International Journal of Hydrology

Research Article

Open Access

Spatial-temporal dynamics of vegetation cover, land use and anthropogenic transformations of landscape in the Cabaçal river basin, Mato Grosso state, Brazil

Abstract

The landscapes are suffering intrinsic changes to the shape of land use, causing increasing forest removal for the insertion of agricultural/livestock activities. This study aimed to evaluate, within the spatial-temporal perspective and through geo-technologies, vegetation cover, land use and anthropogenic transformation of the landscape in the Cabaçal river basin, Mato Grosso state (Brazil). The images were geo-referenced, classified and processed using the SPRING software, and the thematic classes quantified and edited with the ArcGIS software. The degree of human disturbance was verified through the Anthropogenic Transformation Index. It identified ten classes related to land use and vegetation cover. During the analyzed period of 29 years, the vegetation cover was reduced in all subbasins of the study area for livestock development, with an increase of 237% for this activity. At the subbasin *Nascentes do rio Cabaçal* there was an increase of 56.77% from this land use, resulting in the deforestation of both *Amazon* and *Cerrado* biomes. The ATI has shown that forest removal increases gradually, classifying the landscape conservation status of the basin as "Regular". The *Interbacia do rio Cabaçal*, located in the *Amazon* and *Pantanal* biomes, increased by 71.64% in the degree of human disturbance. The projection shows that for the year 2080 the degree of human disturbance is foreseen as "Regular". For the year 2100 the projection demonstrates an Anthropogenic Transformation Index of 5.43 for the basin area as "Degraded", which may result in a substantial loss of the remainder from the *Cerrado*, *Amazon* and *Pantanal* biomes.

Keywords: environmental conservation, landscapes, deforestation, anthropogenic transformation

Volume 6 Issue 2 - 2022

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Received: April 04, 2022 | **Published:** April 20, 2022

Introduction

The current economic model imposed by the need for growth has caused serious changes in natural landscapes. The expansion of Brazilian agriculture affects crucially the modification of ecological scenarios, causing losses of vegetation covered areas and consequent alteration of habitats. The process of occupation and consolidation occurred by the advance of agricultural frontiers encouraged by public policies that fostered the opening of spaces in Mato Grosso state for agriculture activities.[1] Greggio et al.[2] point out that this event resulted in the degradation, fragmentation and depletion of forest resources. In this context, Mato Grosso state has been undergoing intense changes of natural vegetation due to the implementation and expansion of agricultural/livestock activities and consequently this federative unit suffered most under this reality. From 1998 to 2008 over 135,000 km^2[3] were deforested there, constituting one of the major concerns regarding the causes of environmental degradation of this State. The replacement of native vegetation for the insertion of pastures aiming at livestock and agricultural development has caused severe deforestation and fire, causing serious environmental damage throughout Brazil.[4]

Knowledge of the land use dynamics is essential for proper management of geographic and environmental space. According to Flores et al.,[5] the diagnosis of landscape transformations allows us to infer trends and future scenarios. The Brazilian status of current forest removal has aroused attention in all segments, whose lack of environmental planning for agribusiness and small farms led to the formulation of new policies for the environmental conservation.

In order to do that, the adoption of a river basin as the management and planning unit is essential for the conservation, characterization and environmental assessment, because of its importance to maintain life, considering the fragility of human actions.[6] In this context, Tonello et al.[7] defined that the basin constitutes the most appropriate planning unit for use of natural components, because its unchangeable borders are located within the horizon human engineering, which facilitates monitoring of natural changes introduced by man regarding land use and occupation. Considering this perspective, it is inferred that the inappropriate land use and occupation may compromise the integrity of watersheds.[8] The application of geotechnologies have the potential to provide detailed information about the geo-environmental characteristics of the basin under study, constituting, according to Nascimento et al.,[9] an important resource for monitoring deforestation and land use.

The Anthropogenic Transformation Index (ATI) developed by Lémechev[10] and implemented in geo-ecological studies to measure the anthropogenic load level on the landscapes[11–14] provide results about the conservation status of native vegetation areas and from those of former land use. In this frame, this study aimed to evaluate the vegetation cover, land use and anthropogenic transformation of the landscape, in the Cabaçal basin, Mato Grosso state, considering a space-time perspective through geo-technology. For this purpose, a projection for the scenario to be found by the year 2100 was proposed, due to the representativeness of the *Cerrado*, *Amazon* and *Pantanal* biomes in the basin, so that interventions are based on information, to allow a proper management, considering the social-environmental dynamics that influence the Upper Paraguay Basin.

Material and methods

Area under study

This study was conducted in the Cabaçal river basin (CRB), located in the SW Planning Region of Mato Grosso state,[1] with an area of 5,655 km[2] distributes in 10 municipalities: *Reserva do Cabaçal, Salto do Céu, Rio Branco, Lambari D'Oeste, Curvelândia, Araputanga, São José dos Quatro Marcos, Mirassol D'Oeste, Tangará da Serra* and *Cáceres* (Figure 1).

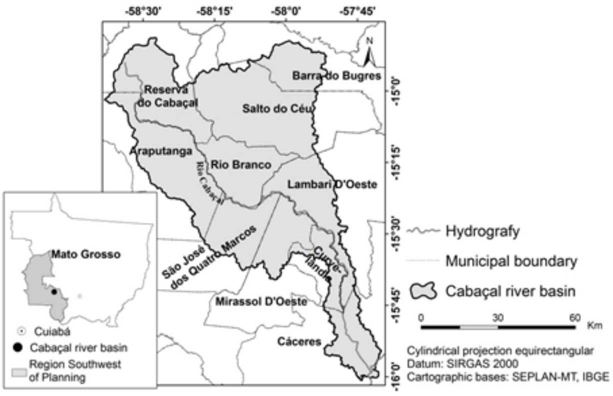

Figure 1 CRB within the SW Mato Grosso state Planning Region and its municipalities.

Source: Labgeo Unemat (2015).

