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Landscape Hemoroby in the eco-socio-systemic perspective of the Turvo River Watershed, Barra do Turvo/SP

Hemerobia da paisagem na perspectiva ecossociossistêmica na bacia hidrográfica do rio Turvo, Barra do Turvo/SP

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ABSTRACT: Anthropic transformations, partly driven by human activity, have been causing disruptions in ecological patterns and processes within watersheds over the years, leading to landscape instability. Within this context, Hemeroby evaluates the intensity of alterations in landscape structure and function, classifying them based on their level of naturalness. Thus, the objective of this study is to analyze the landscape of the Turvo River Watershed in Barra do Turvo/SP according to Hemeroby levels. Vector files of vegetation cover and land uses from 1990, 2000, 2010, and 2020 were integrated using the ArcGIS Intersect tool with vector files of pedology, geology, geomorphology, relief amplitude, slope, climate, and erodibility. After combining the files, Hemeroby levels were classified to produce maps. The results of Hemeroby levels in the studied watershed ranged from Minimum (encompassing forest classes and water), with low technological and energy dependence for maintaining ecological functions, to Very High (covering the urban area of Barra do Turvo/SP), with high technological and energy dependence and low self-regulation capacity. The landscape of the investigated watershed exhibits a high level of human intervention due to agricultural practices, resulting in secondary vegetation and urban influence. Thus, the study of Hemeroby is important for evaluating negative impacts on the local ecosystem, thereby aiding in landscape planning and decision-making at municipal, state, and national levels.

Keywords: geotechnologies; Vale do Ribeira region; protected area; quilombola population.

RESUMO: As transformações antrópicas desencadeadas, em parte, pelos seres humanos têm provocado o desequilíbrio dos padrões e processos ecológicos nas bacias hidrográficas ao longo dos anos e, consequentemente, a instabilidade da paisagem. Nesse contexto, a Hemerobia avalia a intensidade das alterações na estrutura e na função da paisagem e as classifica conforme seu grau de naturalidade. Com isso, este estudo tem como objetivo analisar a paisagem da Bacia Hidrográfica do Rio Turvo no município de Barra do Turvo/SP de acordo com os Graus de Hemerobia. Os arquivos vetoriais de cobertura vegetal e os usos da terra nos anos de 1990, 2000, 2010 e 2020 foram combinados, por meio da ferramenta Intersect do ArcGIS, com os arquivos vetoriais de pedologia, geologia, geomorfologia, amplitude do relevo, declividade, clima e erodibilidade. Após a combinação dos arquivos, os Graus de Hemerobia foram classificados para que os mapas fossem gerados. Os resultados dos Graus de Hemerobia na bacia investigada correspondeu desde Mínimo (compreendendo as classes florestais e água) com baixa dependência tecnológica e energética para a manutenção das funções ecológicas a Muito alto (abrange a área urbana de Barra do Turvo/SP) com alta dependência tecnológica e energética e baixa capacidade de autorregulação. A paisagem da bacia investigada apresenta grau alto de intervenção humana causada pela prática da atividade agropecuária, consequente vegetação secundária e influência urbana. Portanto, o estudo da Hemerobia é importante para avaliar os impactos negativos no ecossistema local, colaborando para a construção do planejamento da paisagem e para as tomadas de decisão em nível municipal, estadual e nacional.

Palavras-chave: geotecnologias; região Vale do Ribeira; área de proteção; população quilombola.

1. Introduction

Human rationality, based on the intensive use of natural components, culminated in the degradation of the natural environment and, consequently, the unsustainability of ecosystems. The socio-environmental context transformed by this relationship has demanded an integrated view of environmental problems at the heart of its multiple ecological relationships. This scenario implies a transformation in established knowledge paradigms, demanding new methodologies that can help to conduct a process of reconstructing knowledge integrated with reality and that systematically considers the totality (Leff, 2011).

From this perspective, Complexity Theory[1] can clarify interactions between *society and nature*, focusing on complex structural characteristics and managing the use of natural components in socio-economic and ecological systems. This management needs to be adaptive in its objects and approaches, seeking the sustainability of the system and its self-organization because, without the latter, the former is simply unattainable (Norberg & Cumming, 2008).

Given the above, there has been discussion about the negative impacts of the way human beings relate to nature when maintaining and conserving natural components, especially when referring to their use in the process of production and reproduction of spatiality. From this perspective, the concept of environmental quality contributes to the understanding of an eco-socio-systemic landscape, which comes from the actions or socio-cultural

[1] Complexity Theory, according to Morin and Moigne (2000), is based on three theories (information, cybernetics, and system) fundamental to the understanding of Organization Theory in conjunction with the ideas of Von Neumann, Von Foerster, and Prigogine on self-organization. This association brings fundamental elements to understanding the three principles (dialogical, recursion, and hologrammatic) that govern the complexity paradigm.

manifestations of society. In this way, thinking about the ecosystem balance and the *society-nature* relationship goes back to the past, in the sense of understanding the process of (de)construction of the transformations that took place in the non-traditional society's way of thinking, integrating, and producing with its territory (Naves & Bernardes, 2014).

