specific areas (Pardos *et al.*, 2008; Gaspar *et al.*, 2008). In addition, the sample should have a larger size in a basic study of an area or region (Castel *et al.*, 2003) than in a specific study of an already characterized area, especially when in this last area the used variables are quantitative and measurements are reliable (Ruiz *et al.*, 2008).

The data can come from the regional (Riveiro-Valiño *et al.*, 2008, in Galicia-Spain), national or supranational administration [Andersen *et al.* (2007) in the EU-15; Caballero *et al.* (2008) in 27 cases of European large scale grazing systems belonging to different countries; Caballero *et al.* (2009) doing a spatial distribution of large scale grazing systems in three Mediterranean countries]. Data can be more explicit when the study is referred to one particular system; that occurs for instance in a study of typology of cereal-sheep farming systems conducted by Caballero (2001) in Castile-La Mancha, wherein the average results are expressed for the entire region and according to each province and the evolution of farming system characteristics between 1989 and 1997 can be observed. Kempen *et al.* (2011) conclude that at this moment the European wide farm information is only available at a rather aggregated administrative level, for example Farm Accountancy Data Network (FADN) and Farm Structural Survey (FSS) or other state or local administration organisations (Keating & McCown, 2001; Lesschen *et al.*, 2005; Clavel *et al.*,

2011). Additionally, geographical information systems (GIS) can deliver geographic, natural and ecological data that are appropriate for the typology of landscape complexity and farming systems at a spatial area unit level (Bertaglia *et al.*, 2007; Jellema *et al.*, 2009). But this kind of data cannot provide all the data on farm management that are needed for the modeling at farm level in EU. Examples of data that are not available in these European datasets are fertilizer and livestock management practices. It is therefore envisaged that this kind of information will have to be collected by consulting farm advisors and researchers at regional or national level (Andersen *et al.*, 2007). Likewise, a lack of differentiated data about the real situation of farms is cited by Riveiro-Valiño *et al.* (2009) in order to use a program for working in the development of a decision support system for Agricultural Production Planning in Galicia, Spain. Furthermore, the data sometimes have different units of measure when coming from different countries. In some cases it is possible to transform the variables to achieve results comparing different countries (Ruiz *et al.*, 2009).

In the case of livestock farming systems, Gibon *et al.* (1999) suggested that conventionally recorded information about the structure of livestock farms and the usual technical-economic indicators do not provide sufficient information for sustainable livestock development purposes and by consequence, researchers usually include a characterization of the diversity of the organization and operation of farming systems by identifying objectives and practices in family farms. Some examples of data collection in livestock farming systems using a structured direct questionnaire for in-depth interviews, including questions properly selected to obtain a general description of farm characteristics and overall management practices are the following: Daskalopoulou & Petrou (2002) and Gelasakis *et al.* (2012) in Greece; Castel *et al.* (2003) in Andalusia, Spain; Gaspar *et al.* (2008) in Extremadura, Spain; Marey-Pérez *et al.* (2011) in Galicia, Spain; Paz *et al.* (2005) in Argentina; Usai *et al.* (2006) in Italy; Milán *et al.* (2006), Castel *et al.* (2010) in Poland and Carmona *et al.* (2010) in Chile.

Variables or indicators

Variables representing all the essential inputs and outputs combined with all others, representing social, operational, production and structural attributes of

agriculture, provide a basis for identification of agricultural (or farming) type systems (Kostrowicki, 1977). This author situated variables related to the characteristics of agriculture in the following groups: (i) social and ownership characteristics (provides answers to such questions as who is the landowner, the holding operator or the decision-maker and what is the scale of operation); (ii) operational (organizational and technical) characteristics (explains what the labour and capital inputs are and how the holding is operated); (iii) production characteristics (discloses how much is produced and for what purpose); and (iv) structural characteristics (answer questions about the proportion of land used for different purposes, about the proportion in which various farm animals are raised, and about how much is sold or delivered off the farm).

The heterogeneity of production system and the difference of difficulty level to collect data in different areas made it necessary structuring indicators in different levels (Toussaint, 2002): level 1 which considers the minimum descriptive elements to identify the production system structure, level 2 which considers quantitative data, level 3, which includes more detailed measures, both quantitative and qualitative, which explain some results of previous levels, and level 4 which includes certain necessary data in the special studies. Toussaint (2002) classified variables in structural and operational. The latter are more important to study the most developed systems, while the former are more important in most primary systems. The variable selection for characterization depends of production system management and objectives, as other factors, but depends over all of information characteristics that can be found in farms and in the farm environment. When the information is scarce qualitative variables are mainly used, being that frequent in level 1 stated by Toussaint (2002), but it occurs also in any cases in the level 2 when qualitative variables are important because of different options are found in farms, for instance in farm activities, characteristics of rangelands, type of feed supplied, presence of infrastructures, animals performance, type of reproduction management (Castel *et al.*, 2003). In some cases, the qualitative variables can be transformed into quantitative expressed in percentages, for example Castel *et al.* (2010) do this to express the quality of soil in each farm. However, whenever possible quantitative variables are used because they are more accurate. In fact, quantitative variables are the most used by of researchers for making multivariate