Within the limits of the basin the following three Brazilian biomes occur: Amazon (83.03%), Cerrado (12.22%) and Pantanal (4.75%). CRB is contained in a large region of the Paraguay River, a fact that makes it one of the main basins of the environmental system of the Upper Paraguay (BAP).[14] The climate in the CRB is humid Tropical and Tropical Continental alternately wet and dry, with annual average rainfall between ranges from 1400 the 2,100 mm and the main climate feature is its regularity. According to the Koppen classification, the CRB is inserted in the climatic unit of type AW humid tropical, with dry seasons that can last five months and rainy seasons for seven months, with the average temperature of the coldest month at 18°C and the average of the warmest temperature is around 25°C.[15] The relative humidity varies from 70% in the rainy season to approximately 50% in the dry season.[16]

The relief is flat to gentle rolling, occurring in the following geomorphologic units: Upper Paraguay Depression, *Parecis* Plateau and Mato Grosso Wetlands (IBGE 2006). According to RADAMBRASIL (BRASIL, 1982), the predominant geological aspects are "marked by geological formations dating from the lower Precambrian (*Complexo Xingu*), from the Upper Precambrian to the Cenozoic (Upper Paraguay Group), Mesozoic-Cretaceous/Tertiary (*Parecis* Group) and Quaternary (current and ancient alluvium)." The Pedology is composed mainly by Typic Paleudalfs, followed by Ferralic Arenosols.[17] A CRB has a population of 201,587 inhabitants (IBGE 2015) and the economy of the municipalities within this hydrographic unit is essentially based on agriculture/livestock.

Methodological procedures

For the elaboration of vegetation cover/land use maps LANDSAT-TM 5 images, orbit/points 227/71, 228/70 and 228/71 were used, for the years 1984, 1993 and 2003. The spatial resolution of these images is 30 m and radiometric resolution 8 bits. They were obtained from the Brazilian National Institute for Space Research (INPE) Catalogue.[18] Images for the year 2013 from the Operational Land Imager Sensor (OLI), aboard LANDSAT-8 were obtained from the image catalogue of the United States Geological Survey.[19] These data have a 16-bit radiometric resolution. The image data-takes were: July 15th 1984, July 21st 1993, July 26th 2003, July 14th 2013, from the dry period, due to a lower presence of clouds, allowing the image classification and interpretation. Using software SPRING, version 5.2.6, from INPE,[18] a Geographic Databank (GDB) was created, system UTM, Zone 21S and Datum SIRGAS 2000. At the GDB images were imported for the preparation of the mosaic and to clip the area under study (mask).

Afterwards, segmentation was performed with the region growth method, with similarity 800 and pixel area of 1,200 for the scenes of LANDSAT-8, and similarity 10 and pixel area 10 for LANDSAT-5 scenes, followed by sampling/training, supervised classification by Bhattacharrya classifier, with 99.9% acceptance and matrix/vector editing. Editing of the maps was done with the ArcGIS software, version 9.2,[20] with overlapping RGB color composite of bands 6, 5, 4 of LANDSAT-8 data and 5, 4, 3 for LANDSAT-5 images. The definition for the legend of the land use/vegetation cover map classes was defined after research in the technical report of the Project Conservation and Sustainable Use of Brazilian Biological Diversity - PROBIO (Brasil 2004) and the Technical Manual of Vegetation and Land use (IBGE 2012), as follows: Fa: Alluvial Forest; Fs: Seasonal deciduous sub-montane forest; Sa: Wooded Savannah; Sd: Forested Savannah; Tp + Sa: Park Savannah + Wooded Savannah; Ag: Agriculture; Iu: Urban Influence

Ap: Livestock; Sc: Forestry.

The map validation was done by GPS (Global Positioning System) points, photos, and verification on high resolution images, available at Internet (Google Earth), for those places with difficult access. The quantification of land use/vegetation cover classes was carried out for each subbasin using ArcGIS,[20] as well as for the preparation of layouts from the maps.

The Anthropogenic Transformation Index (ATI) was determined from percentages of areas of quantified thematic land use/vegetation cover classes from each subbasin. Those areas occupying less than 1% were not considered. The calculation of this index was made, using the following equation:

$$ATI = \sum (\%USE \; x \, WEIGHT)/100 \qquad (1)$$

where:

USE = percentage area of class land use/vegetation cover;

WEIGHT = weight given for the different types of land use/vegetation cover regarding the degree of anthropogenic change, varying from 1 to 10. The highest pressures are indicated by value 10.

The weights can be obtained by the Delphi technique, which advocates the consensus of experts to determine this index. In this study however, they were defined by the author because of her knowledge from the area under study regarding the degree of human modifications of it, as suggested by Mateo[11] and literature analysis. Table 1 shows the values of weights assigned to the thematic classes of the area under study.

According to the level of anthropogenic transformation from the basin, quartiles were defined for the classification of the landscape conservation status, as follows: Slightly Degraded (0 to 2.5), Regular (2.5 to 5), Degraded (5-7, 5) and Very Degraded (7.5 to 10).

Table 1 Weights assigned to thematic classes land use/land cover

Categories	Classes	Weights
Land Use	Agriculture	7
	Livestock	5
Land cover	Alluvial Forest	1
	Wooded Savannah	3
	Forested Savannah	1
	Park Savannah and Wooded Savannah	4

A regression analysis was performed to predict the landscape change states in the basin under study over time. According to Guimarães[5] this type of mathematical equation is scoped to explain satisfactorily the relationship between a dependent variable and one or two explanatory variables, allowing predictions for the values of the variable of interest, in this case the anthropogenic effects on the landscape of Rio Cabaçal basin. So, forecast calculations were made for every 20 years, using the values measured by ATI, until year 2100, presenting the possible landscape statuses due to anthropogenic load in the basin, considering that there is no change in the way the society uses and manages the land as well as the interference from natural phenomena.

Results and discussion

The land uses are related to the thematic classes Agriculture, Urban Influence, Livestock and Forestry, which occupied in 2013, nearly 68% of the land area from the basin, and since the 90's covered over 50% of the investigated area (Figure 2 and Table 2). The anthropogenic process is distributed throughout the entire basin, and its occupation is more accentuated as the expansion of agricultural activity occurs along the years.