In this context, the study of landscape has become a resource for investigating the complex *society-nature* relationship, enabling systemic and integrated understanding. Based on the integrated thinking approach proposed by Bertrand (1968), based on Ludwig Von Bertalanffy's General Systems Theory, the landscape is configured in a hybrid approach, susceptible to the association of opposites: nature and society, subjective and objective, individual and collective, theoretical and practical, science and culture, ordinary and extraordinary.

Thus, the focus redirects to the environmental system based on the integrated perspective between the biotic, abiotic, and anthropic elements in the landscape. In this way, systemic theory contributes to expanding the process of reflection on the concept of landscape, leading to the understanding of natural systems based on their structure and functioning (Guerra & Marçal, 2010; Costa, 2020).

From this perspective, scholars have developed tools and mathematical models that capture multiple spatial layers and connections that involve socio-environmental systems and how they are connected. The assistance of Remote Sensing and the Geographic Information System (GIS) facilitated the identification and analysis of changes in biophysical components through society's actions. Both geotechnologies are "our most important holistic tools for landscape study, planning and management" (Naveh, 2002, p. 15).

Therefore, this study focuses on the *society-nature* relationship through the hemerobic landscape approach, which analyzes the environmental quality of the water unit, considering it an essential body of water for the local society, specifically for quilombola populations, and for connecting the Sustainable Development Reserve Quilombos Barra do Turvo (RDS+QBT). From this perspective, this study aims to analyze the landscape of the Turvo River Watershed in the municipality of Barra do Turvo, São Paulo, according to the Hemeroby Levels.

1.1. Landscape hemeroby

Anthropogenic changes carried out in the landscape, in part, by humans, affect the survival of plant and animal species, energy exchanges, and ecosystem matter. However, the limits the ecosystem imposes on human beings are often overlooked, as they treat the ecosystem as a product that must be explored and subordinated to their interests (Fávero *et al*., 2008).

Therefore, a concept capable of synthesizing these questions about the state the landscape is in and how to describe it is hemeroby. It can be understood as a "totality of changes in landscapes, classified according to the level of naturalness" (Sukopp, 1972, p. 115-116, our translation), as well as the "level of technological and energy dependence for the maintenance of ecosystem services" (Haber, 1990, p. 135-136). Therefore, for Sukopp (1972, p. 113, our translation), hemeroby is "conceived as the totality of the effects of humans on ecosystems," directly or indirectly.

According to Jalas (1955 *apud* Troppmair, 1989), the concept refers to the "domination and/or alteration of landscapes," establishing itself in six hemerobiotic states associated with the level of naturalness, ranging from conserved to anthropized (Table 1):

Given the above, there are no scalar limits to delimit hemeroby from landscapes. For example, Troppmair (1983) applied the concept on a small scale (1:2.000.000) to the state of São Paulo, while Fávero *et al*. (2008) applied it to a river watershed with a scale of 1:250.000. Kröker *et al*. (2005), Kröker (2008), and Silva & Faria (2021) applied it in urban areas, at scales close to 1:10.000. Thus, the concept of hemeroby, developed by Sukopp (1972), is adapted for use at different scales and in urban and rural landscapes.

In recent years, several authors described the hemeroby levels based on a definition that designates the totality of effects that occur when there is human interference in ecosystems and, consequently, in the structure and dynamics of landscapes. Thus, the level of hemeroby results from these effects on the respective location.

1.2. Watershed (WS)

The concept of Watershed (WS) has been increasingly expanded and used in the investigation of Hemeroby in the landscape. From this perspective, according to Christofoletti (1981), WS presents characteristics regarding its shape and structure, which reflect the effects on the ecosystem and, therefore, on the landscape through its constituent elements, in addition to economic and social factors (Cunha, 2008). Barrella *et al*. (2001) add that the WS is formed in the relief's high regions, where rainwater runs superficially and forms streams and rivers or infiltrates the soil to form springs and the water table.

TABLE 1 – Levels of naturalness and hemerobic state.

Naturalness	1*	2*	3*	4*	5*	6*
Natural	A-hemerobic	No	No	No	0	0
Almost natural	Oligo-hemerobic	Little	No	Most spontaneous species	<1	5
Semi (agro) natural	Meso-hemerobic	Little Superficial	Another dominant life	Most spontaneous species	1-5	5-12
Agricultural	Eu-hemerobic	Moderate and drastic	Dominate crops	Few spontaneous species	6	13-20
Almost Natural	Poly-hemerobic	Artificial substrate, drastic change	Open-ephemeral	None and few species	2	21-80
Cultural	Meta-hemerobic	Artificial substrate	-	-	-	-

SOURCE: Sukopp (1972).

NOTE: 1*- Hemerobic state, 2* - Modification in the substrate, 3* - Modification in the structure, 4* - Modification in the floristic composition, 5* - Loss of natural species (%), 6* - Gain of new species (%).

