Dynamics of the natural regeneration of forest remnants in the state of São Paulo, Brazil

Dinâmica da regeneração natural de remanescentes florestais no estado de São Paulo, Brasil

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ABSTRACT

The main factors that favour the regeneration of native vegetation in two regions in southeast Brazil were evaluated over an approximate period of 30 years. Region 1 covers 5.2 million hectares and is situated in the northern and northeastern portions of São Paulo. Region 2, located in eastern São Paulo, is formed by the Paraíba do Sul River basin and spans over 1.4 million hectares. In 2016, the area of native forests in Region 1 accounted for 19.3% of the territory against 16.9% in 1988. In Region 2, forests expanded by 83%, from 250,000 to 455,000 hectares. However, while in Region 1, characterised by competition between agricultural crops, the forest gain was modest, in Region 2, marked by steep terrain and a decline in livestock activities, significant natural forest regeneration was favoured. Restoration of native forest vegetation in the state of São Paulo may vary significantly over regions.

Keywords: Forest restoration. Geotechnology. Change in land use and cover.

RESUMO

Os principais fatores que favorecem a regeneração da vegetação nativa foram avaliados em duas regiões paulistas para um período aproximado de 30 anos. A Região 1, com 5,2 milhões de hectares, está localizada no norte e nordeste paulista. A Região 2, com 1,4 milhão de hectares, está localizada no leste paulista e é formada pela Bacia do Rio Paraíba do Sul. A área das florestas nativas da Região 1 em 2016 representou 19,3% do território ante 16,9% em 1988. Na Região 2, houve aumento de 83% das florestas, de 250 mil para 455 mil hectares. Enquanto na Região 1, caracterizada pela competição entre culturas agrícolas, o ganho florestal foi pequeno, na Região 2, caracterizada pela presença acentuada de áreas declivosas e retração das atividades pecuárias, houve expressiva regeneração natural das florestas. O restabelecimento da vegetação florestal nativa no estado de São Paulo pode variar significativamente nas diferentes regiões.

Palavras-chave: *Recomposição florestal. Geotecnologia. Mudança de uso e ocupação da terra.*

1 INTRODUCTION

Native forest vegetation has been cleared to make way for agricultural activities since the beginning of the 20th century (Solórzano *et al.*, 2021). However, from the mid-1970s onward, a large part of the inland of the state of São Paulo began to experience land use and land cover changes exclusively between agricultural and livestock uses, i.e., no longer involving the clearing of forests for the opening of new fields (Rudorff *et al.*, 2010; Sparovek *et al.*, 2007).

Since 1990/92, a series of mappings initiated by the São Paulo Forest Institute (Instituto Florestal, in Portuguese) through the Forest Inventory project has shown the evolution of native vegetation cover in the state. In 2020, the vegetation cover in the state of São Paulo reached 5,670,532 ha of native vegetation in various stages of restoration and featuring significant fragmentation, altogether an area equivalent to 22.9% of the state's territory (Nalon et al., 2022). Despite the increased number of vegetation fragments in the Mata Atlântica biome (Atlantic Forest) throughout Brazil, more than 97% of these fragments are smaller than 50 ha and mean fragments decreased to 16 ha (Vancine *et al.*, 2023).

This new phenomenon, portrayed by a decrease in deforestation rates for the Atlantic Forest biome in São Paulo from the 1990s onwards, began to occur because, in addition to the relatively small amount of forest remnants, there was an effort by the State to curb deforestation by means of greater control and inspection, rural environmental policies of São Paulo municipalities, fines against illegal deforestation, and respect for environmental laws and instruments, including the Brazilian Federal Constitution of 1988, the Brazilian Forest Code (no. 12.651/2012), and the Atlantic Forest Law (*Lei da Mata Atlântica*, no. 11.428/2006), the only one to protect a biome (Brancalion *et al.*, 2012; Giglio *et al.*, 2013; Vancine *et al.*, 2023). Other factors contributing to preservation were tourism, cultural industry, and the development of initiatives to include populations that make sustainable use of resources (Silva *et al.*, 2020).

Not only has the deforestation rate decreased, there have also been some forest gains due to the spontaneous recolonisation of secondary native vegetation, not to active reforestation (Bicudo da Silva *et al.*, 2023; Silva *et al.*, 2020). Natural regeneration (spontaneous or assisted recovery of native tree species that colonise and establish themselves in abandoned or unmanaged agricultural or pasture areas) has shown ecological and economic results that are similar to or more satisfactory than those obtained by active restoration in tropical forests (Crouzeilles *et al.*, 2017; Inhamuns *et al*., 2021; Zanini *et al*., 2021).

