Methodological proposal to analyze land use and land cover changes: the case of Santa Catarina state in Brazil from 2000 to 2010

Metodologia de análise das dinâmicas do uso e cobertura da terra: o caso do estado de Santa Catarina - Brasil entre 2000 e 2010

Juliana Mio de Souza[a]

Eduarda Marques da Costa[b]

[a] *Doutorado em Geografia, Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Assistente de Pesquisa da Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Florianópolis, SC, Brasil*
E-mail: julianasouza@epagri.sc.gov.br

[b] *Doutora em Planejamento Regional e Local, Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa - IGOT/ULisboa, Lisboa, Portugal*
End. Eletrônico: eduarda.costa@campus.ul.pt

doi:10.18472/SustDeb.v11n3.2020.32395

Received: 05/07/2020
Accepted: 16/11/2020

ARTICLE – VARIA

ABSTRACT

The aim of this paper is to examine land use and land cover changes and to relate it to the potential driving forces observed in the state of Santa Catarina, Brazil, during the period from 2000 to 2010. The methodology consists of identifying trends in land use and land cover changes; indicating possible explanatory factors by means of Principal Component Factor Analysis and elaborating a final typology, based on Cluster Analysis. Results point to the considerable expansion and increased intensity of agricultural activity as well as silviculture throughout the state and the loss of native vegetation, suggesting the need for protective actions and land use and cover regulations, particularly from an environmental perspective, to frame the development of intensive and mechanized agricultural activity.

Keywords: LUCC. Principal component factor analysis. Driving forces. Spatial planning.

RESUMO

Este artigo objetiva verificar a dinâmica do uso e cobertura da terra e relacioná-la com potenciais forças motrizes dessa dinâmica no estado de Santa Catarina, Brasil, para o período de 2000 a 2010. A metodologia consiste na identificação de tendências na dinâmica de uso e cobertura da terra; apontar possíveis fatores explicativos com base na análise fatorial por componentes principais e na elaboração de uma tipologia final, baseada na análise de clusters. Como resultados, nota-se uma forte expansão e fortalecimento da atividade agropecuária e da silvicultura pelo estado, e perda da vegetação nativa, o que aponta para a necessidade de desenvolver medidas de proteção e de regulamentação da cobertura e uso da terra nomeadamente na vertente ambiental, enquadrando o desenvolvimento de uma atividade agropecuária intensiva e mecanizada.

Palavras-chave: Uso e cobertura da terra. Análise fatorial de componentes principais. Forças motrizes. Ordenamento do território.

1 INTRODUCTION

The dynamics of land use and cover involve a set of interactions with highly complex socioeconomic and biophysical processes, thus calling for a systemic approach by which the identification and understanding of the causes and effects of changes depend on their historical, social and geographical contexts (LAMBIN; GEIST; RINDFUSS, 2006).

According to Houghton, Hackler and Lawrence (1999), the dynamics of land reflect the impact of human activity on the global environment. Additionally, Lambin, Geist, and Rindfuss (2006), claim that regardless of whether the impacts of land change are positive or negative, at present, most of them are associated with the expansion of food production, the efficiency of resource exploitation and human well-being. In other words, land change is driven by the needs of individuals or society at large.

It is highlighted in the literature that driving forces, actors and land use are three fundamental factors at play in land dynamics (HERSPERGER et al., 2010). Driving forces usually refer to a set of variables which, according to Hersperger and Bürgi (2009), can be subdivided into five categories: political, socioeconomic, cultural, technological and natural / spatial.

The analysis of land use and cover changes is a highly important subject nowadays, since different systems (environmental, ecological and socioeconomic) are directly influenced by this phenomenon, and the knowledge regarding these processes and their impacts is essential in several domains such as environmental monitoring and spatial planning, at both political and economic level (VALE; REIS; MENESES, 2014).

In different countries, such as Brazil, the dynamics of land occupation have undergone major changes both as a result of an urbanization trend and growth in the primary sector. In fact, it is in this context that the importance of developing methodologies for the analysis of these phenomena and their impacts is brought to light, as a means of supporting the design and evaluation of public policies.

According to the IFFSC Project, the state of Santa Catarina has 29% forest cover and is characterized by depleted forest remnants, threats to vegetation biodiversity, continued human-induced forest degradation and constant changes in the use of the land. Unrestrained land use for grazing and forest plantations are examples of the government's ineffective actions to date to protect the forests (VIBRANS et al., 2012, p.334). In view of this reality, in 2014 the Government of Santa Catarina (SECRETARIA DA AGRICULTURA, DA PESCA E DO DESENVOLVIMENTO RURAL DE SANTA CATARINA, 2014) created the Forest Management Committee – CGFlorestal. This the discussion and formulation of policies for the forest supply chain, guarantying the balance between social, economic and environmental interests.

Thus, in order to contribute to the discussion within the scope of spatial planning in the state, the proposed research question of this study departs from the scenario painted by the IFFSC Project. Are agricultural and silviculture activities a growing trend in the land use and land cover changes of the microregions of Santa Catarina? And does this growth override the urbanization trend? In order to respond to these questions, the aim of this study is to present a methodological proposal, based on multivariate data analysis techniques, to define a typology of land use and land cover changes and to ascertain the extent to which this phenomenon is in line with socioeconomic and territorial changes in the State of Santa Catarina for the period from 2000 to 2010. To such end, the specific objectives are: to the changes between classes of land use and land cover in the state for the period of analysis, in order to pinpoint trends and to identify the relation between the dynamics and the socioeconomic factors.

2 STATE OF THE ART

Information on the dynamics of land use forms (and especially those based on geography, that is, those supported by geographic information technologies) provides considerable support to public managers involved in the development and implementation of environmental and spatial planning policies, insofar as it unveils "where" the changes have occurred; "to what extent", in terms of units of measurement, a given use *was* formerly and *has become*, both in absolute and relative values; "how" these changes occur in terms of shifting from one type of use to another/others, as well as in relation to spatial distribution. According to Verburg et al. (2004, p.147), models for analyzing and preview land use/cover change constitute valuable tools to support an assessment of the causes and effects of this phenomenon. The analysis of scenarios with land use/cover models can offer support to spatial planning and policies.

In this context, the impact of the land use and land cover transition process has been widely studied, as corroborated by the extensive literature published in the last 10 years. Different methodological proposals may be observed, based mainly on statistical analyses (both linear, and more recently, non-linear methods of analysis) supported by Geographic Information Technologies (GIT), such as Geographic Information Systems (GIS) and Remote Sensing techniques (RS).