ELABORATION: Authors (2021).

The WS is a natural catchment area for precipitation water that converges the runoff to a single exit point. "This is composed of a set of sloping surfaces and a drainage network formed by watercourses that converge, resulting in a single bed in its exultation" (Silveira, 2001, p. 36, our translation). It can then be considered a "systemic space, where balances of input from rain and output of water through exultation are carried out, allowing watersheds and sub-watersheds to be delineated, whose interconnection forms water systems" (Porto & Porto, 2008, p. 45, our translation).

In this context, the WS stands out as a landscape management unit through hemerobic analysis and its "direct relationship with the design of a territorial organization, in which all geoecological areas are articulated systematically" (Mateo, 1994, p. 587 *apud* Trombeta & Leal, 2016, our translation). To achieve this, according to Santos (2004), it is necessary to establish action strategies that aim at balancing *society-nature* to rationalize the use and occupation of land.

This consists of adapting actions to the potential and support capacity, seeking the harmonious development of spatiality and the maintenance of the environmental quality of the landscape. It emphatically works under the logic of the potential and vulnerability of the natural environment, defining and spatializing occupations, actions and activities, according to the identified characteristic.

1.3. Eco-socio-systems

The conceptual part on Ecology-Society-System is the basis for understanding *society-nature* interaction, implying the quality of the landscape. Ollagnon (2002, p. 175, our translation), when referring to the term ecosystems, mentions another terminology, eco-socio-systems, to designate "action systems aimed at environmental quality, which are based on an adaptive relationship between human beings and their environment." In this aspect, Guimarães (2004, p. 03, our translation) conceptualizes it as an "ecosystem that comprises natural resources and space, that is, the sociosystem". In other words, the human being, on the one hand, forms the organization of society in its technical, economic, social and cultural aspects; on the other hand, they form the sociosystem — the place where living beings live.

From this perspective, the analysis of the environmental quality of the landscape through Hemeroby directly influences the production of energy and matter, which are responsible for the balance of ecosystem services. Society is also part of this interaction, or rather, this mutual relationship in which human beings develop and improve techniques that conserve the natural components in their territory and that, consequently, contribute to the quality of the environment. "Knowledge of this action, that is, of the behavior and strategy of the actor-situated-in-their-natural-and-human environment, requires a true ecology of action, appropriate to the problems faced" (Ollagnon, 2002, p. 183, our translation).

In this study, the ecology of action is a set of practices developed by quilombola populations, which have been adapting over the years in their living space due to external hegemonic pressures on their territory. These pressures interfere with the dynamics of the landscape, affecting the environmental quality of the place where they live. A systemic approach is necessary to understand these relationships, as traditional populations and their territory can be defined as a "set of material and immaterial elements that contribute to the maintenance and development of the identity and autonomy of their people over time and in space, through the adaptive process" (Ollagnon, 2002, p. 183, our translation). At the same time, this definition is presented as objective and relational, mutual and adaptive. Even better, they are environmental and social systems in symbiosis, forming the totality of traditional peoples who reflect on their identity and are protagonists of their territory.

In this context, the *society-nature* relationship for the study of landscape and environmental quality (hemeroby) integrates different analysis criteria and generates information about the evolution of degradation, the current state directly implying the present and future quality of the investigated area. These characteristics encompass a set of questions related to understanding the biophysical attributes of the place analyzed.

2. Materials and methods

2.1. Turvo River Watershed (BHRT)

The Turvo River watershed is located in the mesoregion of the South Coast of São Paulo, in the Ribeira River watershed region, covering the municipality of Barra do Turvo (Figure 1). It is part of the Atlantic Forest biome, totaling an area of 714.41 km2. It is formed by 16 sub-watersheds: the Cedro II Stream, the Stream of Salto, the Monjolo Stream, the Sem Nome [No Name] Stream, the Ribeirão do Meio, the Ribeirão do Veado, the Ribeirão Grande, the Anhózinho River, the Barreiro River, Bonito River, Herval River, Faxinal River, Fortuna River, Pedra Preta River, Turvo River, and the Turvo River Interwatershed.

The main economic activities are commerce, tourism, and agriculture (IBGE, 2021). Land uses in 2006 and 2017 focused on agriculture, involving permanent and temporary crops, in addition to the cultivation of flowers (IBGE, 2017). There were also other types of uses in the municipality of Barra do Turvo involving pasture and agroforestry systems.

The BHRT comprises seven communities, four of which are quilombolas, recognized by the Palmares Foundation and the São Paulo State Land Institute (ITESP): Cedro, Ribeirão Grande-Terra Seca, Pedra Preta-Paraíso, and Reginaldo, and three non-traditional (Barreiros, Ribeirão Bonito Anhemas, and Água Quente). In addition to Permanent Protection Areas (PPA), the Sustainable Development Reserve Quilombos Barra do Turvo (RDS-QBT) assembles a mosaic formed by 5,826.46 ha, in which there are three quilombos and their respective number of families, namely Cedro (23 families), Ribeirão Grande-Terra Seca (77 families), and Pedra Preta-Paraíso (80 families).