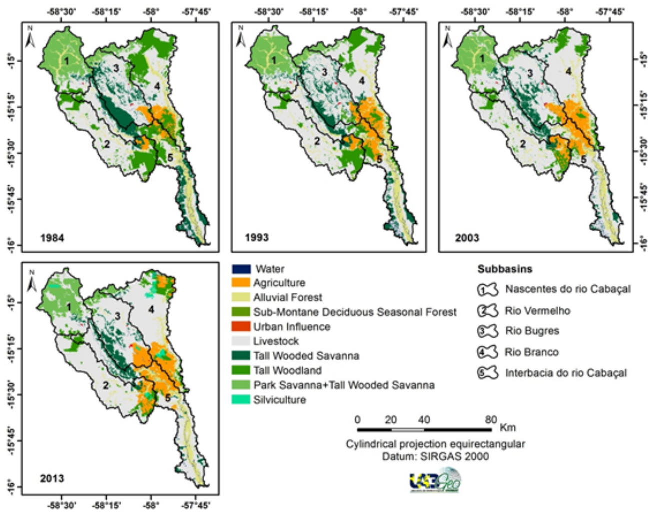

Figure 2 Vegetation cover and land uses in five subbasins of CRB during four decades.

Source: Labgeo Unemat (2015).

The natural vegetation of the CRB includes parts of the *Cerrado*, *Pantanal* and *Amazon* biomes. It has been gradually suppressed and replaced by exotic grasses to form pastures needed for the development of agriculture, especially for livestock and dairy activities, and in recent years by the monoculture of sugarcane. The sugar cane crops are highly adapted to the conditions of Mato Grosso state.[21,22]

Table 2 Vegetation cover and land use in hydrographic units of CRB

Subbasins (ha-1)	Class[(1)]	Area (ha^{-1})				Dynamics (%)
		1984	**1993**	**2003**	**2013**	
Nascentes do rio Cabaçal	Fa	6.427,90	5.840,55	5.006,09	535,99	-91,66
(82.931,51)	Fs	-	-	-	-	-
	Sa	2.628,83	2.404,41	2.201,54	1.925,61	-26,75
	Sd	4.169,73	2.931,77	2.862,94	2.112,40	-49,33
	Sp+Sa	53.760,77	47.789,60	43.240,92	40.713,55	-24,26
	Ag	-	-	-	-	-
	Iu	66,30	73,20	78,71	94,05	41,85
	Ap	15.795,33	23.869,99	29.520,54	36.545,25	131,36
	Sc	-	-	-	985,48	-
	Water	82,66	21,80	20,57	18,99	-77,02
Rio Branco (88.667,08)	Fa	1.664,09	1.647,44	1.423,87	869,14	-47,92
	Fs	-	-	-	-	
	As	26.261,48	22.341,25	18.318,76	13.398,27	-48,98
	Sd	3.662,65	3.163,42	2.140,69	2.011,33	-45,09
	Sp+Sa	6.805,82	6.341,99	5.086,08	4.458,56	-34,48
	Ag	4.341,00	3.818,20	5.467,86	7.353,25	224,62
	Iu	201,34	282,26	346,02	365,78	81,67
	Ap	45.412,03	50.757,97	55.573,80	59.565,18	31,16
	Sc	-	-	-	407,88	-
	Water	318,69	314,56	310,00	237,69	-25,41
Rio dos Bugres (118.207,60)	Fa	4.146,87	4.119,85	3.988,33	3.868,80	-6,70
	Fs	723,69	686,57	527,01	482,41	-33,34
	As	3.918,79	2.902,73	2.537,21	2.114,50	-45,27
	Sd	30.058,95	24.005,73	14.879,30	11.278,83	-62,47
	Sp+Sa	-	-	-	-	-
	Ag	3.216,52	4.836,83	9.243,21	10.631,24	230,51
	Iu	-	-	-	-	-

Citation: Lorenzon TH, Galvanin EADS, Neves SMADS, et al. Spatial-temporal dynamics of vegetation cover, land use and anthropogenic transformations of landscape in the Cabaçal river basin, Mato Grosso state, Brazil. *Int J Hydro.* 2022;6(2):79–86. DOI: 10.15406/ijh.2022.06.00305

Table Continued...

Subbasins (ha-1)	Class[1]	Area (ha^{-1})				Dynamics (%)
		1984	1993	2003	2013	
	Ap	76.100,34	81.614,64	87.006,44	88.872,89	16,78
	Sc	-	-	-	952,10	-
	Water	42,44	41,25	26,11	6,82	-83,93
Rio Vermelho (135.338,18)	Fa	11.962,62	11.633,52	11.070,55	10.304,18	-13,86
	Fs	-	-	-	-	-
	As	1.979,28	1.871,07	1.815,07	1.395,49	-29,49
	Sd	49.054,38	29.935,19	19.375,67	15.434,54	-68,53
	Sp+Sa	6.889,16	6.175,13	4.475,13	4.248,58	-38,32
	Ag	8.882,38	15.475,69	17.759,51	21.348,58	140,34
	Iu	-	-	-	-	-
	Ap	56.302,24	70.054,20	80.653,17	77.503,19	37,65
	Sc	-	-	-	4.964,58	-
	Water	268,13	193,38	189,08	139,03	-48,14
Interbacia do rio Cabaçal (141.676,85)	Fa	26.845,55	22.382,12	19.056,75	15.848,16	-40,96
	Fs	-	-	-	-	-
	As	25.952,47	19.946,14	14.903,87	10.725,99	-58,67
	Sd	16.931,37	10.540,96	8.139,97	6.352,74	-62,47
	Sp+Sa	30.740,77	21.289,74	20.220,96	14.786,99	-51,90
	Ag	3.037,65	12.755,94	13.800,93	16.680,35	449,10
	Iu	66,70	73,20	78,91	94,05	41,00
	Ap	34.958,53	51.678,88	62.621,84	74.166,96	112,15
	Sc	-	-	-	985,48	-
	Water	3.143,80	3.009,88	2.853,62	2.036,12	-35,23

[1] Fa: Alluvial Florest; Fs: Seasonal deciduous sub-montane forest; Sa: Wooded Savannah; Sd: Forested Savannah; Sp+Sa: Park Savannah with Wooded Savannah; Ag: Agriculture; Iu: Urban Influence; Ap: Livestock; Sc: Forestry.

Source: Elaborated by authors (2015).

The vegetation cover in the CRB has diminished over the analyzed decades (Table 2 and Figure 2), with the removal of natural vegetation cover for the insertion of livestock and sugar cane classes. In 1984 the vegetation cover classes occupied more than 51% of the basin and decreased to 30.44%.

