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An Approach to Verify Naturalness Loss and Its Relation with Ecosystems Services in Brazilian Cerrado: Implications to Management

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Abstract

Recent evidence suggests that Brazilian Cerrado has been largely converted, mainly due to agribusiness activities and urbanization. Thus, the present work aimed to obtain the diagnosis of a watershed characterized by the expansion of sugar cane fields in the Brazilian Cerrado (Southeastern), employing integrity landscape indicators (Hemeroby, Urbanity Index, Landscape Vulnerability Index, and Water Quality Index) to verify the landscape naturalness, and the consequences of these actions to the ecosystem services provision. Remote sensing data for the years 1998, 2008, and 2018 were employed to verify the land-use changes in the Feijão River watershed (southeastern Brazil), as well as a matrix that considers the land use typologies and their capability to provide ecosystem services. The study area is classified as mixed land use, with the main categories related to agribusiness (sugar cane, pasture, bare soil). The Hemeroby and Urban Index denote naturalness declines over the years, and the observed patterns negatively impact ecosystem service provision. Landscape Vulnerability Index and Water Quality Index demonstrated that remaining vegetation cannot effectively retain pollutants, and severe impairments in the resilience of natural components of key ecosystem service providers (i.e. water and native vegetation) were observed. The results allowed the identification of priority areas for recovery and the maintenance of ecosystem services in agricultural lands.

Keywords

Tropical Forest, Hotspot, Land Use, Landscape Indicators, Watershed

1. Introduction

Currently, transformation in land use caused many changes in the natural ecosystems (Vitousek et al., 1997; Wrbka et al., 2004; Zhao et al., 2006; Rockström et al., 2009; Costa et al., 2017). In Brazil, this scenario is marked by some aggravating factors, as national policies that do not protect the native vegetation effectively (Ribeiro et al., 2019).

Brazilian Cerrado has been facing area loss and undergoes great anthropogenic pressures due to the human activities' development and the implementation of the Native Vegetation Protection Law—NVPL (Federal Law 12.651/2012), which became more permissive than the previous one, the Forest Code from 1965 (Soares-Filho et al., 2014; Brancalion et al., 2016; Metzger et al., 2019; Grande et al., 2020). The Brazilian Cerrado is considered a hotspot of biodiversity and provides many ecosystem services at the landscape scale, however, there is a high deforestation risk, and "anti-deforestation" policies must be implemented, given the fragile surveillance (Brooks et al., 2002; Stefanes et al., 2018).

Furthermore, the Brazilian Cerrado is a phytogeographic domain that includes tropical grassland, savanna, seasonal forest, and other vegetational groups (e.g. riparian forests, seasonal semideciduous forest) (Batalha, 2011). The Brazilian Cerrado occurs in the central portion of Brazil, is responsible for supplying the eight largest Brazil's watersheds and recharging three aquifers; although, deforestation has been compromising the water cycle, due to reduction in infiltration, groundwater recharge decrease, and evapotranspiration losses (Noojipady et al., 2017; Rekow, 2019). In this sense, deforestation compromises the ecosystem services provision in the Brazilian Cerrado watersheds.

Notwithstanding its great importance for society, the Brazilian Cerrado has been largely converted into other land uses, mainly due to agribusiness activities (Garcia et al., 2017). Agribusiness is the main driver of Brazilian Cerrado conversion, from 1985 to 2019, the agricultural area increased 3.4× (MapBiomas, 2020). The agricultural matrix (e.g. pastures, sugar cane fields, soybean) generates impacts for the natural systems, due to hydro-chemical changes, pesticide input, and the erosion occasioned by marginal vegetation degradation, a situation that directly reduces the provision of water ecosystem services (Mello et al., 2020). Another implication of land-use change is the loss of the landscape's naturalness and, consequently, the biodiversity loss (Fonseca & Venticinque, 2018; Hidasi-Neto et al., 2019). Areas with intensive agricultural use, for example, tend to have a lower degree of landscape naturalness and ecological stability (Rüdisser et al., 2012; Silva et al., 2017).

Recent estimates indicate that by 2050, the deforestation allowed by the NVPL could result in the suppression of 14 million hectares (ha) of Brazilian Cerrado (Soterroni et al., 2018), affecting directly the watershed's integrity and ecological process maintenance. Vieira et al. (2018) point out that compliance with this normative mechanism does not protect biodiversity and ecosystem services. Thus, it can be inferred that the Brazilian Cerrado is subjected to a reduction in ecosystem services due to these and other factors (Resende et al., 2019).

Worth to be mentioned that, in some localities, the situation is even alarming. For example, 32.7% (8,106,085 ha) of the São Paulo State area were originally covered by Brazilian Cerrado, but only 3% (239,312 ha) of the native vegetation remain, surrounded by an agricultural matrix composed of pasture and croplands (MapBiomas, 2020; São Paulo, 2020), mainly sugar cane fields. Besides the tendency of Brazilian Cerrado areas recovery in São Paulo State (São Paulo, 2020), the potential negative impacts of the NVPL require strategies to safeguard the ecosystem services and improve the environmental policy (Guidotti et al., 2020).

Thus, it is essential to develop approaches to verify changes in land use and assess the ecosystem services. Such action can provide information for decision-making and allow the management of the natural ecosystem, especially those in the Brazilian Cerrado. Moreover, an analysis that considers watersheds contribute to verifying the influence of the (in)direct drivers on ecosystem services provision and the assessment of the natural system functioning (Periotto & Tundisi, 2018).

We hypothesize that the direct drivers linked to Brazilian Cerrado at the State scale are capable to promote the conversion of the natural area in small watersheds, a situation that aggravates with the approval of NVPL, given the increase of artificial surfaces and reduction of ecosystem services provision due to the normative permissiveness. Therefore, we evaluated the land use of a watershed characterized by the expansion of sugar cane fields in a Brazilian Cerrado area (Costa et al., 2017) over 20 years, employing structural landscape indicators to verify naturalness and a matrix to verify the main structures that provide ecosystem services.

