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Spatial analysis of cattle movement patterns in Portugal

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Summary

The network of animal contact through movement is an important factor in disease spread within and between populations. The objective of this study was to characterise the spatial and temporal distribution of bovine movements in Portugal, identifying 'local' and 'long-distance' networks on the basis of geographical proximity. Data were obtained from cattle movements in 2005, as recorded in the national database for bovine identification and registration. Geographic information systems were used to represent distribution and flow of movements. Results did not detect any significant temporal variation either in the number of movements or animals moved. Holdings showed a higher density in the north where a larger number of movements occurs. On the contrary, larger shipment lots tend to occur in the south-central area. The greatest number of movements occurs inside and between contiguous districts; animal movements mostly follow a south-north pattern. Records analysed revealed that 60% of the animals in circulation are beef cows under the age of 10 months (only 31% of the registered animals are younger than 12 months of age).

Keywords

Animals, Cattle, Epidemiology, Geographic information system, Movement, Portugal, Spatial analysis.

Analisi spaziale dei modelli di movimento dei bovini in Portogallo

Riassunto

La fitta rete di contatti tra gli animali nel corso della movimentazione costituisce un importante fattore nella diffusione delle malattie all'interno e tra le popolazioni animali. Obiettivo di questo studio è stato quello di caratterizzare la distribuzione spaziale e temporale dei movimenti dei bovini in Portogallo, identificando, in base alla prossimità geografica, tale rete di contatti sia a livello locale sia su lungo raggio. I dati sono stati ottenuti dai movimenti bovini registrati nel 2005, così come raccolti dalla banca dati nazionale per l'identificazione e la registrazione dei bovini. La distribuzione e il flusso dei movimenti sono stati rappresentati utilizzando i sistemi informativi geografici. I risultati non hanno mostrato nessuna variazione significativa temporale né nel numero delle movimentazioni né negli spostamenti animali. Un maggior numero di movimentazioni è stato riscontrato nel Nord laddove si registra la maggiore densità di aziende. Al contrario la maggior parte di spedizione di partite di animali tende a verificarsi nell'area sud-centrale. Il numero più elevato di movimenti si verifica all'interno e tra distretti contigui; i movimenti degli animali per lo più seguono uno schema sud-nord. I dati analizzati rivelano che il 60% degli animali in circolazione sono bovini da carne al di sotto dei 10 mesi (solo il 31% degli animali registrati è al di sotto dei 12 mesi di età).

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Parole chiave
Analisi spaziale, Bovini, Epidemiologia, Movimentazione animale, Portogallo, Sistema informativo geografico.

Introduction

Disease outbreaks have already demonstrated the important role of the pattern of contact between individuals as a determinant factor for disease transmission in a population. A clear understanding of population dynamics may lead to more accurate epidemic models. Several published investigations have already shown contact network structure in human populations. Fewer studies have been undertaken on animal production populations (10, 12, 13).

Animal movements can greatly influence disease spread, as reflected in restrictions imposed to control bluetongue virus in Portugal. The European Commission adopted measures to restrict movements of live ruminants from affected areas to non-infected regions where the vector is present (4). The objective of this rule was to decrease the probability of an infected animal being moved to a free-farm or area, reducing disease transmission rate.

The movement of cattle and sheep in Great Britain were considered critical in the spread of bovine tuberculosis (5) and scrapie (6) which lead to the implementation of movement control strategies. *Mycobacterium bovis* transmission in captive possums (2) and the foot and mouth disease epidemic (8) has clearly illustrated the role of contact network patterns in pathogen transmission.

Council Regulation (EC) No. 820/97 states that each member state should establish a system for the identification and registration of bovine animals, comprising ear-tags to identify animals individually, computerised databases, animal passports and individual registers to be kept on each holding (3). The Portuguese National Bovine Identification and Recording System (SNIRB: *Sistema Nacional de Identificação e Registo de Bovinos*) offers the possibility of accessing information at any stage of the life of an animal, including individual identification and place of origin, to enable the tracking of all animal movements between holdings. This extensive database is updated by the central veterinary services (*Direcção Geral de Veterinária*) and keeps records of all the producers, animals and their movements.

