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Agricultural expansion and environmental degradation in the Sepotuba river basin - Upper Paraguay River basin, Mato Grosso State - Brazil

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Abstract
The diverse forms of appropriation generate important changes and impacts in the landscapes. In this sense, the present work aimed to analyze the spatial-temporal evolution of agricultural expansion and environmental degradation indices in the Sepotuba River basin, Upper Paraguay basin. For this purpose, satellite images were georeferenced, classified and processed for the period 1986-2016. The thematic maps were validated with the aid of the Kappa Index and subsidized the evaluation of the changes through the Anthropic Transformation Index (ATI). The results showed that there is a strong relationship between agriculture and the suppression of important extensions of native coverage. In the upper and middle course, Tangará da Serra as a pole that has an important role concerning monocultures. In the low course, Cáceres exerts its influence with the predominance of Livestock. Important phytophysiognomies that make up the Sepotuba river basin were identified - a result of the convergence between the Amazon, Cerrado and Pantanal biomes. The results obtained indicate different degrees of impairment of environmental quality in the Sepotuba River system, according to the expansion of land use and occupation in its sub-basins.
Keywords: Land use; Environmental analysis; Geotechnologies; Sepotuba river; Mato Grosso.

Introduction

The hydrographic basins constitute an important spatial unit of analysis both for its dynamics and for recording the impacts associated with the extraction and use of natural resources. When we consider their totality and complexity, they are chosen for environmental studies - structure and functioning of their subsystems; assessments and socio-environmental

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diagnoses - in order to contribute to territorial planning (CARVALHO, 2014; SOUZA, 2013).

In the southwest of Mato Grosso, the non-indigenous occupation dates back to the eighteenth century, with the Portuguese-Spanish appropriation (BINDANDI, 2014). However, the exploitation of natural resources, mainly of soil and water, was intensified in 1970, being more expressive in the mid-1980s due to the agricultural expansion. Therefore, the Mato Grosso territory has shown structural changes in the last decades. And, as a consequence, environmental degradation places it as one of the states that most recorded this reality (LORENZON, 2016).

The hydrographic basin of the Upper Paraguay River (UPR), linked to the dynamics in the administrative region, has been occupied by several monocultures. Therefore, studies point to important associated issues and impacts (SERIGATTO, 2006; SOUZA et al., 2012). According to the authors, extensive areas in the river basins of the rivers Bugres, Sepotuba, Cabaçal and Jauru, important affluents of the right margin, had their plant covers replaced, as well as stretches along the Paraguay river itself (PESSOA et al., 2013; SOUZA et al., 2012).

According to Neves et al. (2015), the expansion of productive activities in the Upper Paraguay basin areas has the potential to impact the Pantanal's abiotic and biotic systems. From this perspective, it is possible to highlight the recent work developed within the scope of its hydrographic system. Authors like Pessoa et al. (2013), Neves et al. (2015), Lorenzon (2016), among others, analyzed the dynamics of land use and occupation with important results and indicators.

In this context, geotechnologies, such as Remote Sensing and Geographic Information Systems (GIS), based on orbital images, are an excellent tool for analyzing and quantifying land use and coverage (PESSOA et al., 2013). These technologies can help in the definition of conservation or degradation levels in different spatial-temporal scales, being fundamental to

the planning. This is because they contribute to the reconstitution of scenarios and prognoses.

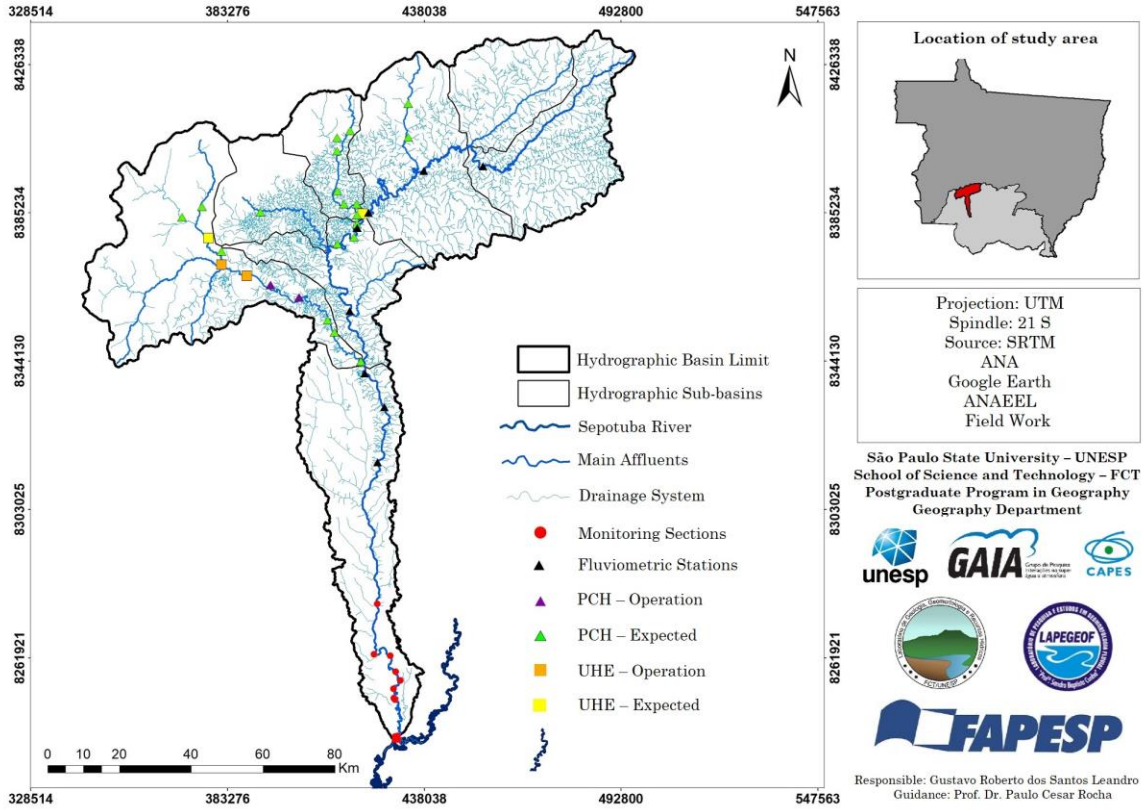
The Sepotuba river basin demands attention regarding the land use and occupation, mainly due to hydromorphodynamic interactions in its system and, consequently, for its relevant contribution as a tributary of the Pantanal. Thus, this work aims to analyze the spatial-temporal evolution of agricultural expansion, as well as environmental degradation indexes in the Sepotuba river basin, Upper Paraguai River - Mato Grosso.