2. Material and Methods

2.1. Characterization of the Study Area

The Brazilian Cerrado is the second-largest biome in South America, extending over more than 2×10^6 km^2 and hosts some of the most intensive agricultural activities for grain and beef production in the world (Del-Claro & Torezan-Silingardi, 2019). This phytogeographic domain is considered one of the hotspots for biodiversity conservation because of its biological richness and high endemism levels (Françoso et al., 2015; Oliveira et al., 2019; Sano et al., 2019). The Brazilian Cerrado occupies a large tropical ecoregion located at the center of Brazil.

In São Paulo State, the Brazilian Cerrado presents low indexes of the remaining vegetation, distributed as fragments surrounding agricultural activities (São Paulo, 2020), a situation also observed in the study area. The remaining vegetation in the municipalities drained by the Feijão River Watershed (southeastern Brazil), is Brazilian Cerrado (**Figure 1**). A tendency of native vegetation recovery is evident in the region, as well as the strong influence of sugar cane fields and

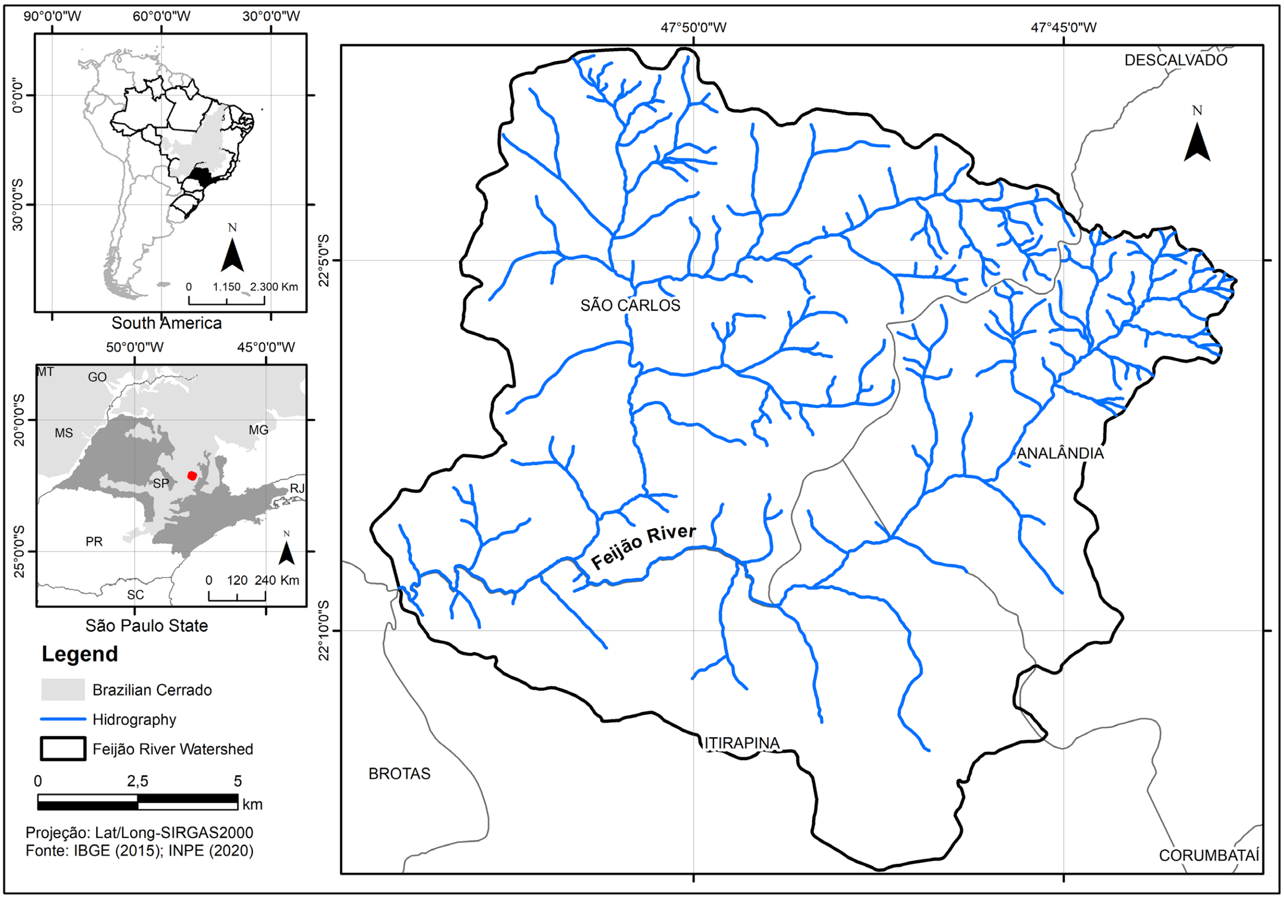

Figure 1. Geographic localization of the study area.

pasture on natural ecosystems (Costa et al., 2017). The Feijão River is the main hydric body in the study unit and the principal source of water supply for the São Carlos city. Therefore, the watershed requires constant monitoring for water quality and biotic diversity maintenance. The main river reaches the fifth-order and drains three municipalities: Analândia, Itirapina, and São Carlos.

2.2. Methods

Land use dynamics were obtained based on Landsat-5 (TM) and Landsat-8 (OLI) images (path: 200/raw: 75), provided by the United States Geological Service (USGS) and the National Institute of Spatial Research (INPE) for the following years: 1998, 2008 and 2018. A multispectral composite of three bands (5R4G3B or 6R5G4B) was carried out to classify the land use typologies based on the texture and tone of the image. The processing and georeferencing were carried out using the software ArcMap 10.2, adopting the projection system Universal Transverse Mercator (UTM), the SIRGAS2000 Datum, and Fuse 23S.

