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DYNAMICS OF SHEEP PRODUCTION IN BRAZIL USING PRINCIPAL COMPONENTS AND AUTO-ORGANIZATION FEATURES MAPS

Dinâmica da Produção de Ovinos no Brasil utilizando Componentes Principais e Mapas Auto-Organizáveis

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ABSTRACT

The present study aims to evaluate the multitemporal dynamics of sheep production in Brazil, considering the Federal Government's official data from 1976 to 2010. Principal Component Analysis (PCA) and Self-Organizing Maps (SOFM) were used. PCA reduced data redundancy and the colour composition of the first three principal components evidenced temporal patterns. In the SOFM classification, a type of Artificial Neural Network (ANN) with non-supervised training, different dimensions of the Kohonen map were tested. The results obtained by the two methods are complementary, evidencing the development of sheep production in the country. The southern and northeast maintained the tradition of sheep production over the analyzed period. The municipalities in the Midwest showed production growth. The techniques used were effective in multitemporal analysis, providing a greater understanding of the dynamics of sheep production in Brazil and providing subsidies for the development of appropriate public policies for its expansion.

Keywords: Multitemporal Analysis; Geographic Information Systems; Multivariate Analysis; Livestock.

RESUMO

O presente estudo objetiva avaliar a dinâmica multitemporal da produção de ovinos no Brasil, considerando os dados oficiais do Governo Federal de 1976 até 2010. No tratamento dos dados foram utilizados Análise de Componentes Principais (ACP) e Mapas Auto-Organizáveis. ACP permitiu a redução da redundância dos dados e evidenciou os padrões temporais a partir da composição colorida das três primeiras componentes principais. Na classificação pelo método SOFM, um tipo de Rede Neural Artificial com treinamento não supervisionado, foram testadas diferentes dimensões de mapas de Kohonen. Os resultados obtidos pelos dois métodos são complementares evidenciando o mesmo padrão de evolução. As regiões sul e nordeste apresentam as principais produções de ovinos no período analisado. Os municípios do Centro-Oeste tiveram crescimento da produção, mesmo que incipiente. As técnicas utilizadas foram eficazes na análise multitemporal, proporcionando uma maior compreensão da dinâmica de produção de ovinos no Brasil e fornecendo subsídios para o desenvolvimento de políticas públicas adequadas para a sua expansão.

Palavras-Chave: Análise Multitemporal; Sistema de Informação Geográfica; Análise Multivariada; Produção Animal.

1. INTRODUCTION

Farm animals arrived in Brazil with settlers about 500 years ago (PRIMO, 2004; MACHADO et al., 2011). Sheep have adapted to the different climatic conditions and ecosystems of the country, even in areas with environmental controls that are quite different from the original environments in Europe and North Africa.

The species was one of the first to be domesticated and it provides meat, milk and wool for human populations (VIANA, 2008). Sheep farming is growing in Brazil, mainly due to increasing investments in non-traditional regions. Among the favourable changes that can be noted are the intensification of research focused on the production and processing of animal products, better organization of farmers, increased technology, a significant participation of financial institutions to facilitate access to credit and higher demand for products derived from sheep and goats (SEBRAE, 2005). In addition to the economic importance of the sheep industry, is has a high socio-economic impact (VIANA et al., 2007, 2009), especially in the northeast region of Brazil, where there are small farmers maintaining these animals for subsistence.

Despite difficulties related to the national agribusiness chain, such as production scale, transportation, storage and marketing (CIRILLO, 2012; XIMENES and CUNHA, 2012), sheep farming has many advantageous characteristics and profitable production is possible, for small to large scale farmers, especially with the increasing demand for healthy foods and a preference for products with high protein and low in cholesterol, saturated fats and calories, such as lamb (NETTO and TORRES, 2008).

The analysis of spatial dynamics of sheep production in the country is important to understand development tendencies and production concentration, to aid in the elaboration of public policies to consolidate this activity. In this context, the use of geo-technologies have the potential to increase knowledge about sheep production (ESCUDERO et al, 2003; ETHERINGTON, 2011) contributing to the development of appropriate public policies for the expansion of production in the country.

The application of geographic information system (GIS) techniques to study the dynamics of sheep production is not common. Several studies have used these techniques in the evaluation of diseases that affect animals (AQ) or the study of vegetation and associated pasture species, but no studies were found using these in the evaluation of production over time. These techniques include Principal Components Analysis - PCA (LI et al, 2012; SMALL, 2012) and classification methods of quantitative data.