DeFries et al. (2010) evaluate economic, agricultural and demographic correlations with forest loss in the tropical forests of 41 countries (Asia, Africa and Latin America) from 2000 to 2005, using a set of possible indicators of this change by means of multiple linear regression, regression tree and cross tabulation methods. Their findings point to growth of the urban population and the export of agricultural products as driving forces in tropical forest loss. Souza and Costa (2018), present a methodology for analyzing land use and land cover changes, based on multivariated data analysis, in the state of Santa Catarina, Brazil, during the period from 2000 to 2010. They identify significant growth in agriculture and silviculture activity as well as loss of forest areas, closely related to the expansion of the crop area, mechanization, and increased herd size.

Yoshikawa and Sanga-Ngoie (2011) addresses deforestation from 1981 to 2011 in the state of Mato Grosso do Sul, in Brazil, by seeking to quantify the changes in vegetation area and to identify its uses and causes, with a particular focus on the relationship between agricultural activities and the road network.

They used Digital Vegetation Models (*DVM Maps*); road maps; hydrography; parks and indigenous areas; annual cattle population data (1974 to 2006) and soy planted areas (1990 to 2006). Based on Cross Tabulation and Spatial Analysis techniques, they identified urban development and soy production as deforestation-inducing forces in Mato Grosso do Sul. In Silva et al. (2011), the authors analyze the evolution of deforestation in the Brazilian Pantanal and surrounding area over a period of 32 years (1976 to 2008) and outline scenarios for the period from 2010 to 2050, using supervised classification of satellite imagery techniques and the geometric mean (2002-2008) for scenario planning.

The authors point to a strong tendency for natural areas to be converted into land use (in monoculture - soy and other grains, sugar cane, pasture and urban expansion) and the scenarios suggest that the natural vegetation in the region will disappear by 2050. The studies, present different methods to analyze the dynamics of deforestation in the different territories which are constituted as relevant methodologies in the pursuit to identify and relate the driving forces behind this phenomenon. As a consequence, both studies predict a trend of natural area (forests) conversion into land use stemming from agricultural activities and urban expansion, caused by market demand. This is due to Brazil's increased exports of agricultural-based products (such as grains and meat) and silviculture products, and to serving the domestic market, characterized by population growth.

Asner et al. (2009) present an integrated environment analysis (ClasLite) to support the mapping of large areas of tropical forests based on a variety of satellite sensors. Different treatments are applied to the images where they manage to provide estimates of forest cover, degradation and deforestation.

As a case study, they use Brazil (known hotspot for logging) and Peru (Amazon Biome) for the period from 1999 to 2002. In order study to analyze the changes and their influencing factors on the dynamics of land use in the Coastal Area of Rio Grande do Sul, Lipp-Nissinen et al. (2018) used remote sensing and field observation techniques to map, quantify and compare the classes of land use and cover of four temporal thematic maps, referring to a period of 26 years (1985 - 2011). They found relevant changes in the landscape over the period under analysis, particularly the occupation of permanent preservation areas (PPA) by Pinus sp. Silva et al. (2013) who had carried out studies using Remote Sensing techniques to map land use and land cover in the municipality of Floresta, in Brazil, from 1987 to 2008.

As a result, they point to a considerable decrease in forest cover to the detriment of urban expansion and agricultural activities. Rodrigues and Leite (2017) analyze the dynamics of land use and cover in the hydrographic basin of the Aquidauana River, in the state of Mato Grosso do Sul, in Brazil, using satellite images from 1970 to 2014. They identify strong anthropic pressure, where the main dynamics denote forest loss due to the expansion of pastures and urban areas. The results presented by Asner et al. (2009), Lipp-Nissinen et al. (2018), Rodrigues and Leite (2017), and Silva et al. (2013) indicates changes from natural to agricultural uses and also identified urbanization as the main conversions in the areas under study.

The proposed methodologies offer basic inputs that are necessary for land use and land cover changes studies, namely relative speed, high temporality and possibilities for different spatial resolutions and levels of detail. Based on the availability of numerous types of satellite images and image classification resources, the development of specific products can be aligned according to the need required in the study.

Abrantes et al. (2016) and Rocha (2012) analyze land use changes in an urban and peri-urban context, that contributed to evaluate territorial policies. Also, they simulate scenarios of evaluation that supported future policy choice. Rocha (2012) developed a model to simulate the dynamics of urban growth for the municipality of Almada in Portugal, based on a non-linear basic approach.

Urban, environmental and institutional data (slopes, road network density, distance to urban environment, index of attractiveness, constructive dynamics, value of the territory, legal restrictions and zoning) were used for the period from 1985 to 2008 along with simulations that enable the prediction of land use evolution scenarios for 2001. From a perspective of evaluation, Abrantes et al. (2016) analyzed the conformities of land use and land cover changes, particularly in terms of urban expansion, with municipal planning instruments for the Metropolitan Area of Lisboa, in Portugal.

The present study focuses on the period from 1990 to 2007 and includes cross tabulation, spatial metrics and gradient analysis. These authors compare the identified dynamic patterns with the instruments that regulate land development. The results shed light upon artificial areas growing along an urban-rural gradient, decreased and more fragmented agriculture, to the detriment of expanding peri-urban spaces and high conversion of agricultural and urban land in protected areas, pointing to a lack of conformity between the regulatory instruments of land use and the actual reality.

3 MATERIALS AND METHODS

3.1 AREA OF STUDY

Santa Catarina State (Figure 1) located in the southern region of Brazil, has a population of approximately 6.5 million inhabitants and an area of approximately 95 thousand km^2. It borders the States of Paraná (to the North), Rio Grande do Sul (to the South), Argentina to the West and has an Atlantic coast of 450km at east. In the south temperate zone of the planet, the state has a subtropical climate and is

located in the Atlantic Forest Biome. Its capital and seat of government is the city of Florianópolis, on the island of Santa Catarina.

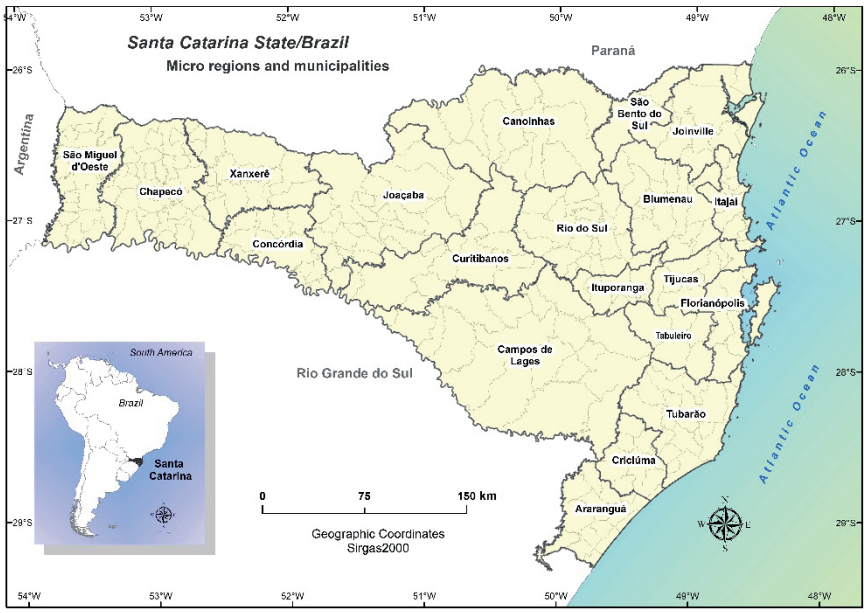

Figure 1 | Map of Santa Catarina State/Brazil, Geographic Microregions and Municipalities.