Study Area

The UPR is constituted by important drainage systems inserted in Plateau areas. Thus, they reach the alluvial plains and megafan system, with emphasis on the Northern Pantanal, also known as Pantanal de Cáceres. Assine et al. (2015) reinforce the importance of plain systems when they point out that Pantanal is a sedimentary basin located in the Center-West of Brazil, characterized by the presence of a modern alluvial depositional tract, as well as by the interaction of several types of systems developed in one of the largest and most important wetlands of the planet.

The hydrographic basin area of the Sepotuba River, an affluent of the right bank, covers an area of 9.903,98 km². Also, important sectors of its system are superimposed by the territories of municipalities like Tangará da Serra and Cáceres, in the Southwest region of Mato Grosso. The main drainage of the area is represented by the Sepotubinha, Sepotuba, Maracanã, Sapo, Formoso, Jubinha, Juba and Tarumã rivers (Figure 1).

Figure 1. Location of the Sepotuba hydrographic basin, Upper Paraguay - Mato Grosso.



Org: the authors (2018).

Thus, the investigation of the Sepotuba river basin was based on its geomorphological context between the edges of the Chapada dos Parecis, the alluvial plains, its phytophysiognomy importance, considering the transitions between the Cerrado and the Amazon, as well as the contribution of its river system for the Pantanal (SILVA et al., 2011; SILVA et al., 2015).

Methodological Procedures

Studies on changes in plant cover are often based on spatial-temporal assessment (PESSOA et. al., 2013). As materials, images of the Landsat 5 and 8 satellites were used, with scenes 227/70, 227/71 and 228/70 from the years 1986 and 2016.

A geographic database was developed in SPRING software, version 5.2.6, by the Brazilian Institute for Space Research - INPE (CÂMARA et al., 1996), using the UTM system, 21S spindle and Datum Sirgas 2000. The images were imported in the BDG for the composition of the mosaic and its cut by the study area (mask).

Then, the segmentation method was performed using the region growth method, with similarity 100 and pixel area 150. Sampling/training, supervised classification (Bhattacharrya classifier) was performed, with 99.9% acceptance and matrix/vector editing. The mapping editing was done in ArcGis software, version 10.3 (ESRI, 2007), with the overlap of the RGB color composition of bands 4, 5 and 6.

The legend of the classes of land use and vegetation cover maps was defined based on research in the technical report of the Project on the Conservation and Sustainable Use of Brazilian Biological Diversity (BRAZIL, 2004) and the Technical Manual on Vegetation and Land Use (IBGE, 2012). In order to verify the reliability of the mapping generated with the Spring 5.2.6 and ArcGis 10.3 software, an accuracy evaluation was performed using the Kappa Index, which varies from -1 to 1, and the closer to 1, the more accurate the classification, as shown in Table 1 (COHEN, 1960; LANDIS; KOCH, 1977; SILVA, 2003).

Table 1. Quality of the classification associated with Kappa statistic values.

Kappa Index	Concordance
< 0	Terrible
0 – 0,20	Bad
0,20 – 0,40	Reasonable
0,40 – 0,60	Good
0,60 – 0,80	Very Good
0,80 – 1,00	Excellent

Source: Adapted from Landis and Koch (1977, p.165).

The Anthropic Transformation Index (ATI) was determined from the area percentages of the thematic classes quantified in the land use and the vegetation cover map of each sub-basin. The index was calculated using the formula: ATI = ∑(%USE X WEIGHT)/100.

Thus, in which: ATI = Anthropic Transformation Index; Use = area in percentage values of the class of use and coverage; Weight = weight given to different types of use and coverage regarding the degree of anthropic change - ranges from 1 to 10 (Table 2). The transposition of quantitatively measured values into qualitative classes occurred through the use of the quartiles method used by Cruz et al. (1998): slightly degraded (0,00 - 2,50), regular (2,50 - 5,00), degraded (5,00 - 7,50) and very degraded (7,50 - 10,00) (RODRIGUES et al., 2015).

Table 2. Weights attributed to the thematic classes of vegetation cover and land use.

Categories	Classes	Weights
Land use	Agriculture	8,00
	Urban influence	9,70
	Livestock	5,50
	Forestry	1,00
Vegetation cover	Ecotone	1,00
	Alluvial forest	1,00
	Submontane forest	2,00
	Lowlands forest	1,00
	Wooded Savannah	1,00
	Park Savannah	1,00
Water	Water slides	2,00

Source: the authors (2018).

Therefore, the ATI is constructed assigning values for each class of land use and vegetation cover that contributes to the transformation of the landscape, through the systematic consultation called "Delphi," which allows for a consensus on how to quantify the degree of landscape modification (SCHWENK; CRUZ, 2008). However, the values presented in this study were attributed by the authors based on the knowledge of the study area.