analysis: Milán *et al.* (2006) and Gaspar *et al.* (2008) in *dehesa* agro-ecosystems, Ruiz *et al.* (2008) in dairy goat systems and Pardos *et al.* (2008) in meat sheep systems. The more frequent quantitative variables used in livestock production system multivariate analysis are related to the following aspects: surface size, flock size, animal density, workforce, feed supply and productivity, among technical variables, and incomes, expenses and margins, among economical aspects (Milán *et al.*, 2006; Gaspar *et al.*, 2008; Ruiz *et al.*, 2008). Variables with a medium-high variability coefficient should be selected for the multivariate analysis. However, when some of them are statistically correlated, only some of the correlated being more important, taking into account the expert criteria, should be used in the analysis (Hair *et al.*, 1998; Lesschen *et al.*, 2005).

Techniques of typology classification analysis

According to Engledow *et al.* (1978), ideally, a classification should be easy to make, the basic data should be readily obtainable and easily manipulated and analysed and the degree of precision should be adjustable to meet the criteria required. The best typology of farms will have to show a maximum amount of heterogeneity between the types, while obtaining maximum homogeneity within particular types or categories (Escobar & Berdegué, 1990).

Assessment of the diversity of farming systems and their typology in rural areas can be performed using expert methods (Clavel *et al.*, 2011) or analytical methods (Riveiro-Valiño *et al.*, 2008; Carmona *et al.*, 2010). The expert methods were the first to be used as tools in order to define concrete areas (Escobar & Berdegué, 1990) and are based on skilled knowledge supported by land cover maps, which guide researchers or agricultural extension experts, and all available official synthetic information collected by state and local administrations (Clavel *et al.*, 2011). An example of this kind of method was presented by Daskaloupoulou & Petrou (2002) who used an empirically method to identify the main types of Greek farms in terms of their structure, evolution and adjustment strategies. Another example of expert-based method was presented by Acosta-Alba *et al.* (2012) who made a classification of dairy farms in Brittany (France) as a function of mode of production, quantity of milk production, and fodder-crop and grass area.

Taken into account that a classification should be made from tests of the data rather than by first arbitrarily defining the groups and then fitting the individual farms to them (Escobar & Berdegué, 1990), the expert methods have frequently been replaced by more formal and reliable analytical (statistical) methods, referred to as analytically based farming system typology or statistical farming system typology (Köbrich *et al.*, 2003; Lesschen *et al.*, 2005) or has been used as complementary tools together with analytical methods (Carmona *et al.*, 2010; van de Steeg *et al.*, 2010; Clavel *et al.*, 2011). However, sometimes, an expert method can also be the subject of statistical analysis (Caballero *et al.*, 2008).

Concerning to analytical methods, statistical ones can be applied at the level of administrative units such as rural sub-districts (Bertaglia *et al.*, 2007) or to other area units covering a certain rural area (Jellema *et al.*, 2009; van de Steeg *et al.*, 2010). But, these methods are especially important at the farm level for identifying the diversity of farming systems and their typology (Köbrich *et al.*, 2003; van der Ploeg *et al.*, 2009; Castel *et al.*, 2010). Some examples for the PBFS are the following: Castel *et al.* (2003, 2010); Serrano-Martínez *et al.* (2004a,b); Usai *et al.* (2006); Gaspar *et al.* (2008); Pardos *et al.* (2008); Ruiz *et al.* (2009).

The more used statistical typology classification methods are the multivariate ones which include two steps: the principal component analysis (PCA) and the cluster analysis (CA) - (Escobar & Berdegué, 1990; Paz *et al.*, 2005). The main objective of the first method (PCA) is to reduce a usually fairly large number of diagnostic variables included in an analysis to a considerably more limited number of formal variables, referred to as principal components (Lesschen *et al.*, 2005). Through the PCA data for the examined diagnostic variables (input variables) are transformed into a small set of new synthetic variables —dimensions, principal components (PC) or principal coordinates— with little loss of information (Escobar & Berdegué, 1990). In many cases, it is possible to reduce a large number of farming system variables to two or three PC with relatively little loss of information (accounting for the total variation among the studied entries to a high degree with the first two or three PC). These first PC usually contain the most essential information characterising the diversity of entries in the studied set, they are often used as variables in CA (Lesschen *et al.*, 2005; Castel *et al.*, 2010). Three kinds