Geographic information systems (GIS) and spatial analysis enable a visual representation and meaningful interpretation of data and thus assume an important role in animal health control strategies (9, 11). Developments in data recording and specific software make it possible to study animal movements. In this paper, we focus on spatial and temporal patterns of cattle movements reported to the central veterinary services in 2005.

Materials and methods

Data sources

Several datasets from the SNIRB database related to the national bovine population were analysed, such as cattle movements in 2005, individual animal records and the location and classification of holdings. 'Holding' refers to any establishment in which animals are held, kept or handled, such as farms, bullfight rings, cattle markets and shows. Only trade movements were analysed as they represented the greatest potential risk. The study area included the entire national territory of continental Portugal and the autonomous island regions of Madeira and the Azores.

The term 'shipment lot' refers to a group of animals moved on the same date, from the same holding of origin to the same destination.

Methods

Movement data management involved geo-referencing the location of holdings, pairing 'within', 'in' and 'out' district movements and querying data to obtain the desired variables required for the analysis. Microsoft Access® and Excel® were used for data storage, management and processing. Descriptive statistical analysis was performed with SPSS® version 14.0 (Chicago, Illinois).

The location of holdings was obtained adding the x,y coordinates of the centroid of the polygon layer of the smaller national

administrative areas, *freguesias*, using ArcGis™ 9.1. Movement distances were calculated as the Euclidean distance between centroids, using Hawth's analysis tools extension version 3.26 (www.spatialecology.com).

In this study, the point location of holdings on which animals were present was selected on 29 December 2005. The distribution of holdings and cattle were smoothed by using Gaussian Kernel methods to produce a density surface (spatial analyst extension). A bandwidth or *h*-statistic (1) of 10 km was used.

'Within district movements' were represented using a flow data model. This analysis was performed using Flow Data Model Tools, version 069m, an ArcGIS™ version of the Flow Mapper software developed by Waldo Tobler (www.csiss.org/clearinghouse/FlowMapper/).

According to the Euclidean distance, routes of movements between holdings can be classified into local and long distance contacts, based on geographical proximity. In this work, we considered local contacts if they were less than 50 km and long distance if they exceeded 50 km.

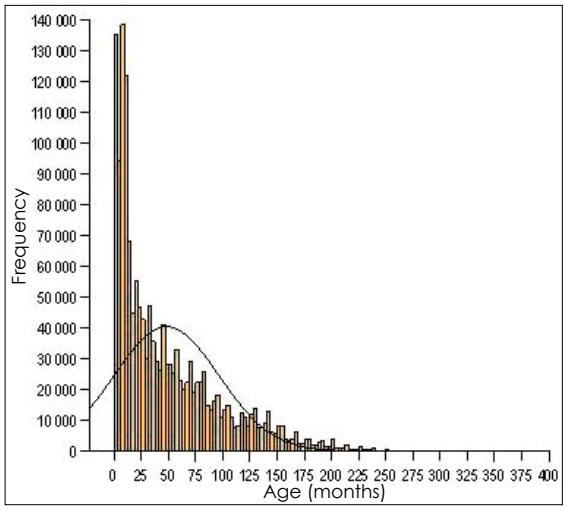
Results

Population characterisation

Records from the active bovine population registered on 29 December 2005 involved the analysis of data on 1 566 710 animals. Female bovines represented 78% of the total population and 63% of the individuals were beef type. Concerning the age of the cattle, the average was 48 months with a maximum age value of 32 years; 45% of the animals were under 25 months of age (Fig. 1a).

Of the total population, 625 744 animals were moved within the national territory; 85% of these animals were characterised by average age (22 months) and maximum age (31 years old). Of these animals, 60% were under 10 months of age (Fig. 1b). Most of the animals were beef cattle (70%); female and male distribution was equivalent. According to the records, over 55% of the individuals accomplished a single movement, 27% two and 18% three or more movements (average: 1.7; maximum: 72 movements).

