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Integrated geo-referenced data and statistical analysis for dividing livestock farms into geographical zones in the Valencian Community (Spain)

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ABSTRACT

The livestock sector in the Valencian Community (Spain) has experienced an increase in the intensity of farming with an increase in the number and size of pig and poultry facilities. The absence of previous environmental requirements in this region has produced a high concentration of facilities in some areas, and urban sprawl has resulted in many farms located in problematic areas close to villages or towns, residential areas and protected areas. Conflicts surrounding land use and environmental issues have been a problem in the region for many years. The initial step to solve this problem is to produce a territorial planning system to intervene and correct the current development and adapt to new European environmental regulations. The objectives of this study are to group farms with homogeneous characteristics in the Valencian Community and to characterise and search for spatial dependency patterns within the livestock sector. These objectives have the final aim of contributing basic scientific information to subsequent administrative planning decisions for livestock. This study presented methodology based on Geographic Information Systems and statistical methods for dividing livestock farms into zones and for characterising these areas. We obtained nineteen livestock geographical areas with unique characteristics (such as livestock species composition) and verified that these areas did not follow a spatial pattern.

1. Introduction

The livestock sector of the Valencian Community (Eastern Spain) has recently experienced a profound change. Generally, this sector has tended towards intensified farming with an increase in the number and size of pig and poultry facilities, characterised by farms with a high level of technology and skilled labour. Farms are independent of the land as a production factor. Thus, there has been a separation between livestock and agriculture.

The absence of previous environmental requirements in this region has produced a high concentration of facilities in some areas, and urban sprawl has resulted in many farms being located in problematic areas close to villages or towns, residential areas and protected areas. Conflicts arising from land use and environmental issues have caused problems in the region for many years (Recatalá et al., 2000). The most recent European Union environmental legislation (Nitrate Directive 91/676/CEE and IPPC Directive 2008/1/EC) and social pressure on food security, environmental pollution and animal welfare protection (Tamminga, 2003) have emphasised these challenges. Therefore, a system was adapted to overcome these conflicts and to establish measures according to the conditions of the territory and the characteristics of the farms. In this context, the Department of Agriculture of Regional Administration developed a strategic plan to establish actions and policies covering different components of the livestock sector.

Consequently, it is necessary to obtain information on the typology, classification, characterisation and spatial analysis of farms, which enables the development of a decision support system that allocated priority activities to each territorial space in the region. Riveiro et al. (2009) discusses some models and systems developed as support for agricultural planning.

The models developed for Classifying Variable farms use qualitative and quantitative analysis, but these models do not use the geographic component to make a spatial planning of livestock. This study has taken into account the geographical location of the farms, and a combinatorial method of statistical analysis and Geographical Information Systems (GIS), have delimited livestock zones.

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Methods for delimiting management zones vary widely in the information and techniques used for creating zone boundaries (Kitchen et al., 2005). Using GIS for suitable delimitation is important to account for the geographical data characteristics and spatial data points. For our purpose, clustering methods were categorised into two groups: statistical and spatial. Statistical clustering methods include partitioning or disjoint algorithms, agglomerative hierarchical algorithms and fuzzy clustering algorithms. Disjoint and hierarchical algorithms have been widely used, either together or separately, for different classifications or separations of groups. In agricultural problems, for example, these types of algorithms have been used for typification, characterising farming systems (Floyd et al., 2003; Köbrich et al., 2003; Ottaviani et al., 2003; Iraizoz et al., 2007), delineating landscapes and/or characterisation zones (Jaynes et al., 2003; Van Eetvelve and Antrop, 2009; Castillo-Rodríguez et al., 2010; Soto and Pintó, 2010), classifying fields according to yield patterns and establishing management zones for precision agriculture (Ortega and Santibañez, 2007). In purpose precision agriculture, fuzzy clustering methods for geographical attributes in different fields have been most widely employed, particularly for delineating management zones (Lark, 1998; Jaynes et al., 2003; Ping and Dobermann, 2003; Kitchen et al., 2005; Yan et al., 2007; Morari et al., 2009; Xin-Zhong et al., 2009). Fridgen et al. (2004) developed software for the fuzzy-based delineation of management zones.

In spatial data analysis methods, researchers use techniques to describe spatial distributions, either grouped or dispersed, in terms of global and local spatial association patterns (Saizen et al., 2010). Due to the geographical nature of the data, many of the authors mentioned above (Kitchen et al., 2005; Yan et al., 2007; Morari et al., 2009; Xin-Zhong et al., 2009) have employed these techniques for studies of management zones in precision agriculture when using various spatial analysis tools. Lark (1998) used fuzzy analysis with GIS to create coherent spatial regions.