This study was guided by the analysis of naturalness, which was based on the following indicators: Hemeroby, Urbanity Index, Landscape Vulnerability Index, and Water Quality Index (Wrbka et al., 2004; Fushita et al., 2016; Fushita et al., 2017). Hemeroby is an index that classifies the landscape according to the naturalness degree, therefore, it is classified from the natural to the cultural. Furthermore, landscapes with a lower level of hemeroby have a greater capacity for self-regulation, as well as promoting social welfare (Sukopp, 1972; Barbara et al., 2014; Walz & Stein, 2014; Artmann et al., 2017) (**Table 1**). Sukopp (1972) defines hemeroby as an integral measurement of human interventions over the ecosystem, that is, the total result of the impacts on a particular area based on land use.

The condition of the Feijão River Watershed was obtained utilizing the Urbanity Index and Hemeroby during the analyzed period (1998, 2008, and 2018). The Urbanity Index is an indicator able to reflect the landscape's naturalness and reflect the extension of the area strongly altered by humans (O'Neill et al., 1988). The following equation was employed (Equation (1)):

$$\text{Urbanity Index} = \log_{10}\left[A + U/(F + W)\right] \quad (1)$$

where: *U*: urban area; *A*: agricultural area; *F*: vegetation and natural area; *W*: aquatic and wetland areas.

The spatial representation of the Urbanity Index was obtained by basing on the RASTER VECTOR, AREA, and fuzzy logic in the software ArcGIS 10.2, transformed by a linear function with a minimum value of 0 and a maximum value of 1; considering IB = 0 (maximum degree of naturalness), IB = 1 (minimum degree of naturalness).

The Landscape Vulnerability Index shows the susceptibility of a landscape to environmental impacts, like the loss of biodiversity and habitats due to the fragmented condition of the natural and semi-natural vegetation (Fushita et al., 2016).

Table 1. Hemeroby description regarding its influence on biodiversity and land use.

Hemeroby levels	Degree of naturalness	Description
Ahemerobiotic	Natural	Natural systems with no or only minimal anthropogenic influence (e.g. global pollution)
Oligohemerobiotic	Near-natural	The structure and type of the ecosystem is the same as naturally expected, but some characteristics (e.g. species composition) are altered due to anthropogenic influences
Mesohemerobiotic	Semi-natural	The natural ecosystem is no longer present but has been transformed into a new ecosystem due to anthropogenic activities
Euhemerobiotic	Agricultural	The landscape is disturbed by anthropogenic activities (e.g. intense fertilization, water management) and the main uses are related to agribusiness
Polihemerobiotic	Cultural	Intense and regular impacts lead to the destruction of the naturally occurring edaphon.
Metahemerobiotic	Artificial	Artificial systems or structures, soil sealing over 30%

Source: Fushita et al. (2016) and Rüdisser, Tasser and Tappeiner (2012).

This index was obtained by two metrics: Vegetation Quality Index and the Water Quality Index. Such index reflects the landscape susceptibility to degradation, indicating the resilience and vulnerability front of human impacts. Values around 0 indicate a high capacity of the landscape to absorb the human impacts; on the other hand, values around 1 reflect a low capacity to absorb those impacts, due to fragmentation, connectivity loss, the compromising of landscape, and artificialization.

The Water Quality Index was estimated from the values of the three metrics of vegetation patches: Area (AREA), shape (SHAPE), and distance (DISTANCE) between patches, which were obtained from the land use reclassification of the Feijão River Watershed for 1998, 2008, and 2018. This environmental indicator reflects the susceptibility of aquatic systems, considering the distance between water resources and the source of impact represented by anthropogenic land use. It was transformed by fuzzy logic. Values around 0 indicate the maximum degree of quality and a distance of 1 km from water resources to anthropogenic areas; although, values around 1 reflect eventual effects from anthropogenic activities (e.g. farming, pesticides, effluents) on water resources due to the proximity (Fushita et al., 2016).

The ecosystem services were evaluated based on the assessment matrix proposed by Burkhard et al. (2009), this matrix considers the land use typologies and their capability to provide ecosystem services. Values were attributed considering the ecological processes that occur in the land use and based on scientific knowledge, as the literature suggests (Burkhard et al., 2009, 2014; Periotto & Tundisi, 2018). The follow ing scale was applied: 1) 0 = no relevant capacity; 2) 1 = low relevant capacity; 3) 2 = relevant capacity; 4) 3 = medium relevant capacity; 5) 4 = high relevant capacity; and 6) 5 = very high relevant capacity.

3. Results

During the evaluated period, nine land uses were identified (**Figure 2**). Although the watershed is categorized as mixed land use, the main categories are related to agribusiness, which corresponds to a high fraction of the total study area, followed by native vegetation and anthropogenic non-agricultural areas. At the same time, it was possible to observe changes in land use, especially the increase of anthropogenic areas and the decrease of the natural ones. This typology decreased massively during the last 10 years, the remaining fragments are associated with hydric bodies.

Bare soil demonstrated loss (from 1998 to 2008) and gain (from 2008 to 2018) in the area. The changes in agricultural activities reflect the increase of natural areas conversion in other land uses. All the modifications resulted in the pasture appearance during the last 10 years, and expansion of sugar cane, which can be associated with harvest periods. Silviculture demonstrated a similar pattern, considering the last 10 years (2008-2018), areas were deforested.