Thus, this study aims to analyze the dynamics of multitemporal sheep production in Brazil, based on official data from the federal government, GIS procedures and multivariate methods.

2. MATERIAL AND METHODS

Data from all municipalities in Brazil were analyzed. The data of sheep production was obtained from the IBGE (Brazilian Institute of Geography and Statistics) website (IBGE, 2012) Municipal Animal Production Research (Pesquisa da Pecuária Municipal), which encompass the period between 1976 and 2010. These data are relative to the number of animals on the 31st December of each year. For this survey a single model questionnaire was used. For each species, regional peculiarities are considered, entities involved in the livestock sector, production aspects (breeds and management techniques) as well as existing resources in each municipality. Maps were generated with sheep production from municipalities' database for each year. Subsequently, these maps were converted to GRID format with spatial resolution of 1km. With the data in matrix format, temporal series of sheep production was developed.

Initial analysis of the dynamics of the production carried out by Principal Components Analysis (PCA). This technique is widely used in remote sensing for the underlying dimensions of multivariate data (FUNG & LEDREW 1987).Therefore, PCA provides a reduction of the complex data set to a lower dimension and simplified structures. Linearly transformed components from the original data are not correlated, such that the first principal component (PC1) describes the maximum possible proportion of the variance of the original data set, i.e. contains the information common to all the original variables. PC2 contains the areas of significant change and the other PCs increasingly less significant changes. The low-order principal components concentrate the noise fraction, being ignored in the analysis. Thus, PCA is an attractive data reducing technique because it preserves the total variance in the transformation and minimizes the mean square approximate errors.

The first components (which containmostrelevant information and images), were used to form a "false-colour" image for colour composite RGB (Red, Green, Blue). This analysis enhances the dynamics of production over time.

Space-time patterns of sheep production were obtained by the classification of municipal data by the S*elf Organizing Features Map* (SOFM) method. SOFM is a type of Artificial Neural Network (ANN) with non-supervised training, which may be described as a nonlinear, ordered, and smooth mapping of high-dimensional input data domains onto the elements of a regular, low-dimensional array (KOHONEN, 1988). The structure of input and output layers of SOFM are shown in Figure 1.

Competitive learning processes determine the set of values {*m*,} that minimizes "*e*" and the signal space is mapped onto the set of codebook vectors (Kohonen Map). Depending on how the competition is targeted, when the winning neuron is determined, its output z_i is fixed at 1. All other signs of the output neurons were fixed at 0. Software was developed in C++ containing functionality for reading and classifying sets of samples.

The main interface of the software allows the user to configure which variables should be considered, the geometric parameters (height and width of the map) and the initial parameters of the SOFM training (initial rates of learning and neighbourhood decay rates) (**Figure 2**). In this interface there are the options for starting the SOFM training process (Start Training button) and sort the data table (Apply Classification button). The graphs are updated every learning cycle with the training error, learning rates and neighbourhoods. Once the classification process is completed, each record in the table is assigned to a group (class) map of neurons within the network.

After the training phase, each neuron of the map represents a centroid due to the dimensionality of the input data that characterizes a group of population samples. These centroids can be exported by the Export Clusters option. Each neuron may be used for a sorting process (grouping) of the input data.

As the method is relevant to the distance between neurons (i.e., the closer the neurons, the greater similarity of the data and the more distant the less similarity), we chose to use the geometry of

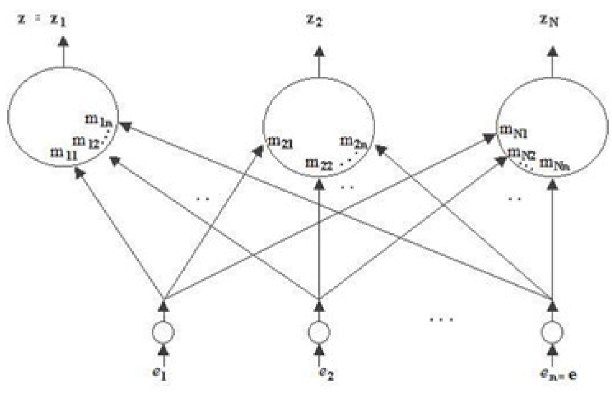

Fig. 1 - The Kohonen layer. Each of the *N* neurons of this layer receive *n* inputs $e_1, e_2..., e_n$. Each input has an associated weight m_{ij}. Neurons compete to find the vector of weights $m_i (m_i = (m_{i1}, m_{i2}, ..., m_{in}))$ which is closer to "*e*"(through function of distance measure *D*).The winner gives a signal $z_i = 1$; others emit the signal $z_i = 0$.