Source: The authors.

The main economic activities of the state are agriculture, cattle raising, manufacturing, extraction and tourism. It is the sixth richest state in the Federation, with a diversified and industrialized economy. It is based on the extractive production of yerba mate and wood, agriculture and pastoral production, and also has textile, metallurgical, ceramic, food and electrical material industries. With only 13% of the national territory and 3% of the Brazilian population, Santa Catarina is today the fifth food producer in Brazil.

The state is among the largest Brazilian producers of corn, honey, apples, onions, poultry and pork and is the largest Brazilian producer of garlic. It also participates with 40% of the domestic production of tobacco. Santa Catarina's apple production corresponds to 60% of the domestic production and its chicken production to 28%. It also has an intensive fishing activity, and the state ranks first place in the country for fish production and third as producer of shellfish (SERVIÇO BRASILEIRO DE APOIO ÀS MICRO E PEQUENAS EMPRESAS, 2014).

The dynamism of the Santa Catarina economy is reflected in the high rates of growth,in literacy, employment and per capita income, which are much higher than the national average. According to data published by the Atlas of Human Development in Brazil, Santa Catarina is positioned within a high range of human development by the United Nations Development Program – UNDP. According to the publication, in 2010, the state reached an HDI of 0.774, the third highest in the country, only surpassed by the Federal District and São Paulo (PROGRAMA NAÇÕES UNIDAS PARA O DESENVOLVIMENTO, 2013).

3.2 THE INFORMATION USED

For the development of this study, data classified as secondary were used, all of which are publicly available on different online databases.

The State of Santa Catarina is divided into 20 geographic microregions defined by the Brazilian Institute of Geography and Statistics (IBGE), based on the grouping of municipalities with economic and social similarities. The map used was made available by the National Planning Secretariat of Santa Catarina for

the year 2013, in vector format, scale 1: 500,000, SIRGAS 2000 Reference System and UTM Projection System - Universal Transverse de Mercator.

Considering that the economy of the state of Santa Catarina is strongly based on agricultural, pastoral and extraction production, a set of variables were initially considered to describe the microregions in terms of their land features, agriculture and cattle raising characteristics, as well as their population, quality of life and economic development characteristics. Data availability for the period under analysis was also considered. Thus, the following variables were selected: Urban Population, Human Development Index, Number of Agricultural Establishments, Workers Occupied on the Land, Number of Tractors, Value of Animal Production and Herd Size. The databases used were the Demographic Census, Agricultural Census, Municipal Cattle Raising Survey of the IBGE Automatic Recovery System - Sidra[1], and the Human Development Atlas of Brazil.

The land use and land cover maps used (years 2000 and 2010) are the result of the Project entitled *Changes in Land Cover and Land Use* conducted and made available by the IBGE. They are in vector format, with a scale of 1: 1,000,000 and SIRGAS 2000 Reference System and UTM Projection System. There are 12 classes in the state, namely: Artificial Area, Agriculture, Mosaic of Agriculture and Forest Remnants, Silviculture, Forest, Mosaic of Forest and Agriculture, Grassland, Natural Pasture, Mosaic of Grassland and Agriculture, Continental Water Body, Coastal Water Body, Uncovered Areas.

Table 1 | List of databases used

Data	Format	Scale	Year	Source
Land use and land cover maps - Santa Catarina	vector	1:1.000.000	2000 e 2010	IBGE
Geographic microregions map - Santa Catarina	vector	1:500,000	2013	SPG
Demographic Census	tabular	Microregion	2000 e 2010	IBGE
Agricultural Census	tabular	Microregion	1995/96 e 2006	IBGE
Human Development Atlas - Brazil	tabular	Microregion	2000 e 2010	Pnud
Municipal Cattle Raising Survey	tabular	Microregion	2000 e 2010	Sidra/IBGE

Source: The authors.

Table 1 presents the information that served as a basis to meet the aims defined in this research, with references to format, scale, year and source. For the year 2000, the data considered were as follows: Classes of land use and land cover - year 2000; variables from the Demographic Census 2000, Agricultural Census 1995/1996 - (IBGE, 1995), data from the Human Development Atlas 2000 and the Municipal Cattle Raising Survey 2000. For the year 2010, the data were as follows: Classes of land use and land cover - year 2010; variables from the Demographic Census 2010, Agricultural Census 2006, data from the Human Development Atlas 2010 and the Municipal Cattle Raising Survey 2010.

3.3 METHODOLOGY

The methodology was developed in three stages. The first consisted of performing a flow analysis of the classes of land use and land cover by means of cross tabulation, in order to identify and quantify the main land use and cover transitions; the second stage involved selecting the indicators deemed representative of the previously identified changes, relating them to the social and economic variables

1 | IBGE Automatic Recovery System – Sidra. Available in: https://sidra.ibge.gov.br/. Accessed on March 02, 2018

with a view to explaining the relationship of use and cover with socioeconomic activity by means of a principal component factor analysis; the third corresponded to the elaboration of a final typology, based on the cluster analysis, in which homogeneous groups of microregions according to the characteristics and relationships found were identified. Further detail is presented in the next section.

In this research, the first stage, with recourse to cross tabulation, is considered an initial phase of the study, as this technique is used to support the verification of changes between classes and the exploration of existing relationships. Thus, it was used to quantify area transitions between classes of land use and land cover for the years 2000 and 2010, and to identify trends in flow. Additionally, the variation rate of the classes was calculated. To this end, vector land use and cover maps and GIS spatial analysis tools were used.

In the second stage, a principal component factor analysis was performed in order to describe the changes in the dynamics of land use and land cover by microregion during the period under study, and to identify some of the factors that may explain these changes (the driving forces). Factor Analysis is a Multidimensional Data Analysis technique that studies the relationship between the set of initial variables (simultaneously considered dependent and independent) and the secondary variables (usually independent of each other), generated from the first set

Prior to the factor analysis, a preliminary processing of the data was required so that the variables could be properly processed in the SPSS statistical software package. The classes of use taken from the state map of land use and cover were regionalized by microregion in order to obtain each microregion's area of use and cover; the socioeconomic data that were sometimes available by municipality were aggregated by microregion. Upon completion of this data systematization by microregion, the variables were then relativized, forming indicators, so that they could be comparable.