Data from the latest mapping of native vegetation cover in the state of São Paulo (Nalon *et al*., 2022) show a net increase of 4.9%, or approximately 214,000 hectares, in 10 years. With the net gains in native forest cover over a broader base of São Paulo cities, some studies suggest the occurrence of a so-called 'Forest Transition' in the state of São Paulo (Calaboni *et al.*, 2018; Molin *et al.*, 2017; Silva *et al.*, 2018).

However, the use and occupation of lands in different regions of the state of São Paulo is very diverse and may show different forest dynamics. In its inland, where the Cerrado and Atlantic Forest biomes are present, occupation occurs mainly by agricultural crops linked to agribusiness. These crops compete with each other for space, influenced by the expansion of sugarcane areas in flatter terrains and more fertile soils (Ferreira *et al.*, 2015; Rudorff *et al.*, 2010; Sparovek *et al.*, 2007).

The regions closest to the coast or the Serra da Mantiqueira and Serra do Mar mountain ranges, within the Atlantic Forest biome, feature rugged terrain, which makes it difficult to manage agricultural crops and are therefore occupied mainly by anthropic cultivated pastures in small and medium-sized rural properties where native forests develop in a considerable portion of the area (Calaboni *et al.*, 2018; Molin *et al.*, 2017; Silva *et al.*, 2020).

Forest recovery or loss processes are distinct in different regions of the state of São Paulo, and understanding them better is necessary. This study aims to identify the biophysical factors related to deforestation, the expansion of agriculture and livestock, and the recovery of native forests in the state of São Paulo in these two regions. The study covers the evolution of these regions over time (about 30 years): one is a place characterised by competition for land between agribusiness sectors, and the other is a region with predominantly irregular terrains and which has livestock as its main agricultural activity. Understanding the factors associated with these processes enables exploring future scenarios of land use changes and their consequences for native forest cover and supporting the establishment of public policies focused on nature conservation and agricultural production.

2 MATERIAL AND METHODS

2.1 STUDY AREAS

The Region 1 delimited in this study is composed of the whole or part of the river basins: Baixo Pardo Grande, Mogi-Guaçu, Pardo, Piracicaba/Capivari/Jundiaí, Sapucaí Grande, Tietê/Batalha, Tietê/Jacaré and Turvo-Grande. This area accounts for 5.2 million hectares or 20.5% of São Paulo's territory and comprises 125 cities (Figure 1). The original vegetation cover of this whole area is predominantly Cerrado and Atlantic Forest biomes, and its terrain varies mostly between flat, gently undulating, and undulating, with slopes varying between 0% and 20%. The region is currently occupied by agroforests linked to agribusiness, such as pastures, eucalyptus, citrus, and large grain crops, which are especially influenced by the expansion of sugarcane areas that have been gaining ever more space (Ronquim; Fonseca, 2018).

Region 2 is located in the São Paulo portion of the Paraíba do Sul River basin and encompasses 34 cities. It has an area of 1.4 million hectares and is situated between two mountain ranges, known as Serra da Mantiqueira and Serra do Mar. The basin is located in the Atlantic Forest biome, in a landscape characterised by 'seas of hills' (Figure 1). Its flat areas or gently undulating reliefs are concentrated in the lower part of the valley and have as their main axis the Paraíba do Sul River, which the Presidente Dutra Federal Highway parallels along much of its length. The Presidente Dutra Highway is the region's main transportation axis and connects Brazil's most important metropolitan areas, the São Paulo-Rio de Janeiro axis (Calaboni *et al.*, 2018; Ronquim *et al.*, 2016).

2.2 MAPPING LAND USE AND LAND COVER AND TERRAIN SLOPE

For Region 1, the analysis period covered the years 1988 and 2016, while for Region 2, it spanned from 1985 to 2015 due to their association with scientific studies and projects produced in different periods.