In this context, in the extension of the BHRT, the quilombola populations practice and develop land management techniques in the middle of the Atlantic Forest and domesticate plants, undoubtedly establishing an agri-food heritage. These groups develop, by their own means, an agricultural calendar capable of offering specific foods throughout the year. They express a reading of nature in their practices, developed in a movement of empirical and everyday relationships that contribute to building their identity and way of life. They are traditions and customs reconciled and adapted to the biophysical space over time in an evolutionary

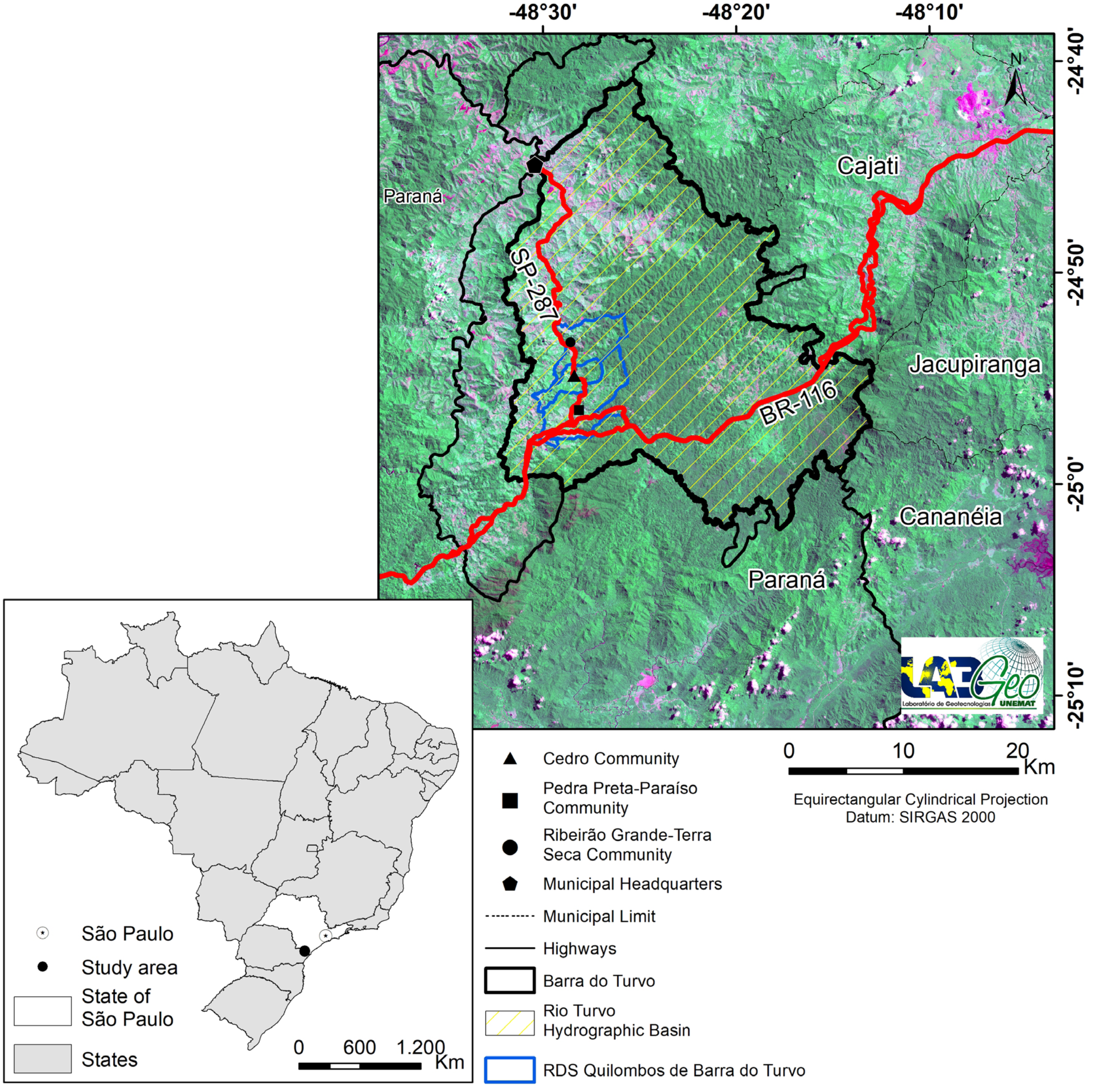


FIGURE 1 – BHRT in the national, state, and municipal contexts, highlighting the location of quilombola communities in the RDS-QBT.
SOURCE: The authors (2021).

process, dependent on the place in which they live. These actions contribute to the conservation of local biodiversity as they are considered sustainable and strengthen agrobiodiversity and genetic heritage in the Vale do Ribeira region (Rodrigues *et al*., 2020).