a) Total population



b) Population moved

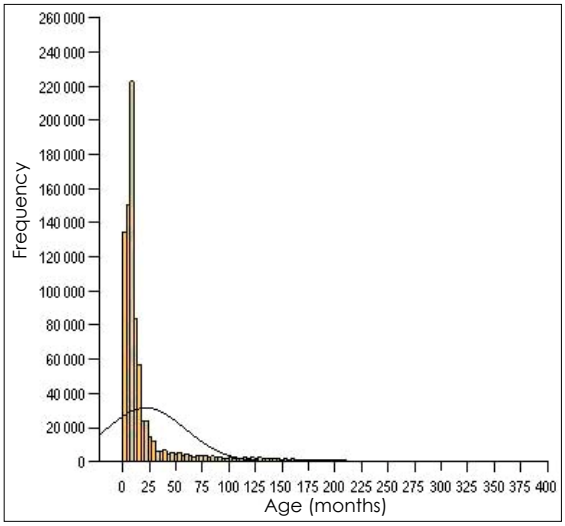


Figure 1
Age distribution of animal population under study

Movement patterns

The locations of 165 265 holdings in the entire national territory were considered.

The distribution of holdings highlights maximum densities in the north-west of continental Portugal where holdings are smaller (Fig. 2). In the autonomous regions, San Miguel Island (Azores) and Madeira revealed the highest concentration of holdings; 11% of the total holdings are located in Azores (Fig. 3).

The bovine Kernel distribution shows an animal cluster in southern Portugal, excluding Faro (Fig. 4). Herds varied from only a few bovines to thousands, with a mean size of 20 animals. Of these holdings, 54% have three or less animals.

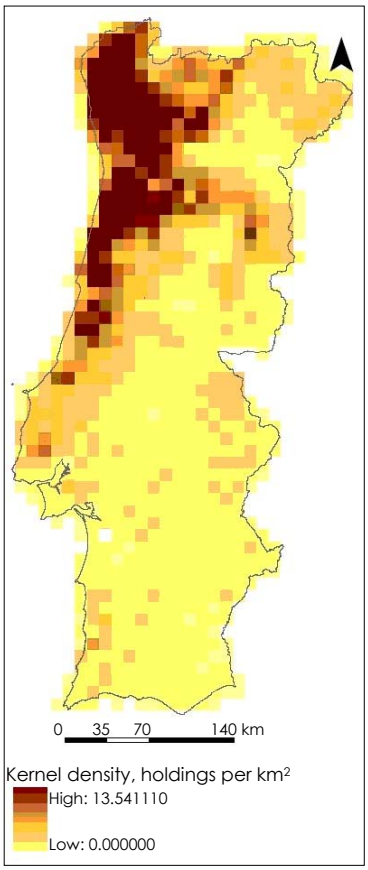


Figure 2
Kernel smoothed surface of the numbers of holdings per km²
The cell size corresponds to 10 km

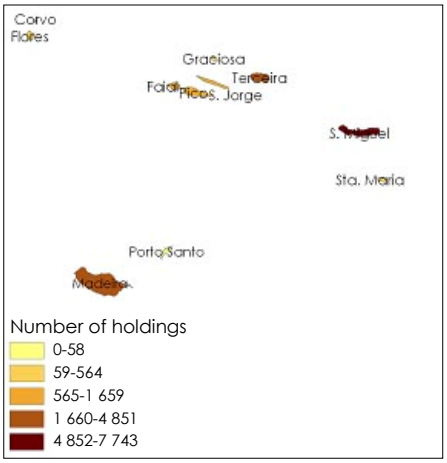


Figure 3
Holdings distribution in autonomous regions
This representation does not reflect real spatial position

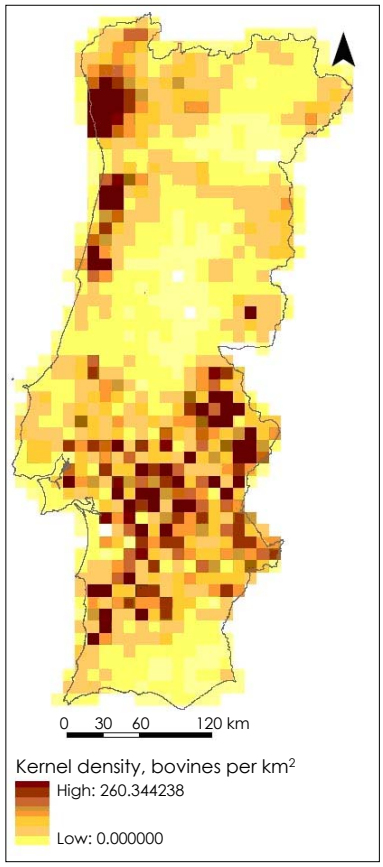


Figure 4
Kernel smoothed surface of the bovine's distribution per km²
The cell size corresponds to 10 km

During the period of the study, 294 214 movements were reported to the central veterinary services.