of PCA can be applied: correspondence analysis, optimal scaling analysis and factorial analysis. The correspondence analysis is used to reduce the dimensionality of the variation system when diagnostic variables are categorical (also referred to as qualitative), including nominal, ordinal and interval variables (Benzécri, 1992; Castel *et al.*, 2003; Asselin & Anh, 2005; Moreno-Pérez *et al.*, 2011). The optimal scaling analysis introduced by Bock (1960) is used when the variables analyzed are both qualitative and quantitative. In the analysis process, the quantitative variables were first stratified to convert them into qualitative variables. The more used principal component analysis is the factorial analysis which need that all the input variables are quantitative. In order to identify the initial indicators with extracted factors (components) a Varimax rotation was done, which allows original indicators to be easily located in the extracted values (Escobar & Berdegué, 1990; Paz *et al.*, 2005; Ruiz *et al.*, 2008).

The CA (Everitt, 1980) is a more used classification analysis method and has been used by numerous authors (Kostrowicki, 1977; Castel *et al.*, 2003, 2010; Köbrich *et al.*, 2003; Carmona *et al.*, 2010). CA allows distinguishing homogenous groups (clusters) of entries with respect to many quantitative and categorical variables. For quantitative continuous and some discrete variables, the Euclidean distance or squared Euclidean distance has most commonly been used. In CA of entries to identify farming system typology, a hierarchical procedure known as Ward's method has frequently been used. Ward's method is a hierarchical clustering method that usually provides a clear division of entries into homogenous groups (Köbrich *et al.*, 2003; Lesschen *et al.*, 2005; Castel *et al.*, 2010). The CA can be made from input variables but if a PCA has been made before, the obtained dimensions in this first analysis should be used as variables (Hair *et al.*, 1998; Lesschen *et al.*, 2005). The number of groups distinguished should not be too large. Researchers usually restrict themselves to distinguishing a few (typically 3 to 6) groups (clusters) of the studied entries that are homogeneous in terms of the multi-variable criterion used for discrimination of the types of these systems (Castel *et al.*, 2003, 2010; Köbrich *et al.*, 2003; Milán *et al.*, 2006; Gaspar *et al.*, 2008). Therefore, the number of distinguished groups of entries in one research case would not be optimal in other circumstances (Köbrich *et al.*, 2003; Lesschen *et al.*, 2005). However, the number of groups can be

predefined by the scientist (k-means cluster analysis) — (Castel *et al.*, 2003, 2010, 2011; Ruiz *et al.*, 2009) or undefined (hierarchical cluster analysis) — (Paz *et al.*, 2005; Usai *et al.*, 2006). The graphical result of grouping entries via hierarchical methods of agglomeration is a dendrogram and, in this case, scientist decides the proper level of similarity to identify groups of entries showing sufficiently discriminated types of farming systems in a studied area. The hierarchical procedure allows much more flexibility in a CA: it is possible to use any of a number of distance or similarity measures, including options for binary and count data, and there is no need to specify the number of clusters a priori (Escobar & Berdegué, 1990). Other statistical methods can also be used to classify farming systems, such as the discriminant analysis or the combinatorial method. The discriminant analysis is a multivariate procedure used to model the value of a criterion factor (dependent variable) on the basis of its relationship with one or more predictors (independent variables) when these relationships and their nature are not completely expected a priori (Marey-Pérez & Rodríguez-Vicente, 2011). The combinatorial method used by Riveiro-Valiño *et al.* (2008) in Galicia (Spain) to determine the different types, production sizes, production systems and location of farms based on data from the agricultural census.

After a farming system classification a validation it is necessary. For instance, if a CA has been made, the typology can be validated by statistical methods such as discriminant analysis, from which gain functions that calculate the probability of the farms belonging to the groups obtained. Whatever the statistical method used to classify, it can be validated using an empirical method by checking if the classification is adapted to the actual conditions. In any case, the results of the classification of farms must be similar regardless of the methods used to make the typology (Escobar & Berdegué, 1990; Riveiro-Valiño *et al.*, 2009).

Once the different clusters are obtained, they can be described and afterward compared using one-way ANOVA or a chi-squared test. In this way, Clavel *et al.* (2011) and Kempen *et al.* (2011) stated that the obtained outcomes allow characterization of the distinguished groups of entries exhibiting similar farming systems and determination of the spatial locations of the groups. This information is particularly important because it allows one to evaluate the spatial

distribution of farms with particular type of system. To evaluate the existence of spatial autocorrelation (*i.e.*, whether farms with the same farming system occur in geographic proximity), spatial statistics are necessary, *e.g.*, analysis based on Moran's *I* or Geary's *c* for univariate data or Mantel correlograms for multivariate data (Lesschen *et al.*, 2005). The combination of classical methods of statistical analysis and spatial statistics allows a comprehensive inference to be obtained and should be recommended for research on farming system typology.

