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IMAGENS AÉREAS NA AVALIAÇÃO DA EXPANSÃO DAS MATAS CILIARES NUMA BACIA HIDROGRÁFICA COM SOLO ARENOSO

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RESUMO: O sensoriamento remoto, por meio de seus produtos, oferece uma visão das mudanças no uso do solo e na cobertura vegetal ao longo do tempo. Possibilitando identificação de desmatamentos, urbanização, mudanças climáticas e outros impactos ambientais. A degradação do solo pode estar relacionada ao manejo inadequado dos recursos naturais, resultando na exposição do solo e perda de sua estrutura original. O uso do solo de forma adequada, utilizando técnicas agronômicas com curvas de nível, cultivo pelo sistema plantio direto, calagens entre outras ações de preservação pode minimizar os efeitos erosivos. As matas ciliares contribuem para reduzir a velocidade do escoamento superficial e na estabilização do solo, além de aumentarem a infiltração da água no solo e a biodiversidade. A pesquisa centrou-se na avaliação da mata ciliar na bacia de Anhembi-SP nos últimos dez anos de cultivo intensivo de eucalipto, comparando imagens aéreas de 2023 com levantamentos anteriores realizados em 2013. Observou-se uma regeneração e expansão considerável das matas ciliares durante o período analisado, associadas à substituição das pastagens nativas por culturas perenes, como o eucalipto, o que foi considerado benéfico para o meio ambiente e para a conservação dos solos arenosos na área de influência fluvial.

Palavras-chave: sensoriamento remoto, erosão, reflorestamento.

AERIAL IMAGES IN THE ASSESSMENT OF THE EXPANSION OF RIVARIAN FORESTS IN A WATER BASIN WITH SANDY SOIL

ABSTRACT: Remote sensing, through its products, offers a view of changes in land use and vegetation cover over time. The identification of deforestation, urbanization, climate change and other environmental impacts is encouraged. Soil manipulation may be related to inadequate management of natural resources, resulting in soil exposure and loss of its original structure. Using the soil appropriately, agronomic techniques with contour lines, cultivation via a direct planting system, liming and other preservation actions can minimize erosive effects. Riparian forests are raised to reduce the speed of surface runoff and stabilize the soil, in addition to increasing water infiltration into the soil and biodiversity. Research has focused on evaluating the riparian forest in the Anhembi-SP basin in the last ten years of intensive eucalyptus cultivation, comparing aerial images from 2023 with previous surveys carried out in 2013. A specific regeneration and expansion of the riparian forests was observed during the period analyzed, associated with the replacement of native pastures by perennial crops, such as eucalyptus, which was considered beneficial for the environment and for the conservation of sandy soils in the area of river influence.

Keywords: remote sensing, erosion, reforestation.

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1 INTRODUCTION

Intensive grazing over many years in native pastures can result in exhaustion not only of the vegetation cover but also of the soil, especially in sandy soils, which can cause environmental damage, including various types of erosion and a reduction in vegetation in regions of floodplains and riparian forests. This practice can lead to soil degradation, increasing vulnerability to erosion processes and reducing plant biodiversity in riverine areas.

The main cause of soil degradation is associated with inadequate management of natural resources (CHAVES, 2012). In agriculture, practices such as indiscriminate deforestation, fires and crops that do not provide adequate assistance to the soil stand out, resulting in the exposure of the soil and the destruction of its original structure. Furthermore, the management of animals in pastures above the carrying capacity also increases soil degradation. Studies indicate that greater vegetation cover is related to less soil loss through erosion (BRASIL, 2002; SHARMA; SHAKYA, 2006).

According to Tambosi *et al.* (2015), the inappropriate use of soil for agricultural activities, accompanied by earth movement and waterproofing, can accelerate erosion processes and the transport of organic and inorganic materials through drainage until final deposition in the beds of watercourses and lakes. These practices result in siltation, consequently limiting the volume of water and compromising the renewal of the oxygen necessary for algae and fish, which can harm water courses as well as springs. In this context, riparian forests can serve as filters to help maintain the ecosystem.

Riparian forests are natural formations that occur along the banks of water bodies and act to reduce siltation and environmental preservation. Mesquita, Cruz and Pinheiro (2012) highlighted that native forests promote balance when they are associated with the management and conservation of natural resources. In addition to protecting natural resources, these forests help restore the chemical and physical conditions of the soil through the layer of leaves and organic materials (litter), resulting in an increase in organic matter levels and improvements in the physical quality of the soil. The characteristics of riparian forests are linked to the high water content present in the soil and atmosphere in which they develop (BARRETO *et al.*, 2009).