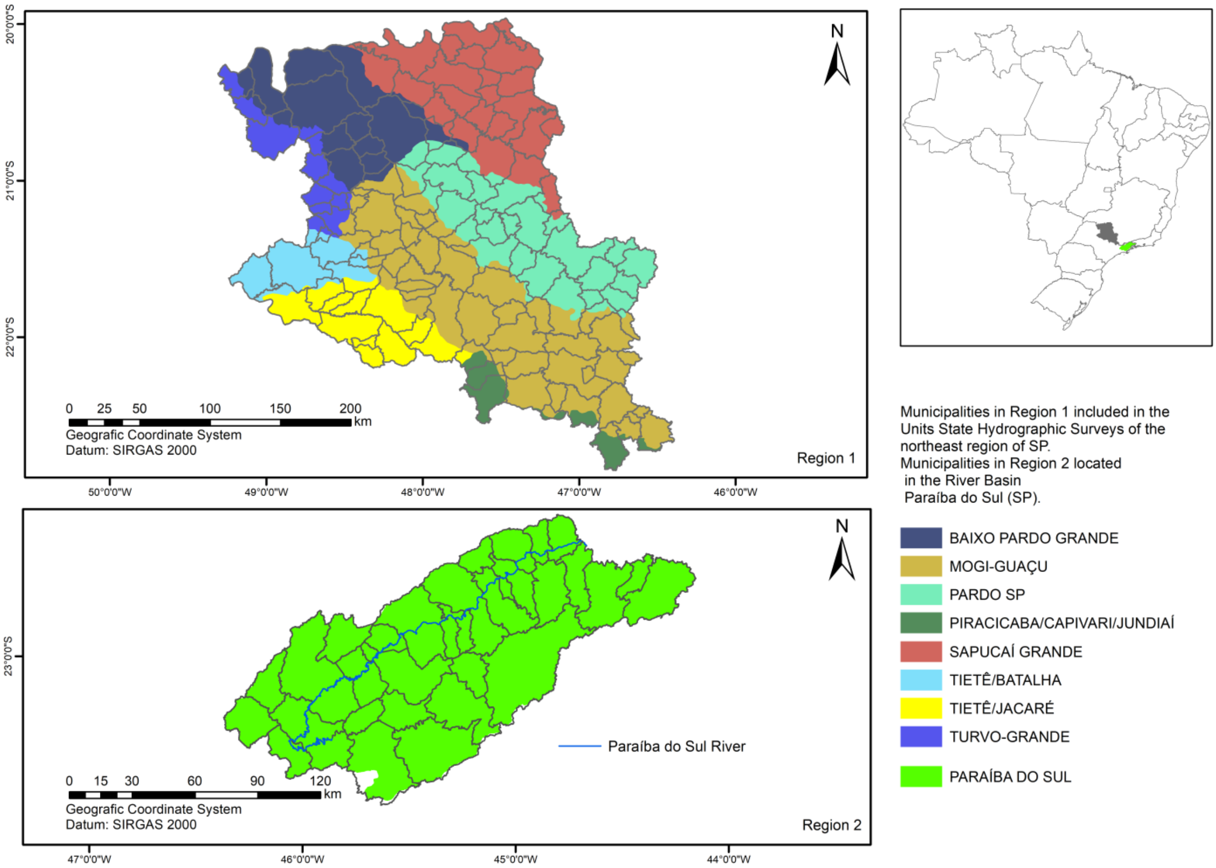

Figure 1 – Maps showing the geographic location of: Region 1 (5.2 million hectares), composed of the whole or part of the river basins Baixo Pardo Grande, Mogi-Guaçu, Pardo, Piracicaba/Capivari/Jundiaí, Sapucaí Grande, Tietê/Batalha, Tietê/Jacaré, and Turvo-Grande; and Region 2 (1.4 million hectares), composed of the Paraíba do Sul River basin

Source: Authors' elaboration.

In the case of Region 1, for the year 1988, the mapping was made using orbital images from the Landsat 5 Thematic Mapper (TM) satellite, RGB321 bands in the visible spectrum, with a spatial resolution of 30 m, and the following orbit-point combinations: 219/75, 219/76, 220/74, 220/75, 220/76, 221/74, and 221/75. After importing and preparing the images in the ArcGIS 10.5 analysis software, land-use classes were mapped by visual interpretation (Ronquim; Fonseca, 2018). For the year 2016, sugarcane crop areas were classified by updating the base maps generated by the Canasat Project (Rudorff *et al.*, 2010). This involved on-screen, visual interpretation of high-resolution images from the Google Earth Pro software and the inclusion of these new areas occupied by the crop into the computational environment. This was achieved by using mapping software, comparing and adding them to the database by means of digitisation, and filling out the attribute table.