Next, a brief of some works made using different farming typology methods is made. Hazeu *et al.* (2011) in order to know the state and trends of the European environments exposed five new European typologies using the spatial environmental datasets. Different methods have been used in each typology: multivariate statistical clustering, multi-scale segmentation (that recognizes objects based on spatial characteristics, the most often used technique in the interpretation of satellite imagery) and finally, methods based on geographical coherence and on expert knowledge. Jellema *et al.* (2009) presented a methodology for landscape character assessment using the pattern of landscape features as stored in a GIS to delineate, characterize and evaluate landscapes using a region growing algorithm. They applied this methodology in the north of the Netherlands and stated that the obtained classification was more consistent than the expert classification of the same region. This methodology was proposed as support for spatial planning processes and policy development for landscape conservation. Carmona *et al.* (2010) constructed a spatial typology of farming systems and assessed their influence on the extent and spatial distribution of deforestation, forest re-growth, and agriculture expansion in southern Chile between 1999 and 2007. Kempen *et al.* (2011) presented an approach to spatially allocate farm information to a specific environmental context which makes possible to aggregate farm types both to natural and to lower scale administrative regions. These authors used multiple sources of information and obtained three allocations of farm types: according to farm size, according to farm intensity and according to farm specialization.

To finish, an example of styles of farming typology is showed (Sturaro *et al.*, 2009). These authors studied the relationships between livestock systems, landscape maintenance and farming styles in the Eastern Italian

Alps. Farm information was collected on technical and productive aspects, on landscape features of land managed, which was identified by aerial photographs and digitized in a GIS environment, and on the farmers' background, attitudes and approach to farming. Six different livestock systems have obtained according intensification level (expert method). After, four different farming styles have been obtained through a hierarchical CA. The different farming styles are distributed across all the livestock systems, and authors stated that this lack of a linkage between the livestock systems and the way the farms are run has the important implication that informative knowledge to address policy decisions needs to integrate the definition of livestock systems with the assessment of farming styles.

Use of farming system typology methodologies on different pasture-based farming system

This section presents different farming system typologies, considered at farm level, studied by different authors. For each one, the main objective, the main animal species and his aptitude, the employed method of classification and the main variables involved in the classification are showed (Table 1).

As said, in general an analytical methods are used for obtain a farming system typology. However, in some cases an expert based method is used. This kind of method is use overall when farming systems are less developed (Perovolotsky, 1990) or when instead farming systems are highly evolved and consequently they are well known by experts (Acosta-Alba *et al.*, 2012). Perevolotsky (1990) stated that moreover of ecological and agricultural factors, the type of land tenure and the human factors (workforce, cooperation, etc.) determine the characteristics of livestock operations. Also, the production and the economy being basically of subsistence, the more or less commercial activity of farmers is an important issue. In the case of Acosta-Alba *et al.* (2012), authors modeled the land use configuration for a sustainable dairy sector in Brittany (France) and explored sustainable farming scenarios at a regional scale.

Sometimes, in the less developed farming systems analysis, when these are a few more known by the scientist, a PCA method is used for the typification

Table 1. Examples of use of farming system typology methodologies on different pasture-based farming systems