The sealed areas also showed an increase, but these spaces are not the major

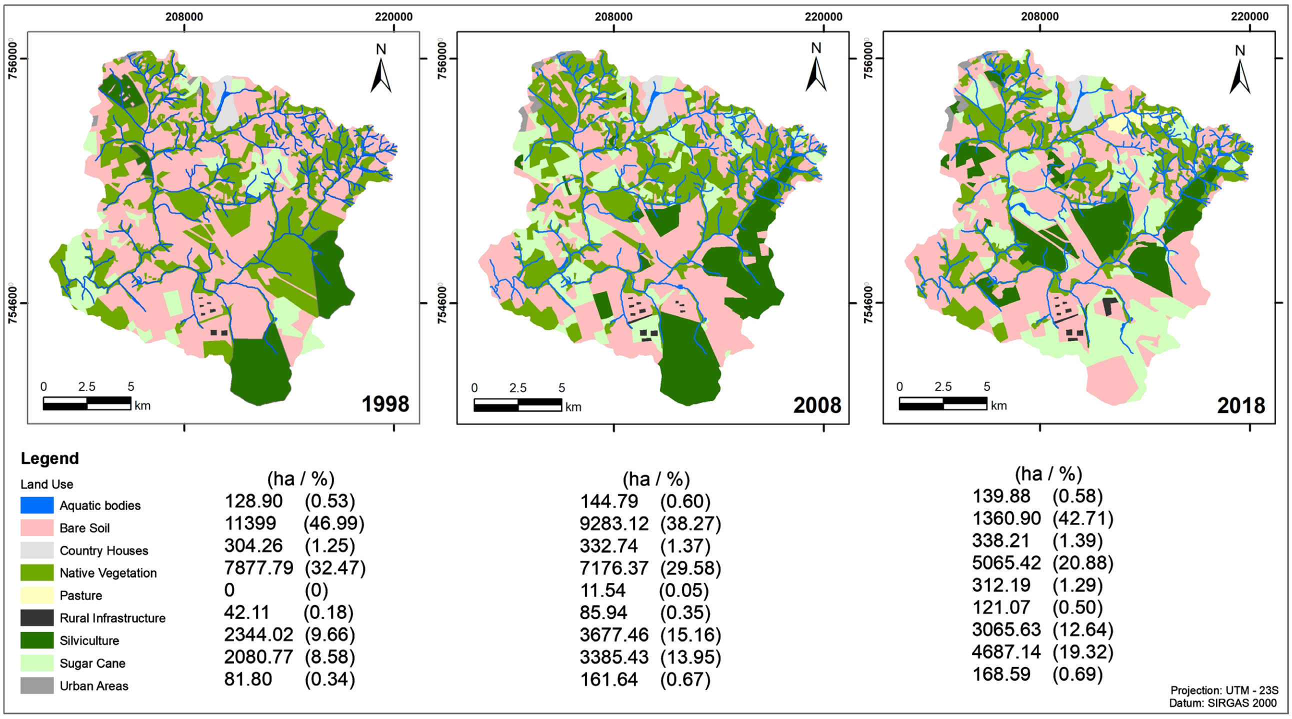

Figure 2. Land use for the Feijão River Watershed for 20 years (1998 to 2018).

driver of changes in the studied areas. Country houses and rural infrastructure doubled during the two decades. The urban area demonstrated a small increase, reflecting minimal changes in São Carlos's urban growth in the Feijão River Watershed, which is one of the expansion vectors considered by the municipality. We stand out that a local normative dispositive of São Carlos Municipality (Law n˚ 13,944/06—*Área de Proteção e Recuperação dos Mananciais*, "Area of Protection and Recovery of Springs" in English) contributes to control the urban expansion in the Feijão River Watershed.

Minimal changes were observed in aquatic environments. The water bodies increased from 1998 to 2008; however, a reduction could be observed during 2018. The mosaic plot elaborated for the assessment of the ecosystem's services provided by the study area demonstrated that environments highly anthropized (i.e. urbanized areas, country houses) have a lower capacity of ecosystem services provision than natural spaces, especially the artificial areas (i.e. country houses, rural infrastructure, and urban areas). Agricultural typologies (i.e. pasture, sugar cane, and silviculture) had the relevant capacity to provision and support services, mainly silviculture. However, the greatest capacities to ecosystem services correspond to native vegetation and water bodies, the higher scores reflect the importance of those areas for the ecosystem's services maintenance. Considering the reduction of natural areas from 1998 to 2018, is evident the loss of the ecosystem services, given the direct impact on the provisioning services maintenance.

The general panorama of the land use classes and the ecosystem services (**Figure 3**) reinforce the importance of the natural ecosystems (aquatic bodies and native vegetation) in the provision of the regulating services and support services. Stand out that, the non-anthropogenic (country houses and urban areas) uses do not provide a diversity of ecosystem services. On the other hand, anthropogenic agricultural uses had higher values for provision, regulation, and support services, when compared to non-anthropogenic uses. The cultural services were higher in aquatic bodies and native vegetation.

Considering the Urbanity Index (Figure 4), it was observed the predominance of intervals that indicates low naturalness (values from 0.6 to 1.0). During the