For Region 2, for the land use and land cover mapping of 2015, we used a pair of Landsat-8 (Operational Land Imager - OLI) images, orbit-point scenes 218/76 and 219/76, which were pre-selected for their lack of significant cloud cover. These two Landsat-8 images covered the entire study area of the Paraíba do Sul River (Figure 1). For the land use and land cover mapping of 1985, we used a set of Landsat 5 Thematic Mapper (TM) images, which were part of the historical archive. The images available on the GloVis Geological Survey platform were generated using Level 1T processing (USGS). Image preprocessing involved atmospheric correction using the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (Flaash) algorithm. Following atmospheric correction, the images were segmented using the parameters: Segmentation Algorithm, Edge; Scale Level, 30; Merging Algorithm, Full Lambda Schedule; and Merge Level (implemented in ENVI 5.1), Feature-Based Extraction. A Texture Kernel Size filter was maintained at 3x3 pixels.

The training dataset was collected using visual interpretation of high spatial resolution images available on the Google Earth platform. For each scene, a different number of random samples was selected for each land use and land cover class, as each Landsat-8 image used for mapping in the year 2015 covered different percentages of the study area: scene 219/76 covered approximately 35% of the Paraíba do Sul River basin in the state of São Paulo, while scene 218/76 covered the remaining 65%. Approximately 1,000 samples were collected for each class in the land use and land cover classification to assess the overall accuracy of scene 218/76, and 200 samples from each class were collected for scene 219/76. Based on the total training dataset for each Landsat-8 image, we randomly allocated 90% for training and classification procedures and reserved the remaining 10% for accuracy assessment. The maximum likelihood supervised classification algorithm was used for the classification procedure.

In addition to the land use and land cover map for Region 1, a majority filter procedure was applied with a window size of 3x3 pixels to reassign a land use and land cover class to the centre of the 3x3 window. After the mosaic, the mapping results of both scenes' mapping were evaluated using an independent set of 100 samples for each land use and land cover class. These samples were selected by visual interpretation of high spatial resolution images from Google Earth to assess the accuracy of the mapping.

The DEM (Digital Elevation Model) based on data from the Shuttle Radar Topography Mission (SRTM, NASA) was used to generate the slope percentage map for both study regions, with a spatial resolution of 30.0 m. The Slope tool from the Spatial Analyst extension in the ArcGIS 10.5 software was also employed. Subsequently, the Reclassify geoprocessing tool was used to create a reclassified raster file based on slope classes: 0% to 12% (flat to gently undulating), 12% to 20% (gentle undulating to undulating), 20% to 75% (undulating to hilly), and greater than 75% (steep). Once the slope map was obtained, a spatial overlay was performed with the land use and land cover map to determine the location of these categories within their respective slope classes for all the cities studied. Then, the Tabulate Area tool in the ArcGIS software was used to extract, by city, the respective areas in hectares for this set of information layers. This study focuses on analysing the classes of native tree vegetation areas and their spatiotemporal regeneration in both study regions.

3 RESULTS AND DISCUSSION

The clearing of lands for new agricultural crops and livestock has contributed to the destruction of the native flora in the state of São Paulo since the 19th century. The use of numerous controlled burns to clear forests and make way for pastures hindered forest regeneration and helped establish an anthropic landscape that currently predominates over a significant portion of the lands in the two evaluated regions (Rudorff *et al.*, 2010). Both these areas went through these phases of forest exploitation.

Since the 1980s, the landscapes of Regions 1 and 2 had already been predominantly characterised by anthropic agricultural use. Region 1 was already occupied by large-scale monocultures competing for space, with a notable expansion of sugarcane areas and a significant decrease in pasture areas (Figure 2 and Table 1). Region 2 was characterised by extensive pasture cultivation (Figure 2 and Table 1), even on steep terrain (Table 2 and Figure 3).