Authors (Main classification subject)	Main animal production (Country)	Typology analysis methods (Sample size)	Main classificatory variables
Castel <i>et al.</i> (2003) (Socio economical and flock management)	Dairy goat (Spain)	PCA ⁽¹⁾ and CA ⁽²⁾ (89 farms)	Numerous variables related to all the system
Maseda <i>et al.</i> (2004) (Farmer quality of life)	Dairy cattle (Spain)	PCA ⁽³⁾ and CA ⁽⁴⁾ (103 farms)	Socio-economic and structural aspects
Paz <i>et al.</i> (2005) (Characterization of farm structure and production parameters)	Dairy goat (Argentina)	PCA ⁽³⁾ and CA ⁽⁴⁾ (41 farms)	Share of agrarian incomes, animal stocks and milk facility indicators
Nahed <i>et al.</i> (2006) (Sustainability)	Dairy goat (Spain)	PCA ⁽³⁾ , CA ⁽²⁾ and MESMIS (25 farms)	Total area and net energy obtained from grazing
Ruiz <i>et al.</i> (2008) (Technical-economic analysis to pasture-based farms)	Dairy goat (Spain)	PCA ⁽³⁾ and CA ⁽²⁾ (18 farms)	Farm and flock size, feed, workforce, milk production
Ruiz <i>et al.</i> (2009) (Comparison between Mediterranean systems)	Dairy goat (France, Italy and Spain)	PCA ⁽³⁾ and CA ⁽²⁾ (45 farms)	Farm and flock size, % of cultivate area, forage supply
Castel <i>et al.</i> (2010) Farm characteristics and management including all farmer activities	Dairy cattle (Poland)	PCA ⁽³⁾ and CA ⁽²⁾ (123 farms)	Soils quality, farm area, workforce, % of incomes, animal density, % fodder crops
Castel <i>et al.</i> (2011) (Less favoured farming system evolution)	Dairy goat (Spain)	PCA ⁽⁵⁾ and CA ⁽²⁾ (23 farms)	Farm area and family, farm management and production level
Milán <i>et al.</i> (2011) (Farm structure, production and management)	Dairy sheep production (Spain)	PCA ⁽¹⁾ and CA ⁽⁴⁾ (69 farms)	Use of land, milk yield, management practices, feeding dependence
Acosta-Alba <i>et al.</i> (2012) (Sustainability)	Dairy cattle (France)	Expert method (all population of regional dairy farms)	Milk production, % grass area, intensification level
Gelasakis <i>et al.</i> (2012) (Farm characteristics and management)	Dairy sheep production (Greece)	PCA ⁽³⁾ and CA ⁽²⁾ (66 farms)	Land use (pasture), feed supply, mating season and production level
Perevolotsky (1990) (Limiting production factors or economic returns)	Goat production (Peru)	Expert method (200 farms)	Climate, soil and vegetation; Crops and stubbles availability
Serrano-Martínez <i>et al.</i> (2004 a,b) (Classification process)	Cattle production (Spain)	PCA ⁽³⁾ and CA ⁽⁴⁾ (111 farm observations)	Numerous variables about production factors and economy
Usai <i>et al.</i> (2006) (Intensification farm level)	Goat production (Italy)	PCA ⁽³⁾ and CA ⁽⁴⁾ (151 farms)	Numerous variables related to all the system
Milán <i>et al.</i> (2006) (Structural characterisation and typology)	Beef cattle production (Spain)	PCA ⁽¹⁾ and CA ⁽⁴⁾ (130 farms)	Numerous variables related to all the system
Pardos <i>et al.</i> (2008) (Technical and economical farm aspects)	Meat sheep production (Spain)	PCA ⁽³⁾ and CA ⁽⁴⁾ (56 farms)	Flock size and forage area; production and costs
Gaspar <i>et al.</i> (2008) (Technical and economic aspects)	Extensive livestock (Spain)	PCA ⁽³⁾ and CA ⁽⁴⁾ (46 farms)	Intensification, profitability, animal species, workforce
López-Gelats <i>et al.</i> (2011) (Farm diversification)	Extensive livestock (Spain)	PCA ⁽³⁾ and CA ⁽⁴⁾ (57 farms)	Structural, management and socio-economic

PCA: principal component analysis. CA: cluster analysis. ⁽¹⁾ Correspondence analysis. ⁽²⁾ k-means cluster analysis. ⁽³⁾ Factorial analysis. ⁽⁴⁾ Hierarchical cluster. ⁽⁵⁾ Optimal scaling analysis.

analysis (previous to a CA). In this case, the more proper PCA is a correspondence analysis (Castel *et al.*, 2003) or an optimal scaling method (Castel *et al.*, 2011). But, whatever are the method (expert or analytical) used for the less developed farming systems classification, it is necessary to be account of qualitative variables are important, for instance the importance of each farmer activity, the animal milk aptitude, the reproductive behavior of animals, the production destination, etc. (Perovolotsky, 1990; Castel *et al.*, 2003, 2011).

In the case of more developed livestock systems, the more used typology method is a multivariate analysis that includes a factorial analysis (a kind of PCA) and a CA (Table 1). The more is the heterogeneity of farming systems (which are less known by the scientist) more input (observed) variables should be chosen to the typology of these systems and more of the variables contribute substantially to main principal components. For instance Castel *et al.* (2003), Usai *et al.* (2006), Milán *et al.* (2006) and Gelasakis *et al.* (2012) use numerous variables in PCA, mainly due to their structural nature, while Ruiz *et al.* (2008) and Castel *et al.* (2011) use lesser number and they refer to the farm dimension, farm management and animal productivity. At the same time, it occurs that the more is the heterogeneity of farming systems more should be the farm sample size. When data come from a monitoring process (for instead monthly), this size can be lower (for instance in the work of Ruiz *et al.*, 2008). Anyway, quantitative variables included in PC are frequently related to the farm size (surface and flock) – (Castel *et al.*, 2003, Pardos *et al.*, 2008; Milán *et al.*, 2006; Ruíz *et al.*, 2008, 2009). The variables related to the presence of different animal species (indicating farmer pluri-activity) are also frequently used in the PCA (Usai *et al.*, 2006; Nahed *et al.*, 2006; Gaspar *et al.*, 2008; Castel *et al.*, 2010).