An analysis of 'within-district movements' showed that more shipment lots are moved in the northern coastline districts of Braga, Porto and Aveiro. On the other hand, Portalegre and Évora were also important in regard to the number of animals moved (45 391 and 73 145 animals, respectively) (Fig. 5).

'Between-district movements' also presented a similar pattern, as shown in the flow maps presented in Figure 6. Islands were excluded from the within-district representation because of their geographic separation. As illustrated by Figure 7, 'within-district movements' were clearly predominant in the number of shipment lots moved by each district. Movements related to autonomous regions are presented in Figure 8.

a) Number of animals b) Shipment lots

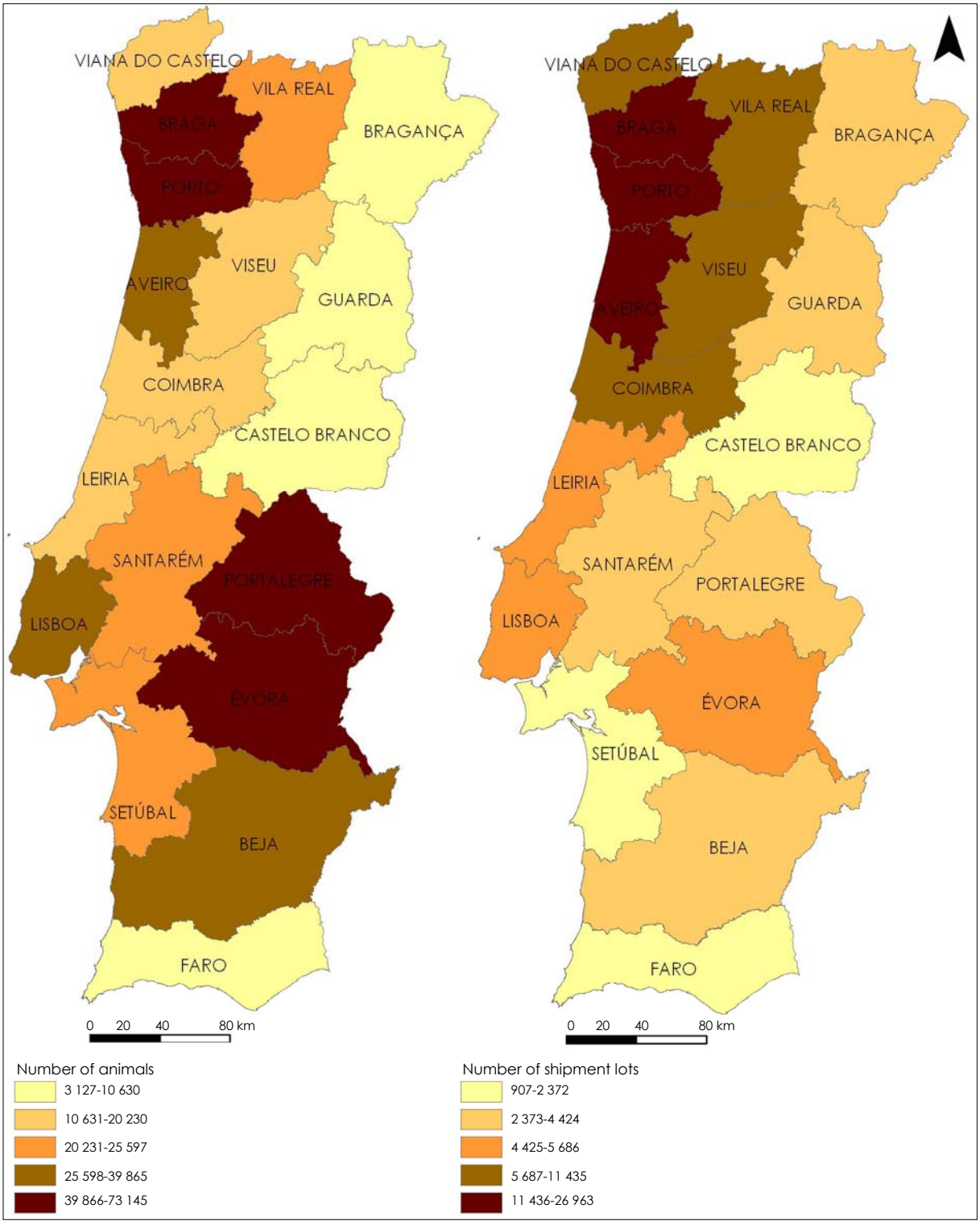


Figure 5
Representation of movements within districts

The size of shipment lots varied from 1 to 484 animals (mean size: 4 animals; mode: 1 animal; standard deviation: 9.4); 80% of shipment lots comprised 1 to 3 bovines. The movement distribution pattern was similar in the spring, summer, autumn and winter,

although fewer animals were moved in the cooler months. In regard to movement distances, approximately 80% of the movements registered in 2005 were classified as local (Fig. 9).

Discussion

Preliminary work to characterise the movements of the national bovine population has been presented. Younger animals are mainly moved within the national territory. Among the records analysed, 60% of the animals moved were beef cows under 10 months of age (only 31% of the registered animals were younger than 12 months).

No significant temporal pattern was revealed either in the number of shipment lots or animals moved. Survey results suggested a regional variation in the pattern of bovine movements, where northern Portugal presents a higher number of movements of small shipment lots. In opposition, larger shipment lots are observed in the south-central area.