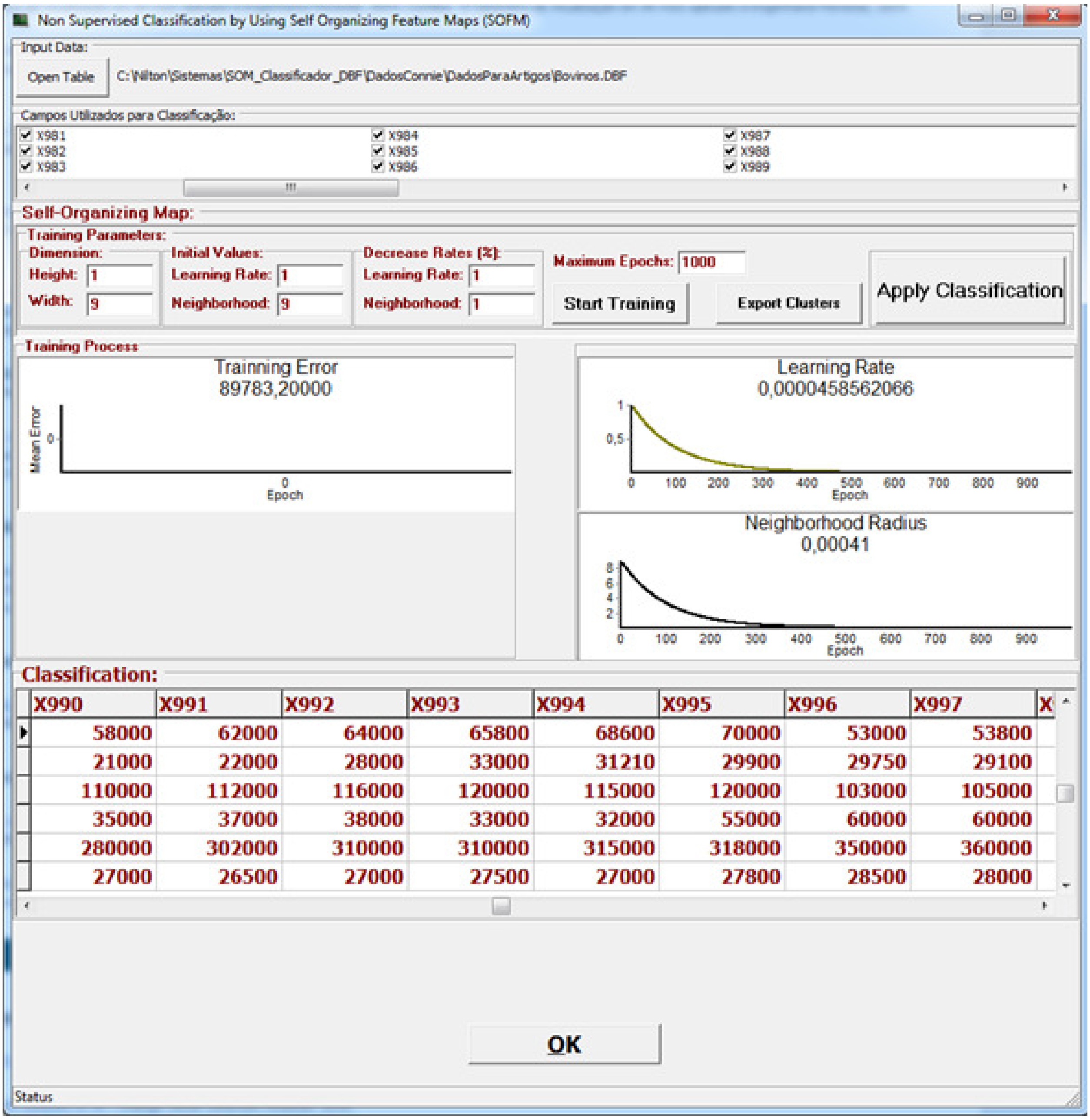

Fig. 2 - Main Interface of the system.

the data as vectors and not matrices, to highlight the extreme differences between the groups in the classification. Therefore, Kohonen maps were generated with geometry of 1x3, 1x6, 1x9, 1x12, 1x15 and 1x18.

3. RESULTS

Results of the PCA concentrate the information in thefirst three components, as shown by the inflection point of the eigenvalues plot (Figure3). Near-unity eigenvalues and noise-dominated maps were observed from the fourth component. Thus, the dimensional complexity of the data is reduced to a three-dimensional space, ensuring maximum variance and emphasizing the differences in time series.

