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Spatial and temporal land use and land cover of the Upper Jardim River Basin, Distrito Federal, Brazil

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ABSTRACT

Monitoring natural resources of the Brazilian Savannah is important to preserve and conserve the biodiversity and the life quality of the populations in this biome. In the last decades, this biome underwent an intense occupation process, converting native vegetation cover into anthropic areas. The objective of this study was to evaluate the spatial and temporal land use and land cover over the last three decades in the Upper Jardim River Basin (UJRB), in Planaltina, Distrito Federal, Brazil. This basin has approximately 10,500 ha and its land is predominantly used for agricultural activities, especially grain production. Landsat images were used to perform a multitemporal mapping of the years 1985, 2000, 2010, 2015. The database of the EcoValuation, and Productive Transition and Environmental Services projects (Embrapa Cerrados) assisted in this mapping. This allowed spatializing and analyzing information about regional production classes and their cultural aspects according to the origin of the families in the production units. The UJRB underwent land use changes, with a slight reduction in its native vegetation cover in the first years evaluated, remaining close to the legal limit up to the 2000's, according to the in-force legislation — forest code — in that period. Then, the most significant changes observed was the conversion of pastures in to annual crops until 2015.

Keywords: Cerrado; remote sensing; cultural aspects; householders; corporate farming.

Dinâmica Espaço-Temporal do Uso e Cobertura da Terra da Bacia Hidrográfica do Alto Rio Jardim, Distrito Federal, Brasil

RESUMO

O monitoramento do Cerrado é importante para a preservação e conservação da biodiversidade e da qualidade de vida das populações, uma vez que, nas últimas décadas, o bioma vem passando por um intenso processo de mudança do uso da terra, com conversão de sua cobertura natural em áreas antropizadas. O presente estudo tem como objetivo analisar a dinâmica espacial e temporal do uso e cobertura da terra, no decorrer das últimas três décadas, na Bacia Hidrográfica do Alto Rio Jardim (BHARJ), Região Administrativa de Planaltina, Distrito Federal. Com aproximadamente 10.500 ha e de ocupação predominante voltada para atividades agropecuárias, a bacia se destaca pela produção de grãos. Foram utilizadas imagens do programa Landsat, resultando no mapeamento multitemporal dos anos de 1985, 2000, 2010, 2015, complementado pelo banco de dados dos projetos “Ecoavaliação” e “Transição Produtiva e Serviços Ambientais” (Embrapa Cerrados), que permitiu a espacialização e análise de informações das categorias produtivas e aspectos culturais relacionados à origem das famílias presentes nas unidades de produção. Foi possível notar que a BHARJ passa por mudanças no uso da terra, com leve queda na cobertura vegetal natural nos primeiros anos de análise, se mantendo próximo ao limite legal nos anos posteriores a 2000, de acordo com o código florestal vigente à época. Nesse caso, as mudanças mais significativas correspondem à conversão das pastagens para as culturas anuais até 2015.

Palavras-chave: Cerrado; sensoriamento remoto; aspectos culturais; agricultura familiar; agricultura patronal.

Introduction

Agricultural development in the Middle West region of Brazil was intensified from the

1930s to supply the country's Southeast consumer market (Bezerra and Cleps Junior 2004). This affected significantly the regional landscape. The soils of approximately 90 million hectares of the Brazilian Savannah is Oxisol, and these areas are

suitable for the grain production due to its favorable characteristics, usually with slopes less than 3%. This contributed for an intense mechanization and consequent pronounced changes in these areas (Chaves, 2008), and made the Brazilian Savannah one of the most threatened biomes of the country (MMA, 2015).

Information about the land use and vegetation cover of a given area assists in managing problems related to degradation of environmental quality, such as loss of agricultural lands, destruction of important wetlands, and threatens to biodiversity (Anderson et al., 1976).

Mapping land use is a pressing need for the understanding of land occupation over time, since land occupation is rarely planned, generating environmental problems, and compromising the conditions for life.

Inadequate land uses can cause serious long-term consequences for agroecosystems, such as degradation of areas, whose recovery can be irreversible, or reversible at high costs — usually economically unviable. Moreover, it can cause direct impact on fauna and flora habitats, with extinction of endemic species, intensification of erosive processes, silting of drainage networks, and other typical changes of the soil degradation processes.

Basins are appropriate spatial units for planning and manage land occupation. They have well-delimited areas for studies and their natural components work systemically. Thus, they are strategical for the preservation of the natural resources, since activities practiced in a basin affect its total operation. Analysis and control of land use in a basin is an efficient mean to protect its natural resources (Leite and Ferreira, 2013).

The Upper Jardim River Basin (UJRB) is located at the Rural Center of Tabatinga. This area has a diverse production, with large-scale agriculture for grain production, especially mainly corn and soybeans, and medium- to small-scale agriculture for production of vegetables, fruits, and livestock, carried out by householders. The area of this basin is occupied by householders, corporate

farming, and small areas intended for leisure.

The Rural Center of Tabatinga — a governmental colonization program — was created to meet the demand for food due to development of Brasília, and to expand the country's agriculture. The UJRB has currently an important local agriculture and livestock, with diverse production, and yields above the national average. Farms in this area have singular characteristics of productive, technical, social, and public safety infrastructures, and everyday needs, which make them more resistant to urban pressure (Mattos, 2014).

The objective of this study was to evaluate the spatial and temporal land use and land cover in the UJRB. This objective was derived from three goals: the understanding of the basin occupation and its changes over the last three decades; the definition of the land use by householders and corporate farming; and the description of the land use considering cultural aspects related to the regions of origin of householders migrated to the basin.

Material and Methods

Study area

The Upper Jardim River Basin (UJRB) has approximately 10,500 ha (Lima et al., 2007). Its land area has a predominant rural use, with diverse agricultural production, especially grain production, with high yields. This area is currently used as an experimental basin of Brazilian Agricultural Research Corporation (Embrapa Cerrados) for studies about the Brazilian Savannah, because of its agricultural production and easy access (Figure 1).

The Jardim River (Figure 1) is an important tributary of the Preto River, which flows into the Paracatu River, which flows into the São Francisco River. The Jardim River basin, including Upper, Middle, and Lower sections, has a total drainage area of 52,755.15 ha (527.55 km²), representing approximately half of the area contributing to the Rio Preto Basin, in the eastern limit of the Distrito Federal (Reatto, 2000).