Riparian forests are important for the conservation of sandy soils and act as a natural barrier against wind and water erosion. The vegetation present in these areas reduces the speed of surface runoff, which helps maintain soil stability. Furthermore, riparian forests represent a transition between terrestrial and aquatic environments, facilitating the transfer of energy and nutrients (CORRELL, 1996; CAVALCANTI; LOCKABY, 2006; COLLINS *et al.*, 2010).

According to Wang, Yin and Shan (2005), as a riparian forest deteriorates, its efficiency in retaining sediments decreases because of its ability to limit the speed of particle transport, resulting in less biological control. The roots of trees and other plants in the riparian forest penetrate deep into the sandy soil, strengthening its resistance to erosion and minimizing sediment loss. This physical stabilization capacity of the soil protects the banks of water bodies and mitigates degradation. Additionally, plant roots facilitate the infiltration and storage of water underground in sandy soils, which naturally have a low water retention capacity, helping to maintain soil moisture and reduce surface runoff.

The benefits of riparian forests on sandy soils include preserving biodiversity and promoting ecological connectivity. By providing suitable habitats for diverse plant and animal species, they contribute to the health and recovery of the original state of riverine ecosystems as a whole.

Eucalyptus cultivation has been studied as an effective strategy to combat erosion in sandy soils. The deep and extensive root system of eucalyptus is capable of penetrating the deepest layers of the soil, increasing its stability and resistance to erosion caused by water and wind.

Eucalyptus cultivation provides dense and uniform vegetation cover, which acts as a physical barrier against the direct impact of

raindrops and wind on the soil. This vegetation cover effectively reduces surface erosion, resulting in the moderation of surface runoff speed and facilitating water infiltration into the soil. Furthermore, eucalyptus has the ability to improve the physical and chemical properties of soil. The deposition of eucalyptus leaves and plant residues increases organic matter in the soil, improving the soil structure and water retention capacity. These changes in the soil can reduce erosion and create favorable conditions for the development of other agricultural crops, especially in livestock forest systems.

The areas reforested with eucalyptus can serve as ecological corridors, facilitating the movement of animal species and recolonizing degraded areas. Eucalyptus has been used in Brazil and other regions of the world with the aim of improving soil fertility and aeration in certain areas to prepare them for subsequent agricultural cultivation (VITAL, 2007).

Modern forms of land use and occupation, as well as its history of occupation, have been important in environmental studies in several regions. These studies clearly reveal how the adverse impacts resulting from inadequate land use lead to environmental degradation. Such degradation manifests itself through processes such as erosion, desertification, flooding and silting of water courses. Knowledge of these standards can help identify and reduce the environmental impacts resulting from inadequate soil management.

In this context, the use of remote sensing technologies, aerial images, can be considered a tool to acquire, monitor, manage and update records related to land use and, therefore, riparian forests. This method allows periodic observations of changes in terrestrial landscapes, facilitating analyses of the impacts of human activities on biomes and their possible changes.

The use of data from remote sensing, such as aerial images, represents a valuable tool for planning and analyzing environmental impacts, as well as for carrying out inventories of water resources, as highlighted by Rosa (2009).

The sandy soil in the Municipality of Anhembi-SP is highly susceptible to different erosion processes, particularly in river basins that were occupied for decades with native pastures without adequate renewal or annual crop rotation, as observed in neighboring municipalities. This study aimed to evaluate whether the riparian forest in the basin under study showed visible changes in the last ten years due to the intensive cultivation of eucalyptus, using aerial images from 2023 and comparing them with previous surveys carried out by other researchers in 1965 and 2013. This analysis aims to provide insights into the impacts of eucalyptus cultivation on riparian vegetation and soil conditions over time.

2 MATERIALS AND METHODS

2.1 Location and characterization of the river basin

The basin called Ribeirão dos Remédios is located in the Municipality of Paulista de Anhembi, south-central region of the state of São Paulo, Brazil (Figure 1), coordinates 48°11'16” WGr, 22°11'51” S and 48°13'16” WGr 22°53'05 " S.

Figure 1. Location of the Municipality of Anhembi, SP.

Source: Barros *et al*. (2018)

The climate of the region where the Municipality is located, according to the Köppen classification, is of the Aw type, with an average annual temperature of 22.3°C and an average annual precipitation of 1307.2 mm. It is part of the Peripheral Depression with altitudes of approximately 495 m (CEPAGRI, 2016).

The Anhembi planialtimetric map (SF-22-ZB-VI-4), on a scale of 1:50000, with a vertical equidistance between contour lines of 20 m, edited by the Brazilian Institute of Geography and Statistics (IGBE), was used as a cartographic base.), and 1969 and 1970 (Figure 2).

For identification, demarcation of areas and preparation of the river basin study plan, an image from Google Earth from 2023 was used.

The Google Earth images were corrected, using the aerophotogrammetric restorer, to the scale of the cartographic base used, that is, 1:50,000, with the purpose of making delimitations and subsequent evaluations of land occupation, erosion and evolution of riparian forests, with the help of the digitizing table through the plan–planimetry system.