Thus, over the years, the transformations of the landscape in the BHRT present different perspectives, as they include quilombola groups (traditional) and farmers who develop pasture activities (non-traditional), both providing individualized ways of using the land. These groups contribute to landscape changes at different levels. However, the investigated watershed is an important water source, essential for maintaining the region's socio-biodiversity.

2.2. Methodological procedures

To prepare maps of vegetation cover and land use, which are the basis for identifying Hemeroby Levels, images from the years 1990, 2000, 2010, and 2020 were used, referring to orbit/point 220/77 of the satellites Landsat 5, Thematic Mapper - TM sensor and Landsat-8, Operational Land Imager (OLI) sensor, both with 30 meters of spatial resolution. To prepare the mappings for the dates from 1990 to 2010, we used the images generated by the Landsat 5 satellite, whose scenes were obtained free of charge on the website of the Brazilian National Institute for Space Research (INPE), and for the year 2020, we used the scene from the Landsat 8 satellite, obtained free of charge from the United States Geological Survey website (USGS, 2020).

The processing of the images covering the BHRT on each date used GIS Spring, version 5.4.3 (Câmara *et al*., 1996). We selected the images with less cloud cover. In Spring, the Geographic Database (BDG) was created, adopting the following cartographic parameters: Datum SIRGAS 2000, metric coordinate system, and Time Zone 22 South. The 2020 image was used in two ways to generate the maps: in recording images from the Landsat 5 satellite using the Screen by Screen method in Spring, due to the 2020 image being made available with georeferencing, and in preparing the map of vegetation cover and land use in 2020. The images were cropped by the vector file according to BHRT.

After cropping, the stages of segmenting and classifying the dates began. Area similarity values of 8 and 8 were adopted for 1990 to 2010, respectively. Due to the radiometric characteristics of the Landsat 8 Satellite being different from those generated by Landsat 5, values of 80 were adopted for similarity and 80 for area. The similarity parameter shows the smallest pixel value the GIS will use to form a class or whether a class will be created from a given pixel (Vasconcelos & Novo, 2004). The area parameter is calculated in pixels by the GIS, indicating the minimum number of pixels that will be grouped to form a class (Kreitlow *et al*., 2016).

Next, the segmentation and classification stages of the date scenes began—segmentation using the region growth method and classification according to the scenes of each date. This stage was divided into two parts in the GIS. The first is called training by the GIS, according to Florenzano (2011), and the second stage, classification, was performed as explained by Neves *et al*. (2019).

The last phase performed in Spring was the matrix-vector conversion. Once completed, the vector files were exported in vector format (.shp) so that adjustments could be made to the classes in ArcGIS (ESRI, 2019) when necessary. Subsequently, map layouts for each date were created, and the areas in hectares and square kilometers that each class occupied on each of the mapping dates were quantified.

The validation of the vegetation cover and land use maps occurred through IBGE data and through fieldwork carried out in June 2021, when the observed landscape was recorded through photographs (photographic camera and Unmanned Aerial Vehicle - UAV), and that the locations where the photographs were taken were georeferenced via GPS.

For the analysis of Hemeroby, we adopted the proposal by Kröker (2008), adapted by Mezzomo & Gasparini (2016), in which landscapes are classified in levels according to the level of their alteration. The vector files of vegetation cover and land use (1990 to 2020) associated with the attributes of pedology, geology, geomorphology, relief amplitude, declivity, climate, and erodibility were combined using the ArcGIS Intersect tool, whose vector files were partially acquired on the INPE website (INPE, 2021). After downloading, the study areas were cropped into the vector file, thematic maps were created, and the classes of each attribute were quantified in hectares, kilometers, and percentages.

Subsequently, the Hemeroby Levels were classified (Table 1), and the area values of each BHRT class investigated were quantified:

3. Landscape hemeroby at the BHRT

The human actions in the BHRT landscape resulted in different Hemeroby Levels (Table 2), as they refer to the various transformations that occurred in its structure and functioning, resulting in changes in its state (Figures 2, 3, 4, and 5).

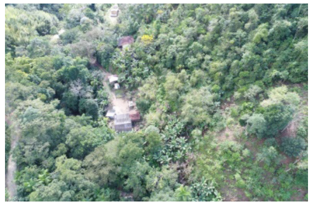
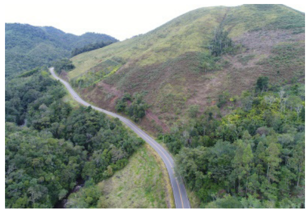
The *minimum* level, over the years researched at BHRT, was greater than 70%, showing that there are conserved areas in which there is little or no human interference. It is noteworthy that natural phenomena, such as rain and fires, among other factors, can alter the state of the landscape and, as a consequence, cause instability in ecosystem services.