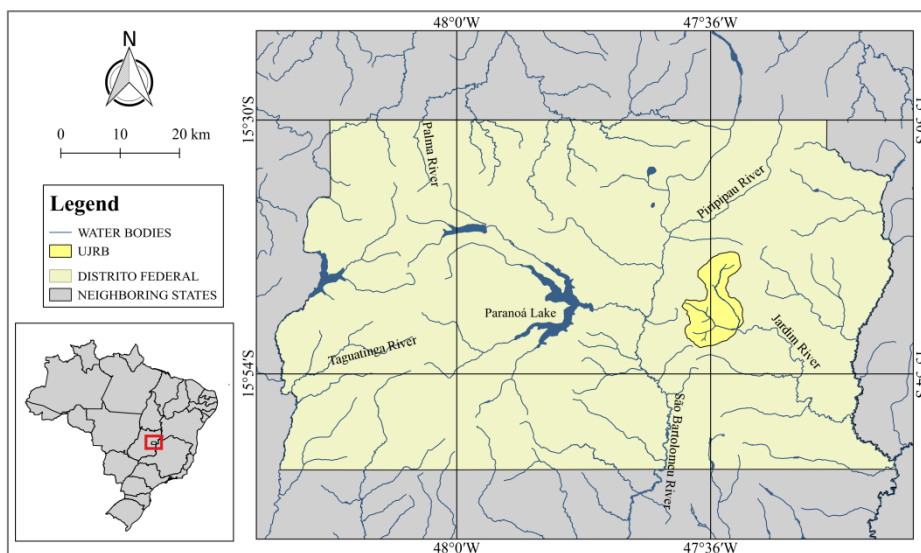


Figure 1. Map of the study area, Planaltina, Distrito Federal, Brazil.

Methodology

The UJRB area was analyzed through satellite images from 1985, 2000, 2010, and 2015. Images acquired by the Landsat 5 satellite — Thematic Mapper sensor, and spectral bands 4, 5, and 3 — were used to analyze 1985, 2000, and 2010; and images acquired by the Landsat 8 satellite — OLI sensor, spectral bands 5, 4, and 6 — were used to analyze 2015. All the patch/row of the area is 221/71.

The images were processed in the SPRING software (Câmara et al. 1996) to obtain RGB compositions, and perform image cuts based on a vector of the study area, and contrast adjusts for segmentation (Erthal et al., 1991). The segmented file generated was converted from raster to vector using the QGIS software, in which the visual interpretation was performed. This interpretation was supported by field expeditions to identify the land use pattern observed — semiautomatic processing (Sano et al. 2007). The interpretation of the segments resulted in a thematic map divided in the classes: annual crops, perennial culture crops, pasture, forest cover, eucalyptus, and others (Figure 2).

Interviews

The database from the Ecoevaluation, and Productive Transition and Environmental Services projects conducted in the UJRB — both coordinated by the Embrapa Cerrados — was used to analyze the land use evolution of the productive classes — householders, corporate farming — and the cultural aspects related to the regions of origin of the householders in the basin. This analysis was based on the 49 production units that could be spatialized. Some potential units were not analyzed because of their size considering the spatial resolution of Landsat images.

Householders and corporate farming have different characteristics. Corporate farming is focused on the business, on increasing production and profit by using technologies to reduce the demand for employees. Contrastingly, in the householders, the property management is shared by a family, the productive activities developed in the farm is the main source of jobs and income for the family, and the family has a singular relationship with the land and the property as a production unit, source of food and leisure, and housing (MDA, 2016; Mattos, 2010).

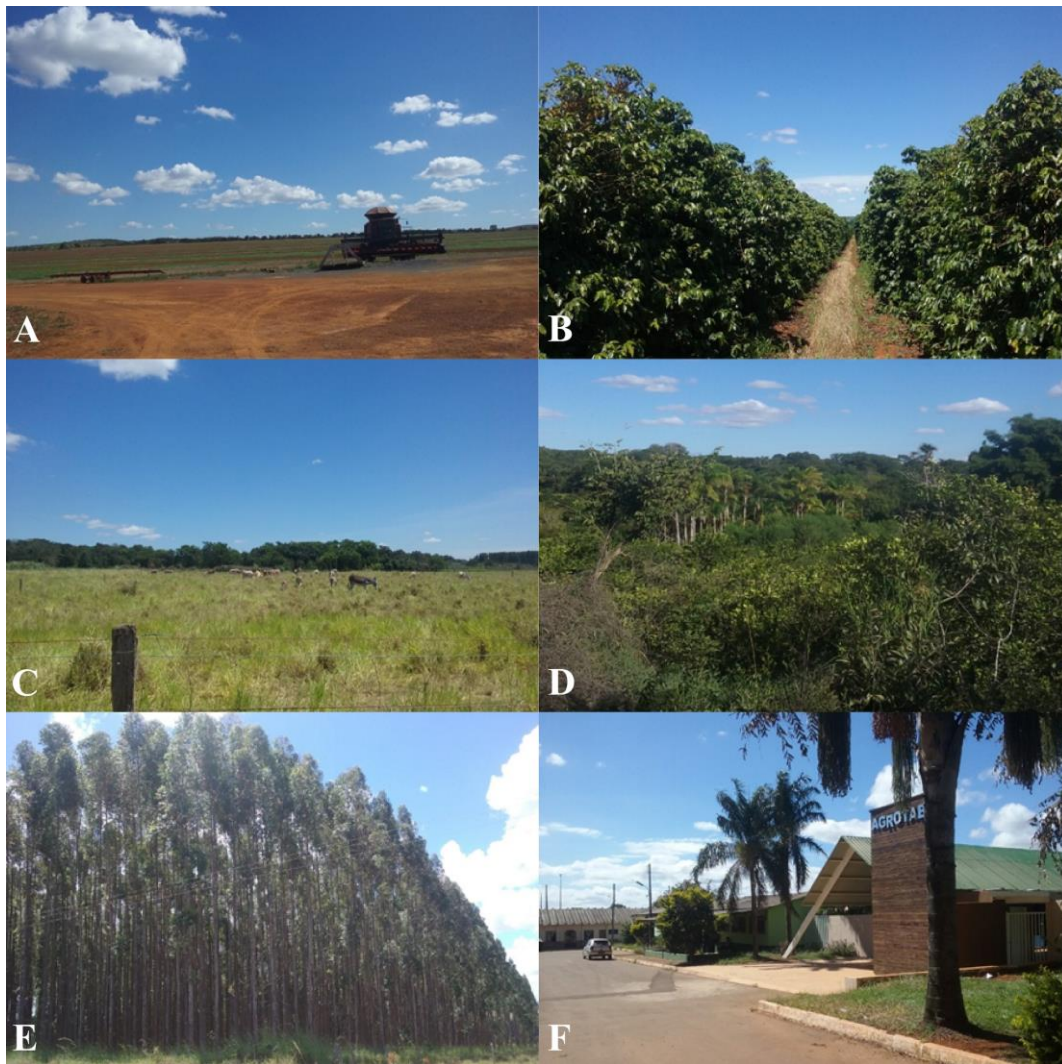


Figure 2. Areas classified as annual crop (A), perennial crop (B), pasture (C), forest cover (D), eucalyptus (E) and others (F), in the Upper Jardim River Basin, Planaltina, Distrito Federal, Brazil.