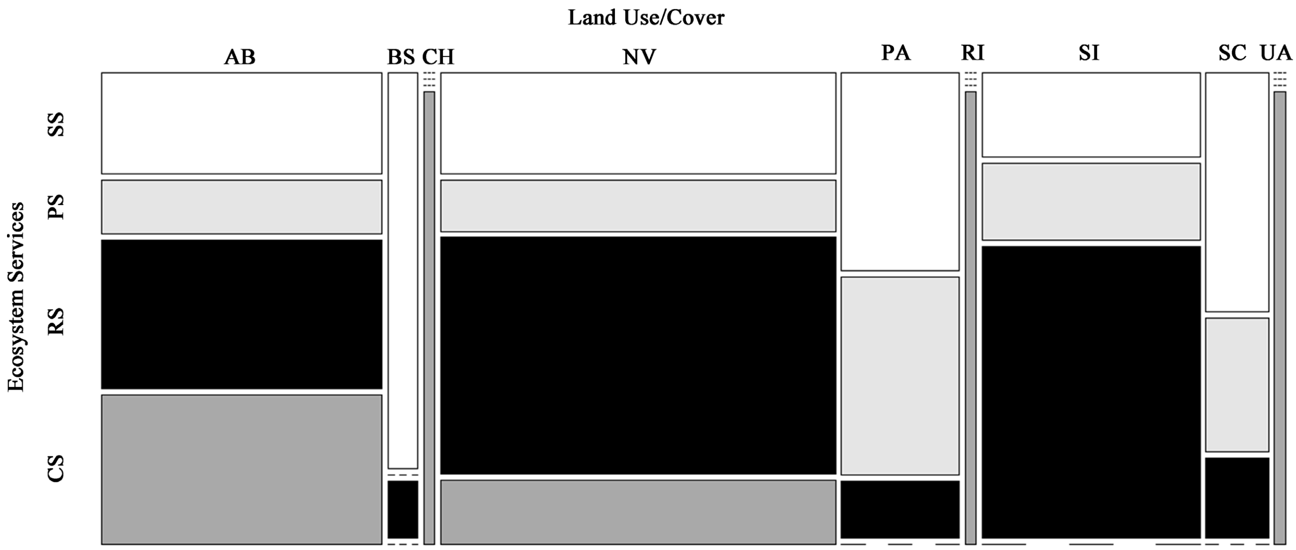

Figure 3. Mosaic Plot representing the association of ecosystem services and land use. Legend = Support Services (SS), Provision Services (PS), Regulating Services (RS), Cultural Services (CS), Aquatic Bodies (AB), Bare Soil (BS), Country Houses (CH), Native Vegetation (NS), Pasture (PA), Rural Infrastructure (RI), Silviculture (SI), Sugar Cane (SC), Urban Areas (UA).

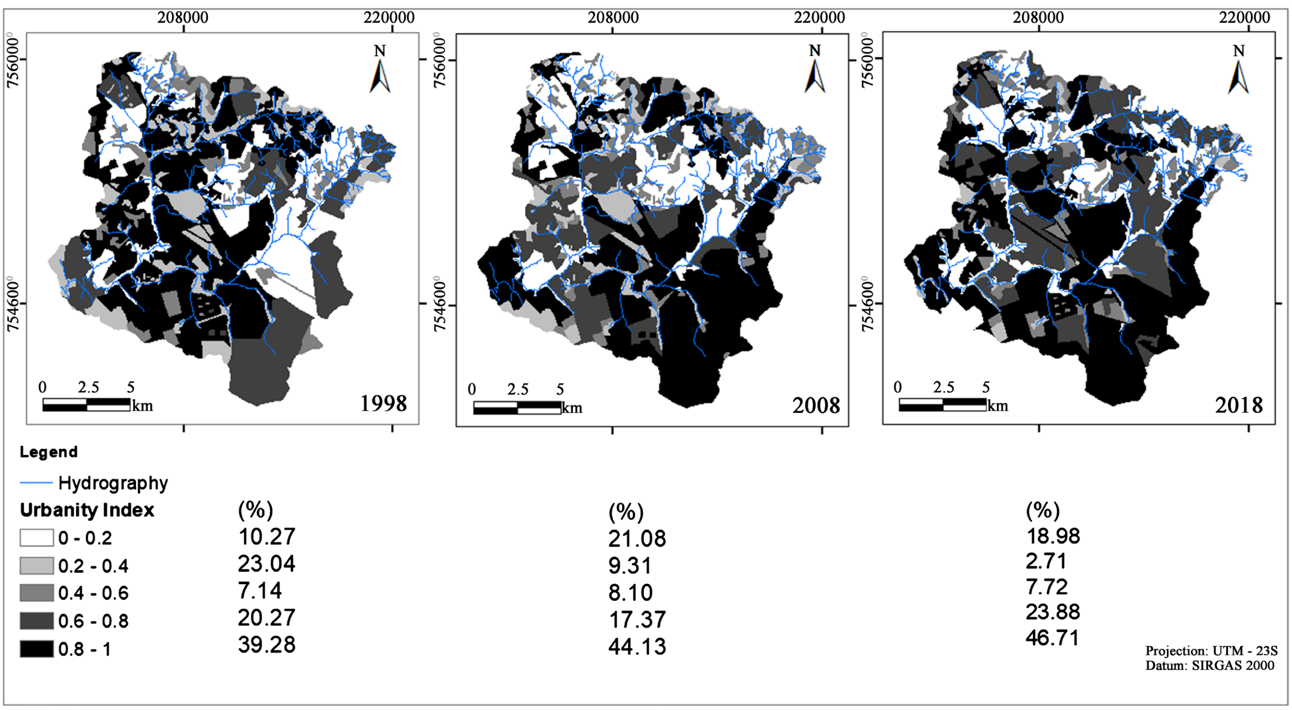

Figure 4. Urbanity Index for the Feijão River Watershed from 1998 to 2018.

evaluated period, the class corresponding to a high naturalness (0 - 0.2) increase from 1998 to 2008, but declined in the last 10 years, remained quantitatively less than 19% of the Feijão River Watershed. On the other hand, the low naturalness areas demonstrated an expansion. The worst situation was verified during 2018, those areas amount to almost 71% of the territory. The intermediary class (0.4 - 0.6) remained linear, small changes were verified. Concerning the fourth class (0.2 - 0.4), a considerable reduction occurred, mainly from 2008 to 2018.

The Urbanity Index demonstrated the predominance of areas with high anthropogenic interference, indicating that the systems are highly altered by human activities. This situation was related to the agribusiness areas and natural cover reduction. The high naturalness levels are concentrated in the superior region of the basin, given the direct relation with native vegetation and associated hydric bodies. According to **Figure 4**, a dynamic process can also be detected around the Feijão river's headspring. Despite the gains from 1998 to 2008 in the superior area, the naturalness decreased during the last 10 years. Areas with high urbanity levels and human interference were concentrated in the Feijão River middle course, where major changes were observed. Also, low naturalness levels were constated in the middle course; however, an improvement can be observed in 2018.