The other Hemeroby Levels (*low*, *medium*, *high*, and *very high*) in the watershed studied fluctuated — that is, they are anthropized areas. Among the main negative impacts influenced by humans is agricultural activity, which creates extensive areas of secondary vegetation, in addition to the expansion of urbanization. Therefore, the hemerobic classification of the landscape in the BHRT proved to be heterogeneous and could not be classified with a single level, as it would not represent the particularities of the dynamics of change in the components of the watershed's landscape.

The impacts mentioned along the territorial extension of the watershed may be related, according to Ferreira (2005), to the construction of the Regis Bittencourt highway (BR-116) in 1961, which contributed to the increase in the flow of people interested in acquiring land in the watershed region, interfering in the dynamics of the local landscape. As a result, occupation in the watershed intensified, but the population density increased from the 1980s onwards.

From that decade onwards, another point, according to Bim (2013), refers to the state economy in the Vale do Ribeira region, which comprises the BHRT, the intensification of the commercialization of agriculture, and the transformation of

TABELA 1 – Critérios para classificação da Hemerobia da paisagem na BHRT.

Hemeroby Levels	Landscape Feature	Landscape Composition*	Example (Drone Images)	Color
Minimum	Low technological and energy dependence to maintain the functionality of ecological functions	Water, FloO+Am, and FloO+Dm		
Low		VegS+Sp		
Medium		Ap		
High		Ap		
Very High	High technological and energy dependence for maintaining ecosystem functionality; low capacity for self-regulation and little or no natural vegetation	Iu		
Maximum		-	-	

SOURCE: Mezzomo & Gasparini (2016), adapted for the landscape study at BHRT.

NOTE: *Agriculture (Ap), Montana Dense Ombrophylous Forest Upper-Montana (FloO+Am), Dense Ombrophylous Forest Montana (FloO+Dm), Secondary Vegetation without Palm Trees (VegS+Sp), Urban influence (Iu).

ORGANIZATION: The authors (2021).

TABLE 2 – Areas and relative percentage of Hemeroby Levels in the BHRT.

Hemeroby level	1990	%	2000	%	2010	%	2020	%
Minimum	62.251,79	87,14	50.854,84	71,18	52.393,61	73,34	53.454,63	74,82
Low	2.582,70	3,62	1.800,46	2,52	1.868,23	2,62	3.464,65	4,85
Medium	3.258,43	4,56	10.519,54	14,72	9.206,84	12,89	8.223,29	11,51
High	3.307,61	4,63	8.216,07	11,50	7.917,08	11,08	6.230,17	8,72
Very High	40,43	0,06	50,05	0,07	55,20	0,08	68,23	0,10
Total	**71.440,96**	**100**	**71.440,96**	**100**	**71.440,96**	**100**	**71.440,96**	**100**

SOURCE: The authors (2021).

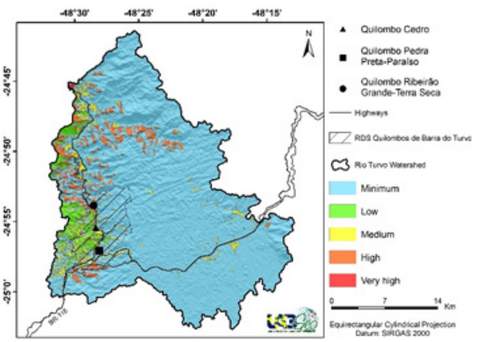


FIGURE 2 – Hemeroby Levels at BHRT in 1990
SOURCE: The authors (2021).

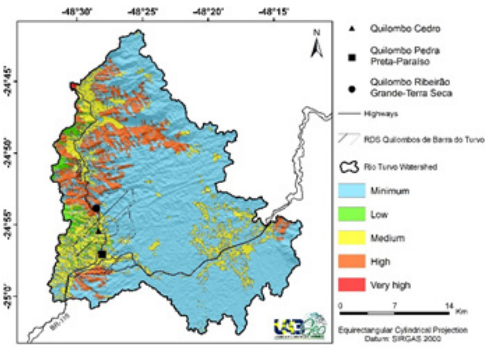


FIGURE 3 – Hemeroby Levels at BHRT in 2000
SOURCE: The authors (2021).

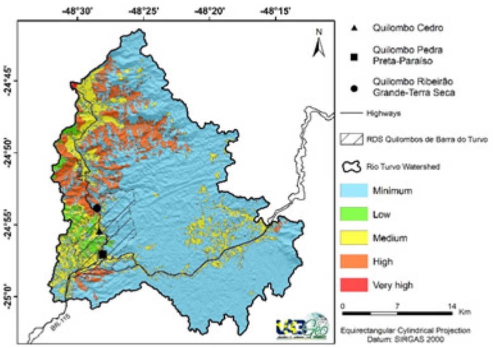


FIGURE 4 – Hemeroby Levels at BHRT in 2010
SOURCE: The authors (2021).