Results and Discussion

Land use and land cover

The Upper Jardim River Basin (UJRB) had an increase in annual crops from 1985 to 2000 (Table 1 and Figure 3), especially through conversion of livestock areas and eucalyptus forest areas, which completely disappeared from the basin, and conversion of a small area of the native forest, which remains close to the legal limit of 20% of the area. Annual crops covered almost all livestock areas from 2000 to 2015 (Vieira et al., 2016; Mattos et al., 2014).

Conversion of native vegetation cover into

anthropic areas in the Brazilian Savannah biome was also found by Neves et al. (2015), who evaluated the correlation between expansion of agricultural activities and relief in the São Bartolomeu River Basin in the Brazilian Central Plateau. According to these authors, 813.6 km² of this basin area — approximately 5487 km²; 48% in the Distrito Federal, and 52% in the state of Goiás — was converted into anthropic areas from 1991 to 2011; and 599.2 km² of this converted area was used for agricultural and livestock activities, which are predominant in the Chapada and Dissected Depression geomorphological units.

Table 1. Land Use and land cover in the Upper Jardim River Basin (UJRB).

Land Use and Land Cover	1985		2000		2010		2015	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest cover	2171	21%	1841	18%	1880	18%	1893	18%

Annual crop	3397	32%	5261	50%	6439	61%	6979	66%
Perennial crop	114	1%	143	1%	88	1%	89	1%
Pasture	3693	35%	3253	31%	2011	19%	1482	14%
Eucalyptus	1128	11%	0	0%	63	1%	47	1%
Others	12	0%	17	0%	34	0%	25	0%
TOTAL	10515	100%	10515	100%	10515	100%	10515	100%

Leite and Ferreira (2013) evaluated the spatial and temporal (1995 to 2010) land use in the Tabuas River Basin, in the northern state of Minas Gerais, Brazil, which has predominant savannah vegetation, and found removal of natural vegetation for expansion of anthropic activities, especially livestock. According to these authors, 11% of the native vegetation of this basin was converted into anthropic areas in the period evaluated, reaching 49% of the total area (181 km²) of the basin. Contrastingly, the UJRB had 82% of its area used for anthropic activities in 2010, especially agriculture.

Martins et al. (2015) found changes in vegetation cover and land use in the Upper Tocantins River Basin, in the state of Goiás, Brazil, over the last 29 years, with conversion of Brazilian Savannah native vegetation areas into anthropic areas related to agriculture and urban activities in expansion.

This landscape change pattern was observed also in the Atlantic Forest biome by Coutinho et al. (2013), who evaluate land uses, and permanent preservation areas in the Rio da Prata Basin, in Castelo, Espírito Santo, Brazil, and observed deforestation of Atlantic Forest for agriculture and livestock expansion, even in areas that was supposed to be preserved. According to these authors, large part of this deforestation occurred before the 1965 Forest Code approval, when no satellite images were available to monitor these areas; and currently, about 60% of the total basin area is occupied by agriculture, even the riverbanks; the remained areas have in general difficult access or shallow soils for native forest cover, representing 36.85% of the total area.

Freire e Castro (2014) assessed the

correlation between land use and occupation and water quality in 13 tributary sub-basins of the Itapemirim River Basin, in the state of Espírito Santo, Brazil, and found a decreasing water quality with increasing human activity in the greater sub-basin, and pastures and exposed soils as the land uses that most affect water quality of the most degraded sub-basins. The water dissolved oxygen concentration decreases, and nitrate concentration increases in these situations, probably due to the diffused organic material from the livestock activity when carried out with inadequate management.

In the UJRB, conventional agriculture is conducted with production systems based on monoculture of grains, and livestock, which remained stable, with a slight increase of the forest cover near the water bodies.

Contrastingly, Pinheiro et al. (2011) evaluated land use in riparian areas of small and medium-sized agricultural areas in the Upper Itajaí River Basin, in the state of Santa Catarina, Brazil, and found occupation of riparian zones by agriculture and pastures — historically established because of the arable, drained, and high-fertility soils, and low slope relief —, and most of the permanent preservation areas with crops. Atlantic Forest areas of the Upper Itajaí River Basin have pronounced slopes, thus, agricultural activities are practiced in lowlands, by the riverbeds. The UJRB have areas with flat surface, then, the riverbeds could be better preserved. Similar to this mapping of the UJRB from 1985 to 2000, the study on the Upper Itajaí River Basin indicated a trend of decreasing native forests with increasing distance from watercourses, with a significant reduction rate (Pinheiro et al., 2011).