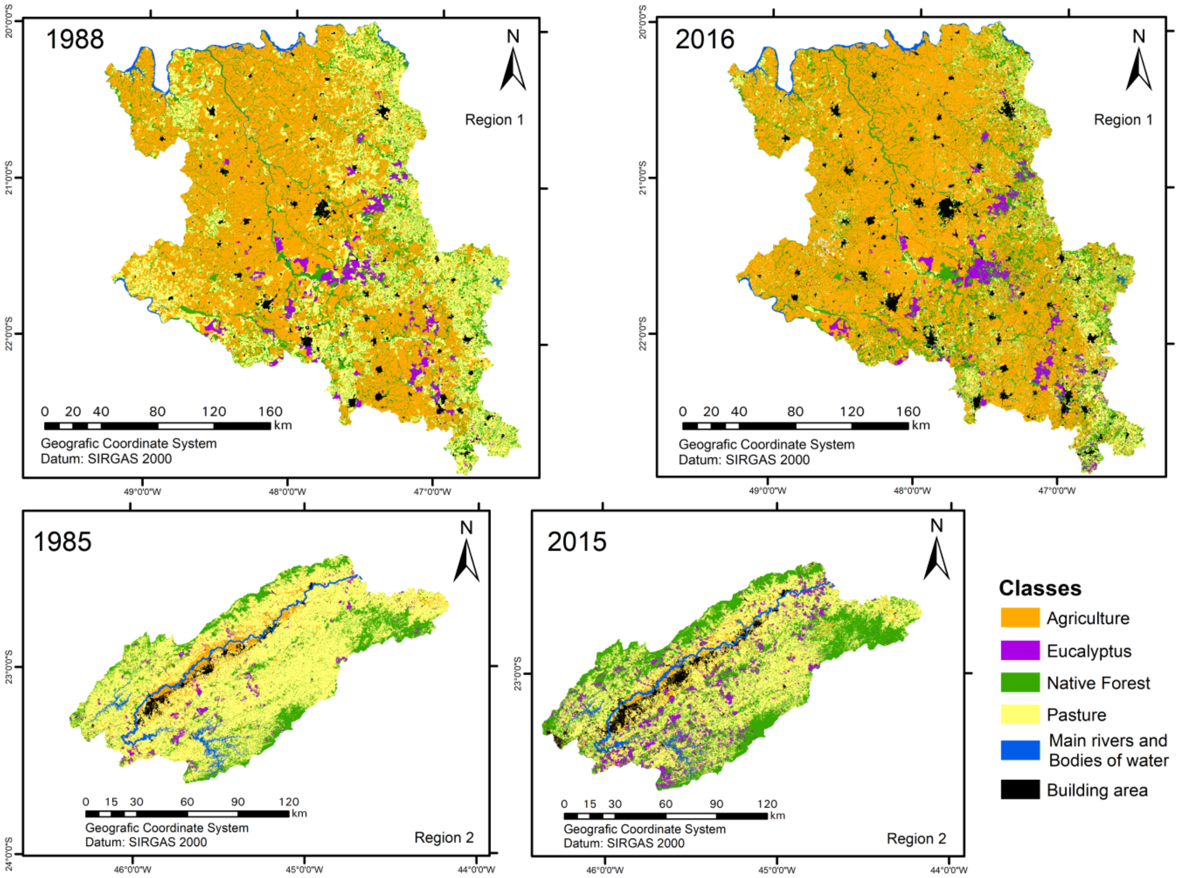

Figure 2 – Maps depicting the dynamics of land use and land cover change in areas of native forest, pasture, agriculture, eucalyptus, built-up areas, and water bodies in Region 1 (5.2 million hectares) for the years 1988 and 2016, and in Region 2 (1.4 million hectares) for the years 1985 and 2015

Source: Authors' elaboration.

In Region 1, agricultural areas showed the most significant expansion. The expansion of sugarcane fields was the primary driver of land use and land cover change, mainly encroaching upon pastures and areas previously occupied by annual crops, similar to many other regions in São Paulo's inland (Ferreira *et al.*, 2015; Ronquim; Fonseca, 2018; Rudorff *et al.*, 2010; Sparovek et al., 2007). During this same period, there was an increase in the area occupied by eucalyptus and built-up areas (Table 1). Native forests in 2016 accounted for 19.3% of the area, compared to 16.9% in 1988, and grew from 872,000 ha to 998,000 ha (Table 1), a 14.5% increase in native forest cover.

In Region 2, beef and dairy production pastures accounted for the largest land cover in 2015: 651,000 ha. However, over 30 years, this area decreased by 31% (Table 1). During these 30 years, pastures gave way to eucalyptus reforestation, which now occupies 8.1% of the basin area (Table 1). Eucalyptus crops for cellulose production were established in the region in the 1960s, and a significant portion of the pulp produced is sold to markets in China and Europe (Ronquim *et al.*, 2016). The growing global demand for sustainable products has compelled companies to adhere to specific environmental management standards and practices to achieve environmental certification, which has had a positive impact on the recovery of native forests in the surrounding areas (Bicudo da Silva *et al.*, 2023; Silva *et al.*, 2020; Vancine *et al.*, 2023). Areas occupied by native forests increased substantially, from 249,542 ha to 455,232 ha, i.e., an 82% gain over 30 years, totalling 205,690 ha of additional native forest area (Table 1).