Therefore, as units of analysis, the 20 microregions of the state and 11 variables were used. To help assess the quality of the data, the Kaiser-Meyer-Olkin Measure - KMO and the Bartlett Sphericity Test were calculated, where the recommended KMO value is above 0.5 and Bartlett below 0.05. The extraction method used was the Principal Component Analysis and the Varimax rotation method.

Thus, and according to the change trends identified in the previous step, the variables were classified into the following dimensions of analysis: Silviculture/Forest, Animal Production and Agriculture. The fourth dimension was then added, corresponding to Population and Socioeconomic Development, representative of the urban characteristics and social and economic development, comprising: artificial area (urban occupation area, organized by buildings and road system - %), the Human Development Index - HDI (considering life expectancy at birth, education, and per capita income) and the urban population. In the Silviculture/Forest dimension, areas occupied by Forest (%) and Silviculture (%) were selected to measure their evolution. As for the Animal Production dimension, the following were included as indicators: Herd Size and Value of Animal Production, intended to measure both the quantity of livestock and the valuation of this activity (for which all herd types were considered: Bovine, Bubal, Equine, Swine - total, Goats, Sheep, Poultry - total, Quails).

Finally, for the Agriculture dimension, the following were considered: Agriculture (% occupied area), Density of Agricultural Establishments (as a means of assessing the land structure), Rural Workers (to observe their evolution) and Number of Tractors for every 100 rural workers. These indicators were selected to ascertain the development of the activity based on its level of mechanization. It should be noted that the Agriculture variable refers to the sum of occupied areas with Agriculture and the Mosaic of Agriculture and Forest Remnants and Forest refers to the sum of areas occupied with Forest and Mosaic of Forest and Agriculture.

The third and final stage of analysis is based on the numerical taxonomy in order to present a final typology of synthesis. Numerical taxonomy (cluster analysis) refers to the general techniques of grouping or classifying individuals, cases, elements or units of analysis. They are said to be numerical

since the basis for grouping or classifying these individuals or units of analysis is based on the numerical values presented by each in one or more indicators. To this end, hierarchical classification, with the method of grouping by the farthest neighbour and the Euclidean distance measurement were used as the classification methodology. The dendrogram method was used, with a cut-off point at 15, obtaining 4 homogeneous groups for the years 2000 and 2010.

4. RESULTS AND DISCUSSION

4.1 IDENTIFICATION OF TRENDS IN LAND USE AND LAND COVER CHANGES

The cross tabulation result is presented in the form of a table, which contains the distribution of the intersections between the different classes and allows for the numerical analysis of the changes that occurred during the period. As previously described, in Santa Catarina there are 12 classes, however, for this analysis and presentation of the result, 7 classes were considered, excluding those that represent bodies of water (unchanged), uncovered areas and grassland (little representation). Figure 2 illustrates changes in km² between land use and cover classes for Santa Catarina between 2000 and 2010.

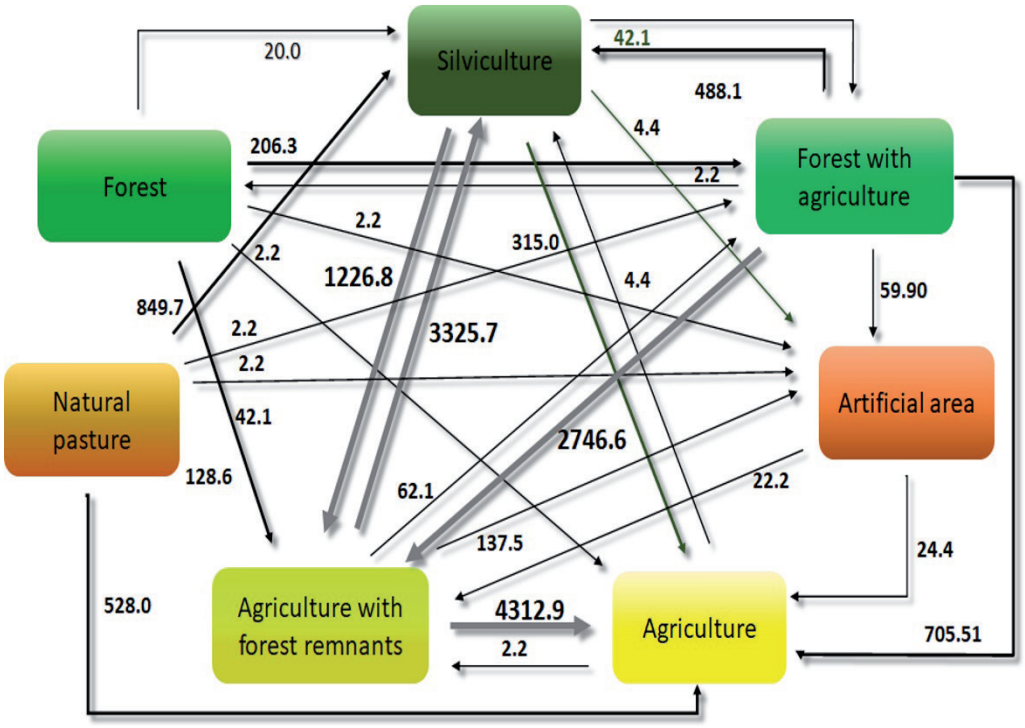

Figure 2 | Land use and land cover changes from 2000 to 2010 (km²).

Source: The authors.

According to Figure 2, it should be noted that the most relevant transitions for the period under analysis were from Mosaic of Agriculture and Forest Remnants to Agriculture (4312.94km²) and Silviculture (3325.67 km²), from Mosaic of Forest and Agriculture to Mosaic of Agriculture and Forest Remnants (2746.62 km²) and Silviculture to Mosaic of Agriculture and Forest Remnants (1226.88km²).

It is also noteworthy that, according to the mapping methodology adopted by the Brazilian Institute of Geography and Statistics - IBGE (2016), the classes referred to as Mosaic of Agriculture and Forest Remnants and Mosaic of Forest and Agriculture are areas that contain more than 50% and less than 75% of the polygon used for agriculture and forest vegetation, respectively. In other words, there is

a predominance of one class to the detriment of another, as in this case, namely a predominance of agriculture over forest area and conversely, a predominance of forest vegetation over agriculture.

Thus, it should be stressed that the analysis of class use and cover transitions carried out for the period under study suggests that a class previously deemed mosaic, or mixed, was predominantly defined as Agriculture and Silviculture, as in the case of the Mosaic of Agriculture and Forest Remnants class. Another relevant transition occurred as an inversion, as in the case of Mosaic of Forest and Agriculture to Mosaic of Agriculture and Forest Remnants. In other words, over the period, agricultural use became more predominant than forest vegetation and less frequent. Additionally the area of Silviculture is also noteworthy, with higher representation in the agricultural area.