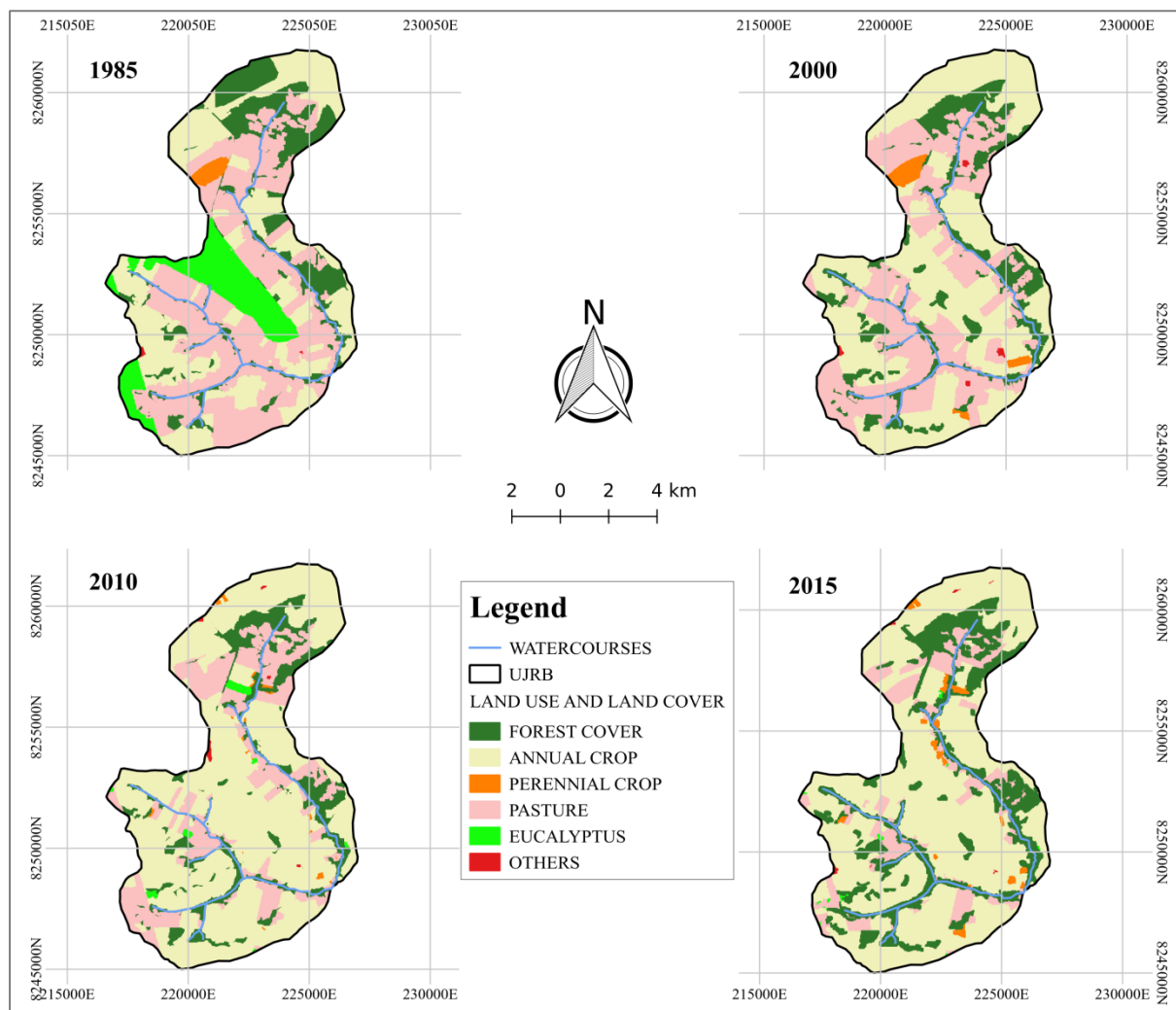


Figure 3. Map of the spatial and temporal land use and land cover of the Upper Jardim River Basin, Planaltina, Distrito Federal, Brazil.

Almeida and Vieira (2014) assessed land use problems in a permanent preservation area of biodiesel production in Moju, in the state of Pará, Brazil, and even though a basin area was not used as space for analysis, these authors highlighted the use of thematic maps for land use studies as a basis for analysis of changes over time.

The UJRB mapping showed the proximity of agricultural activities to water springs. A more detailed study can probably show more precisely these problems in the area. Donadio et al. (2005) evaluated the water quality of springs in areas with different land uses in the Córrego Rico Basin, in the state of São Paulo, Brazil, and found better water quality in the water springs nearby native vegetation remnants than nearby areas with agricultural use; color, turbidity, alkalinity, and total nitrogen were the variables that most explained these differences.

Therefore, not only the changes deriving from the land occupation must be identified, but also the remaining natural assets, following their transformations. Such studies are a valuable

instrument to develop environmental indicators, evaluate environmental support capacity, and contribute to the identification of alternatives that promote sustainable development (IBGE, 2013).

The continuous monitoring of the UJRB is important, since its status indicates a limitation for expansion of production based on monoculture of grains, and the UJRB has only 14.4% of pasture areas. This indicates that production systems must be redesigned to harmonize economic interests with environmental conservation. An alternative for this redesigning is the development of production systems that can be used as preservation reserve areas (Mattos et al., 2014).

Production systems

The existing production units in the database of the Embrapa Cerrados' projects was overlapped with the multitemporal mapping of land use, using 26 production units of family agriculture, representing 11.5% of the total area of the UJRB (Figures 4A and 5), and 23 production units of corporate farming, representing 18% of the

total area of the UJRB (Figures 4B and 6). The evolution observed in both productive classes was similar; however, family agriculture had greater

reduction of forest cover, probably due to the smaller area of its units.