Table 1 – Amount of areas, in hectares (ha) and percentage (%), covered with native forest, agriculture, pasture, eucalyptus, built-up areas and water bodies in 1988 and 2016 in Region 1 and 1985 and 2015 in Region 2

Change in Land Use and Cover	*Region 1*				*Region 2*			
	1988		*2016*		*1985*		*2015*	
	thousand ha	*(%)*	*thousand ha*	*(%)*	*thousand ha*	*(%)*	*thousand ha*	*(%)*
Native Forest	872.1	16.9	998.8	19.3	249.5	17.9	455.2	32.6
Agriculture	2,580.2	49.9	3,079.5	59.6	102.0	7.4	83.7	6.0
Pasture	1,410.6	27.3	692.6	13.4	946.4	67.7	651.2	46.7
Eucalyptus	139.6	2.7	159.3	3.1	35.2	2.5	113.6	8.1
Built-up Areas	90.6	1.8	166.4	3.2	38.5	2.8	63.6	4.6
Water Bodies	77.5	1.5	74.1	1.4	24.4	1.7	28.7	2.1
Total	**5,170.6**	**100**	**5,170.6**	**100**	**1,395.9**	**100**	**1,395.9**	**100**

Source: Authors' elaboration.

Although in Region 1 agriculture no longer competes with native vegetation, the percentage increase in native forest cover, 14.5% over 30 years, was small compared to what was achieved in Region 2. Region 1, known as the country's main sugarcane centre, has witnessed significant changes in land use and land cover dynamics in recent decades, primarily driven by the expansion of sugarcane areas (Molin *et al.*, 2017; Rudorff *et al.*, 2010).

In two other studies on the dynamics of natural forest regeneration in an area of approximately 25,000 square kilometres in the northwest (FERREIRA *et al.*, 2015) and central-south (Silva *et al.*, 2018) portions of the state of São Paulo, characterised by sugarcane cultivation, the percentage of forest gain was also small, even smaller than what was observed in Region 1. Silva *et al.* (2018) considered the occurrence of a significant forest transition in the region; however, the increase in forest cover in this part of São Paulo's inland may be primarily explained by the expansion of commercial eucalyptus plantations, which were not considered as an expansion of native forest cover in this study, as they are non-native commercial plantations.

The areas in Region 1 are mostly flat: 83% have slopes of up to 12% (Table 2). However, the increase in native forests in this region was more significant on slopes greater than 12%, as only 17% of the basin area with such slopes concentrated approximately 46% of the native vegetation. Slope plays a more significant role in natural regeneration in areas occupied by mechanised agriculture (Molin *et al.*, 2018), which is consistent with the machinery operations for sugarcane production, the dominant crop in the region, which requires slopes below 12% for mechanised management (Rudorff *et al.*, 2010).

The native forest vegetation in Region 1 is primarily concentrated near the border with the state of Minas Gerais or following the direction of the Paulista basaltic cuestas (Figure 3). Both the region near southern Minas Gerais and the cuestas (plateaus) areas are characterised by steep terrain that has either ceased to be used for agriculture and livestock or is minimally managed. This situation favours the retention or recolonisation of native forest vegetation on the escarpments.

Table 2 – Slope classes with the total area of all land use within each slope category and increase in native forest cover over a period of approximately 30 years in Region 1 and Region 2

River Basins	*Slope classes*	*Total Area*		*Increase in Native Forest*	
	(%)	*thousand ha*	*(%)*	*thousand ha*	*(%)*
Region 1	0 - 12	4,309.0	84.4	65.3	53.6
	12 - 20	549.5	10.3	25.2	20.5
	20 - 75	306.2	5.2	31.2	25,7
	> 75	0.01	0.1	0.8	0.07
	Total	**5,170.6**	**100**	**122.5**	**100**
Region 2	0 - 12	336.4	24.2	31.2	14.8
	12 - 20	234.4	16.8	30.1	14.1
	20 - 75	814.6	58.2	141.9	70.0
	> 75	11.5	0.8	2.5	1.1
	Total	**1,395.9**	**100**	**205.7**	**100**

Source: Authors' elaboration.

The 54% increase in native forest cover, even on small slopes of up to 12% (Table 2), likely represents the regularisation of permanent preservation areas (APP), especially along riverbanks and legal reserve (RL) areas, carried out by the sugarcane sector, the main landholders of sugarcane areas.

Large sugarcane areas owned by agro-industries are subject to greater environmental scrutiny by public authorities, requiring them to regularise their areas through reforestation and to reduce cultivated land boundaries to establish APPs along riverbanks. Environmental regularisation has led to the restoration of riparian forests along lakes, rivers and springs and has significantly increased forest cover within many rural properties in São Paulo over the last two decades, particularly those cultivated with sugarcane (Rother *et al.*, 2018).