The significant reduction of Wooded Savannah Tree (*Campo Cerrado*, *Cerrado* and *Open Cerrado*), Forested Savannah (*Cerradão*), Park Savannah + Wooded Savannah (*Cerrado* and Open *Cerrado*) and Seasonal deciduous sub-montane forest are closely linked to the development of agricultural activities in CRB. Studies from Abdon et al.[23] in the Pantanal biome showed that the planted pasture accounts for 98% of the areas which had its natural vegetation cover removed.

In the same context, studies from Silva[24] showed that until 2008 deforestation in the *Pantanal* lowlands reached 12.14% of its area, while on the plateau this figure reached 58.90%. If there are no effective control interventions the natural vegetation of the region can be totally suppressed by the year 2050. Probably one of the serious problems of severe silting in the *Pantanal* rivers is related to the soils with specific texture, which are being widely used in agricultural activity, whereas the soil with a high sand content, disaggregates more easily, influencing strongly the erosion process.[25] Livestock was the predominant class found in the five sub-units of CRB in the period under investigation, corresponding to 44.35% in 1984 and to 58.77% in 2013. Among the sub-basins, livestock showed the highest increase (56.77%) in the unit *Nascentes do rio Cabaçal*.

Livestock is one of the main categories of activities that cause deforestation in the Brazilian *Amazon*.[26,27] Micol et al.[28] point out that the suppression of the *Cerrado* areas for the agribusiness occurs at the same extent of conversion from grassland areas in agricultural fields in North-Central Mato Grosso State, as well as a shift from livestock to new frontiers in the far North and NW, which has contributed to the increase of deforestation in new areas. Mato Grosso state is the country's largest cattle producer.[29] The occupation of the basin is due mostly to pasture areas. Avelino[30] found out that from the 1980's onwards most areas occupied by agricultural activities within the CRB have been replaced by pastureland, encouraged especially by the economic value added to this practice and to financial difficulties attributed to other agricultural activities such as greenery, legumes and citrus.

However, although soils cultivated under pastures present less impact than bare soil or with other types of crops, it is inferred that the extensive activity of livestock can cause a decrease in ecological dynamics, affecting directly the gene flow between fauna and flora due to the formation of forest islands. Borges et al.[31] stress that the damage of fragmentation can influence particular species or plant communities, and may lead to modification or even elimination of the ecological relationships between the original plant species, pollinators and seed dispersers.

The introduction of pastures in natural environments can influence directly the soil biota. Monitoring in the *Pantanal* biome, point out that there is a disorderly expansion of agricultural/livestock activities in the *Pantanal*[32] which favors the degradation of natural environments, as well as the intensification of laminar erosion, silting and contamination of rivers with biocides, loss of fauna, flora and biodiversity from the *Pantanal*.[33]

The agriculture activities, inexistent only at the headwaters of subbasin *Nascentes do rio Cabaçal*, in the CRB, analyzed until last year, increased over 65%, mainly due to large sugarcane planted areas. The progression of its expansion occurred towards the subbasin *Rio dos Bugres*, whose cultivation areas are destined to produce ethanol in a distillery in the municipality of Mirassol D' Oeste and, in 2013, this culture appeared in the subbasin *Rio Vermelho*, a period of sugarcane expansion in the municipality of Barra do Bugres. Areas near the municipality of Lambari D'Oeste, located in the subbasin *Rio Branco*, present more than 7,300 ha^{-1} of planted area, where there is a distillery.

The class Agriculture, represented especially by sugarcane, located mostly in the central portion of CRB, occurs in 4 of 5 CRB subbasins. It is a widespread economical alternative in the area under study, since the 1980's, and its expansion occurred by the installation of distilleries in Lambari D' Oeste and Mirassol D' Oeste, as well as in areas of sugarcane cultivation located in the subbasin *Rio Vermelho*, which supply a sugar and alcohol plant in Barra do Bugres.

Data released by Conab[34] show that sugarcane is a crop settled in Brazil, producing during the last harvest (2014/15 - 2015/16) 634.8 million tons, and SE and Central West Brazil account for about 84% of Brazilian production. Mato Grosso state, although not among the largest producers in the country, concentrates the sugarcane cultivation for ethanol production, being the sixth largest producer.[34]

Studies from Aguiar et al.[35] based on geotechnologies, point out that classes Livestock, Agriculture, Reforestation and Forest were replaced by the expansion of sugarcane cultivation in the years 2007/08 and 2008/09, in the states Minas Gerais, Goiás, Paraná, Mato Grosso do Sul and Mato Grosso, and that the classes Agriculture and Pasture gave way to 99.0% for the expansion of sugarcane planted area in these states.

The *Interbacia do rio Cabaçal* has restricted areas for sugarcane plantation to its northern part, because the southern portion is located at the borders of the *Pantanal* biome. Decree Nr. 6,961/2009[36] on the agro-ecological zoning for sugarcane, determines standards for the sugar and alcohol sector financing operations, defining the exclusion of expansion of this culture in *Pantanal* areas, the *Amazon* and the Upper Paraguay Basin, as argued by Neves et al.[37]. The *Pantanal* holds 86.77% of its native vegetation, and most of the 11.54% from the biome altered by human action is used for extensive cattle ranching on planted pastures (10.92%) and only 0.26% is used for farming.[38]

According to Moreira and Malavolta[39] the productivity of natural ecosystems and agro-ecosystems introduced and rarely fertilized, depends on the recycling of mineral nutrients in the plant litter and in the soil organic matter.

In a study in the Southern *Pantanal* from Mato Grosso, Lorenzon and Machado Filho[40] warn on the importance of the soil meso-fauna contained in the litter which is the major route of natural recycling. It can be recognized as a bio-indicator of soil life quality, since it promotes the mineral reintegration and, consequently, the fertilization which is important for both native and grown plants.

The class Forestry class was mapped only in 2013, corresponding to 1.27% of the total basin area and to 3.67% of the land area of the subbasin *Rio Vermelho*. The advance of sugarcane plantations in this sub-unit occurs mainly in the NE portion. This thematic class is present in all river basin sub-units investigated, but was more evident in the *Rio Vermelho* subbasin, reflecting also the expansion of sugarcane to the NE of this sub-unit.