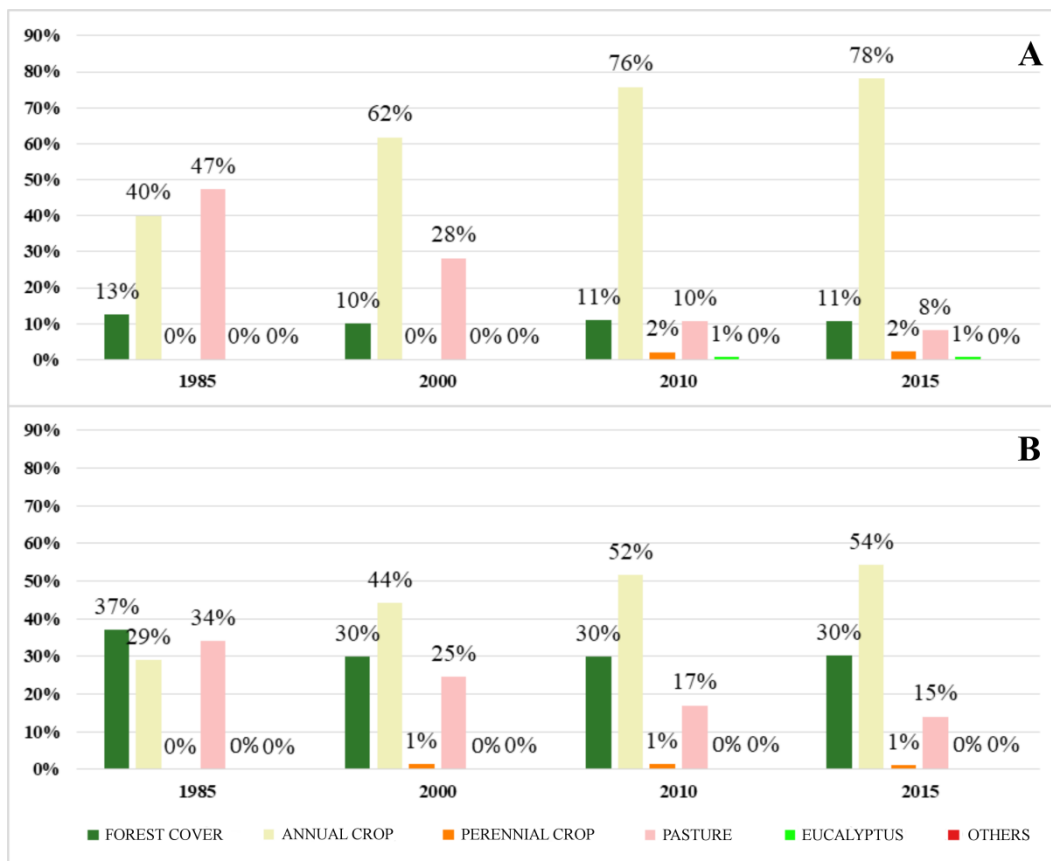


Figure 4. Land use and land cover in householders (A) and corporate farming (B).

Similarly, Abramovay (1997) studied householders and land use in the state of São Paulo and found that householders has a more intensified land use than corporate farming; annual crops are three times, and perennial crops are five times more important in the householders. According to these authors, householders outperforms corporate farming in the production of 15 important agricultural products, even using a much smaller area, and the yields of householders are higher than that of the corporate farming in most activities.

Mattos (2010) assessed the use of land and natural resources in Amazonian householders and found a direct relationship between the land area and capacity of maintenance of preservation reserve areas — the lower the area, the greater the relative importance of crops that are demanding in labor and has highly intensive use of land and natural resources. Contrastingly, corporate farming has more capital, larger areas and, consequently, higher incomes than householders. However,

according to Mattos (2010), the area size is not responsible to their higher income and growth.

According to Abramovay (1997), prejudices that are not yet overcome are barriers to the recognition of the social importance of householders from the economic point of view. According to this author, these prejudices are the correlation of householders with small production, and the thought that large areas conducted with employees are the actual expression of agricultural development. Abramovay (1997) also emphasize the importance of soil specialists in assisting in set up environmentally sustainable and economically profitable productive systems for householders.

Data connecting positively area size and preservation reserve area are found in the literature. However, Mattos (2010) point out exceptions, such as householders in the Transamazon road, and estuarine açai-producing farms in the North region of Brazil.

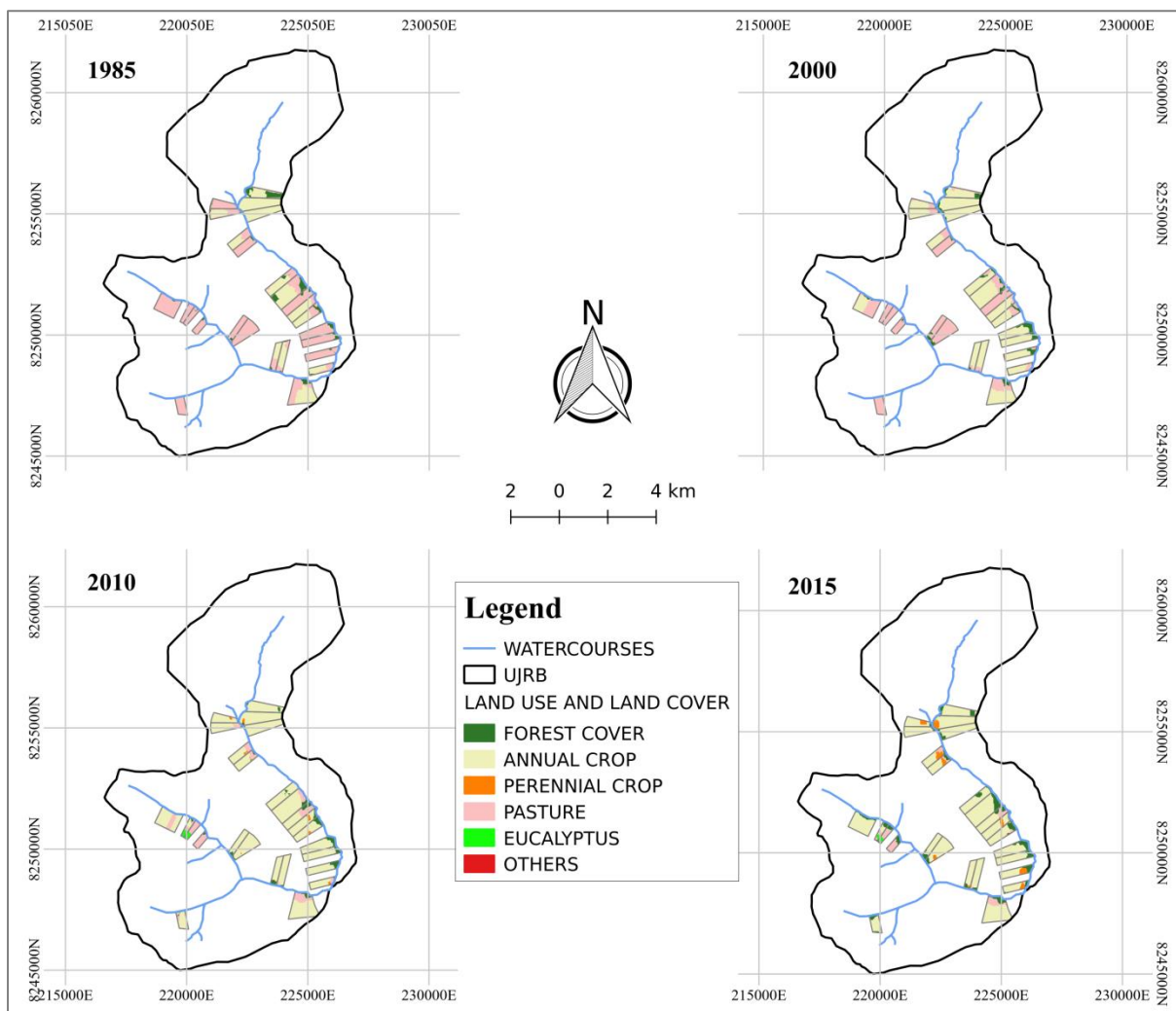


Figure 5. Map of the spatial and temporal land use and land cover of the householders, Planaltina, Distrito Federal, Brazil.