The first component summarizes a typical pattern that was predominantly observed over the period (Figure 4a). The two traditional regions of sheep production in the Northeast and South are highlighted when compared with other areas of the country.

The second principal component, while still evidences the spatial pattern of the major sheep producing regions (although their values are opposite of the first component), begins to show deviations from typical behaviour. Thus, comparing spatial

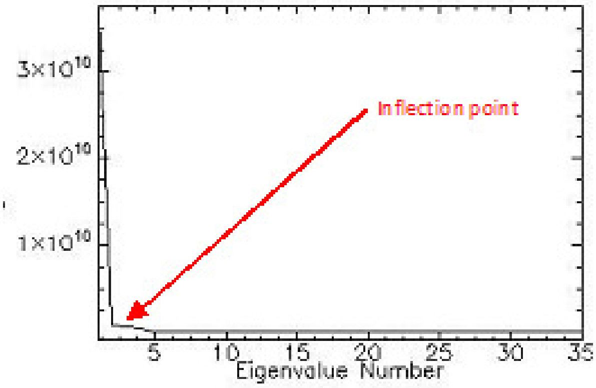

Fig. 3 – Eigenvalues plot.

maps of the first and second component, a high similarity of patterns is noted. The main differences occur within the sheep-producing areas, between municipalities with constant and variable production. The municipalities with constant production have clear tonality, being confused with the other areas with less sheep production but continuous along time. The main groups observed in PC2 have the following characteristics: (a) white municipalities that maintained constant values along the period (no, low or high productivity); (b) black municipalities that maintained high productivity; and (c) greyscale municipalities that had variation in production over the period (Figure 4b).

More interestingly, the third principal component enhances the deviations from typical behaviour. In the PC3, the differentiations have stronger responses in areas of high production and weaker in areas of low production and monotonous behaviour (Figure 4c).

Thefirstthreecomponentswere used to form the colour composite image (Red - PC1, Green - PC2 and Blue - PC3) (Figure 5), which summarizes the dynamics of sheepproductionin the Brazilian municipalities along the analyzed period (1976-2010).Municipalities in the northeast and south, in red, show a fairly stable production over the period analyzed, with no particular variations in scale of production. In green are the municipalities that maintained low or had no production during the period. Municipalities in yellow, union of the colours red and green, i.e., PC1 and PC2, defines the municipalities which maintained high production throughout the period analyzed. Municipalities in blue were from PC3 represent those where production was unstable, i.e., they had showed variation in production over the period. Those that are in magenta, a mixture of red (PC1) with blue (PC3), represent those who maintained high productivity over the period analyzed.

The classification maps of municipalities from SOFM showed the production patterns according to different numbers of class (Figures 6 and 7). Each class has an associated weight vector with a dimension equal to the input time series. The individual assessment of weight vectors gives an indication of the behaviour of sheep production for a particular class. Graphs show the curves of the weight vectors for the class maps. The extreme points on a Kohonen map always indicate distinctive production groups, i.e., sites with higher or lower

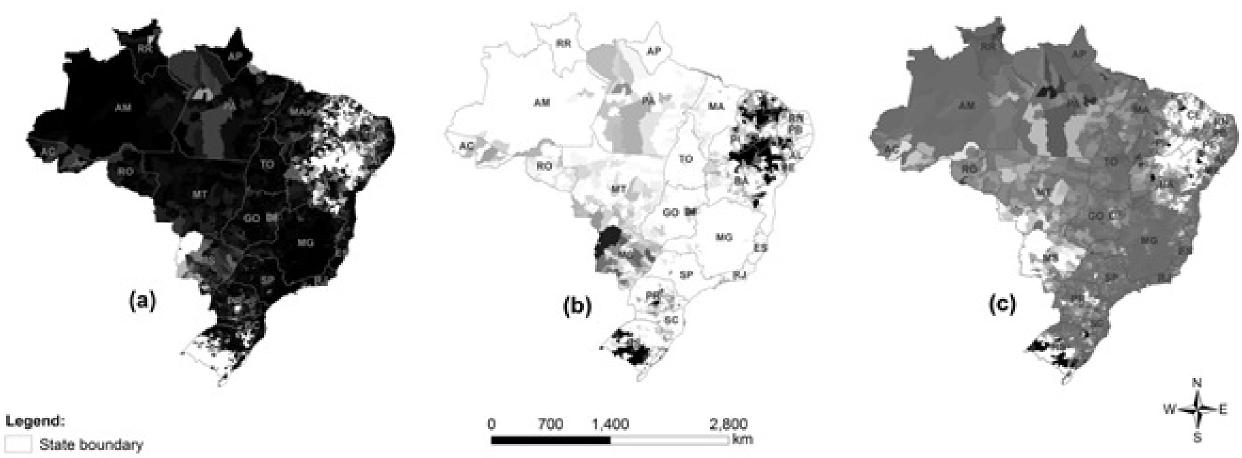

Fig. 4 – First three principal components (a-PC1, b-PC2, c-PC3) of sheep production between 1976 and 2010 in Brazil