With a legal obligation to restore degraded areas assigned to the advancement of agriculture, initially supported by the System of Environmental Licensing of Rural Properties (SLAPR) in 2000 and encouraged by Legal MT in 2008, it is noted that only from that moment on, that class was mapped in this basin, especially in areas of sugarcane plantations. In contrast, Azevedo and Saito[41] in their studies about the deforestation results in Mato Grosso state until 2007, supported by a public policy for the implantation of environmental licensing, signal a significant increase of deforestation in large licensed properties.

The Compulsory Rural Environmental Registry, established by Law in the Forest Code, Law Nr. 12.651/2012,[42] will possibly promote the increase of the Forestry class in form of Reforestation from the date of the last review. Also in this aspect, the agreement signed by the Federal Government in the "Joint Brazil-United States Climate Change Declaration", Brazil is committed to restore and reforest 12 million hectares of forest by 2030 and combat illegal deforestation.[43] Based on these principles, it is expected that with federal legislation and signed official agreements, there is action on this issue, especially in Mato Grosso which, according to Valdiones et al. (2015), increased by 45% deforested area between the years 2014 and 2015.

There is an expressive reduction of the native vegetation within CRB. The Alluvial Forest had its area reduced within CRB in the 29 years analyzed. The deforestation appears more drastically at the subbasin *Nascentes do rio Cabaçal,* where class Water was reduced by 30.16%. This physiognomy suffers under an intense pressure, especially at this subbasin, which is a big problem, considering that it is responsible for the greatest part of the springs that contribute to the maintenance of the *Pantanal* biome. This biome depends on the inundation pulse for the establishment of its cycle.[37]

The inundation cycle is the fundamental ecological factor of the Pantanal biome, determining the pulses of its main biotic and abiotic processes as well as the specific compositions of the landscape units.[44] The inundation from the *Pantanal* depends on the water originated from the springs at the plateau of the Upper Paraguay Basin (UPB), because these waters guarantee the periodical inundation of the *Pantanal* (Brasil 2011). The hydric availability is strongly compromised by the drastic reduction of class Water from the sub-unit *Nascentes do rio Cabaçal* , due to the water reduction in the reservoirs, rivers, creeks and salines, and this impact is associated to the suppression of the alluvial forest.

The Tree Savanna (*Campo Cerrado*, *Cerrado* and Open *Cerrado*), Forested Savanna (*Cerradão*) and Park Savanna together with Tree Savanna (*Cerrado* and Open *Cerrado*), covered 44.14% of CRB in 1983. Its area was reduced to 22.29% in 2013. A similar reduction was verified in the class Seasonal Deciduous Sub-montane Forest whose area was reduced by 33% during the period analyzed in this study.

The class Urban Influence, although little represented in the basin area (0.04%), almost doubled in 29 years, totaling 0.07%. The increase occurred in the same rhythm as the insertion of livestock/agriculture activities, especially with the population growth of municipalities Reserva do Cabaçal, Rio Branco, Salto do Céu and Lambari D'Oeste.

Classes Agriculture and Livestock are larger than the other ones, resulting in the highest landscape anthropogenic indices of CRB, which confirms the findings of a study developed by Silva et al.[45] identifying the opening of new areas for pastures or cultures in Mato Grosso state.

When ATI from thematic classes Land Use/Vegetation Cover of CRB in the year 2013 (Table 3) are evaluated together (Table 4), the landscape status was classified as "Regular" (4.55).

The index showed the evolution of degradation and/or removal of the vegetation cover from the basin landscapes, especially in the *Interbacia do rio Cabaçal,* which although it expressed not the highest index, presented the highest evolution of ATI, with an increase of 71.64% of anthropogenic change (Table 4). The areas of landscapes defined as "Regular" totaled 79.15% of the basin under study. The exception was the river subbasin of *Rio dos Bugres,* whose landscape status is characterized as "Degraded", corresponding to 20.75% of the CRB area.

The anthropogenic influence of *Interbacia do rio Cabaçal*, where the highest ATI values were quantified between years 1984 and 2013, are due to pasture and sugarcane, constituting the classes occupying the largest area within the unit. This result corroborates those found by Rodrigues et al. who found out that the "Very degraded" status in 2011 of the *Queima-Pé* /Mato Grosso state, was related to areas occupied by these cultures.

The river subbasin *Rio dos Bugre*, which has the highest value of the Index, presents at more than 20% of the area the "Degraded" status, which sets a concern to the maintenance of habitats in this subunit, typically characterized as the Amazon biome. It can be inferred that the advancement of deforestation in the Brazilian Amazon forests is attributed to the fact that there is a misinterpretation of the new Brazilian Forest Code, related to the Legal Reserve to be maintained in each biome. For Alencar et al.[46] some land owners in Mato Grosso are characterizing part of the forest as the *Amazon* biome, in the transition region with the *Cerrado* as a "*Cerradão*" (Forested Savanna), so that the Legal Reserve limit set by law for a property located in the Amazon biome, which is 80%, falls to 35%, being this percentage determined for those within the *Cerrado* biome.

For Valentim and Andrade[47] intra-regional and inter-regional integration of the Brazilian markets, particularly in the *Amazon*, stimulated the deforestation of new areas, promoting the advancement of the agricultural frontier in the *Cerrado* and Amazon biomes. According to Carneiro Filho and Souza[48] it is estimated that livestock is responsible for 80% of deforestation in the Amazon, and this activity progresses mainly in the states Rondônia, Pará and Mato Grosso. The same problems can be seen in the study by Ferreira et al.[49] which relates the beginning of the *Amazon* deforestation process to the official or clandestine opening of roads that allow human illegal occupation of land with the predatory exploitation of hardwoods to subsequently convert the explored forest in family farming and pastures for extensive livestock, especially in large estates, being this factor responsible for about 80% of logged forests in the *Amazon*.

The ATI projection has shown that by the year 2080 the landscape status, regarding human disturbance will be "Regular". However, in the year 2100 ATI will reach the 5.43 value characterizing the landscape status of the basin area as "Degraded" if nothing is changed, either from the perspective of human actions or of natural phenomena (Table 5).