The significant increase in forested areas in the cities of Region 2 did not result from planting new trees but rather from the natural regeneration of vegetation in areas where agriculture and livestock are not competitive, primarily on steep terrain. In Region 2, approximately 59% of the total area is dominated by slopes with gradients exceeding 20% (Table 2), which are rugged terrains challenging for agricultural crops and mechanisation. These areas account for 71% of the forest increase observed over the approximately 30-year period assessed.

Region 2 is primarily suited for extensive pasture cultivation and is responsible for meat and milk production. However, even livestock farming faces challenges regarding production profitability on such uneven terrain and has been struggling to remain competitive with other regions in Brazil that are more suitable (Novo *et al.*, 2012; Silva *et al.*, 2018).

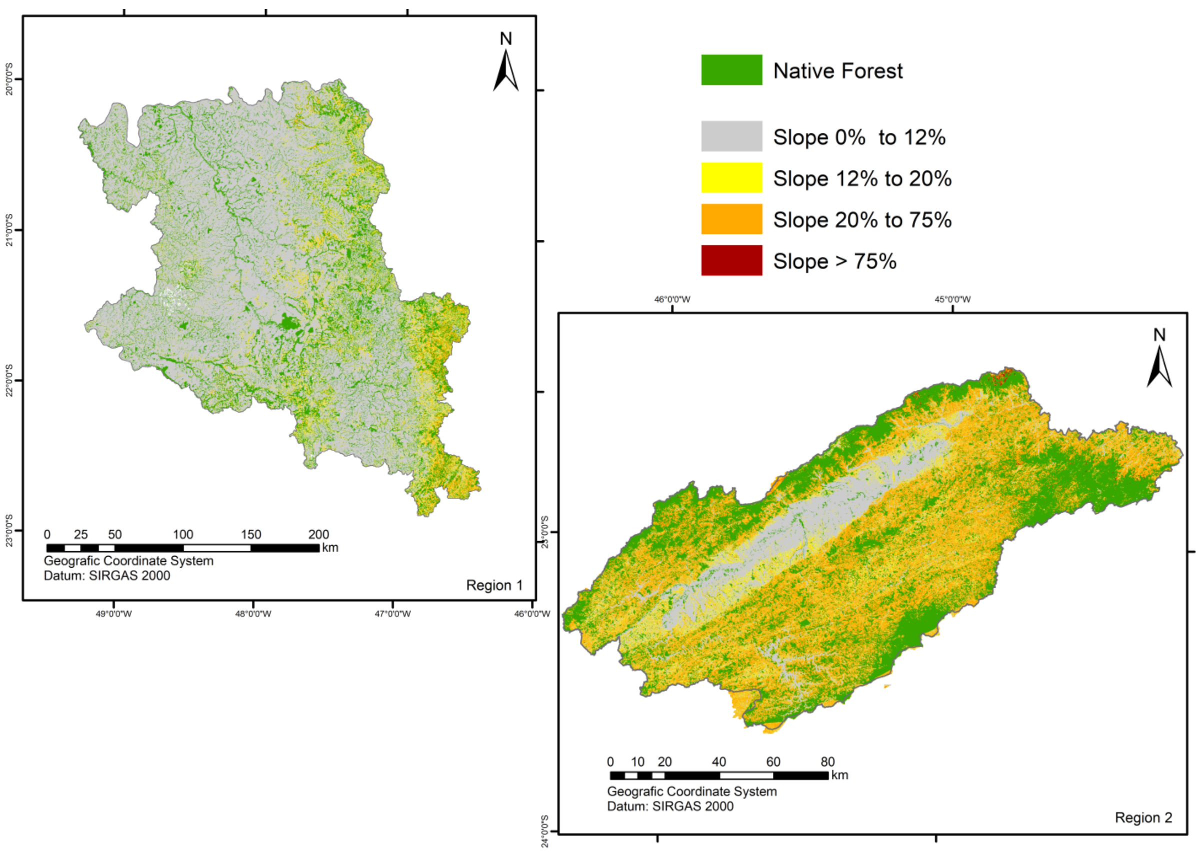

Figure 3 – Slope classes with the distribution of native forest area in Regions 1 and 2.

Source: Authors' elaboration.