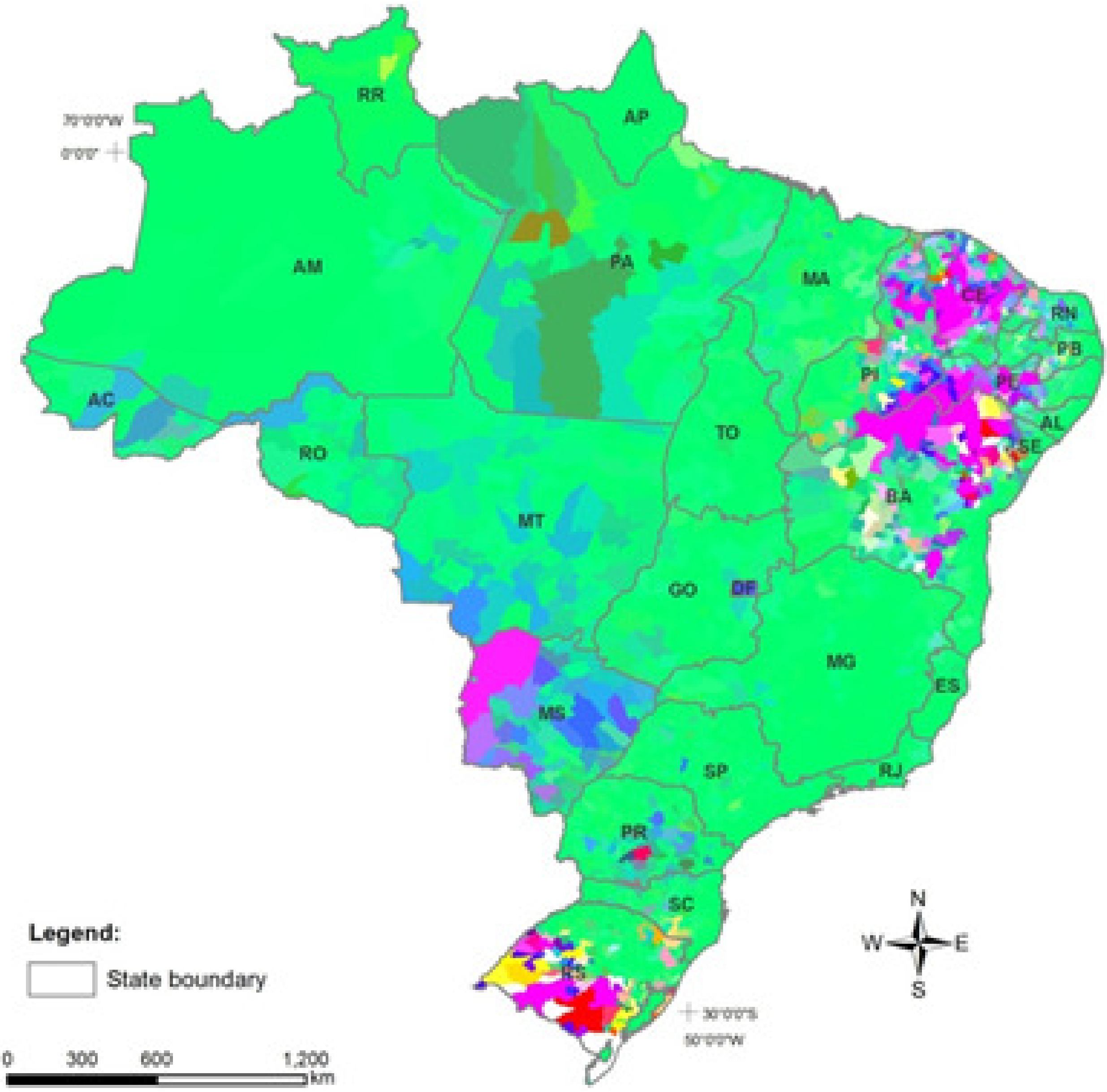

Fig. 5 - Colour composition (RGB) of the first three principal components (PC) for changes in sheep production in Brazil between 1976 and 2010: PC1 (Red), PC2 (Green) and PC3 (Blue).

production over time. Increasing the number of classes enables to establish a progressive sequence for sheep production among municipalities.