Table 3 Thematic classes of land use and vegetation cover in the Cabaçal river basin and its Indices of Anthropogenic Transformation

Category	Classes	Areas (%)				ATI			
		1984	1993	2003	2013	1984	1993	2003	2013
Land use	Agriculture	3.04	5.79	6.96	9.2	0.21	0.41	0.49	0.64
	Livestock	44.35	50.48	59.24	58.48	2,22	2.52	2.96	2.92
Vegetation Cover	Alluvial forest	7.6	9.92	8.57	8.15	0.08	0.1	0.09	0.08
	Wooded Savanna	13.4	9.43	7.62	7.21	0,40	0.28	0.23	0.22
	Forested Savanna	19.39	12.37	7.38	6.36	0,19	0.12	0.07	0.06
	Park Savanna + Wooded Savanna	11.35	11.09	9.42	8.72	0,45	0.44	0.38	0.35
ATI total in the basin						3.75	3.87	4.22	4.27

Source: Elaborated by authors (2015).

Table 4 ATI by CRB subbasin and classification of landscape conservation status during the decades analyzed

Subbasin	Area (ha^{-1})	1984		1993		2003		2013	
		ATI	Status	ATI	Status	ATI	Status	ATI	Status
Nascentes do rio Cabaçal	82.931,51	2.61	Regular	3.02	Regular	3.31	Regular	3.7	Regular
Rio Branco	88.667,08	3.61	Regular	3.92	Regular	4.17	Regular	4.36	Regular
Rio dos Bugres	118.207,60	4.39	Regular	4.71	Regular	5.17	Degraded	5.33	Degraded
Rio Vermelho	135.338,18	3.55	Regular	4.36	Regular	4.84	Regular	4.89	Regular
Interbacia do rio Cabaçal	141.676,85	2.61	Regular	3.57	Regular	3.99	Regular	4.48	Regular
Total	566.821,22	3.35	Regular	3.92	Regular	4.3	Regular	4.55	Regular

Source: Elaborated by authors (2015).

Table 5 ATI Projection for each 20 years until 2100 for CRB related to the Regression equation

Time	Regression equation	Projection	Classification
2020	y= 0,025*(-47,07)	3,43	Regular
2040	y= 0,018*(-30,58)	3,93	Regular
2060	y= 0,018*(-30,58)	4,43	Regular
2080	y= 0,018*(-30,58)	4,93	Regular
2100	y= 0,018*(-30,58)	5,43	Degraded

Source: Elaborated by authors (2015).

Corroborating this result, studies from Ferreira et al.[50] found that Mato Grosso state would count on less than 23% of vegetation cover in 2020 and about 10% in 2033 if deforestation rates from 2003-2004 in this State were kept without conservation and recovery measures. Teixeira (2010), evaluating PRODES data for the year 2009,[51] listed the 20 Mato Grosso municipalities with the highest deforestation growth rates in the period 2000-2008. Among them Reserva do Cabaçal and Curvelândia stand out, both located in the subbasins of CRB, *Nascentes do rio Cabaçal* and Interbacia *do rio Cabaçal* respectively. In contrast, Prodes data from the years 2013 and 2014 (Brasil 2015) show that none of the municipalities from this unit are found in this list, setting an advancement on the fight against deforestation in CRB, although the projection points to a future landscape strongly modified by Men.[52–62]

Conclusion

In the Cabaçal river basin agricultural uses, especially livestock and sugarcane are the main economic activities developed. Livestock was the predominant land use in all rivers sub-units, occupying larger area in the subbasin *Nascentes do rio Cabaçal*. Agriculture (sugarcane) is absent only in the subbasin *Nascentes do rio Cabaçal because* livestock is a consolidated activity in this region. However, the area occupied by class Livestock could suffer a decline in the entire basin due to the closure of two meat fridges in 2015 in the municipalities of Mirassol D' Oeste and Pontes e Lacerda, both located in SW Mato Grosso state. In 2013 the status of the CRB landscape was classified as "Regular", with predominance of cultivated fields derived from the suppression of forest cover and the use of these areas for the insertion of pasture and sugarcane. The projection of ATI showed that if there are no effective interventions implemented, the status of the basin landscape will change from "Regular" to "Degraded" in the year 2100. The degradation of natural environments will take place at the expense of ecosystems, setting up a loss of natural local biodiversity and consequent environmental implications for the portion of the Upper Paraguay Basin situated downstream of the CRB. Thus, it is of fundamental importance to perform new studies on the dynamics of land use within CRB, so that conservation and preservation actions are executed, securing the maintenance and expansion of the vegetation cover of the basin under study.

Acknowledgments

Information derived from the project "Modeling of environmental indicators for the definition of priority areas and strategic recovery of degraded areas of the southwest region of Mato Grosso/MT", tied to the sub-network of social studies, and environmental technologies for production in the region of southwestern Mato Grosso - NETWORK ASA, were financed under the Edict Edital MCT/CNPq/FNDCT/FAPs/MEC/CAPES/PRO-CENTRO-OESTE Nº 031/2010. The authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES) for their awarding of scholarship grants.

Conflicts of interest

The author declares there is no Conflicts of interest.