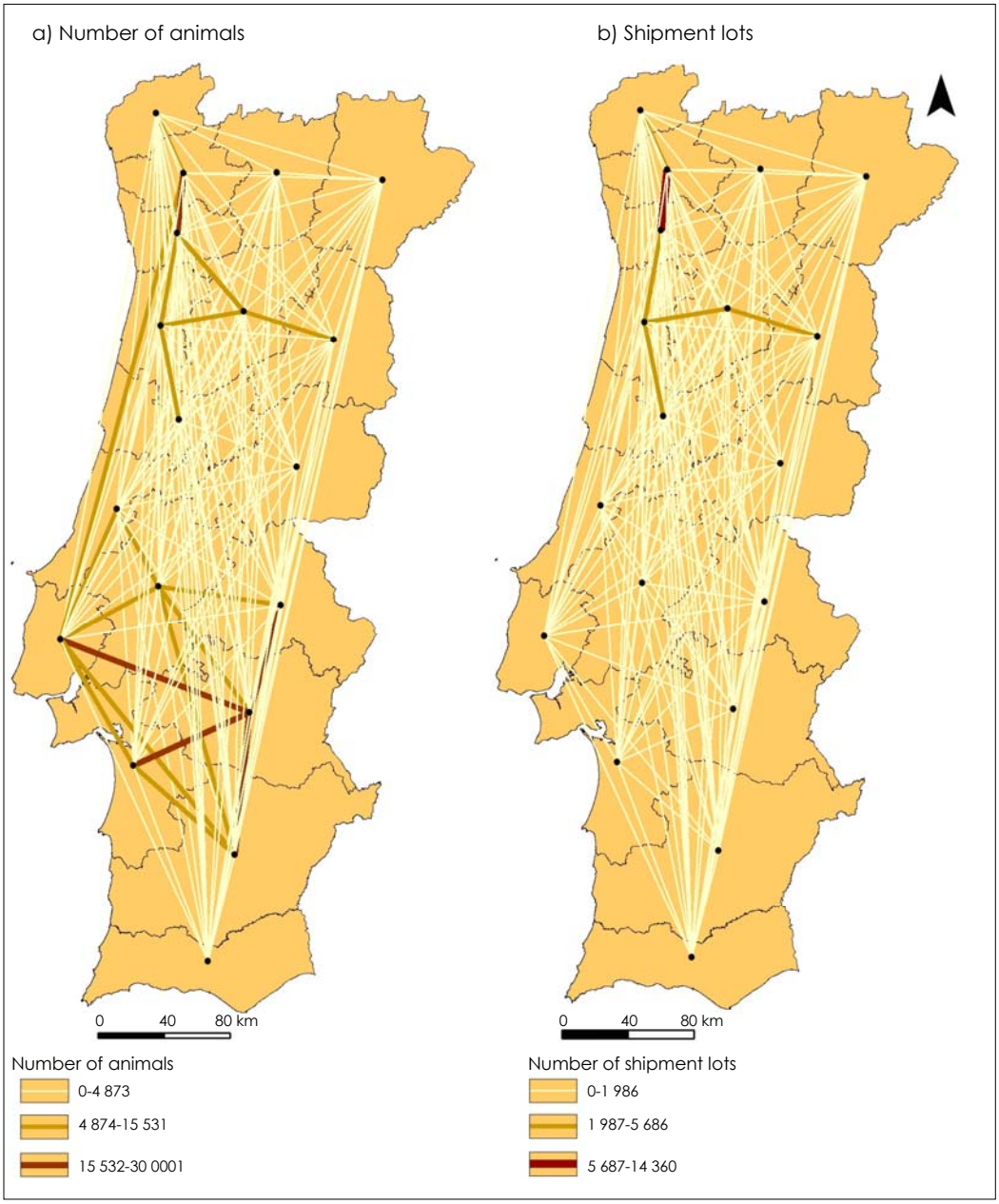


Figure 6
Representation of movements between districts