3 RESULTS AND DISCUSSION

Intensive grazing of pasture areas on sandy soils, with native grasses, without due care in management, without liming, without rotation with annual crops, often without the construction of contour lines for a better or only way of detaining. The speed of the flow can cause irreversible damage to the environment.

Over time, the lack of these precautions could favor the occurrence of soil losses in the form of erosion, from laminar erosion to furrow erosion and, ultimately, the most serious type of erosion in the environment, which is the gully type. This erosion, in addition to the loss of tons of soil per year, restricts cultivation areas and silts up floodplains and rivers, harming the good development of riparian forests.

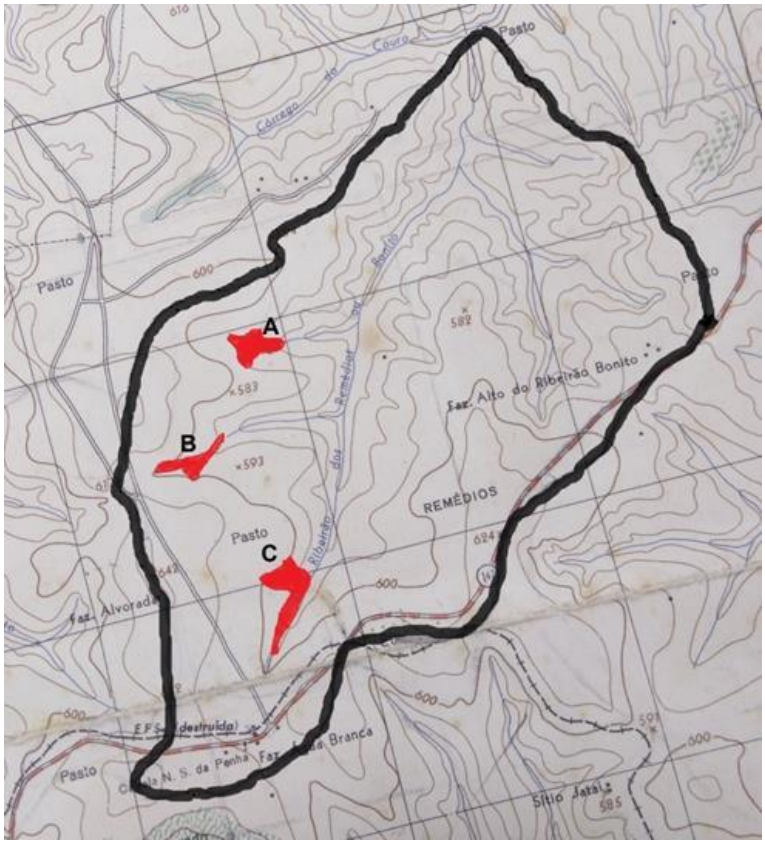
Eucalyptus cultivation is a much discussed topic in the literature, and many authors are against it, claiming that culture has many environmental impacts.

The controversies related to the possible negative environmental impacts caused by eucalyptus cultivation include the following: the removal of water from the soil, which results in a water balance deficiency, leading to the drying of springs; the depletion of nutrients and drying of the soil; the desertification of areas, which causes the green desert effect; and

allelopathic effects and consequently the extinction of fauna (VIANA, 2004).

In Figure 2, according to Barros *et al.* (2018), in the river basin in 1965, the occupation by pastures totaled 1421.05 ha, corresponding to 98.70% of the basin, where gully type erosion was concentrated in the southern and western portions of the main river and where riparian forests did not exist at that time.

Figure 2. Hydrographic basin in the 1965 IBGE Charter.



Source: Barros *et al.* (2018)