Cultural aspects related to the regions of origin of the householders in the basin

The study of cultural aspects related to the regions of origin of householders is relevant to describe how their cultural roots, influenced by their origin, are relevant in decisions of land use. Production systems can be complex, and its results have long and serious social, economic, ecological, and cultural implications (Mattos, 2010).

According to the database assessed, the main origins (States of Brazil) of the householders were Rio Grande do Sul (RS), with 18 production units, representing 10.1% of the UJRB total area (Figures 7A and 8); Espírito Santo (ES), with 7 production units, representing 3.1% of the UJRB total area (Figures 7B and 9); and Minas Gerais (MG), with 5 production units, representing 2.3% of the UJRB total area (Figures 7C and 10).

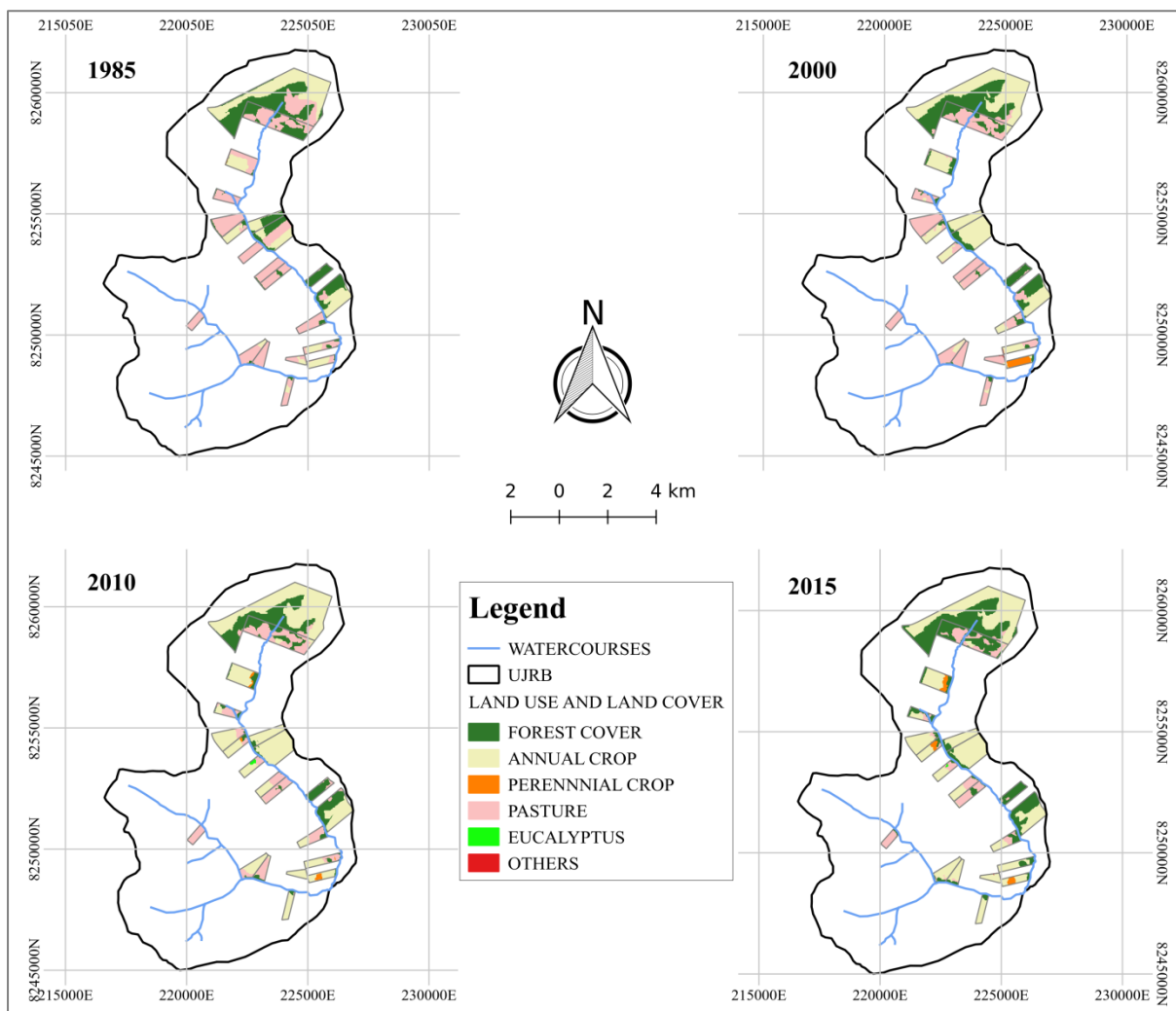


Figure 6. Map of the spatial and temporal land use and land cover of the corporate farming, Planaltina, Distrito Federal, Brazil.

The significant presence of landowners from RS in the UJRB is explained by Caliman (2013), who attributes this to the development of Tabatinga, which required expropriation of three large cattle farms in the mid-1970s. These farms were divided with the objective of bringing experienced landowners to the region, mainly from the South of Brazil, to produce food. Public policies and rural credit at that time were directed to the occupation of these areas by government employees, businessmen, and interested people that could apply the technological package of the green revolution, giving an incentive to production of agricultural commodities, aiming high productivity.

The results found regarding the productive profile of land use by landowners from RS reinforce those found by Mattos (2010) and Mattos et al. (2014) in the Amazonian householders and in the UJRB itself, respectively, with landowners from RS connected to annual crops, and tradition of grain production in large areas.

High percentage of annual crops (80% in

2015) was also found by Mattos et al (2014) for the land use by landowners from ES. However, in these cases, these crops were conducted as a capitalization strategy, by leasing part of their properties, to leverage their main productive activity — growth of perennial crops. This was shown by their highest percentage of perennial crops (7%) in 2015.

This was also observed by Caliman (2013), who observed another crop standing out in the region, the pupunha palm tree, whose seedlings was brought by some producers from ES who found that these plants adapted well to the climate of the Brazilian Savannah.