Results and discussion

The classification of land use and occupation, as well as vegetation cover, with representation in thematic maps, was verified by the error matrix, using the Kappa Concordance Index. The results obtained using the accuracy estimator for the classification performed in the years 1986 and 2016 are values considered to be excellent (K > 0,80), indicating that the classification reached the expected result (Table 3). The average confusion recorded for the year 1986 occurred associated with the transition between the Ecotone and the Alluvial Forest.

Table 3. Results obtained for the classification of land uses and cover.

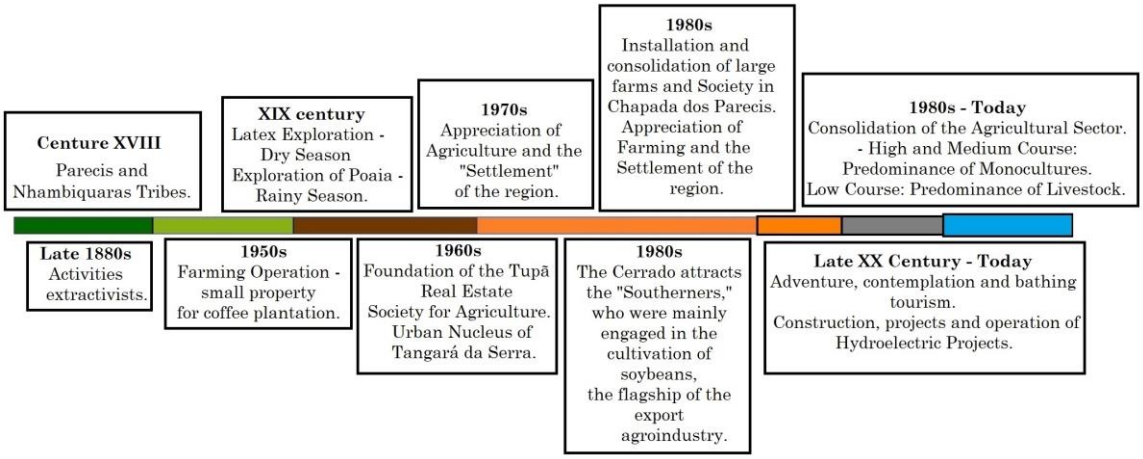
Year	General Performance	Average Confusion	Kappa Index
1986	94,42%	5,58%	0,92
2016	100%	0%	1,00

Org: the authors (2018).

Advancement of economic arrangements: the role of the agricultural sector

The state of Mato Grosso was economically consolidated as one of the Brazilian flagships, with support in the exploration of its lands. That way, Dubreuil et al. (2005) contextualized the evolution of the so-called "pioneering conquest," as in the social-spatial dynamics in the Center-West of Mato Grosso (Figure 2). It should be noted, therefore, the agricultural and livestock consolidation applied to important river systems that previously contributed to the non-indigenous colonization of the region. For such, the implementation of important projects such as the Incentive Plans "Nova Amazônia" and Polocentro were fundamental (DUBREUIL et al., 2005).

Figure 2. Synthesis of the stages and occupation plans in the region superimposed on the Sepotuba river basin, Upper Paraguay - Mato Grosso.



Adapted from: Dubreuil et al. (2005).

Six types of vegetation cover, three forms of land use and occupation were identified through the spectral analysis, as well as the water slides for the year 1986. Considering the totality of the Sepotuba river basin, it was possible to verify that the economic matrix is focused on agricultural activities, mainly with regard to the extension of areas occupied by the sector and their expansion.

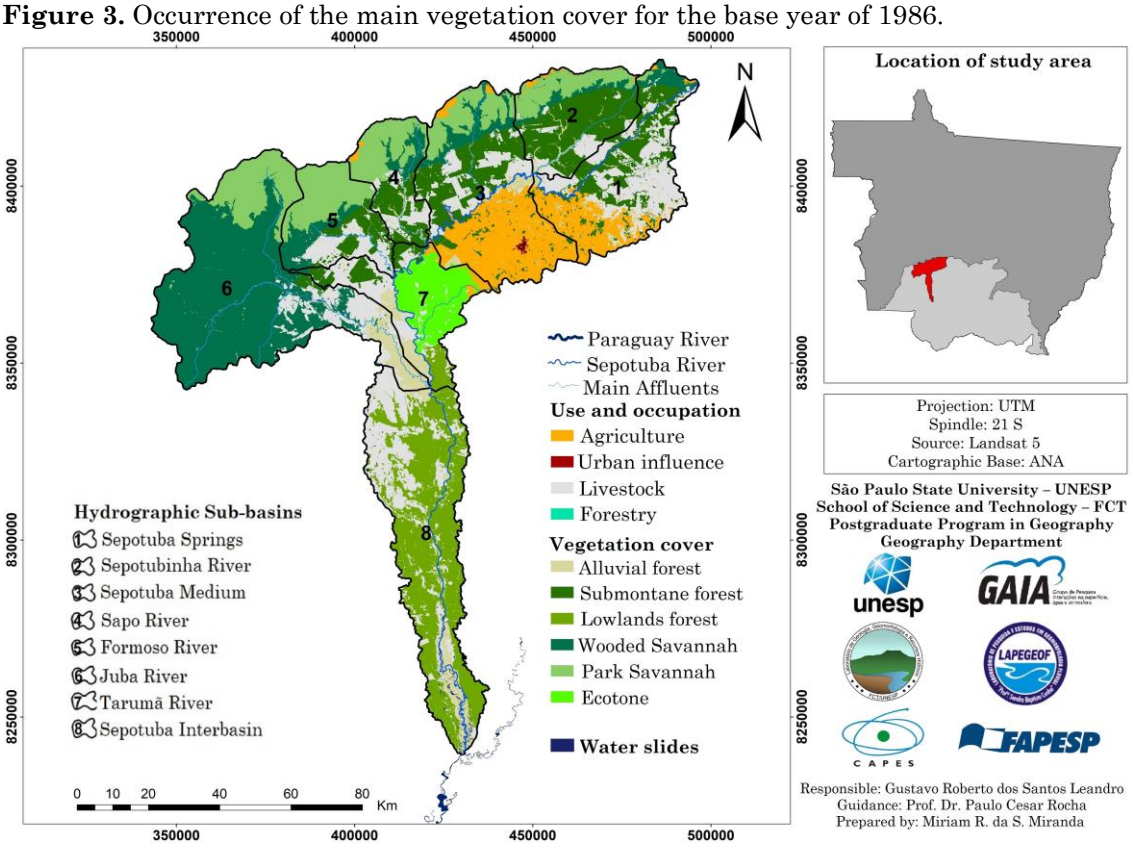
However, the introduction of land use and its occupation occurred in different ways, depending on the river basin sectors. Therefore, the segmentation of its system by river sub-basins allowed the detailed identification of each use dynamic, as well as its peculiarities.