SOFM classification using three classes shows the south with the highest values over time and the rest of Brazil (**Figure 6a**). The increase of number of classes enables to highlight spatial patterns more complex with the inclusion of other producers regions that lying in the range between these two extremes. The map with six classes (Figure 6b) shows the initial inclusion of municipalities in the Northeast, confirmed in the nine class map (Figure 6c) with an increasing number of these municipalities. The map 1x12 (Figure 7a) shows the inclusion of municipalities in Central Brazil, along with the 1x15 map (Figure 7b), until the result of the 1x18 map (Figure 7c), which also shows the inclusion of municipalities in the North. Thus, increasing the number of classes provides sensitive change in the detection in sheep production, in which municipalities are added with incipient growth, mainly in the Midwest (IBGE, 2010).

The Kohonen maps corroborate the result of colour composition with three first principal components, indicating the separation of municipalities from production over time. The main

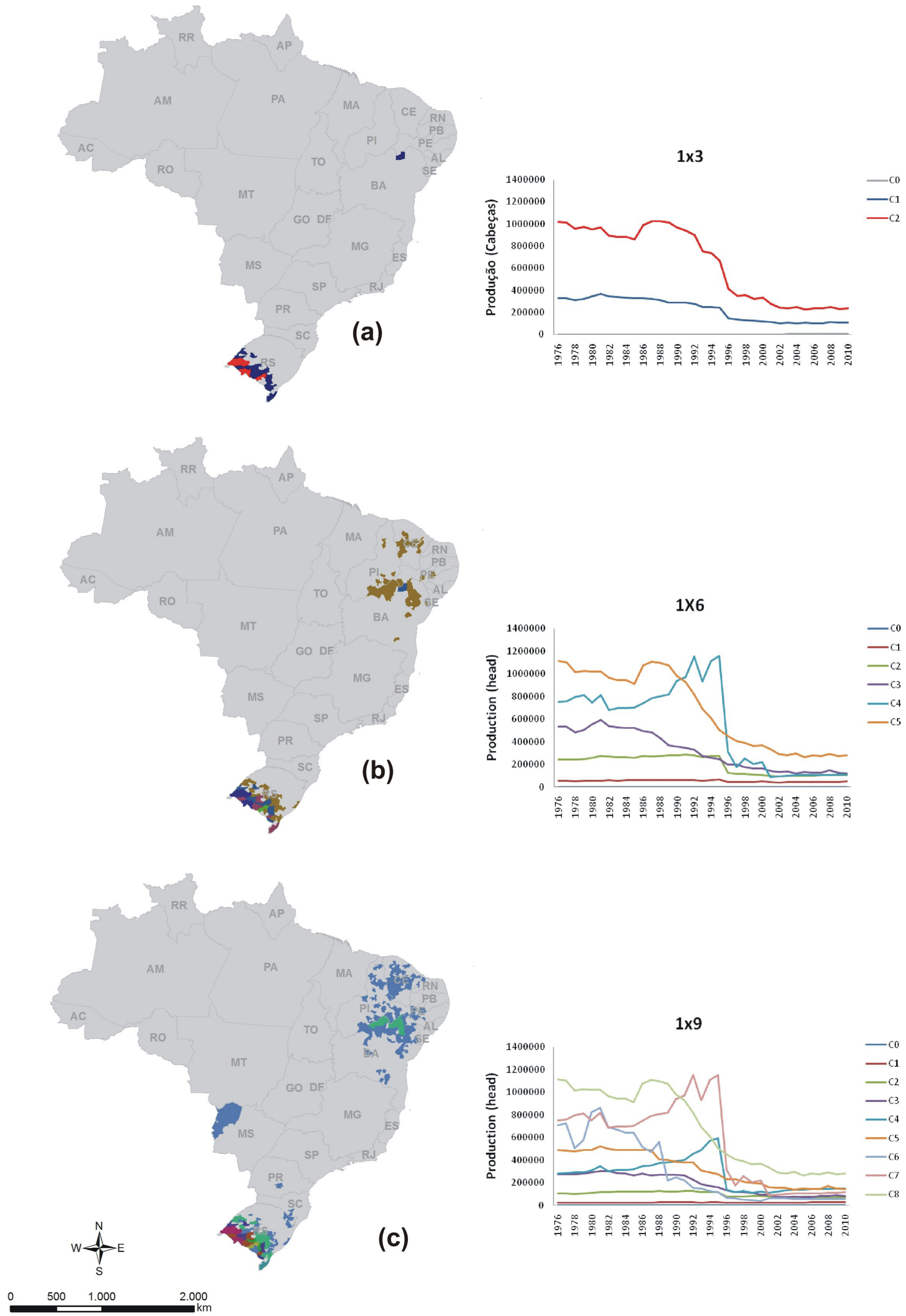

Fig. 6 - SOM classification maps for sheep production with: (a) 3 classes (b) 6 classes, and (c) 9 classes. The graphs show the temporal curves of sheep production for classes mapped.

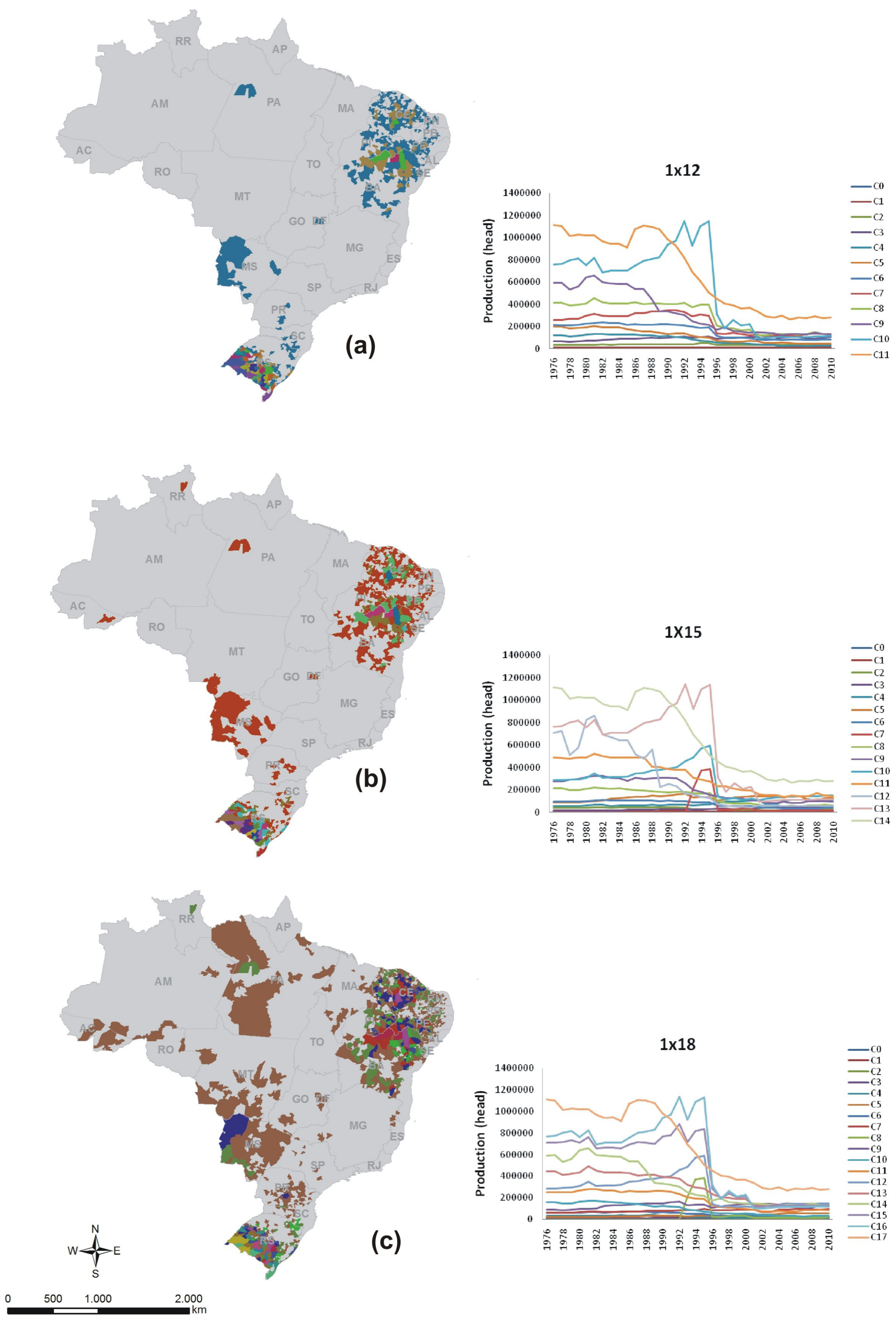

Fig. 7 - SOM classification maps for sheep production with: (a) 12 classes (b) 15 classes, and (c) 18 classes. The graphs show the temporal curves of sheep production for classes mapped.

classes are: (a) municipalities of the south with high production throughout the period; (b) municipalities in the Northeast with further growth to the south, where production remained high over time analyzed; (c) municipalities in the Midwest and North with intermediate or variable growth over time, and (d) municipalities that maintained little or no production.