The hemeroby degrees for Feijão River Watershed are presented in **Figure 5**. Variations were constated during the period, but the eumerobiotic environments are predominant and occupied more than 60% of the unit during the two initial periods and almost 76% of the total area in 2018. This category is represented by agribusiness activities, indicating that the landscape is characterized by being artificial and dependent on anthropogenic control.

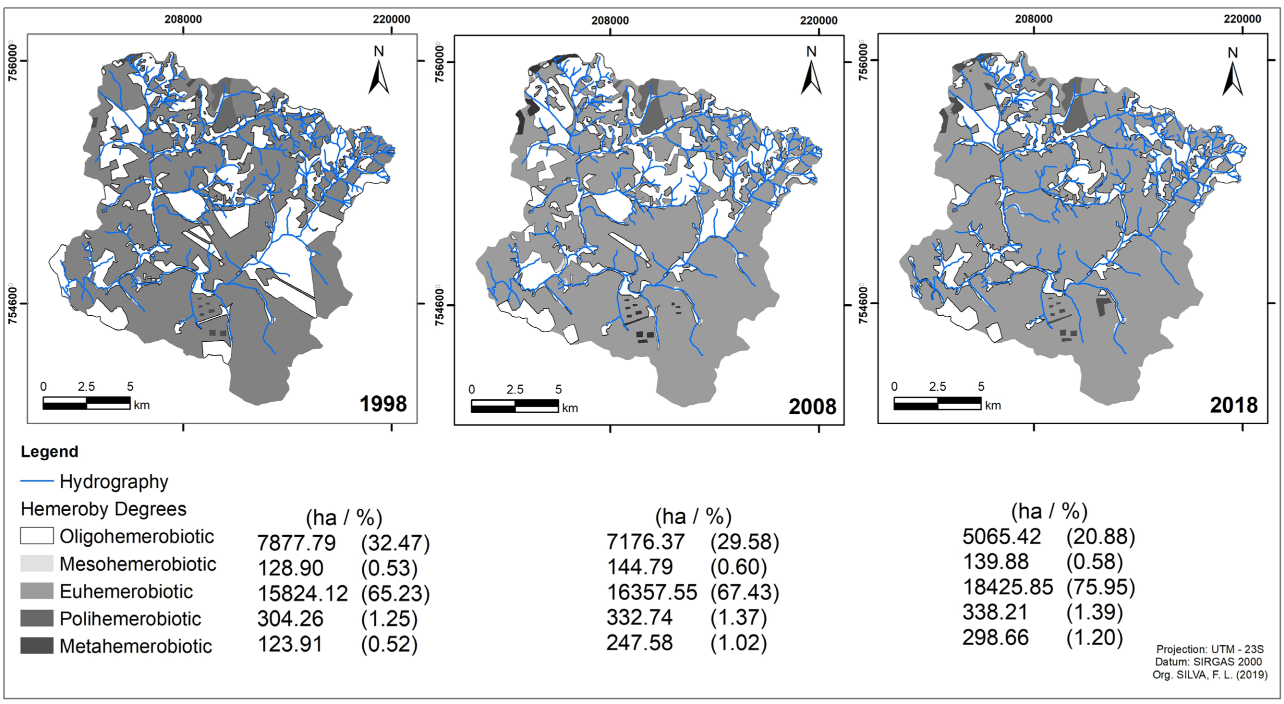

Figure 5. Hemeroby pattern for the Feijão River Watershed.

Likewise, categories that indicate higher anthropogenic interference and dependence (i.e. polihemerobiotic and metahemerobiotic) demonstrated a small increase during the analysis. Although the amount is inferior to 3% of the territory, metahemerobiotic class expanded more than twice as much from 1998 to 2018.

Oligohemerobiotic areas suffered reductions, especially during the period from 2008 to 2018. Portions of the landscape with self-regulation are losing area because of the anthropization that is associated with agricultural and non-agricultural uses expansion.

The semi-natural areas (i.e. mesohemerobiotic) demonstrated a small variation in their area, but a loss can be observed from 1998 to 2018. These areas are categorized by reservoirs and categorized by limited self-regulation.

As shown for the Urbanity Index, the results revealed similar patterns in the longitudinal gradient of the Feijão River. Strong human dependence and influence are related to agribusiness activities and consolidated areas, which are the main contributors to low watershed self-regulation. The major anthropogenic interference can be verified both in the middle and the low course of the Feijão river. Considering the headspring, a better situation was observed during 2008, but a loss of oligohemerobiotic areas occurred.

Figure 6 illustrates the Landscape Vulnerability Index and the Water Quality Index obtained for the study area. In general, the hydric resources in the Feijão