References

1. Mato grosso (Estado). *Secretaria de Estado de Planejamento e Coordenação Geral. Plano de Longo Prazo de Mato Grosso: macro-objetivos, metas globais, eixos estratégicos e linhas estruturantes*. In: Prado JGB, et al., editors. Plano de Longo Prazo de Mato Grosso. Cuiabá/MT: Central de Texto. 2012;4:108.
2. Greggio TC, Pissarra TCT, Rodrigues FM. Avaliação dos fragmentos florestais do município de Jaboticabal-SP. *Revista Árvore*. 2009;33(1):117–124.
3. Mato Grosso. Secretaria de Estado de Meio Ambiente. *Plano de Ação para preservação e controle do desmatamento e queimadas do estado de Mato Grosso (PPCDMT)*. Cuiabá: SEMA, 2009. p. 55.
4. Pessoa SPM, Galvanin EAS, Kreitlow JP, et al. Análise espaço-temporal da cobertura vegetal e uso da terra na interbacia do rio Paraguai Médio-MT, Brasil. *Revista Árvore*. 2013;37(1):119–128.
5. Flores PM, Guimarães RF, Carvalho Júnior OA, et al. Análise multitemporal da expansão agrícola no município de Barreiras-Bahia (1988-2008). *Revista de Geografia Agrária*. 2008;7(14):1–19.
6. Nascimento WM, Vilaça MG. Bacias Hidrográficas: Planejamento e Gerenciamento. *Associação dos Geógrafos Brasileiros*. 2008;5(7):102–121.
7. Tonello KC, Dias HCT, Souza AL, et al. Análise hidroambiental da bacia hidrográfica da cachoeira das Pombas, Guanhães, MG. *Revista Árvore*. 2005;30(5):849–857.
8. Donatio NMM, Galbiatti JA, de Paula RC. Qualidade da água de nascentes com diferentes usos do solo na bacia hidrográfica do córrego Rico, São Paulo, Brasil. *Engenharia Agrícola*. 2005;25(1):115–125.
9. Nascimento MC, Soares VP, Ribeiro CAAS, et al. Uso do geoprocessamento na identificação de conflito de uso da terra em áreas de preservação permanente Bacia Hidrográfica do Rio Alegre, Espírito Santo. *Ciência Florestal*. 2005;15(2):207–220.
10. Lémechev T. On hydrological heterogeneity catchment morphology and catchment response. *Journal of Hydrology*. 1982;100:357–375.
11. Mateo J. *Geoecologia de los Paisajes*. Universidad Central de Caracas. Monografia. 1991.
12. Teixeira AJA. *Classificação de bacias de drenagem com o suporte do Sensoriamento Remoto e Geoprocessamento – O caso da Baía de Guanabara*. 2003. 156f. Dissertação (Mestrado em Geografia) - Instituto de Geociências, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2003.
13. Gouveia RGL, Galvanin EAS, Neves SMAS. Aplicação do Índice de Transformação Antrópica na análise multitemporal da bacia do córrego do Bezerro Vermelho em Tangará da Serra - MT. *Revista Árvore*. 2013;37(6):1045–1054.
14. ANA. Agência Nacional De Águas. *Panorama da qualidade das águas superficiais no Brasil: superintendência de planejamento de recursos hídricos*. Brasília. 2006.
15. Tarifa JR. *Mato Grosso – Clima: análise e representação cartográfica*. Cuiabá: Entrelinhas. 2011. p. 102.
16. SEPLAN. Secretaria de Estado de Planejamento e Coordenação Geral. Ligia Camargo (Org). Atlas de Mato Grosso: abordagem socieconomico-ecológica. Cuiabá: Entrelinhas. 2011.
17. Carvalho JM, Cuiabano MM, Neves RJ, et al. *Conflitos de uso da terra na bacia hidrográfica do rio Cabaçal – MT, Brasil*. In: Simpósio de Geotecnologias no Pantanal, 5, 2014, Campo Grande, *Anais*... São José dos Campos: INPE, 2014. p. 166–176.
18. Câmara G, Souza RCM, Freitas UM, et al. Integrating remote sensing and GIS by object-oriented data modeling. *Computers & Graphics*. 1996;20(3):395–403.
19. Usgs. *Geological Survey*. Serviço de Levantamento Geológico Americano. 2013.
20. Esri. *ArcGis Desktop: release 9.2*. Redlands, CA: Environmental Systems Research Institute. 2007.
21. Fietz CR, Comunello E, Cremon C, et al. *Estimativa da precipitação provável para o Estado de Mato Grosso*. Dourados: Embrapa Agropecuária Oeste, 2008. p. 237.
22. Toledo AMA, Sperotto FCS, Fontenelli JV, et al. Determinação da aptidão edafoclimática da cana-de-açúcar no pólo regional de Rondonópolis – MT. *Enciclopédia Biosfera, Centro Científico Conhecer*. 2011;7(13):381–399.
23. Abdon MM, Silva JSV, Souza IMS, et al. Desmatamento no bioma Pantanal até o ano 2002: relações com a fitofisionomia e limites municipais. *Revista Brasileira de Cartografia*. 2007;1(59):17–24.
24. Silva JSV, Abdon MM, Neves SMAS, et al. Evolution of deforestation in the brazilian Pantanal and surroundings in the timeframe 1976 – 2008. *Revista Geografia*, 36 (Número Especial). 2011;35–55.

25. Azevedo AA, Monteiro JLG. Análise dos Impactos Ambientais da Atividade agropecuária no Cerrado e suas inter-relações com os recursos hídricos na região do Pantanal. Brasília: *WWF*. 2006.

26. Margulis S. *Causas do desmatamento da Amazônia brasileira*. Brasília: Banco Mundial. 2003.

27. Moran EF. Human strategies for coping with El Niño related drought in Amazônia. *Climatic Change*. 2006;77(3):343–361.

28. Micol LA, Börner J. Redução das Emissões do Desmatamento e da Degradação (REDD): potencial de aplicação em Mato Grosso. Cuiabá: *Instituto Centro de Vida*, 2008. p. 92.

29. IMEA. Instituto Mato-grossense de Economia Agropecuária. Bovinocultura. 2008.

30. Avelino PHM. Análise Ambiental com Uso de Geotecnologias da Bacia Hidrográfica do Rio Cabaçal - MT – Brasil (1984 A 2005). *Revista Eletrônica da Associação dos Geógrafos Brasileiros – Seção Três Lagoas*. 2007;1(6):5–29.

31. Borges LFR, Scolforo JR, Oliveira AD. Inventário de fragmentos florestais nativos e propostas para seu manejo e o da paisagem *Cerne*. 2008;10(1):22–38.

32. Brasil. *Ministério do Meio Ambiente (2011) Monitoramento do desmatamento nos biomas brasileiros por satélite*. Acordo de cooperação técnica MMA/IBAMA. Centro de Sensoriamento Remoto – CSR/IBAMA. 2008-2009. 2011.

33. Santos JR. *Avanços das pesquisas e aplicações de sensoriamento remoto no monitoramento da paisagem: contribuições aos estudos do Pantanal*. In: Simpósio de Geotecnologias no Pantanal, 1, 2006, Campo Grande, *Anais...* São José dos Campos: INPE, 2006, p. 675–683.

34. Conab. *Companhia Nacional de Abastecimento*. Levantamentos de safra: cana-de-açúcar. 2015.

35. Aguiar DA, Adamil M, Rudorff BF, et al. *Avaliação da conversão do uso e ocupação do solo para cana-de-açúcar utilizando imagens de sensoriamento remoto.* In: Simpósio Brasileiro de Sensoriamento Remoto, 14, 2009, Natal. *Anais...* São José dos Campos: INPE, 2009. p. 5547–5554.