Many authors in the farming system typology studies at the farm level consider technical and also economic indicators (Serrano *et al.*, 2004b; Nahed *et al.*, 2006; Pardos *et al.*, 2006), but in some cases authors give more importance to the economic aspects (Gaspar *et al.*, 2008; Ruiz *et al.*, 2008). On the other hand some authors give more importance to sociological (Maseda *et al.*, 2004) or to environmental aspects. Nahed *et al.* (2006), through a MESMIS analysis after applying a multivariate analysis, take into account the overall sustainability. Many authors after presenting the strengths and weaknesses of the

different obtained groups, provide strategies for improving production systems. For example, Ruiz *et al.* (2008) proposed improvements in the grazing use and labor management as well as the increase of farmer's advices and Gelasakis *et al.* (2012) established four different farmer attitudes related to the on-farm feed production and the extent of pasture which aim to achieve the decrease of the production costs. However, some authors present the strengths and weaknesses of different obtained clusters (diagnosis) but propose making more studies to draw up such strategies (Castel *et al.*, 2010). To finish, it should be noted that more specific aspects related to the livestock production system typology such as the production of cheeses (Gaspar *et al.*, 2011) or the organic production in dairy goat Spanish have been recently considered (Mena *et al.*, 2012).

Conclusions

The first step in the application of farming system typology methodologies should be to analyze the objectives of the study. They may relate to different areas: a region, a country, the EU or simply at farm level. The studies at farm level are rather specific and they use data taken from surveys or data collection systems (annual or periodic).

Studies at farm level can refer to all elements of the system (sub-systems) or only some of them. The more primary systems are in general more unknown by scientists and more parts thereof should be considered and more variables should be engaged to establish a classification of farms. On the other hand, qualitative variable are of special importance in this kind of systems.

In typology studies at farm level for PBFS, often methods that take into account the statistical analysis are used. The most common used is the multivariate analysis (a CA after a PCA).

Further progress in the use of new technologies (GIS, etc.) to support the typology farming system methodologies should be done. These, together with efficient collaboration of scientists from different countries in the sharing of the indicators used, contribute to the results of the analysis are more useful for everyone. When making large-scale studies (national or supranational) a special care should be taken in the results application. It is necessary to distinguish between different situations. In general, to

farming system classification, we should try to integrate some environmental or sociological variables, as well as the technical and economic, in the study of typologies.