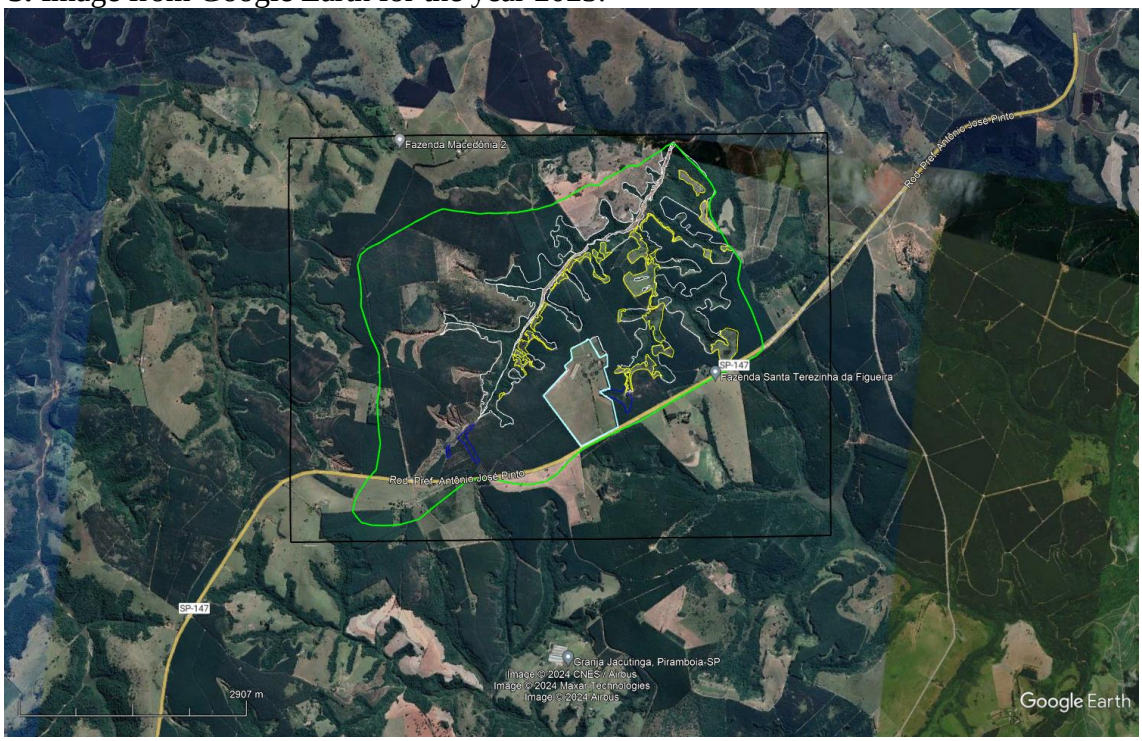
According to Barros *et al.* (2018), the basin had 18.78 ha of degraded area in the form of gully erosion, that is, 1.30% of the basin, certainly showing a lack of crop diversification in the region and supporting intensive farming of cattle since before the 1960s.

Additionally, according to the authors, the areas occupied by pastures in 2013 significantly decreased from 1421.05 ha in 1965 to 177.23 ha, providing space for the cultivation of eucalyptus via soil conservation techniques. According to Barros *et al*. in 2018, the gullies reached an area of 64.28 ha, or 4.46% of the basin area, and the riparian forest represented, in 2013, a total of 186.35 ha, or 12.94%.

Figure 3, obtained through Google Earth in the year 2023, illustrates the location of the 3rd-order branching river basin, highlighting its perimeter in green and the riparian forests in white, which occupy not only the banks of the main river but also its tributaries.

The areas delimited in yellow correspond to places reserved for the expansion of native species to favor drainage and protect water courses from possible silting, thus mitigating environmental impacts in the studied basin.

Figure 3. Image from Google Earth for the year 2023.



Source: Anhembi (2023)

Table 1 presents data in hectares and percentages related to the occupation of the river basin for the year 2023.

Table 1. Land use and occupation in the basin in 2023.

Year 2023	Erosion	Erosion recovery.	riparian forest	Pasture	Eucalyptus
there is	39.43	9.30	215.00	139.94	1036.16
%	2.74	0.64	14.93	9.72	71.96

Source: Survey data (2023)

The data in Table 1 and Figure 2 show that eucalyptus cultivation has undergone very strong evolution in the basin, ranging from zero ha in 1965 to 792.23 ha in 2013 (Barros *et al.* 2018) and 1036.16 ha in 2023. Gully erosion, with 64.28 ha in 2013, was reduced to 39.43 ha in 2023, with 9.30 ha of this total being occupied by eucalyptus.

Pastures represent 9.72% of the basin area (Table 1), or 139.94 ha, which corresponds to the limits of a rural property inserted in the basin that does not provide space for eucalyptus planting, as shown in Figure 3.

The riparian forests that did not exist in 1965, according to Barros *et al.* (2018), totaled 186.35 ha in 2013, increasing to 215.00 ha in 2023, that is, 28.06 ha in ten years. The riparian forest has regenerated and expanded its area since the basin has stopped being occupied by intensive livestock farming without due care; eucalyptus crops can be occupied with appropriate techniques to contain the progression of gullies already installed and the recovery of others with adequate soil conservation measures.

4 CONCLUSIONS

The present study verified that over ten years, the riparian forests experienced considerable regeneration and expansion in the period that coincided with the eucalyptus plantations and the end of intensive grazing, with free access to the banks of the rivers and

their sources. Therefore, replacing native pastures in the basin with perennial crops, such as eucalyptus, was beneficial for the environment.

In summary, the preservation of riparian forests guarantees the conservation of sandy soils and the maintenance of environmental quality in areas influenced by rivers, understanding the various benefits provided by these ecosystems to guide management policies and sustainable management of these areas.

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