36. Brasil. *Decreto nº 6.961, de 17 de setembro de 2009*. Diário Oficial [da] União, Poder Legislativo, Brasília, DF, 17 de setembro de 2009. p. 1.

37. Lorenzon TH, Paiva SLP, Neves SMAS, et al. Analysis of the conservation state from the Permanent protection areas at the springheads and of the water from Cabaçal river drainage basin, Mato Grosso State, Brazil. *Revista Geografia*, 40 (Número Especial): 2015;159–175.

38. Brasil. Companhia Nacional de Abastecimento. Cana-de-açúcar – Safra 2014/2015. 2015;1(4).

39. Moreira A, Malavolta E. Dinâmica da matéria orgânica e da biomassa microbiana em solo submetido a diferentes sistemas de manejo na Amazônia Ocidental. *Pesquisa Agropecuária Brasileira*. 2004;39(1):1103–1110.

40. Lorenzon TH, Machado Filho LC. Levantamento da diversidade edáfica em serapilheira de mata ciliar da Bacia do Rio Paraguai no Pantanal sul-mato-grossense - Brasil. *Ecologic@*. 2012;4(4):59–63.

41. Azevedo AA, Saito CH. O perfil dos desmatamentos em Mato Grosso, após implementação do licenciamento ambiental em propriedades rurais *Cerne*. 2003;19(1):111–122.

42. Brasil. *Lei nº 12.651, de 25 de maio de 2012*. Diário Oficial [da] República Federativa do Brasil, Poder Executivo, Brasília, 28 de maio de. 2012. p. 1.

43. Brasil. Ministério de Minas e Energia. *Declaração Conjunta Brasil - Estados Unidos sobre Mudança do Clima. Acordo de cooperação entre Brasil e Estados Unidos*. Brasília: MME. 2015.

44. Adami M, Freitas RM, Padovani CP, et al. Estudo da dinâmica espaço-temporal do bioma Pantanal por meio de imagens Modis. *Pesquisa Agropecuária Brasileira*. 2008;43(10):1371–1378.

45. Silva GB, Formaggio AR, Shimabukuro YE. Áreas alteradas em função de atividades antrópicas no bioma Cerrado localizado no Estado do Mato Grosso (MT), até o ano de 2001: uma abordagem espaço-temporal. *Revista Brasileira de Cartografia*. 2004;2(62):363–371.

46. Alencar A, Nepstad D, Mcgrath D, et al. *Desmatamento na Amazônia: Indo além da "emergência crônica".* Manaus: Instituto de Pesquisa Ambiental da Amazônia – IPAM. 2004.

47. Valentim JF, Andrade CMS. Tendências e perspectivas da pecuária bovina na Amazônia brasileira. *Amazônia: Ciência & Desenvolvimento*. 2009;4(8):9–32.

48. Carneiro Filho A, Souza OB. *Atlas de pressões e ameaças às terras indígenas na Amazônia brasileira*. São Paulo: Instituto Socioambiental, 2009.

49. Ferreira LV, Venticinque E, Almeida S. O desmatamento na Amazônia e a importância das áreas protegidas. *Dossiê Amazônia Brasileira*. 2005;19(53).

50. Ferreira DAC, Noguera SP, Carneiro Filho A, et al. Mato Grosso até quando? *Ciência Hoje*. 2008;42(248):26–31.

51. Brasil. Instituto Nacional de Pesquisas Espaciais. *Programa de cálculo do desflorestamento na Amazônia (Prodes).* São José dos Campos: INPE, 2015.

52. BRASIL/MME. *Projeto RADAMBRASIL*. Rio de Janeiro: 1998. p. 401–452.

53. Brasil. *Lei Complementar nº 343, de 24 de dezembro de 2008*. Diário Oficial [da] Assembleia Legislativa do Estado de Mato Grosso, Poder Executivo, Cuiabá, 24 de dezembro de 2008. p. 1.

54. Brasil. *Ministério do Meio Ambiente*. Relatório Probio-Pantanal. 2004.

55. Brasil. *Ministério do Meio Ambiente*. Pantanal. Brasília: MMA. 2015.

56. IBGE. Instituto Brasileiro de Geografia e Estatística. *Mapa de Unidades de Relevo do Brasil: segunda edição*. Rio de Janeiro: IBGE, 2006.

57. IBGE. Instituto Brasileiro de Geografia e Estatística. *Manual técnico da vegetação brasileira*. Rio de Janeiro: IBGE, 2012. p. 271.

58. Mato Grosso (Estado). *Lei nº 9.619 de 04 de outubro de 2011***.** Diário Oficial [do] Estado de Mato Grosso. Poder Legislativo, Cuiabá, MT, 04 de outubro de 2011. p. 1.

59. Neves SMAS, Nunes MCM, Neves RJ, et al. Susceptibility of soil to hydric erosion and use conflicts in the microregion of Tangará da Serra, Mato Grosso, Brazil, *Environmental Earth Science*. 2015;74(1):813–827.

60. Rogrigues LC, Neves SMS, Neves RJ, et al. Dinâmica da antropização da paisagem das subbacias do rio Queima Pé, Mato Grosso, Brasil. *Revista Espacios*. 2015;36(10):5–13.

61. Rogrigues LC, Pessoa SPM, Neves RJ, et al. Análise multitemporal e índice de transformação antrópica da bacia do rio Queima-Pé - Tangará da Serra/MT, Brasil. In: Simpósio de Geotecnologias no Pantanal, 4, 2012, Bonito. *Anais...* São José dos Campos: INPE, 2014;838–848.

62. Teixeira RFAP. *Amazônia Legal e o estado de Mato Grosso: dois ensaios sobre o processo de convergência espacial para o desmatamento*. 2010, 142f. Dissertação (mestrado em Economia) – Universidade Estadual Paulista "Júlio de Mesquita Filho", Araraquara, SP, 2010.

Citation: Lorenzon TH, Galvanin EADS, Neves SMADS, et al. Spatial-temporal dynamics of vegetation cover, land use and anthropogenic transformations of landscape in the Cabaçal river basin, Mato Grosso state, Brazil. *Int J Hydro.* 2022;6(2):79–86. DOI: 10.15406/ijh.2022.06.00305