According to the main categories of land use and cover change in Santa Catarina between 2000 and 2010 presented by Ribeiro, Vale, Reis (2014) and Geist et al. (2006), two of the categories were the most frequent, namely "agricultural intensification" - where internal intensification of land use in agricultural areas occurs (including the forest planted for economic purposes such as silviculture as an agricultural activity); "natural to agricultural conversion", another process, with less intensity, but not less important in the context of the main dynamics, characterized by the conversion of forest and mosaic of forest into agricultural areas.

Complementarily, and in order to aid the identification of trends for the period, the variation for the two years was calculated, as shown in Table 2.

Table 2 | Variation of land use and land cover classes in Santa Catarina (2000 and 2010)

Classes	Variation (%) 2000 - 2010
Artificial area	12.09
Agriculture	131.10
Agriculture with forest remnants	-8.88
Silviculture	64.12
Forest	-9.05
Forest with agriculture	-13.83
Natural pasture	-16.48

Source: The authors

The variation shown in Table 1 indicates that the classes related to Agriculture and Silviculture increased by 131.1% and 64.1% respectively. Artificial Area also recorded growth, however, with little expression compared to the others. Natural Pasture area was observed to experience the greatest loss, -16.48%, followed by Forest with Agriculture (-13.83%), Forest (-9.05%) and Agriculture with Forest Remnants.

In view of the methodology adopted, it is possible to observe that for the period under study, an increase in agricultural and silviculture activities coupled with a loss of natural areas (not in the same proportion) is a strong trend, namely Forest and Natural Pasture.

The changes identified in the state of Santa Catarina corroborate the studies of DeFries et al. (2010), Silva et al. (2011), Silva et al. (2013) and Yoshikawa and Sanga-Ngoie (2011) in which these authors demonstrate that in the most different parts of the world there is a strong expansion of agricultural exploration area to the detriment of natural areas, whether through planted forests, grain cultivation or cattle raising activity, and these transitions/conversions occur to meet a high demand for agricultural products, mainly from the foreign market. The results are also in line with the findings of the IFFSC project, where Vibrans et al. (2012) state that the advance of agropastoral use and forest plantations has been one of the major causes of the depletion of native forests in the state of Santa Catarina, both in terms of quantity and biodiversity.

4.2 IDENTIFICATION OF LAND USE AND LAND COVER CHANGE BY MEANS OF FACTOR ANALYSIS

The principal component factor analysis enabled the identification of 11 factors, the first three of which represented an explanation of 82.9% and 84.6% for the years 2000 and 2010 respectively. Table 3 shows the indicators with the highest relational component in each factor (bold).

Table 3 | Highlighted indicators with high explanatory component (2000 and 2010)

Dimension	Indicator	2000		
		Factor1	Factor2	Factor3
		Urban	Animal production and agriculture	Silviculture
Pop. and socioeconomic develop.	Artificial area (%)	**0,797**	-0,104	0,404
	HDI	**0,741**	0,203	0,529
	Urban population (%)	**0,947**	-0,005	-0,159
Silviculture /Forest	Forest (%)	0,604	-0,563	0,435
	Silviculture (%)	0,000	-0,090	**-0,926**
Animal Production	Herd size	-0,067	**0,867**	0,167
	Animal production value (%)	0,072	**0,851**	0,337
Agriculture	Agriculture (%)	-0,694	0,586	0,058
	Tractors/100 rural workers	0,065	**-0,735**	0,202
	Density of agricultural establishment	-0,567	0,520	0,470
	Rural workers (%)	**-0,960**	0,080	0,073
Dimensin	Indicator	2010		
		Factor1	Factor2	Factor3
		Urban	Animal production and agriculture	Silviculture
Pop. and socioeconomic develop.	Artificial area (%)	**0,715**	-0,111	0,538
	HDI	0,524	0,211	**0,710**
	Urban population (%)	**0,969**	-0,001	0,006
Silviculture /Forest	Forest (%)	0,470	-0,601	0,556
	Silviculture (%)	0,130	-0,084	**-0,921**
Animal Production	Herd size	0,010	**0,906**	0,110
	Animal production value (%)	-0,070	**0,904**	0,167
Agriculture	Agriculture (%)	-0,646	0,633	0,055
	Tractors/100 rural workers	-0,031	**-0,828**	0,137
	Density of agricultural establishment	-0,543	0,633	0,402
	Rural workers (%)	**-0,946**	0,056	-0,064

Source: The authors

Thus, based on the factor loadings of each factor, some inferences may be drawn as to the extraction of these factors. Factor 1, designated as Urban, refers to the indicators mainly from the dimension entitled "Population and Socioeconomic Development" (Artificial Area, Urban Population and Human Development Index), and also reveals a strong correlation with Forest Area. This points to a predominance of urbanization over agricultural activities, leaving the remaining forest area. Factor 2 relates Herd Size, Animal Production Value and Density of Agricultural Establishment indicators, referring to Animal Production and Agricultural activities. Factor 3, which has the lowest explanatory percentage of the three, relates the indicator to Silviculture (the highest negative), which emerges as an activity.

Based on the factor analysis by microregions (scoring matrix), as illustrated in Figures 3a and 3b, it may be observed that in relation to the Urbanization Factor, in 2000, the microregions of Florianópolis, Itajaí, Joinville and Blumenau emerge as the major urban centres of the state, presenting the highest scores for Urbanization (Factor 1) in that year. This, in fact, was an expected finding since the largest urban concentration in the state of Santa Catarina is located along its coastal strip.

Moreover, according to the demographic census 2000 of the IBGE, compared to other microregions in the state, on average, over 86% of the inhabitants of these microregions live in urban areas and also present the highest human development indexes - HDI, with average values above 0.75, above the national average of 0.699 (PNUD, 2013). In 2010, Blumenau and Joinville presented less representation, which may be justified by a reduction of their scores in this factor and, in general, the urbanization factor for the year 2010 was weaker compared to the year 2000, denoted by a reduction in the correlation of its indicators.