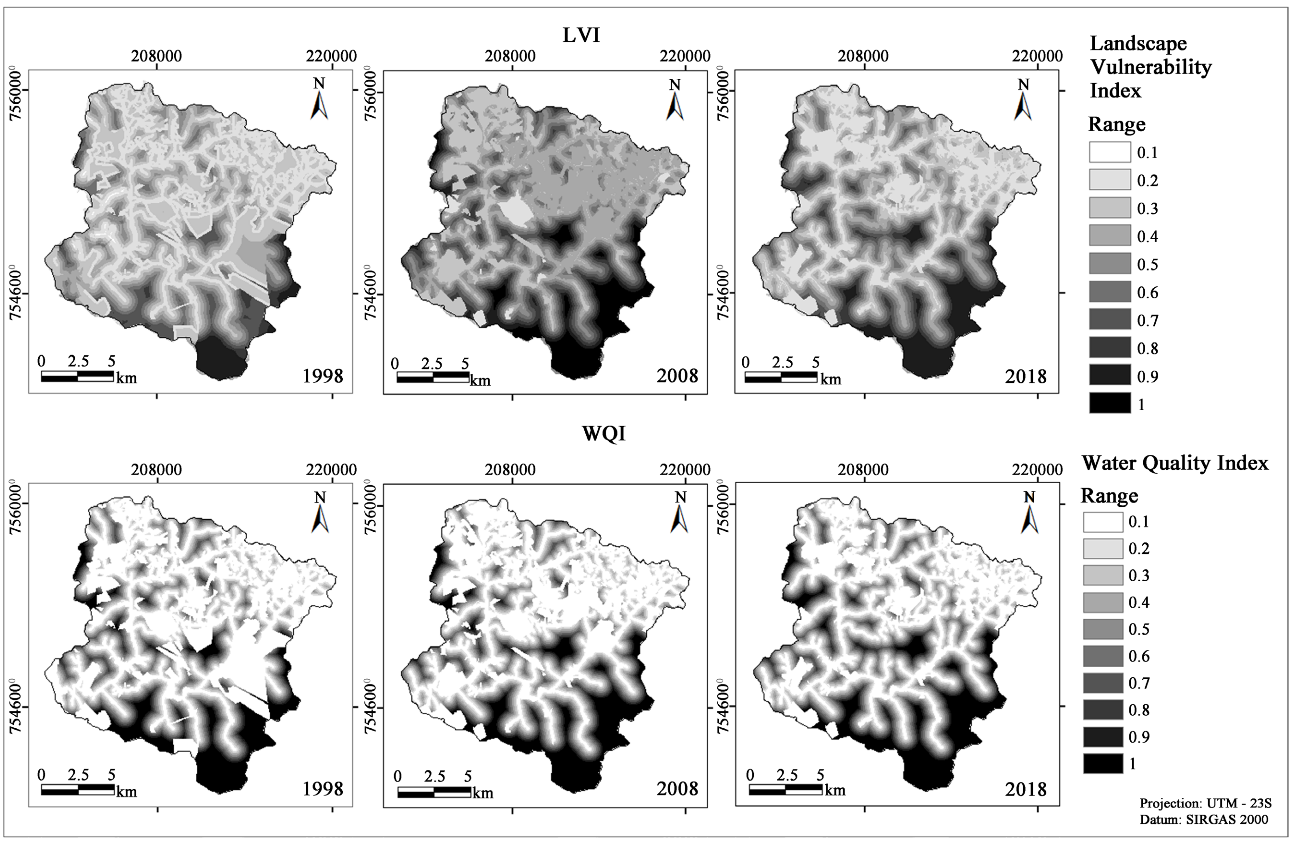

Figure 6. Landscape vulnerability index and water quality index for Feijão River Watershed.

River Watershed are characterized by the proximity of impacting sources (e.g. sugar cane fields, bare soil, sealed areas), given the low environmental quality. The proximity with impacting sources contributes to substances input into the aquatic systems. The remaining vegetation cannot effectively retain pollutants and sediment because of their small area and fragmentation process. The better scenario was spotted during 1998, but a tendency of quality loss was verified during the evaluated period. Higher impact and anthropogenic interference were verified in the inferior region of the watershed, as well as in the spring showed a better quality concerning environmental risks from impacting sources.

The Landscape Vulnerability Index demonstrates the quantitative and qualitative conditions of vegetation, water compromising, and biodiversity loss according to land use. The scenario reflects a high compromising of the resilience of the natural components (i.e. water, vegetation, and biodiversity) and the main driver corresponds to the agribusiness. The areas characterized by a low vulnerability are correspondent to native vegetation. During 1998, the watershed demonstrated a better situation when compared to 2008 and 2018, the low vulnerability areas were distributed in the watershed. However, the pattern found in 2018 indicates an increase in the element's vulnerability (values from 0.6 - 1), mainly for deforestation, connectivity loss, and agricultural activity intensification.

4. Discussion

Different human activities can generate a significant threat to water quality in anthropogenic areas (Costa et al., 2018; Fushita et al., 2016; Liyanage & Yamada, 2017). Considering the study area, there was an increase both in agricultural activity, specifically in the area of sugar cane cultivation, and silviculture due to the economic growth associated with these crops (Sousa et al., 2019; Vieira et al., 2016). This type of production, as part of the agribusiness, does not apply conservation techniques in rural properties, which causes accelerated erosion (Souza et al., 2013). An agricultural expansion on the areas of native vegetation contributes to the commitment of ecosystem services, such as water provision (Stefanoski et al., 2013; Vieira et al., 2018).

Indeed, in the Feijão River Watershed, agribusiness and urbanization are the main drivers responsible for natural area conversion, as observed on a national scale. Furthermore, the high deforestation occurred in the period that succeeds the NVPL approvals, probably linked to the flexibilization concerning rural owner's obligations and the deforestation incentives, which implies in landscape artificialization and naturalness reduction, and directly reduce the ecosystem services provided by natural structures. Artificial elements and agribusiness have a lower capacity to provide ecosystem services when compared to natural ecosystems (Burkhard et al., 2009, 2014; Periotto & Tundisi, 2018). In the study area, such a situation is observed, given that native vegetation and water are the main structures that provide ecosystem services. On the other hand, the artificial elements are marked by the low capacity of ecosystem services provision. There is a need to promote the adequate management of the natural elements in the watershed, aiming at the benefits provided for social and ecological processes maintenance.

Furthermore, the remaining vegetation is essential for ecosystem services in agricultural areas, but the managing of the agricultural landscape contributes to ecosystem disservices (Zhang et al., 2007). Alterations caused by anthropogenic actions can compromise the homeostasis of the natural system (Kikuchi et al., 2018). Natural capital reduction generates adverse impacts for ecosystem services, many services are irreplaceable, situations of stress increase the value of ecosystem services (Costanza et al., 1997).