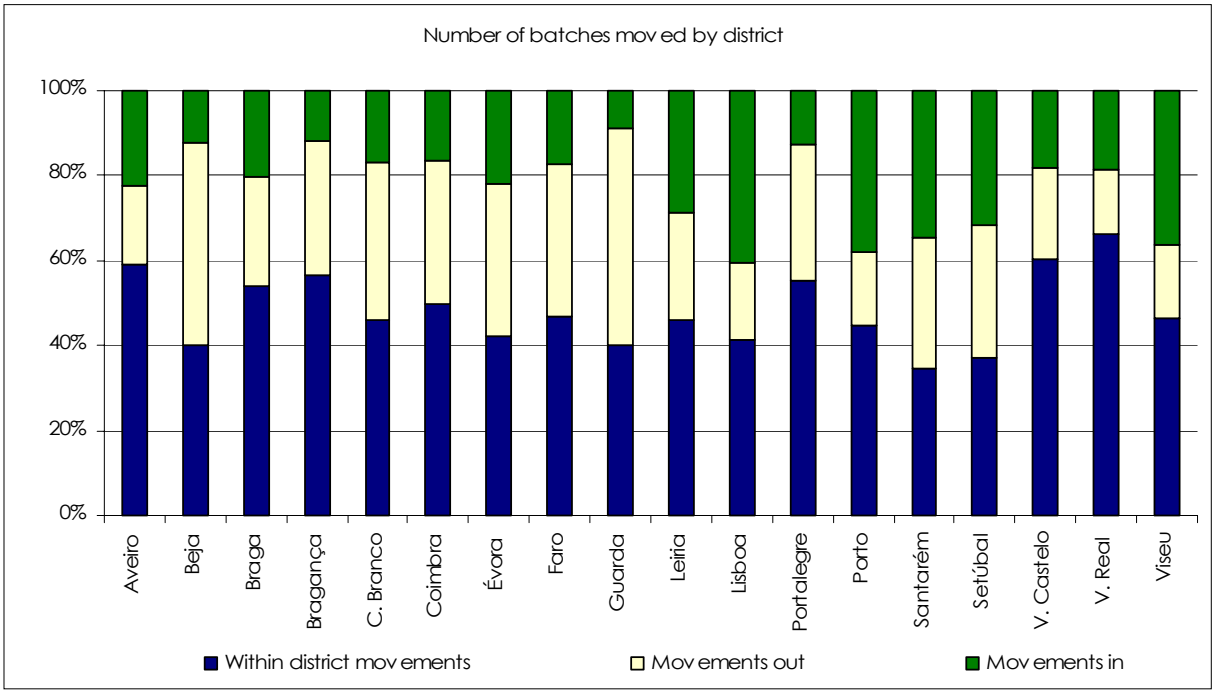
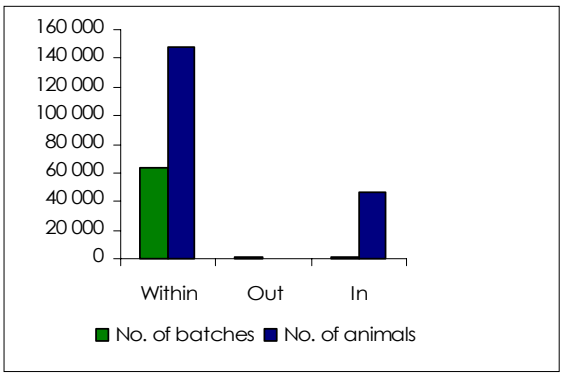