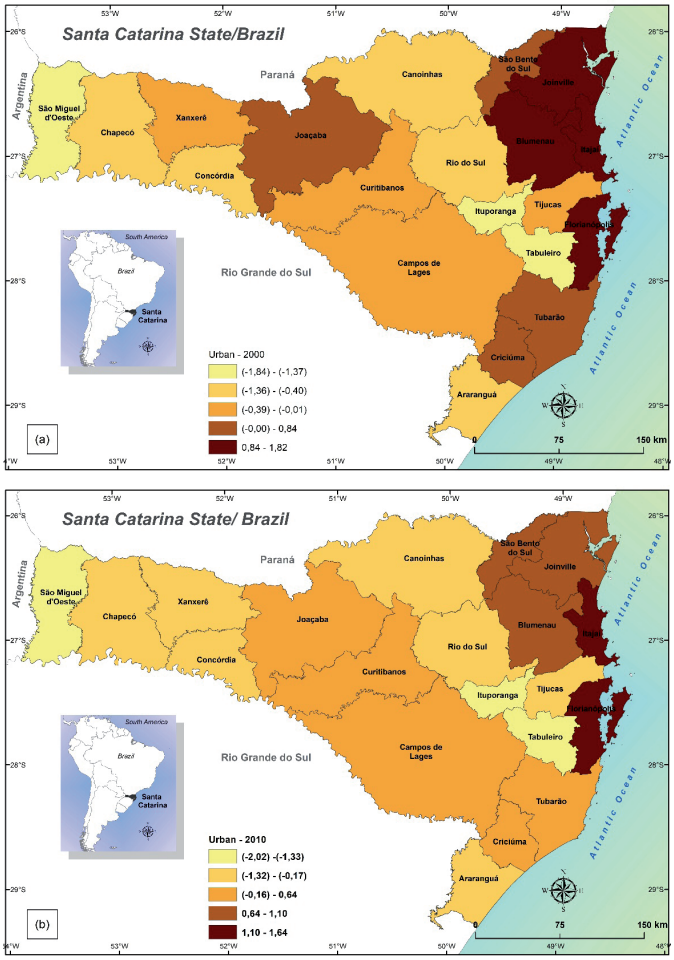

Figure 3a | Microregions of Santa Catarina - Factor 1: Urban - 2000 and
Figure 3b | Microregions of Santa Catarina - Factor 1: Urban – 2010.

Source: The authors.

In relation to Factor 2 - Animal Production and Agriculture (Figures 4a and 4b), the dynamic was the opposite of the Urban Factor. A considerable increase in the explanatory factor of the variables of this factor for the year 2010 is observed, and in 2000, a high correlation is already observable. In 2000, the microregion with the highest score is Concórdia. However, in 2010, the microregion of Chapecó joins Concórdia in this regard. This dynamic may be attributed to the high growth of animal production in Chapecó, for which herd size for the period shows a positive variation of approximately 72%, according to data from the Municipal Cattle Raising Survey, IBGE.

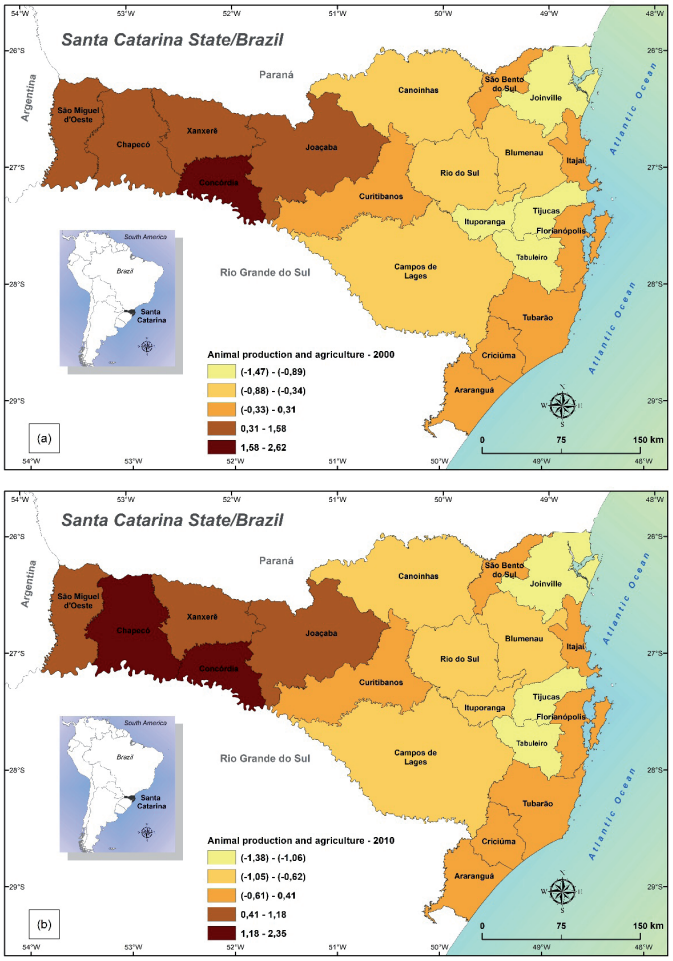

Figure 4a | Microregions of Santa Catarina - Factor 2: Animal Production and Agriculture - 2000 and **Figure 4b |** Microregions of Santa Catarina - Factor 2: Animal Production and Agriculture – 2010.

Source: The authors.

As for Factor 3, which generally presents the lowest loadings, the correlation with the Area with Silviculture variable should be noted, thus its designation as Silviculture. In 2000, the microregions of São Bento do Sul, Canoinhas, Joaçaba, Curitibanos and Campos de Lages have the highest scores in this factor and in 2010, the Curitibanos and Campos de Lages microregions continue this trend. Such dynamics may be associated with the fact that in 2010, the urban HDI and artificial area indicator had a greater correlation with this factor compared to 2000. Additionally, based on the mapping of land use and land cover (2000 and 2010) developed by the IBGE, the variation rate calculated for the Silviculture area for the period was 177% in Campos de Lages and 60% in Curitibanos, substantially higher compared to the other microregions previously associated with this group.

4.3 FINAL TYPOLOGY

In order to present a final typology of synthesis, a cluster analysis was carried out, which identified homogeneous groupings of the microregions, considering the 3 factors extracted from the factor analysis: Urban, Animal Production and Agriculture, and Silviculture.

The group referred to as Agriculture is characterized by microregions with a higher concentration of rural workers and number of tractors, in addition to the extension of agricultural area. The Urban Group is related to Factor 1 and is composed of microregions with the largest extensions of urban area, urban population and the highest development index - HDI. The Silviculture Group, related to Factor 3, groups together the microregions with the largest area of silviculture combined with a lower density of agricultural establishments, which refers back to a land structure characterized by medium and large properties, as opposed to a predominant land structure of small properties in the state.

According to the Agricultural Census 2006 (IBGE), the average area of agricultural establishments in this group is 54.02 ha, while the average in the state is 31.3 hectares. As far as the microregions involved in the Animal Production and Agriculture group are concerned, some display a higher percentage of agricultural area in the state (an average above 75%), smaller agricultural establishments (average 19 ha) and larger herd size and value of animal production. Compared to the other microregions, the herd size in this group stands above 5100 head/km^2, twice as high as the state average of 2358 head/km^2), according to data from the Municipal Cattle Raising Survey – IBGE.

Figures 5a and 5b illustrate respectively the Typology of Land Use/Cover and Economic Activity, considering the Microregions of Santa Catarina for the years 2000 and 2010.