Portions intended for agriculture for the year 1986 were concentrated in units 1 - Sepotuba Springs and 3 - Sepotuba Medium (24,54% and 39,86%, respectively). Initially, this phenomenon was directly related to the influence of Tangará da Serra. More precisely, with the lease of the urban site - sub-basin 3 - Sepotuba Medium (Figure 6). According to Dubreuil et al. (2005), the municipality tends to establish itself as a regional hub concentrating essential services. Most large farmers opt, respectively, for living and installing their administrative headquarters in Tangará (DUBREUIL et al., 2005).

Also, agricultural areas, initially fragmented, were identified in Units

2 and 4, inserted in bedside compartments between Chapada dos Parecis and the escarpment system, and also between the Tapirapuã Plateau (Unit 7 - Tarumã river), providing continuity to the agricultural areas of Unit 3 (Figure 3). As pointed out by Dubreuil et al. (2005), the agricultural production areas in Mato Grosso are divided into three main poles, and the region of Chapada dos Parecis is an important producer.

Figure 3. Occurrence of the main vegetation cover for the base year of 1986.



Legend adapted from PROBIO (2004) and IBGE (2012).
Org: the authors (2018).

In this sense, the use and occupation of land in the Sepotuba river basin play a fundamental role in the transformations and changes in its landscapes. Therefore, firstly, the removal of the vegetation cover, which can generate a series of processes, such as the decrease of biodiversity.

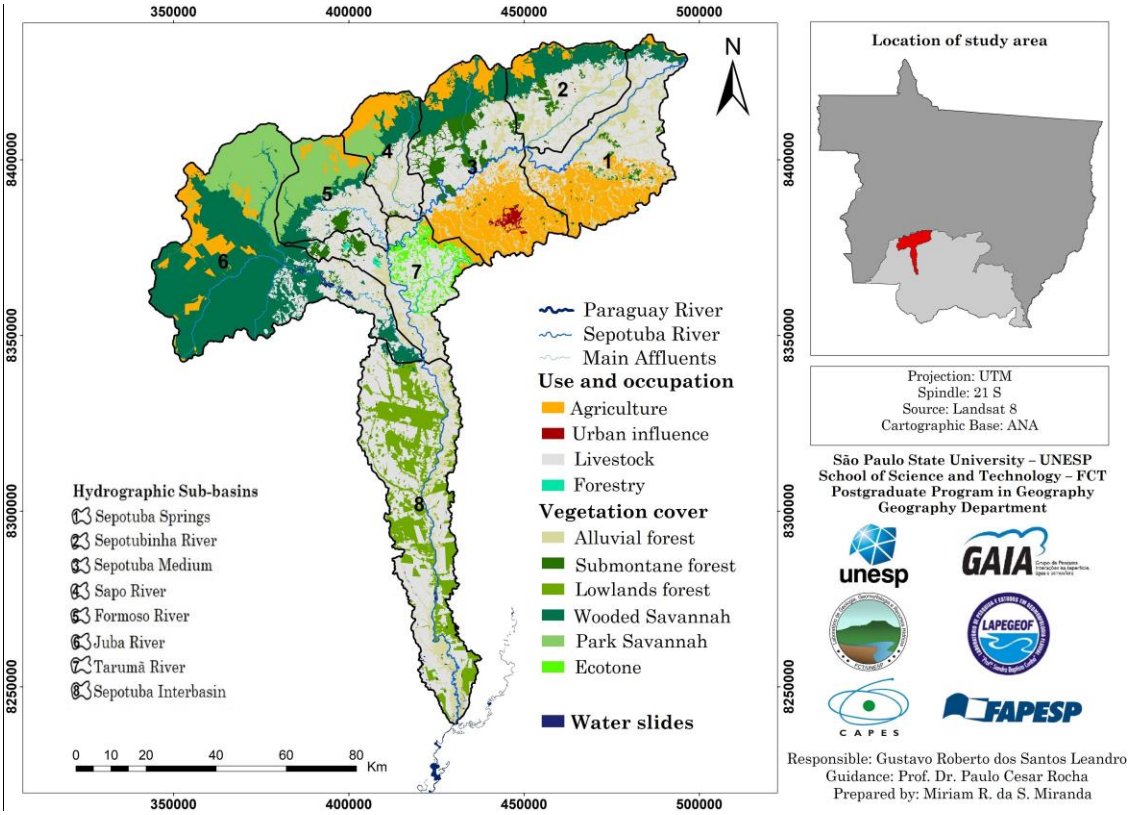
According to Schwenk and Cruz (2008), the improper technique on the Mato Grosso soils, brought by immigrants from the south and southeast regions, resulted in a negative response by the environment, which later led

to the search for the most appropriate use, besides correction of soils. Also, by transforming poor soils into productive soils, coupled with low land prices, there has been accelerated progress in the production of highly technified soybeans on the vast plains of the Plateau and the Chapada dos Parecis.