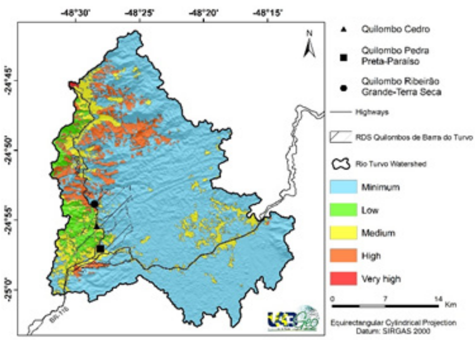


FIGURE 5 – Hemeroby Levels at BHRT in 2020
SOURCE: The authors (2021).

traditional production techniques, demanding the use of agricultural inputs and implements, which contributed to changing the environmental state of the landscape. The author states that two movements occurred during this period: family farmers, who migrated from the countryside to urban centers, and those who went to areas less suitable for agriculture, that is, to areas of parks and reserves, accentuating the land problems in the region.

In this context, the potential and limitations of the environment must be analyzed to study which compatible technologies should be used. Mota (1981, p. 192) and Nucci (2008, p. 03, our translation) call them "natural capacity for use or support," a term related to the limits and the occupation of the territory, considering that the ecosystem can offer self-regulation and the cycling of nutrients and matter. The concepts of support capacity and sustainable development are interconnected since this duality is only possible when thinking about sustained production over time if the environment can support it (Pires & Santos, 1995).

The support capacity of the ecosystem must be related to the use of natural components and the intensity at which they are used, which, in turn, is directly or indirectly linked to demographic numbers. Junk (1995, p. 52, our translation) questions how the "capacity of an ecosystem can sustainably support the maximum number of human population under a given production system." This analysis is one of the priority objectives for proposing a suitable scenario for the occupation of any geographic area, taking as reference the limits of its support capacity associated with the local ecosystem.

From this perspective, it is worth highlighting the functions performed by the ecosystem, according to Constanza *et al.* (1997), De Groot (2006), and Belém & Nucci (2011). Based on the transformation of the landscape, the level of energy and technological dependence, and the self-regulation capacity of ecosystem services, they can be classified into:

- regulation (*minimum* level): areas whose capacity of natural and semi-natural ecosystems to regulate essential ecological processes contributes to the maintenance of environmental health by providing good quality air, water, temperature, climate, and soil,

- support (*low* level): these areas provide support for housing, infrastructure, tourism, and research. Vegetation provides support for countless species of terrestrial and aquatic plants and animals,

- production (*medium*, *high* and *very high* levels): the ecosystem provides raw materials for industry, food, energy resources, and genetic materials,

- information (*minimum* level): natural ecosystems that contribute to mental health by providing opportunities for reflection, spiritual enrichment, cognitive development, and aesthetic experiences.

From this perspective, the landscapes classified as *minimum level of hemeroby* or *a-hemerobic* in the BHRT presented a level of naturalness classified as "natural," exhibiting minimum technological and energy dependence since they are areas covered by Dense Ombrophylous Forest Alto-Montana and Montana, in addition to the water bodies being in good condition with little or no human influence (Figure 6). The relief ranges from flat to mountainous, with acrisol, which has medium erosion capacity, cambisol with high erodibility, and neosol with very high erodibility.

In this case, the ecosystem performs regulatory and information functions, contributing to the maintenance and conservation of the landscape. It

FIGURE 6 – Landscape with minimal hemeroby in the BHRT, riparian vegetation is preserved, contributing to water conservation.
SOURCE: LabGeo/UNEMAT (2021).

has a high capacity for self-regulation as it does not suffer direct anthropogenic actions (Belém & Nucci, 2011). However, if it is deforested for agricultural use, erosion processes will be triggered, and the soil will be carried by rain into water courses, causing siltation.

In the BHRT, the landscape classified as *low level of hemeroby* or *oligo-hemerobic* has an "almost natural" level of naturalness, with low technological and energy dependence. It comprises areas covered by secondary vegetation (Figure 7), whose relief covers the flat to mountainous phases, with the presence of acrisol (medium erodibility), cambisol (high erodibility), and neosol (very high erodibility). The watershed area includes areas deforested for agricultural, livestock, and leisure purposes, as well as those abandoned shortly after use so that the forest regeneration process can occur.

The function performed by the ecosystem in this landscape is supportive because the area was anthropized but has ease of infiltration due to the presence of plant species in the process of regeneration, which minimizes the damage caused by human action. However, the capacity for self-regulation is limited due to changes in the landscape (Belém & Nucci, 2011). Therefore, in some situations, for the maintenance of these areas, the use must be interrupted, aiming at the regeneration of vegetation and land, which will contribute to the completion of ecosystem services, as the predominant vegetation provides support and shelter for several species of plants and animals. Despite not being culturally elaborated landscapes, these areas are maintained and conserved due to traditional agricultural practices developed by quilombola groups in the BHRT.