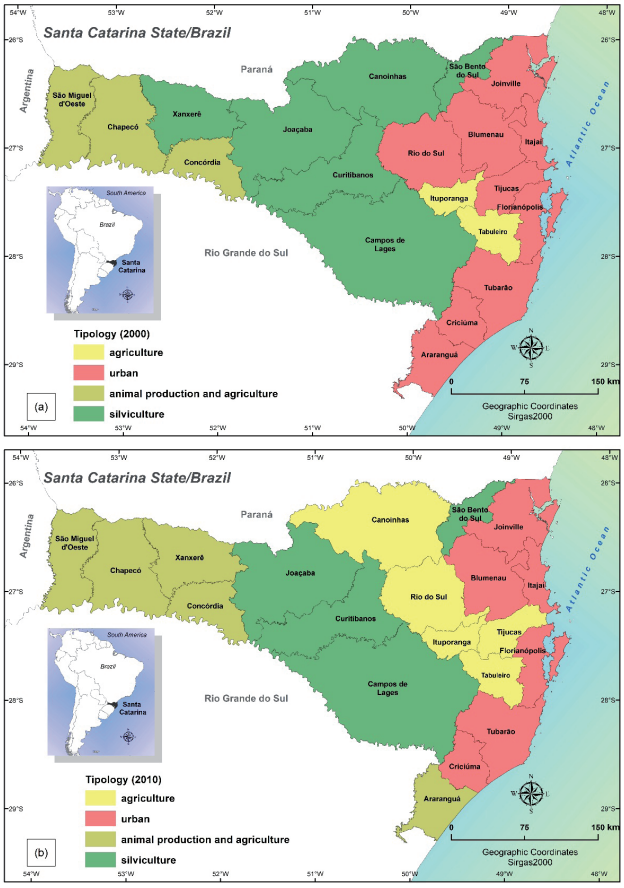

Figure 5a | Typology of Land Use/Cover and Economic Activity by microregion – year 2000 and **Figure 5b |** Typology of Land Use/Cover and Economic Activity by microregion – year 2010.

Source: The authors.

As for the dynamics observed in the state for the period from 2000 to 2010, some inferences can be drawn, namely the overall expansion and intensification of agriculture, animal production and silviculture. In 2000, the Silviculture group emerged as a more heterogeneous group in activities while in 2010 Silviculture is observed as an activity in its own right.

Some microregions were associated with other groups, such as Xanxerê, which in 2010 was part of the "Animal Production and Agriculture" group, as a result of increased mechanization by the number of tractors indicator and by an increase in herd size of more than 41%, namely bovine, swine and poultry. Canoinhas, on the other hand, became part of the Agriculture group, the conditioning factors being the expansion of agricultural area and increased number of tractors by rural workers. São Bento do Sul, Joaçaba, Curitibanos and Campos de Lages gain strength in the Silviculture group, due to the indicated area of Silviculture, for which the group presented a positive variation rate of 85%. Of the microregions making up the Urban group, in 2010, Araranguá became part of the Animal Production and Agriculture group, due to a significant increase in herd size, especially among the poultry population, with a growth of 170%, according to the Municipal Cattle Raising Survey - IBGE. Tijucas and Rio do Sul are grouped in the Agriculture category by the number of tractors indicator, which displayed an average growth of 71%, pointing to higher levels of mechanization of agricultural activity.

5 FINAL CONSIDERATIONS

The methodology developed in this study allows for significant considerations regarding the analysis of the dynamics of land use and landcover of Santa Catarina from 2000 to 2010, considering the 20 microregions of the state.

From the perspective of the 4 dimensions, namely Population and Socioeconomic Development, Silviculture, Animal Production and Agriculture, it is evident that agriculture, cattle raising and silviculture activities are distributed across the inland area, while the highest concentration of Urban and Native Forest are concentrated in the coastal microregions. The higher conservation levels of Forest Vegetation in this region may also be explained by a natural block, since the mountains of eastern Santa Catarina (Serra do Mar and Serra Geral) extend in the North - South direction of the State, from Joinville to Laguna

An increase from 2000 to 2010 was identified of agricultural activity of 131.1% and 64.1% for silviculture, mainly driven by the expansion of the area occupied by agriculture and silviculture, as well as high mechanization, shown by the number of tractors indicator. To the detriment of an increase in these economic activities, Forest Vegetation presented an area loss of approximately 20% (Forest and Mosaic of Forest and Agriculture). This dynamic points to two patterns of land use and cover transitions in Santa Catarina for the period under analysis, namely the agricultural intensification category and the natural-agricultural conversion category.

The findings corroborate the studies of the Floristic and Forest Inventory of Santa Catarina - IFFSC, which point to the expansion of agricultural activities and silviculture as the cause of forest loss, and also refer to the variables related to herd size, number of tractors and area occupied with the activity as being highly correlated in the land use and land cover dynamics for the period under study.

Thus, in response to the initial research question of this paper, it may be said that a considerable increase in the importance of primary market activity throughout the state (agricultural and silviculture sector) may be observed, with a direct relationship to land use and land cover changes. In the case of the coastal area, there is pressure from agriculture and loss of native vegetation; inland, urban development coexists with the growth of primary market activity (agriculture, animal production and silviculture)

The state of Santa Catarina is associated with this scenario as it reasserts itself in the agribusiness sector and international market, where constant Gross Value of Production (GVP) growth may be

observed for state agriculture, particularly the value of swine and chicken production. Additionally agribusiness was seen to increase its share of the state's total exports in 2019 to 68.3%, the main products being chicken, wood and wood products, pork, soy, tobacco, paper and cellulose and wooden furniture (EPAGRI/CEPA, 2019).

This evolution points to the need for measures to protect and regulate occupation and use, particularly in environmental terms, in order to frame economic, social and environmental development.

REFERENCES

ABRANTES, P. et al. Compliance of land cover changes with municipal land use planning: evidence from the Lisbon metropolitan region (1990-2007). **Land Use Policy**, v. 51, p 120-134, 2016. https://doi.org/10.1016/j.landusepol.2015.10.023

AQUINO, J. G. P. **Dimensões, características e desafios das cadeias agropecuárias do estado de Santa Catarina**. 93 p. 2016. Dissertação (Mestrado em Economia) – Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brasil.

ASNER, G. P. et al. Automated mapping of tropical deforestation and forest degradation: CLASlite. **Journal of Applied Remote Sensing**, v. 3, 033543, 2009, https://doi.org/10.1117/1.3223675.

DEFRIES, R. et al. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. **Nature Geoscience**, v. 3, p.178-181. 2010, https://doi.org/10.1038/ngeo756.

EMPRESA DE PESQUISA AGROPECUÁRIA E EXTENSÃO RURAL DE SANTA CATARINA/CENTRO DE SOCIOECONOMIA E PLANEJAMENTO AGRÍCOLA. EPAGRI/CEPA. **Síntese Anual da Agricultura de Santa Catarina**, 197p. Florianópolis, 2019. Disponível em: <https://cepa.epagri.sc.gov.br/index.php/publicacoes/>. Acesso em: 09 nov. 2020.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. **Planning for sustainable use of land resources**. FAO land and water bulletin 2. 67p. 1995. Disponível em: http://www.fao.org. Acesso em: 02 de abril de 2018.