In the year 2016, the agricultural domain in the region and the important changes in the vegetation cover were evident (Figure 4). As a consequence, extensive areas were deforested for the introduction of pasture and agriculture, expanding the monoculture domain. In the BPA, the economic relations anchored in its agriculture have recorded, through several studies, an advance in the last three decades. However, Forestry starts to comprise the forms of use and occupation of land in the Sepotuba river basin (Unit 7).

In the upper reaches of the Sepotuba River, especially in the Chapada and Parecis Plateau compartments, the predominance of agricultural activity is observed. However, the distinction between agriculture in the Chapada and cattle raising in the Plateau is clear. Farias (2012) pointed out that, in relation to the use and occupation in the Sapo Basin - an affluent of the right bank of the Sepotuba River, it is possible to observe a great prominence for agricultural activity. In general, it can be observed that in the context of agricultural use, cattle farming is the main economic activity, especially through the farming by an extensive system, which uses pasture as the main food.

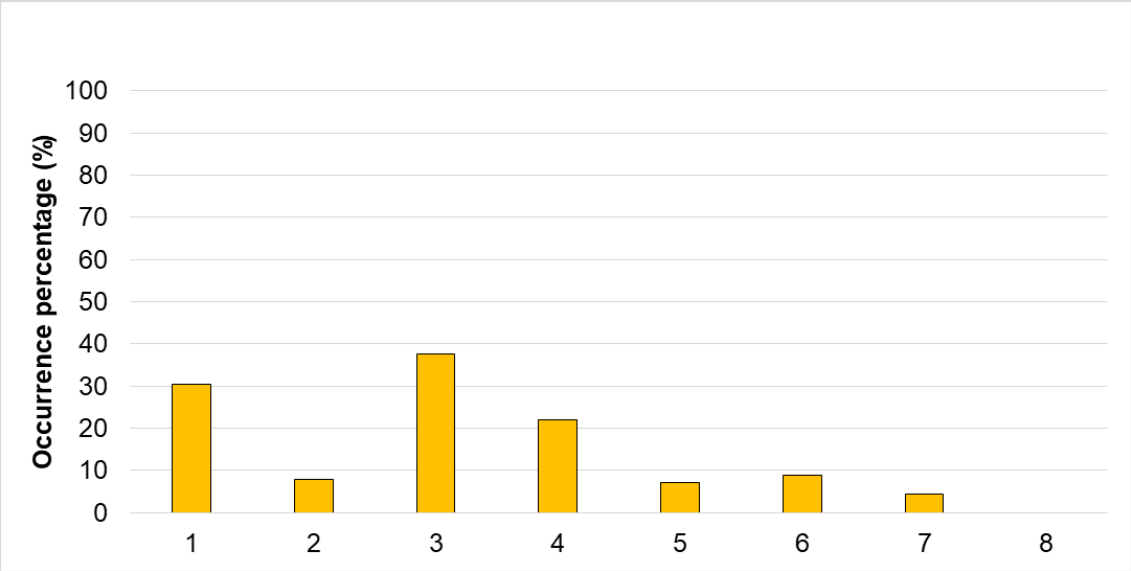
Figure 4. Main classes of use and current coverage for the base year of 2016, denoting the expansion of the occupied areas, thus, consequently, reduction of natural formations.



Legend adapted from PROBIO (2004) and IBGE (2012).
Org: the authors (2018).

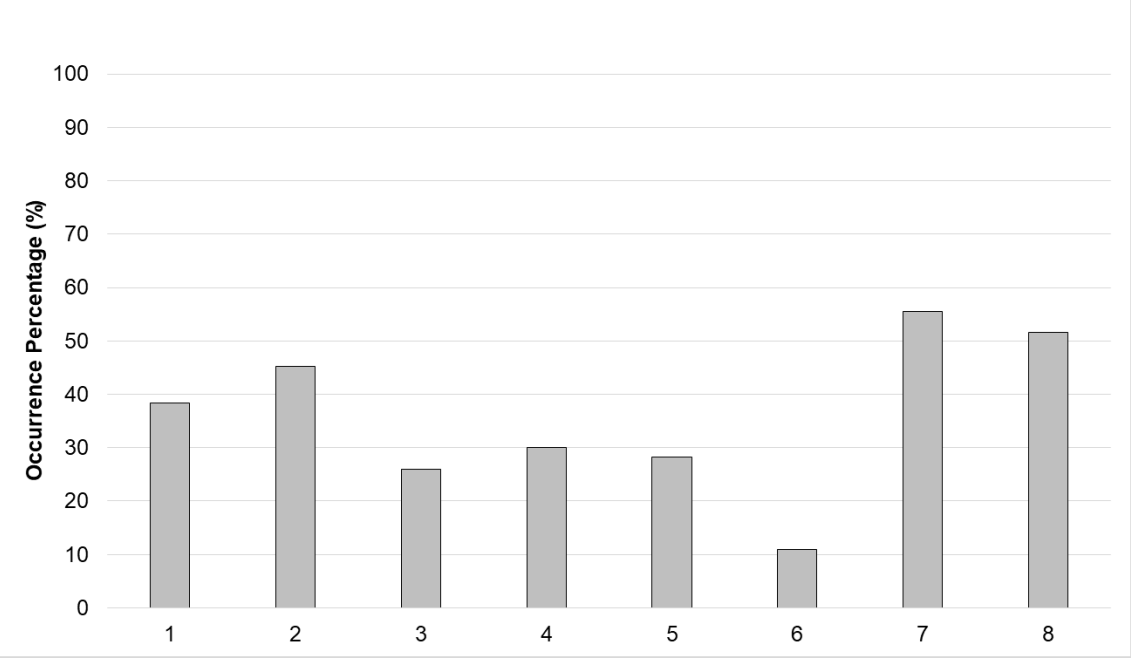
Therefore, in addition to monocultures, the Livestock sector occurs in all subunits. The areas destined to the pasture occurred mainly in its central axis emphasizing the average and low course of the affluents. Therefore, cattle use in the 1980s was already present, becoming more intense in important morphological compartments. In this case, it's necessary more attention to the Units 1 and 2 - drainage headland, as well as to transition areas - Ecotone in Unit 7, considering that more than 55% of its area was converted to pasture (Figures 5 and 6).