In the landscape classified as *medium hemerobic* or *meso-hemerobic*, corresponding to the "semi (agro) natural" level of naturalness, with medium technological and energy dependence, the research area corresponds to areas destined for agricultural activity, with the presence of exposed soils, and with the implementation of the BR-116 highway, which contributed to the environmental imbalance (Figure 8). This level comprises several phases of relief, such as flat, gently undulating, strongly undulating, and mountainous, with the presence

FIGURE 7 – Landscape with a low level of hemeroby in the BHRT, resulting from disturbance to the vegetation, presence of traditional buildings, and agricultural cultivation.
SOURCE: LabGeo/UNEMAT (2021).

FIGURE 8 – Landscape with a medium degree of hemeroby in BHRT, resulting from the implementation of Régis Bittencourt highway (BR-116) and the presence of farmers.
SOURCE: LabGeo/UNEMAT (2021).

of acrisol (medium erodibility) and cambisol (high erodibility) soils:

The role played by the ecosystem in this landscape is support and production. However, the capacity for self-regulation is limited due to human activities (Belém & Nucci, 2011).

This type of landscape is intentionally created by society, whose technological dependence is necessary for its use and management of the area. In this context, the landscape, in the face of the development of agricultural and livestock practices, is destabilized, resulting in damage to environmental services, requiring landscape planning to indicate the need to adopt strategies for the recovery of degraded areas or that are in the process of degradation.

The territorial extensions of the watershed whose level of hemeroby in the landscape is *high* *hemerobic* or *eu-hemerobic* comprise an "agricultural" level of naturalness with high technological and energy dependence. Although these are areas intended for agriculture and livestock, there are buildings and soil sealing, causing, over the years, soil compaction, destabilization of ecological functions, and disturbance of habitats that impact environmental quality (Figure 9). The relief phases vary from flat, gently undulating, strongly undulating, and mountainous, with neosol (very high erodibility).

The function performed by the ecosystem in this landscape is support and production, and the need for technologies for self-regulation occurs due to the structures created by society, such as buildings. Thus, the excessive use of natural elements and the increase in the adverse effects of human activities lead to increased pressure on ecosystems (Suchara, 2018). In this way, the need to maintain natural areas in the BHRT is reinforced to avoid adverse effects on terrestrial and aquatic ecosystems, a situation that tends to contribute to a scenario of intensification of urban densification and the degradation of water bodies, reducing the effect exerted by surface runoff (Silva *et al*., 2021).

The BHRT landscapes with a *very high level of hemeroby* or *poly-hemerobic*, classified as "almost natural" according to the level of naturalness, have a very high technological and energy dependence (Figure 10) as they have characteristics similar to those of the *high level of hemeroby* or *eu-hemerobic*. However, it differs due to the greater urban density (Figure 10), whose capacity for soil erosion is average (acrisol).

The role played by the ecosystem in this landscape is also support and production, even though the capacity for self-regulation is limited due to built areas, requiring strategic environmental planning and municipal environmental management. This relationship helps farmers to better execute productivity and profit processes and protect and conserve natural components. Therefore, the aspects responsible for this success are the sustainable management strategies applied in rural and urban areas, thus bringing social, financial, and environmental benefits (Melo *et al*., 2021).

FIGURE 9 – Landscape with a high level of hemeroby in the BHRT, resulting from the presence of buildings and areas intended for agriculture.
SOURCE: LabGeo/UNEMAT (2021).

FIGURE 10 – Landscape with a very high level of hemeroby in the BHRT, resulting from the city.
SOURCE: LabGeo/UNEMAT (2021).

Given the above, the concern demonstrated by the new paradigm in which *society-nature* relates is linked to the adequate management of natural components and the planning of actions aiming to discipline their uses to make it possible for as long as possible and for the higher number of people. Landscape planning can be conceived as a positive process, which aims to "accommodate certain uses on lands with better reception capabilities for them, and as a negative process that aims to avoid the deterioration or consumption of natural components, such as agricultural soil and good quality water" (Laurie, 1982 *apud* Nucci, 2021, p. 54, our translation).

Therefore, the eco-socio-systemic landscape, from the hemerobic perspective of BHRT, must be understood as a mitigating instrument to minimize or eliminate negative impacts that can potentially cause future losses. Hence, it is necessary to view it as an object of analysis capable of preventing and promoting sustainable use in the investigated watershed.

4. Final considerations

The forms of land use and management in the study area, developed in part by quilombola groups, contribute to reducing technological and energy dependence on the BHRT due to the adoption of traditional techniques in production systems, which enhance the functions of the ecosystem, favoring self-regeneration.

Thus, the importance of conserving the landscape and, consequently, environmental quality in the watershed is highlighted, as it comprises an essential conservation unit that is home to numerous species of terrestrial and aquatic plants and animals, in addition to quilombola groups in the Atlantic Forest biome.

Therefore, the analysis of Hemeroby in the BHRT in different periods is fundamental for diagnosing the environmental quality of the landscape and as a monitoring tool whose future projections can be made based on its current state. In this sense, if adequate planning does not occur, the current

Hemeroby Levels may change due to the negative impacts triggered by human action.

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