The Landscape Vulnerability Index denotes a reduction in natural conditions. Some studies show that different anthropogenic actions, as well as, the absence of conservation actions, can lead to impairment of ecosystem services, generating risky situations for the natural systems (e.g. loss of riparian vegetation, erosive process, siltation, physical change on soil structure) (Fernández-Raga et al., 2019; Gomes et al., 2018; Narducci et al., 2019) and population. Such disruptions endanger native species because of eventual invasive organisms (Zanzarini et al., 2019) and confer onus for all society.

Anthropogenic inappropriate actions intensify events related to climate change (Mahmoud & Gan, 2018; Ramalho & Guerra, 2018) and confer risks to ecosystem services provided by water (Mello et al., 2020). The forms of land use influence the intensity changes in the local microclimate (Penereiro et al., 2018), the primary sector has a direct dependence on natural resources and contributes to Greenhouse Gas Emissions (Singh & Singh, 2017).

Furthermore, the Brazilian legal system provides elements for water use and vegetation maintenance, but the lack of regional planning and the no integration of the legal framework compromise the ecosystem services provided by the Feijão River Watershed (Oliveira-Andreoli et al., 2019). In this sense, landscape indicators can collaborate with conservation and biomes maintenance through public policy formulation, especially in a scenario of natural ecosystem conversion and normative dispositive failures. The construction of public policy must have a holistic vision and be elaborated adopting an interdisciplinary manner, especially in watersheds that are marked by man-managed areas predominance (Sterner et al., 2019; Guidotti et al., 2020).

There is a clear association between the inadequate use of natural resources, notably water resources, and anthropogenic activities in Brazil (Ribeiro & Johnsson, 2018). In addition to social tensions, there are conflicts between landowners and urban activities involving protected areas and agricultural lands (Gomes et al., 2018; Pereira et al., 2016). For example, in Mato Grosso do Sul there was a 111% increase in farmland and, and 14.9% of the planted grazing areas in the Brazilian Cerrado from 2000 to 2016 (Bonanomi et al., 2019). Another aspect to be considered in the absence of practices aimed at the conservation of native vegetation is the permissiveness of the NVPL (e.g. the inclusion of permanently protected areas in the legal reserves) with the purpose of agricultural expansion as well as economic finalities (Brancalion et al., 2016; Metzger et al., 2019).

Despite the significant progress in the field of water resources management, there is a deficiency in the establishment of connections among the instruments (e.g. Master Plan, Zoning, Hydrographic Basins Plans), and the strategic environmental planning can be effective to assist the development of Brazilian Cerrado and contribute to the ecosystem services provision in the evaluated hydrographic basin (Oliveira-Andreoli et al., 2019; Silva et al., 2019). The landscape indicators employed in the analysis (i.e. Urbanity Index, Hemeroby, Landscape Vulnerability Index, Water Quality Index) were successfully adopted by other studies conducted in another watershed in Brazilian Cerrado areas (Fushita et al., 2016; Costa et al., 2017; Mazzuco et al., 2017; Silva et al., 2017; Ferreira et al., 2018). The results provide bases for management and demonstrate the human interference on natural systems, as well as the anthropogenic interference and the risk involving the ecosystem services provisions.

Pastures, sugar cane fields, and crops are the main activities related to the Brazilian Cerrado conversion (Arruda et al., 2019). Brazil is an agricultural country that has been facing an increase in production across the years, as well as is responsible for 34% of the sugar and the 22% of the meat consumed in the world (https://www.abagrp.org.br/numeros-do-agro). The increased production inevitably results in a decrease in native vegetation, aggravating the situation because of the Brazilian government's "death agenda" that threaten the natural environment (Ferrante & Fearnside, 2019).

In this view, the employed approach provides elements for the sustainability in the watershed level, concerning the elaboration of environmental public policies aiming at the maintenance of ecosystem services in Brazilian Cerrado, improving the quality of the population, and giving bases for promoting ecosystem functioning and negative externalities mitigation (Schaefer et al., 2015; Karam-Gemael et al., 2018; Roque et al., 2018).

5. Conclusion

In Feijão River Watershed, the direct drivers (i.e. urbanization and agribusiness) linked to Brazilian Cerrado conversion on a national scale are observed in the study area, a situation aggravated by NPVL. The provision of ecosystem services by natural elements demonstrated reductions due to agricultural matrix and artificialization. The Feijão River Watershed is characterized by the predominance of anthropogenic agricultural uses, a situation favored by the economic dynamics of the region, which implies the expansion of these activities to the detriment of the natural areas. The Urbanity Index and Hemeroby reflect the landscape naturalness loss during the evaluated period, given the increasing anthropogenic pressure on the protected and natural areas. Consequently, the low naturalness levels are reflected in a greater commitment of the water resources, due to the proximity of the impacting sources and the no effective protection conferred by the remaining vegetation. Such a situation can not only affect the connectivity of the landscape but can also lead to biodiversity loss, which is responsible for ecosystem services maintenance. Thus, the observed patterns generated negative effects in the ecosystem services provided by natural systems, conferring externalities for the entire resident population. The planning process and the recovery of the native vegetation in the localities with greater commitment, besides the increase of the connectivity between the fragments, can contribute effectively to the improvement of the observed scenario. The methods employed greatly assist decision-makers; their applicability reflects the environmental quality and provides guidelines for reversion of the degradation process in the landscapes dominated by agricultural activities, as well as the establishment of priority areas for revegetation and the maintenance of ecosystem services. Future works can use the environmental indicators to promote the management in large units, as well as combine the use of these indicators with other analyses (e.g. limnological, biotic).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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