Figure 5. The occurrence of agriculture in 2016, by sub-basin. 1 - Sepotuba Springs; 2 - Sepotubinha River; 3 - Sepotuba Medium; 4 - Sapo River; 5 - Formoso River; 6 - Juba River; 7 - Tarumã River and 8 - Sepotuba Interbasin.



Org: the authors (2018).

Figure 6. The occurrence of livestock in 2016, by sub-basin. 1 - Sepotuba Springs; 2 - Sepotubinha River; 3 - Sepotuba Medium; 4 - Sapo River; 5 - Formoso River; 6 - Juba River; 7 - Tarumã River and 8 - Sepotuba Interbasin.



Org: the authors (2018).

According to Abdon et al. (2007), in the Pantanal, the predominant activity is extensive cattle raising (raising and restocking) with more than

three million head of cattle, whose food base is native pasture. Thus, Cáceres has an important role in the sector (MIRANDA et al., 2018; SILVA et al., 2011). Therefore, we highlight the relationship between the advance of pasture and livestock in the low course of the Sepotuba river, considering the municipal influence, from the territorial point of view, as mentioned in Unit 8, as well as from the economic point of view. Miranda et al. (2018) identified a growth of the sector in the order of 29,44%, in the period from 2003 to 2013, in the municipality.

The municipality of Cáceres, the oldest in the region, founded in the 18th century, not only has the largest regional cattle herd in the State but ranks fourth in the national ranking. The characteristics of its natural framework point to livestock farming as inherent to the productive scenario and, consequently, to the socioeconomic group of the region. This places cattle ranching as an important element within the so-called "regional vocations" of Mato Grosso (FERREIRA, 2017; SOARES et al. 2017).

Also, according to Soares et al. (2017), the topography of the relief, as well as the abundance of water and the natural pastures of the great plains, contributed to the development of livestock as an economic activity, responsible for a large portion of the municipal Gross Domestic Product. Regarding the collection, Cáceres has two main sources: Services and Livestock. It should be noted that the former is directly related to the latter.

Negative impacts were identified associated with livestock use, especially in the low course - Unit 8. Regarding the main channel, erosive processes occur naturally; however, at various points, there was an intensification of the marginal erosion associated with access and cattle trampling, according to field verification. Miranda et al. (2018) also highlighted the role of burnings as soil management practices with influences on the vegetation cover of the Forests and Cerrados occurring in the compartments of the River Terraces of the Sepotuba River.

The impacts of the current productive model

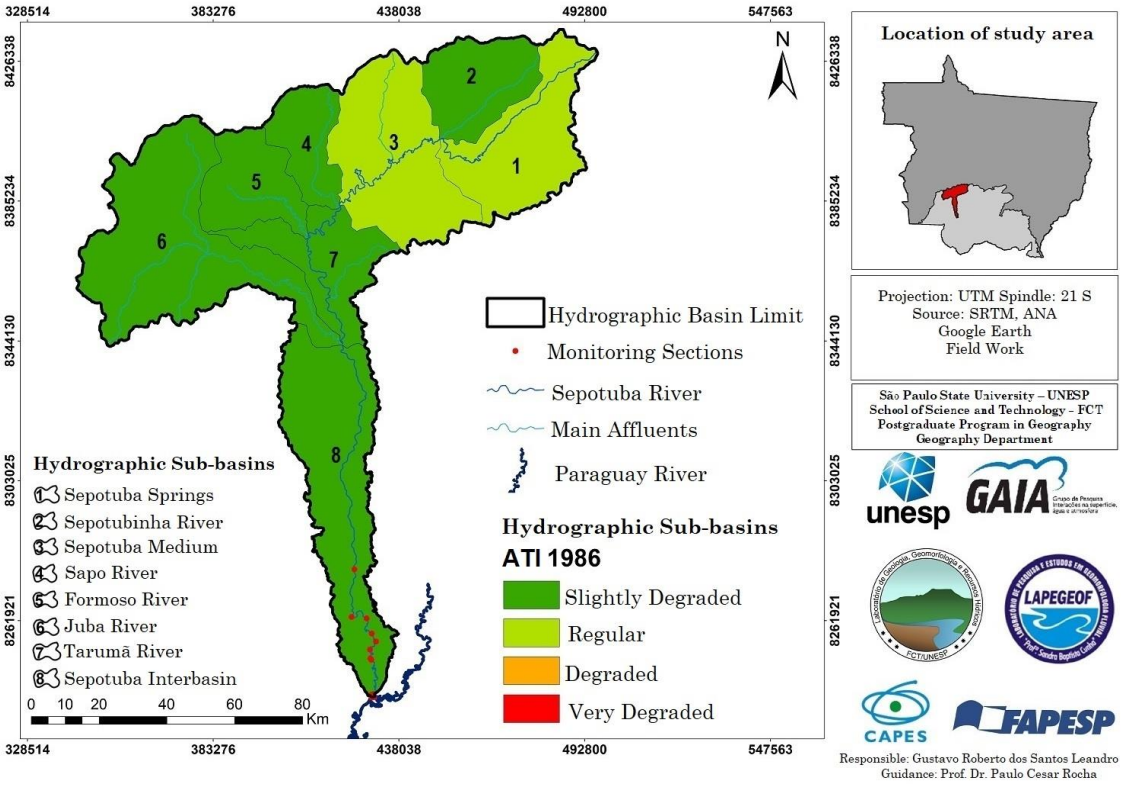
The use of indicators is of great importance as they are valuable instruments in the analysis of information on the environment. Furthermore, they collaborate in the execution of the territory's structuring (PÉREZ; CARVALHO, 2012). Therefore, according to the authors, the planning and management approaches that use the basin as the basic unit are more adequate for the compatibility of production with environmental preservation.