In addition, the spatial planning of territories involves dividing a geographical area into different units. The partitioning of a geographical group occurs in units of smaller areas to create a new spatial structure that reflects livestock criteria.

Integrating geographical information systems allows access to the data and immediate display of the results, allowing verification of the suitability of the solution (Kalcsics et al., 2005). There are several methods to solve design problems of the territory, but they have limitations. The primary limitations of these models include integrity, compactness and contiguity, with the latter being the most important (Shirabe, 2005). Alternative methods that use spatial information, such as Voronoi diagrams (Moreno et al., 2012), have been applied in various fields of study, such as economics, urban geography, market analysis and resolution optimum location services (Okabe and Suzuki, 1997; Okabe et al., 2000).

In recent years there has been the development of tools in ArcGIS spatial statistics, designed to describe patterns of spatial data (Scott and Janikas, 2005).

The main purpose of this study is to group livestock farms into geographical zones with similar livestock characteristics using multivariate statistical analysis. The results will be presented by using a GIS to generate a new spatial structure that allows livestock spatial planning. In addition, spatial dependency patterns within the livestock sector in each group will be identified and characterised.

2. Material and methods

2.1. Study area

The study area, illustrated in Fig. 1, is the entire territory of the Valencian Community, a region located in eastern Spain that belongs to the West Mediterranean area of Europe, with an area of 23,250 km^2. More than 4 million inhabitants live in this area, and agriculture is one of the main economic activities. Approximately 44% of the land area is used for agricultural purposes, whereas approximately 52% of the Valencian Community is forest area. There is a large variety of different soil types, ranging from arenosols (AR) to chernozems (CH), passing through fluvisols (FL), calcisols (CL), leptosols (LP), luvisols (LV) and regosols (RG), defined reference soil groups of the World Reference Base for Soil Resources 2014 (IUSS Working Group WRB, 2014), with varying degrees of degradation (De Paz et al., 2006).

The climate is mainly arid to semi-arid (51% of the territory) with dry, hot summers and rainy autumns. However, in the north, the climate is frequently sub-humid to dry sub-humid with rainy autumns and warm summers influenced by the Mediterranean Sea.

The regional environments differ substantially in terms of topography, landscape and territory use between the inland, intermediate and coastal zones. The inland zone is characterised by pasture, forest, scrub, thicket, towns, extensive wood production, land abandonment and terraces. The intermediate zone includes towns, intensive wood production, dry land uses, urbanisation, and irrigation crops. There are conflicts in land use in the coastal zone next to the Mediterranean Sea, where substantial industry and tourism occurs (Recatalá et al., 2000).

Valencian agriculture is characterised by its diversity. In general, two groups can be distinguished: one group that is based on irrigation near the coastal zone and one group in the intermediate and inland zones where more extreme weather occurs, with low levels of water and less fertile soils. The first group is intensively managed with a specialisation in the production of citrus, fruits and vegetables. The second group specialises in Mediterranean dry crops based on olives, almonds and grapes.

The livestock structure is characterised by two distinct subsectors: extensive and intensive (or landless livestock production systems). The most important livestock sector is the intensive farming of poultry and pigs followed by bovines and rabbits, whose geographical distribution is more uniform throughout the region but is concentrated mainly in the Castellon and Valencia provinces. Extensive livestock farming is comprised of bovine, sheep and goats and occurs particularly in inland areas.

2.2. Step 1 and 2. Data input and GPS and GIS procedures

Data processing was performed using the following sources:

(1) A database with all of the farms in the Valencian Community, i.e., 4984 farms with basic information on the numbers and types of animals and their locations.
(2) The base cartography of the Valencian Community on a scale of 1:10,000 in a shapefile format from the Valencian Cartographic Institute.

This information was processed as shown in Fig. 2, which represents the various steps in the process. The following section describes the entire procedure.

In Step 1 (Fig. 2), 4984 holdings were registered with a GPS to obtain their coordinates. The process of defining the geographical position of an object, georeferencing or geocoding, simply consists of attributing latitude and longitude values (and possibly altitude) to any sample. For livestock, the coordinates correspond to farm location and can be recorded with a GPS. The use of a GPS delivers the required level of accuracy, particularly if a standard procedure is followed, thereby avoiding any bias associated with employing different operators. These protocols permit the recording of sampling sites within a unified and standardised geodetic reference system (Joost et al., 2010).