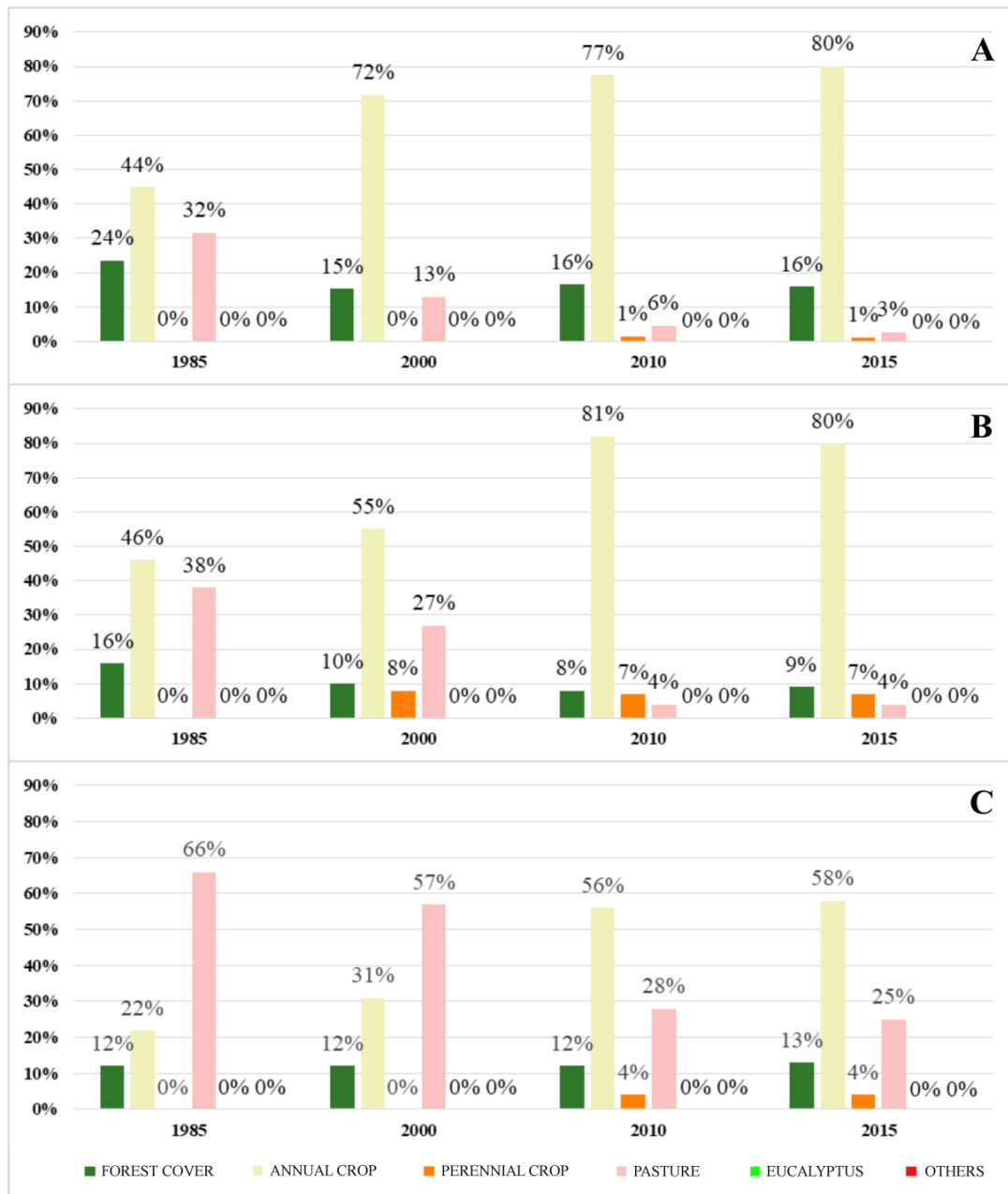


Figure 7. Land use and land cover of landowners from (A) Rio Grande do Sul, (B) Espírito Santo, and (C) Minas Gerais.

According to Mattos (2014), landowners from MG have five types of land use in the region, thus, their profile is inconclusive. This was shown by the mappings, which presented different percentages of land use by these landowners in 2015, 25% of pastures, followed by 58% of annual crops. However, annual crops are usually a secondary

productive activity, as shown by the greater adhesion to livestock production.

An exception for these profiles is the organic agriculture, in which cultural roots influenced by the origin of the landowners has no influence in the designs of production systems, due to the characteristics of organic agriculture, which is dependent on common norms (Mattos, 2015).

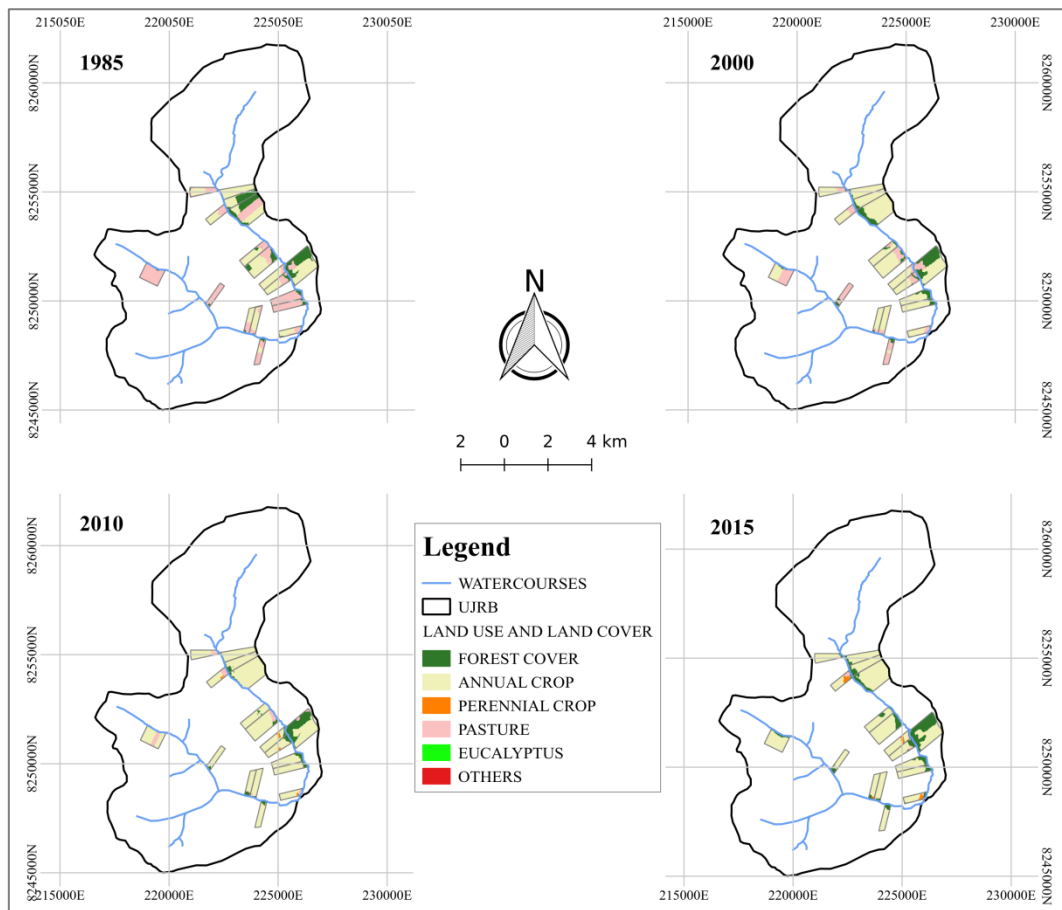


Figure 8. Map of the spatial and temporal land use and land cover of landowners from Rio Grande do Sul.