References

- Acosta-Alba IS, Lopez-Ridaura S, van der Werf MG, Leterme F, Corson MS, 2012. Exploring sustainable farming scenarios at a regional scale: an application to dairy farms in Brittany. *J Clean Prod* 28: 160-167.
- Andersen E, Elbersen B, Godeschalk F, Verhoog D, 2007. Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. *J Environ Manage* 82: 353-362.
- Asselin LM, Anh VT, 2005. Multidimensional poverty in Vietnam 1993-1998 according to CBMS indicators. *Vietnam Socio-Economic Development Review*: 41.
- Benzécri JP, 1992. Correspondence analysis handbook. Marcel Dekker, NY, 665 pp.
- Bernués A, Ruiz R, Olaizola A, Villalba D, Casasús I, 2011. Sustainability of pasture-based livestock farming systems in the European Mediterranean context: synergies and trade-offs. *Livest Sci* 139: 44-57.
- Bertaglia M, Joost S, Roosen J, 2007. Econogene consortium identifying European marginal areas in the context of local sheep and goat breeds conservation: A geographic information system approach. *Agr Syst* 94: 657-670.
- Bock RD, 1960. Methods and applications of optimal scaling. Psychometric Laboratory Report # 25, Univ North Carolina, Chapel Hill, NC, USA.
- Caballero R, 2001. Typology of cereal-sheep farming systems in Castile-La Mancha (South-central Spain). *Agric Syst* 68: 215-232.
- Caballero R, Gil A, Fernández Santos X, 2008. An experts survey on sustainability across twenty-seven extensive European systems of grassland management. *Environ Manage* 42: 190-199.
- Caballero R, Fernández-González F, Pérez-Badia R, Molle G, Roggero PP, Bagella S, D'Ottavio P, Papanastasis VP, Fotiadis G, Sidiropoulou A, Ispikoudis I, 2009. Grazing systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. *Pastos XXXIX*(1): 9-152.
- Carmona A, Nahuelhual L, Echeverría C, Báez A, 2010. Linking farming systems to landscape change: An empirical and spatially explicit study in southern Chile. *Agric Ecosyst Environ* 139: 40-50.
- Castel JM, Mena Y, Delgado-Pertínez M, Camúñez J, Basulto J, Caravaca F, Guzmán-Guerrero JL, Alcalde MJ, 2003. Characterization of semi-extensive goat production systems in southern Spain. *Small Ruminant Res* 47: 133-143.
- Castel JM, Mądry W, Gozdowski D, Roszkowska-Mądra B, Dąbrowski M, Lupa W, Mena Y, 2010. Family dairy farms in the Podlasie province, Poland: farm typology according to farming system. *Span J Agric Res* 8: 946-961.
- Castel JM, Mena Y., Ruiz FA, Camúñez-Ruiz J, Sánchez-Rodríguez M, 2011. Changes occurring in dairy goat production systems in less favoured areas of Spain. *Small Ruminant Res* 96: 83-92.
- Clavel L, Soudais J, Baudet D, Leenhardt D, 2011. Integrating expert knowledge and quantitative information for mapping cropping systems. *Land Use Policy* 28: 57-65.
- Daskalopoulou I, Petrou A, 2002. Utilising a farm typology to identify potential adopters of alternative farming activities in Greek agriculture. *J Rural Stud* 18: 95-103.
- Dixon J, Gulliver A, Gibbon D, 2001. Farming systems and poverty: Improving farmers' livelihoods in a changing world. FAO, Rome.
- Engledow F, Barker MG, Ridgman WJ, 1978. A system of farm classification as an aid in formulating policies and for measuring the effects of changes in agricultural strategy. *Agr Admin* 5: 195-209.
- Escobar G, Berdegué J (eds), 1990. Tipificación de sistemas de producción agrícola. Ed. RIMISP, Santiago de Chile.
- Everitt E, 1980. Cluster analysis, 2nd ed. Heinemann, London.
- Gaspar P, Escribano M, Mesías FJ, Rodríguez de Ledesma A, Pulido F, 2008. Sheep farms in the Spanish rangelands (dehesas): Typologies according to livestock management and economic indicators. *Small Ruminant Res* 74: 52-63.
- Gaspar P, Escribano AJ, Mesías FJ, Escribano M, Pulido AF, 2011. Goat systems of Villuercas-Ibores area in SW Spain: Problems and perspectives of traditional farming systems. *Small Ruminant Research* 97: 1-11.
- Gelasakis AI, Valergakis GE, Arsenos G, Banos G, 2012. Description and typology of intensive Chios dairy sheep farms in Greece. *J Dairy Sci* 95: 3070-3079.
- Gibon A, Sibbald AR, Flamant JC, Lhoste P, Revilla R, Rubino R, Sorensen JT, 1999. Livestock farming systems research in Europe and its potential contribution for managing towards sustainability in livestock farming. *Livest Prod Sci* 61: 121-137.
- Hair JF, Anderson RE, Tathaam RL, Black WC, 1998. Multivariate data analysis, 5th ed, Prentice Hall Int, 799 pp.
- Hazeu GW, Metzger MJ, Múcher CA, Perez-Soba M, Renetzeder CH, Andersen E, 2011. European environmental stratifications and typologies: An overview. *Agr Ecosyst Environ* 142: 29-39.
- Jellema A, Stobbelaar DJ, Groot JCJ, Rossing WAH, 2009. Landscape character assessment using region growing techniques in geographical information systems. *J Environ Manage* 90: 161-174.
- Keating BA, McCown RL, 2001. Advances in farming systems analysis and intervention. *Agr Syst* 70: 555-579.
- Kempen M, Elbersen BS, Staritsky I, Andersen E, Heckelei T, 2011. Spatial allocation of farming systems and farming indicators in Europe. *Agr Ecosyst Environ* 142: 51-62.
- Köbrich C, Rehman T, Khan M, 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. *Agr Syst* 76: 141-157.