GEIST, H. et al. Causes and Trajectories of Land-Use/Cover Change. In: LAMBIN, E. F.; GEIST, H. (Ed.). **Land Use and Land Cover Change**, p. 41-70, 2006. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-32202-7_3

GEOAMBIENTE Sensoriamento Remoto Ltda. Projeto de Proteção da Mata Atlântica em Santa Catarina – PPMA/SC. **Relatório Técnico do Mapeamento Temático Geral do Estado de Santa Catarina**. São José dos Campos, SP. Agosto de 2008, 90p.

HERSPERGER, A. M.; BÜRGI, M. Going beyond landscape change description: quantifying the importance of driving forces of landscape change in a Central Europe case study. **Land Use Policy**, v. 26, n. 3, p.640-648, 2009.

HERSPERGER, A. M. et al. Linking Land Change with Driving Forces and Actors: four conceptual models. **Ecology and Society**, v. 15, n. 4, 2010.

HOUGHTON, R. A.; HACKLER, J. L.; LAWRENCE, K. T. The U.S. Carbon Budget: contributions from land-use change. **Science**, v. 285, p. 5.427, p. 574-578, 1999.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Mudanças na Cobertura e Uso da Terra do Brasil 2000-2010-2012-2014**, 29p. Rio de Janeiro, 2016. Disponível em: <https://biblioteca.ibge.gov.br>. Acesso em: 06 mar. 2018.

LAMBIN, E. F.; GEIST, H.; RINDFUSS, R. R. Introduction: Local Processes with Global Impacts. In: LAMBIN, E. F.; GEIST, H. (Ed.), **Land Use and Land Cover Change**, p. 1-8, 2006. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-32202-7_3

LIPP-NISSINEN, K. H. et al. Temporal dynamics of land use and cover in Paurá Lagoon region, Middle Coast of Rio Grande do Sul (RS), Brazil. **Journal of Integrated Coastal Zone Management**, p. 25-39, 2018, https://doi.org/10.5894/rgci-n106.

PADILHA, D. G. **Modelo de apoio à decisão aplicado ao planejamento territorial de silvicultura baseado em análise multicritério de redes neurais artificiais**. 2014. 285 p. Tese (Doutorado em Engenharia Florestal) – Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul, Brasil.

PROGRAMA DAS NAÇÕES UNIDAS PARA O DESENVOLVIMENTO. **Atlas do Desenvolvimento Humano no Brasil.** Índice de Desenvolvimento Humano – IDH. (2000 e 2010). 2013. Disponível em: <http://www.atlasbrasil.org.br/2013/>. Acesso em: 10 abr. 2018.

RIBEIRO, M.; VALE, M. J.; REIS, R. Identificação das Principais Forças Motrizes: abordagem quantitativa. In: DGT (Ed.). **Uso e Ocupação do Solo em Portugal Continental:** avaliação e cenários futuros. Projeto Landyn, 2014. (p. 87-96). Lisboa: DGT.

ROCHA, J. **Sistemas Complexos, Modelação e Geosimulação da Evolução de Padrões de Uso e Ocupação do Solo**. 2012. 954 p. Tese de Doutoramento em Geografia, Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Lisboa.

RODRIGUES, L. P.; LEITE, E. F. Dinâmica do uso e cobertura da terra na bacia hidrográfica do Rio Aquidauana, MS. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO. **Anais...** Santos, SP. p. 6817-6825, 2017. Disponível em: <https://proceedings.galoa.com.br/sbsr?lang=en>. Acesso em: 05 jun. 2018.

SANTA CATARINA. Secretaria de Agricultura, da Pesca e do Desenvolvimento Rural. Resolução nº. 20, de 14 de agosto de 2014. Institui o Comitê Estadual de Gestão Florestal – CG Florestal. Data da resolução: 14/08/2014. **Diário Oficial**, n. 19.882, de 19 de agosto de 2014.

SANTA CATARINA. Secretaria da Agricultura, da Pesca e do Desenvolvimento Rural. Projeto Inventário Florístico Florestal de Santa Catarina. **Relatório do Projeto Piloto**. Florianópolis, 2005. 170p.

SERVIÇO BRASILEIRO DE APOIO ÀS MICRO E PEQUENAS EMPRESAS. **Coletânea de Informações Socioeconômicas de Santa Catarina**. 2014. Documento elaborado para o Planejamento Plurianual do Sebrae/SC. Disponível em: <http://www.sebrae.com.br/sites/PortalSebrae>. Acesso em: 27 abr. 2018.

SILVA, E. A. et al. Dinâmica do uso e cobertura da terra do município de Floresta, PE. **Revista Floresta**, Curitiba, v. 43, n. 4, p. 611-620, 2013. Disponível em: <https://revistas.ufpr.br/floresta/article/view/27931/21732>. Acesso em: 04 jul. 2018.

SILVA, J. S. V. et al. Evolution of deforestation in the brazilian pantanal and surroundings in the timeframe 1976 – 2008. **Geografia**, Rio Claro, v. 36, número especial, p. 35-55, 2011.

SOUZA, J. M.; COSTA, E. M. Dinâmica do uso e cobertura da terra nas microrregiões do estado de Santa Catarina, Brasil. Uma análise entre 2000 e 2010. In: XVI COLÓQUIO IBÉRICO DE GEOGRAFIA, 2018, Lisboa, Portugal. **Atas...** Lisboa: Centro de Estudos Geográficos, Universidade de Lisboa, 2018. p. 877-884. DOI: 10.33787/CEG20190003

TURNER II, B. L. et al. **Land use and land cover change** (LUCC). Science/Research Plan. IGBP and HDP, 133p. 1995. Disponível em: <http://lcluc.umd.edu/>. Acesso em: 18 fev. 2018.

VALE, M. J.; REIS, R.; MENESES, B. M. A caracterização do uso e ocupação do solo de Portugal Continental. In: DGT (Ed.). **Uso e Ocupação do Solo em Portugal Continental:** avaliação e cenários futuros, p. 9-14. Projeto Landyn, 2014. Lisboa: DGT.

VERBURG, P. H. et al. Land use change modelling: current practice and research priorities. **GeoJournal**. Issue 4, v. 61: p. 309-324, 2004. Disponível em: <https://link.springer.com/article/10.1007/s10708-004-4946-y>. Acesso em: 24 jan. 2019.

VIBRANS, A. C. et al. **Diversidade e conservação dos remanescentes florestais.** Inventário Florístico Florestal de Santa Catarina, v. 1. Blumenau, 2012.

YOSHIKAWA, S.; SANGA-NGOIE, K. Deforestation dynamics in Mato Grosso in the southern Brazilian Amazon using GIS and NOAA/AVHRR data. **International Journal of Remote Sensing**, v. 32, n. 2, p. 523-544, 2011. https://doi.org/10.1080/01431160903475225