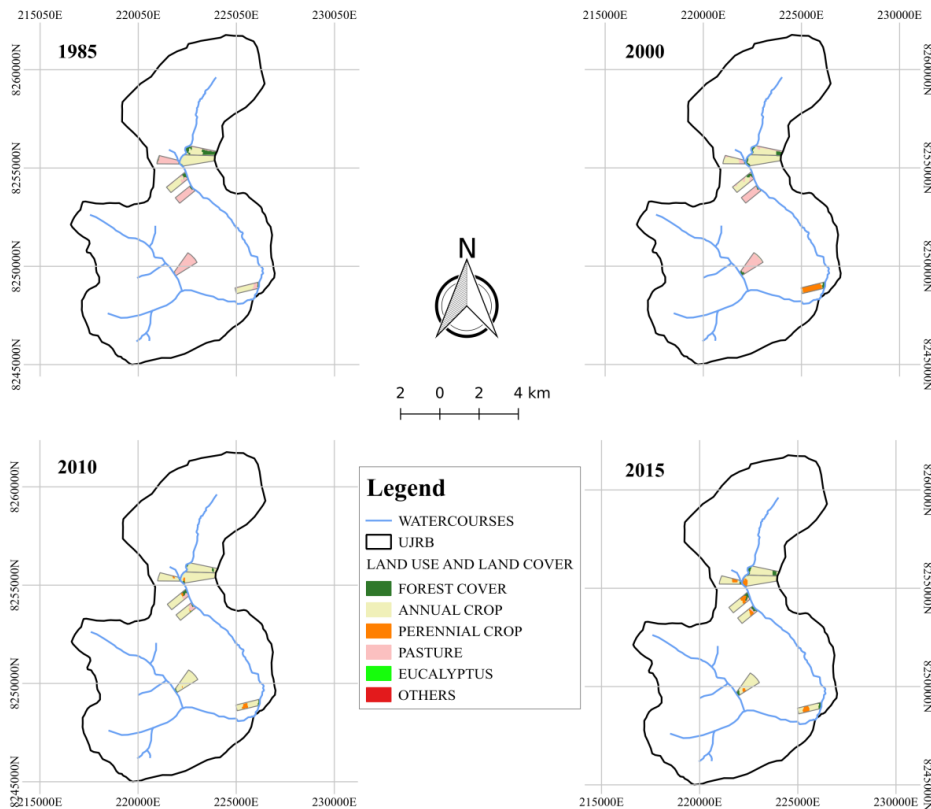


Figure 9. Map of the spatial and temporal land use and land cover of landowners from Espírito Santo.

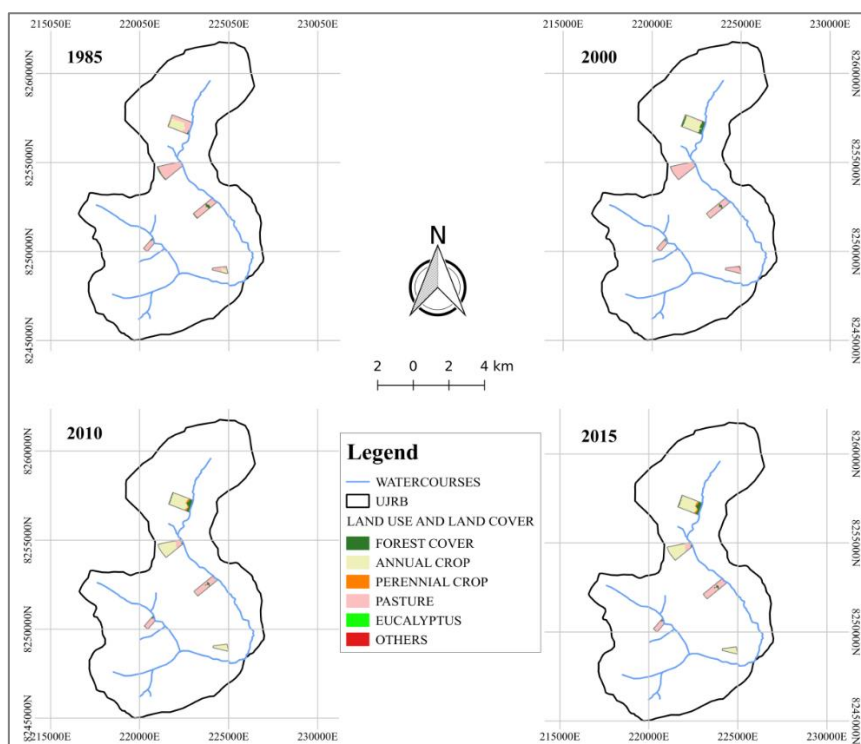


Figure 10. Map of the spatial and temporal land use and land cover of landowners from Minas Gerais.

Conclusions

1 - The spatial and temporal analysis showed how the landscape changed over time in the UJRB. In the last 30 years, annual crops have expanded to areas of livestock and eucalyptus, maintaining the forest cover areas close to the legal limit.

2 - The classification of productive classes showed that householders faces more obstacles in combining production expansion with maintenance of native vegetation cover due to the small size of their land units.

3 - According to the database assessed, the main origins (States of Brazil) of the householders were Rio Grande do Sul (RS), followed by Espírito Santo (ES), and Minas Gerais (MG). Landowners from RS and ES have agriculture as their main activity, and those from MG have agriculture as a secondary activity. The analysis of the distinct areas showed that landowners from RS are mainly connected to annual crops; landowners from ES are mainly connected to production of perennial crops; and landowners from MG are mainly connected to livestock production, but also presenting more diverse activities.

4 - These results assist in the understanding of processes that may be dependent on the rural landscape, thus providing subsidies for the qualification of public policies, and information on the connections found considering cultural aspects, productive classes, and land use.

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