Figure 7
Proportion of shipment lots moved by all the districts in continental Portugal

a) Azores movements



b) Madeira movements

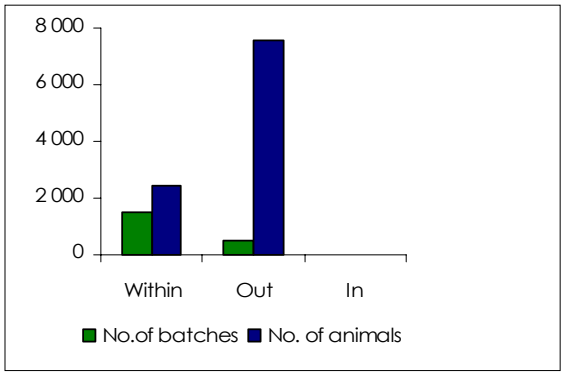


Figure 8
Movements in the autonomous regions of the Azores and Madeira

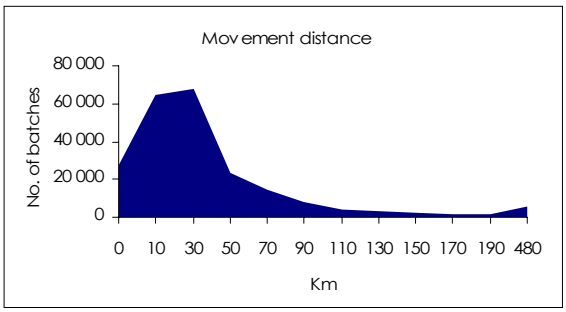


Figure 9
Stacked area graph showing movement distances

Animal movements mostly follow a south-north route. Several factors, such as climatic and soil conditions, are responsible for a clear distinction between the production systems in the north and south. In the north of Portugal, family-based enterprises are the most common, while in the south, herd sizes and enterprises are larger (7). Traditionally, beef cattle management in the southern region includes a finishing period in the central region.

This study demonstrates that animals are more likely to be moved within the same administrative area and to contiguous districts. Nevertheless, the results of this analysis show

that all districts are connected. This conclusion is also supported by the geographic proximity analysis of movement distance which revealed the preponderance of 'local networks'.

In relation to autonomous regions, Azores assumes a prevailing position in both the numbers of shipment lots and animals moved. 'In movements' are predominant in Madeira.

Study limitations included the assumption that all movements are reported to the SNIRB. Administrative movements may also occur although it is not possible to determine its extent to national territory. In this paper, to better understand the potential animal-animal transmission only movements between farms, bullfight rings, cattle markets and shows were analysed. Abattoir movements were excluded from the analysis although they should be considered in further work to accurately characterise the overall network. Large temporal data is required for seasonality identification (repeated trends in systematic intervals over time). Further analysis may be developed to identify the network of contact between individuals and should include similar SNIRB data for other years to detect possible changes. Large datasets of movement records may be an accurate tool to predict future trends in cattle movements.

Conclusions

This paper shows how the data recorded by the central veterinary services can be managed to characterise production animal population dynamics.

The results identify spatial trends in cattle movements. Districts in the north have higher holding densities as well as recorded movements while central-south districts move less animals but have larger shipment lots. The large majority of movements are south-north. According to movement distances, 'local networks' are the predominant pattern in Portugal.

Elucidating the structure of contacts in the bovine population and trade movements could be very valuable to disease surveillance schemes that would consequently be accurately adjusted to the true situation.

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