In this context, Lorenzon (2016) evaluated the relationship between the dynamics of use and the level of degradation in the hydrographic basin of the Cabaçal river, an affluent adjacent to the Sepotuba river. According to the author, in 1984, the basin presented a Regular state, having advanced to Degraded in some of its sub-basins. So, the forecast for the end of this century becomes worrying. If some recovery and monitoring measures are not taken, the Cabaçal river system will reach the Degraded state (LORENZON, 2016).

About Sepotuba River, different stages of appropriation, according to the conditions of each sub-basin, were identified from the ATI. Of the eight units mapped, six showed a change of class for the period between 1986-2016. In the land use assessment of 1986, six sub-basins were classified as Slightly Degraded, a condition different from that identified by Lorenzon (2016) for the Cabaçal River. Four units are areas that form important affluents.

However, Units 1 - Sepotuba Springs and 3 - Medium Sepotuba, for this year, already had a Regular condition due to the intense agricultural use in their sub-basins (Figure 7). We recall the changes in structures from small to medium and large monoculture properties, as well as the role of Tangará da Serra in the process of appropriation.

Figure 7. Anthropogenic Transformation Index referring to the land use and land cover mapping of 1986, Sepotuba river basin, Upper Paraguay River - Mato Grosso.



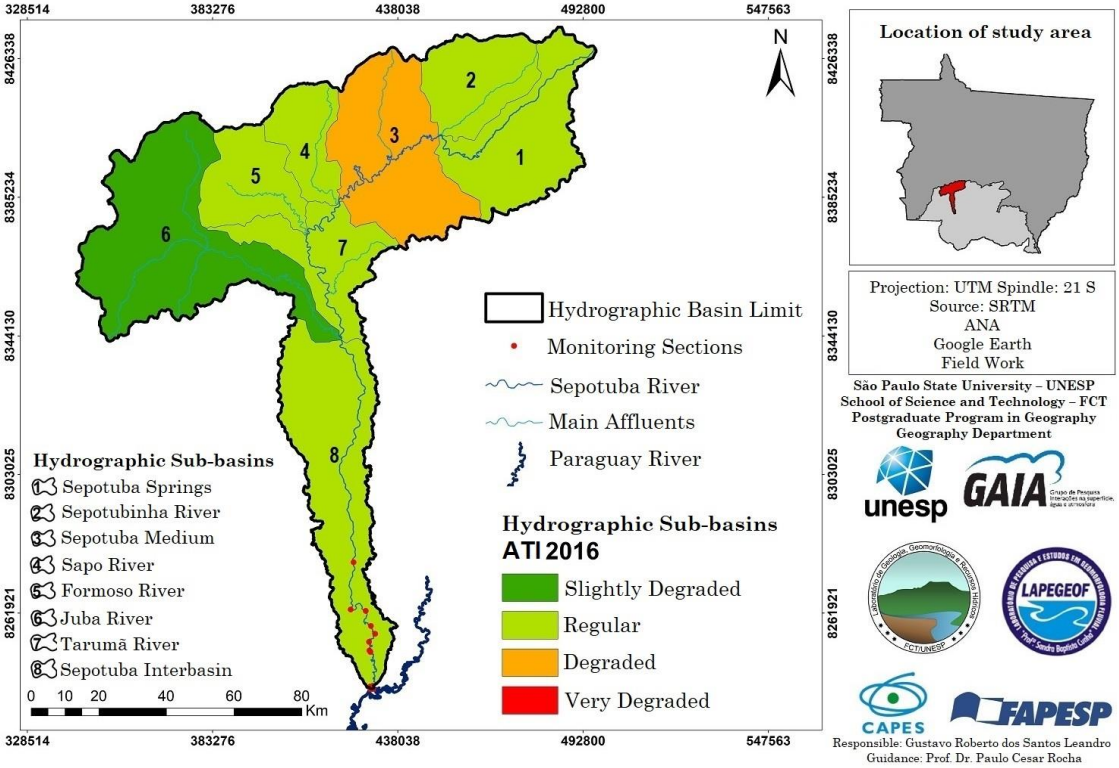
Org: the authors (2018).

For the year 2016, it can be observed that the only unit still classified as Slightly Degraded was Unit 6 - corresponding to the sub-basin of Juba river. We also point out that this was the only one that did not present a change in the ATI obtained in 1986.

However, it is necessary to observe the proximity of the values and the possible change of classification according to the intensification of the land use and occupation to the detriment of the vegetation cover. Unit 1, which corresponds to Sepotuba Springs, for example, presented a value of 4,84 for the year 2016. Thus, it is possible that it may change to the Degraded class (values between 5,0 - 7,5) when it is related to the high land use index, with more than 68% of its area occupied by Livestock and Agriculture. Also, its sub-basin needs to be considered because it presents the highest percentage of the Alluvial Forest class (more than 24% for the year 2016). Therefore, the importance of recovery and conservation plans for

the unit is verified (Figure 8).