4. DISCUSSION

According to statistics from the Food and Agriculture Organization of the United Nations - FAO (2012), Brazil has the 8th largest sheep flock of the world and with an estimated size of about 16 million head, with regions Northeast and South concentrating more than 50% of the herd (IBGE, 2012). Currently, the Northeast region holds the majority of the total sheep flocks in Brazil with 56.35%. The South is in second place with 31.6% (IBGE, 2012), but this situation has changed over time.

In the 1970s, the South had the largest flock in the country, with approximately 13 million head. This explains the result of 1x3 Kohonen map, which highlights the municipalities of the south. In the 1990s, with the advent of synthetic fabrics came "the wool crisis" when the sheep flock in Brazil decreased, mainly in the southern region, causing the farmers changed the focus from wool to meat production (ALBUQUERQUE, 2009). This situation has caused serious damage to wool-producing countries such as Brazil, resulting in a large reduction in the growth of wool sheep production (BOFILL, 1996), which were concentrated in the southern region of Brazil. This situation favoured the growth of production in the Northeast, specializing in hair breeds. Those municipalities with stable or increasing growth should be considered as being more viable for receiving investments.

In 1990, a reversal of sheep production became the Northeast the largest producer, evidenced by increased production from large farmers, while the southern region decreases production.

The SOFM maps analysis of according to the geometry clearly indicated the trend of production growth over time, starting in southern Brazil, extending to the northeast and subsequent growth (although incipient) in the Midwest, mainly in the state of Mato Grosso do Sul. The latter had increased production over the period analyzed, demonstrating a new trend in sheep in Brazil (RESENDE et al., 2010), especially derived from government incentives to expand production of meat.

There was a sharp drop in the sheep production of all groups from the year 1996.This can be explained by a change in the methodology for collecting data by the IBGE (2002). According to the document "Agricultural Research" (IBGE, 2002), there were changes in data collection instruments in relation to structure, form and content to adapt them to the electronic data processing system.

As the results show, there is an increase in area of sheep production in Brazil showing that farmers consider it a promising livestock activity, mainly for meat production. Resende et al. (2008) state that effective productive capacity of the species has evolved due to several factors, including genetic improvement aimed at producing meat and milk, nutrition, health, among others.

There is a need, however, greater integration between the sheep industry, the development of new technologies, modernization of production and animal breeding, and these indispensable tools to enhance competitiveness in the sector (REIS, 2009; SORIO and RASI, 2010).

According to McManus et al. (2010) variable production levels may be due to an inability of matching breeds to production environments. This also affects the confidence of investors in the systems leading to a lack of definition of the production chain. According to Garcia (2004), only 7.8% of what is produced is inspected, moreover, within what is formally consumed 50% of the meat consumed in Brazil comes from countries such as Uruguay, Argentina and New Zealand.

Accordingly, the ANNs allowed the treatment (sorting and / or grouping) of multivariate data and, in the case of SOFM, they were used to reduce the dimensionality of the data to facilitate understanding of its statistical behaviour. According to Nepomuceno (2003), since the 90s, there is significant increase in the use of ANNs mainly in remote sensing data, but in recent years many researchers are applying ANNs to spatial data (ATKINSON & TATNALL, 1997), and these currently widely used for spatial data, whether supervised or unsupervised (ENGEL, 1993; TODT, 1998; NEPOMUCENO, 2003), as in the present work.

5. CONCLUSION

The analysis of the colour composition with the first principal componentsof the data set of sheep production in Brazil together with the SOFM classification method showed more clearly the dynamics of sheep production in the municipalities of Brazil between the years 1976 to 2010, demonstrating great potential for use of these methods in analysis of multitemporal production data. SOFM was essential for understanding the dynamics of sheep production in Brazil, demonstrating relations between groups of municipalities and behaviour of this production over the period analyzed. Using these methods it was possible to confirm that Southern and Northeastern municipalities maintained high levels of production throughout the period, reaffirming the tradition of sheep breeding in these regions. The techniques used to analyze the dynamics of production proved to be efficient.

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