- Kostrowicki J, 1977. Agricultural typology concept and method. *Agr Syst* 2: 33-45.
- Lesschen JP, Verburg PH, Staal SJ, 2005. Statistical methods for analyzing the spatial dimension of changes in land use and farming systems. LUCS Report Series No. 7.
- López-Gelats F, Milán MJ, Bartolomé J, 2011. Is farming enough in mountain areas? Farm diversification in the Pyrenees. *Land Use Policy* 28: 783-791.
- Marey-Pérez MF, Rodríguez-Vicente V, 2011. Factors determining forest management by farmers in northwest Spain: Application of discriminant analysis. *Forest Policy Econ* 13: 318-327.
- Maseda F, Diaz F, Álvarez CJ, 2004. Family dairy farms in Galicia (N.W. Spain): classification by some family and farm factors relevant to quality of life. *Biosyst Eng* 87: 509-521.
- Meert H, Van Huylbroeck G, Vernimmen T, Bourgeois M, van Hecke E, 2005. Farm household survival strategies and diversification on marginal farms. *J Rural Stud* 21: 81-97.
- Mena Y, Nahed J, Ruiz FA, Sánchez-Muñoz JB, Ruiz-Rojas JL, Castel JM, 2012. Evaluating mountain goat dairy systems for conversion to the organic model, using a multicriteria method. *Animal* 6: 693-703.
- Milán MJ, Bartolomé J, Quintanilla R, Garcia-Cachan MD, Espejo M, Herraiz PL, Sanchez-Recio JM, Piedrafita J, 2006. Structural characterisation and typology of beef cattle farms of Spanish wooded rangelands (dehesas). *Livest Sci* 99: 197-209.
- Milán MJ, Caja G, González-González R, Fernández-Pérez AM, Such X, 2011. Structure and performance of Awassi and Assaf dairy farms in northwestern Spain. *J Dairy Sci* 94: 771-784.
- Moreno-Pérez O, Arnalte-Alegre E, Ortiz-Miranda D, 2011. Breaking down the growth of family farms: A case study of an intensive Mediterranean agriculture. *Agr Syst* 104: 500-511.
- Nahed TJ, Castel JM, Mena Y, Caravaca F, 2006. Appraisal of the sustainability of dairy goat systems in Southern Spain according to their degree of intensification. *Livest Sci* 101: 10-23.
- Pardos L, Maza MT, Fantova E, Sepulveda W, 2008. The diversity of sheep production systems in Aragon (Spain): characterisation and typification of meat sheep farms. *Span J Agric Res* 6: 497-507.
- Paz R, Togo J, Usandivaras P, Castel JM, Mena Y, 2005. Análisis de la diversidad en los sistemas lecheros caprinos y evaluación de los parámetros productivos en la principal cuenca lechera de Argentina. *Livestock Research for Rural Development* 17: Art. #8. Available in <http://www.lrrd.org/lrrd17/1/paz17008.htm> [Nov 12, 2012].
- Perevolotsky A, 1990. Goat production systems in Piura, Peru: a multidisciplinary analysis. *Agr Syst* 32: 55-81.
- Riveiro-Valiño JA, Marey MF, Marco JL, Alvarez CJ, 2008. Procedure for the classification and characterization of farms for agricultural production planning: Application in the Northwest of Spain. *Comput Electron Agric* 61: 169-178.
- Riveiro-Valiño JA, Álvarez-Lopez CJ, Marey-Perez MF, 2009. The use of discriminant analysis to validate a methodology for classifying farms based on a combinatorial algorithm. *Comput Electron Agric* 66: 113-120.
- Ruiz FA, Castel JM, Mena Y, Camuñez, J, González-Redondo P, 2008. Application of the technico-economic analysis for characterizing, making diagnoses and improving pastoral dairy goat systems in Andalusia (Spain). *Small Ruminant Res* 77: 208-220.
- Ruiz FA, Mena Y, Castel JM, Guinamard C, Bossis N, Caramelle-Holtz E, Contu M, Sitzia M, Fois N, 2009. Dairy goat grazing systems in Mediterranean regions: A comparative analysis in Spain, France and Italy. *Small Ruminant Res* 85: 42-49.
- Serrano Martínez E, Lavín González P, Giráldez García FJ, Bernués Jal A, Ruiz Mantecón A, 2004a. Classification variables of cattle farms in the mountains of León, Spain. *Span J Agric Res* 2: 504-511.
- Serrano Martínez E, Giráldez García FJ, Lavín González P, Bernués Jal A, Ruiz Mantecón A., 2004b. The identification of homogeneous groups of cattle farms in the mountains of León, Spain. *Span J Agric Res* 2: 512-523.
- Spedding CRW, Brockington NR, 1976. Experimentation in agricultural systems. *Agr Syst* 1: 47-56.
- Sturaro E, Cocca G, Gallo L, Mrad M, Ramanzin M, 2009. Livestock systems and farming styles in Eastern Italian Alps: an on-farm survey. *Ital J Anim Sci* 8: 541-554.
- Toussaint G, 2002. Notice des indicateurs de fonctionnement des systèmes laitiers (Report on working indicators for dairy systems). *Opt Mediterr* A-39: 147-157.
- Usai MG, Casu S, Molle G, Decandia M, Ligios S, Carta A, 2006. Using cluster analysis to characterize the goat farming system in Sardinia. *Livest Sci* 104: 63-76.
- van de Steeg J, Verburg P, Baltenweck I, Staal S, 2010. Characterization of the spatial distribution of farming systems in the Kenyan Highlands. *Appl Geogr* 30: 239-253.
- van der Ploeg JD, Laurent C, Blondeau F, Bonnafous P, 2009. Farm diversity, classification schemes and multi-functionality. *J Environ Manage* 90: 124-131.