Figure 8. Change in the Anthropogenic Transformation Index referring to the land use and land cover mapping of 2016, Sepotuba river basin, Upper Paraguay River - Mato Grosso.



Org: the authors (2018).

Also in relation to ATI - 2016, the role of the advance of the use in Unit 3 - Medium Sepotuba - change from Regular to Degraded, is evident. Studies of important affluents that drain this unit corroborate the relationship between land uses and class change. Gouveia et al. (2013) found that more than 80% of the Bezerro Vermelho stream basin presented an anthropogenic status in 2011. Rodrigues et al. (2015) reported that the Queima-Pé river also presented a similar condition with a Regular-Degraded variation.

In Unit 8, the Sepotuba River Interbasin, the main vegetation cover is associated with depositional environments, such as River Terraces and Flood Plain. According to the ATI, the respective unit was classified as Regular. The indicator with the greatest weight was Agriculture (8 points), an economic activity not developed in this unit due to factors associated

with flood dynamics. However, the second activity with greater representativeness is the main form of use in the unit, since livestock is responsible for the occupation of more than 50% in the interbasin of the Sepotuba river (Table 4).

In Table 4, the area of the Alluvial Forest increased, an inverse process when considering the reduction dynamics in the other vegetation covers, as well as the Wooded Savannah - Sa in some units of the river basin. In fact, its succession may be related to transitions of use or even to the advance of pioneer species on sediment deposits when considering its occurrence along the river channels. Another important change in the landscape is related to the occurrence of water slides. Area increase occurred in Units 4, 5 and 6. However, it has an association with reservation practice and not natural availability. On the other hand, the reverse process occurred in the other units, with a significant reduction, especially in Unit 8, where the dynamics between the channel and the floodplain are striking.

Table 4. Changes in the Landscape with losses and accumulations by units (sub-basins) for the 1986-2016 period.

Classes (1) Km²	1	2	3	4	5	6	7	8	Balance 30 years
Land use and occupation									
Ag	+ 73,78	+ 48,80	-33,61	+112,46	+50,08	+201,86	-0,01	0	Increase
Ap	+ 18,14	+ 276,18	+224,16	+87,13	+40,93	+16,17	+282,54	+445,59	Increase
Sc	0	0	0	0	0	0	+6,53	0	Recovery
Iu	+ 0,02	+0,16	+27,63	0	0	0	0	0	Increase
Vegetable covers and water									
Fa	+260,44	+118,90	+104,80	+48,64	+40,49	-59,55	+48,11	+86,33	Succession
Cs	-330,73	-384,06	-197,43	-139,14	-101,73	-17,79	-59,54	0	Reduction
Fb	0	0	0	0	0	+0,29	-65,93	-533,49	Reduction
Sa	-12,79	+133,75	+81,59	+34,62	-17,90	-256,33	+9,88	+9,99	+ Reduction
Sp	-7,72	-193,67	-198,48	-144,48	-12,24	+101,62	0	0	Reduction
Ecotone	0	0	-7,43	0	0	0	-221,15	0	Reduction
Water	-0,27	0	-1,00	+0,76	+0,37	+13,88	-0,42	-7,94	Increase

(1) Ag: Agriculture; Ap: Livestock; Sc: Forestry; Iu: Urban influence; Fa: Alluvial forest; Cs: Submontane seasonal deciduous forest; Fb: Lowlands Forest; Sa: Wooded Savannah; Sp: Park Savannah (PROBio, 2004; IBGE, 2012). **Org:** the authors (2018).

In general, the main economic activity in the Sepotuba river basin is Livestock, followed by Agriculture, in 1986 and 2016, with the exception of Unit 3 - Sepotuba Medium. In Unit 7, the Tarumã river, the sector is responsible for the occupation of more than 55% of its area. Therefore, even

with lower scores in the ATI, livestock has an important role in relation to the dynamics of use and occupation in Units 7 and 8. Therefore, it is essential to recover and maintain the vegetation cover in all units, especially due to the important role it plays in the conservation of river channels and Water Resources (irrigation, animal watering and hydroelectric production).

Final Considerations

This study demonstrated that the use and coverage are an important variable to be considered for territorial planning, since they incorporate important sectors of the Sepotuba river basin - spring areas and flood channel-plain.

It is evident that the transformations in the Sepotuba river basin have intensified in the last thirty years when compared with previous periods. The time cut was marked by the following periods: 1970-1980 with colonization, mainly southern; 1980-1990 with intensification and advance of the uses, associated with changes in vegetation cover; 1990 - current increase in grain production and cattle herd, as well as the start of projects focused on the hydroelectric sector (2000s).

The municipalities of Cáceres and Tangará da Serra play an important role when considering the forms of use in the Sepotuba river basin. The first is highlighted by the Livestock sector and its progress on the low course of the Sepotuba River basin. The latter is considered an important pillar of the monoculture sector in the upper and middle course. In this sense, the regional pole role of the two municipalities directly influences the economic dynamics and land-use methods.

Environmental aspects such as soil types and morphological units of the area pre-indicate their fragility to human interventions. The use of the Anthropogenic Transformation Index allowed for the qualification of environmental degradation levels in the Sepotuba river basin, based on the

land uses and cover previously identified. Thus, the application of the methodology evidenced changes in six of the eight sub-basins analyzed.

Therefore, all sub-basins present disturbing levels of change, even Unit 6 - Juba River, classified as Slightly Degraded due to the Hydroelectric Complex already installed in its system. In this sense, prevention and recovery should be considered in order to avoid greater impacts or, in addition, their transfer with the production of downstream sediments.

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