Low profitability of the dairy sector, increased quality standards required by dairy industries, and difficulties in hiring and finding qualified labour, among other factors, make it challenging for rural landowners to sustain this activity (Novo *et al.*, 2012). Reduced investments by cattle ranchers contribute to less management in areas less suitable for grazing, such as hilltops and steeper slopes, which favours the regeneration of native vegetation (Ronquim *et al.*, 2016). Current environmental laws also impose restrictions that hinder the cutting or burning of 'capoeira' (secondary growth) that forms in these unmanaged areas (Brancalion *et al.*, 2012; Molin *et al.*, 2018; Rother *et al.*, 2018; Vancine *et al.*, 2023). Consequently, the abandonment of pasture areas favours the return of native tree vegetation.

According to Ronquim *et al.* (2016), the regeneration of native vegetation in the landscape of the Paraíba River Valley in São Paulo (Region 2) is primarily related to the abandonment of areas with topography unsuitable for mechanised agriculture, rural population migration to large urban centres, and environmental preservation projects involving eucalyptus cultivation.

Eucalyptus cultivation is one of the few forms of commercial exploitation that has managed to establish itself in the Paraíba do Sul River Basin despite the steep terrain. Areas of rural properties with eucalyptus crops in the Paraíba do Sul River Basin have shown an increase in native forest areas (Ronquim *et al.*, 2016). Unlike sugarcane crops, eucalyptus reforestation is naturally more environmentally friendly and conducive to native forest regeneration (Leite *et al.*, 2020; Molin *et al.*, 2017). Silvicultural companies that use eucalyptus as raw material follow a rigorous protocol of commercial certifications based on sustainable development, contributing to the export of timber and paper products and ensuring compliance with environmental legislation (Leite *et al.*, 2020).

Molin *et al.* (2017), while studying sub-basins of the Piracicaba River (1.3 million hectares) in São Paulo's inland, also found distinct patterns of native vegetation regeneration. In areas predominantly covered by sugarcane, there was a loss of native forest cover. However, native forests increased in the sub-basins of the Atibaia River, where more rugged terrain prevailed, cultivated with pastures and, in some cases, eucalyptus.

Forest cover increased in both regions studied. However, even though Regions 1 and 2 are located within the state of São Paulo and are subject to the same restrictive environmental laws due to market influences, rural exodus, labour shortages, and other factors which are characterised as important for the forest transition hypothesis (Bicudo da Silva *et al.*, 2023; Calaboni *et al.*, 2018; Molin *et al.*, 2017; Silva *et al.*, 2018), the more significant percentage of return of native vegetation occurred only in the Paraíba do Sul River basin.

This vegetation that has emerged from natural regeneration in abandoned tropical agricultural landscapes due to a lack of management has shown ecological, economic, and carbon sequestration results that are similar to or even more satisfactory than active restoration processes (Crouzeilles *et al.*, 2017; Inhamuns *et al.*, 2021; Zanini *et al.*, 2021).

If the relief of the Paraíba do Sul river basin were favourable to agricultural crops, it would likely be occupied by agricultural cultures that require more and more area, such as sugarcane, which has expanded extensively in São Paulo's inland, and secondary native vegetation would not have spontaneously recolonised the landscape.

4 CONCLUSIONS

The re-establishment of native forest vegetation in the state of São Paulo varies significantly in different regions and depends mainly on the interactions between biophysical terrain characteristics and economic activities. This can potentially hinder the cultivation and occupation by agricultural crops. In Region 1, the native forests grew from 872,000 ha to 998,000 ha, a 14.5% increase in native forest cover. In Region 2, areas occupied by native forests increased substantially, from 249,542 ha to 455,232 ha, i.e., an 82% gain over 30 years. The predominant presence of steep and unsuitable terrain for commercial agriculture in the Paraíba do Sul river basin was the primary factor influencing its non-occupation by large agribusiness-related crops. Instead, the region has been primarily used for cattle farming, which in recent years has shown signs of economic decline, resulting in the loss of large areas to secondary native forests, particularly in higher and steeper areas.

For the entire state of São Paulo, increases in secondary native forest cover are expected in the coming years. This multifaceted phenomenon will depend on both conservation policies and the relationship between society and the environment, and these factors represent possibilities for additional studies. This process is likely to occur as lands unsuitable for agriculture on steep terrain become increasingly recolonised by native vegetation, as more non-agricultural rural activities emerge alongside multifunctional landscape activities, and as permanent preservation (APP) and legal reserve (RL) areas on rural properties, as defined by the Brazilian Rural Environmental Registry (CAR), are truly and effectively reforested or recolonised by native vegetation (a requirement of the New Forest Code, Law No. 12,651 of May 25, 2012), which has not yet occurred to a large extent.

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