INTENSITY OF ANTHROPIC ACTION IN THE DIAMANTINO RIVER SUB-BASIN, MATO GROSSO STATE/BRAZIL

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Abstract

The objective of this study was to quantify and analyze the level of anthropic changes and its relations with land use, land cover, and soil types in the Diamantino river sub-basin, Mato Grosso State. For this purpose, satellite images of Landsat-5 and Landsat-8 were used, which were processed and classified with the Spring software. The thematic classes were quantified using the ARCgis software. The degree of human disturbance was verified by the Anthropic Transformation Index. The soil types in the basin were quantified, considering a cut-out of the Soils Map from Mato Grosso State, also using ARCgis. Among the classes mapped, pasture presented a significant expansion in the last 20 years, to the detriment of suppression from the natural vegetation in all sub-basins. The soil types Red Latosol and Red-Yellow are prominent in the Diamantino river sub-basin. The calculation of the Anthropic Transformation Index indicated that the level of changes at the Diamantino river sub-basin increased. In all sub-basins, this level was degraded between 1993 and 2013. In this study, the main factor that favored the increase of the Anthropic Transformation Index was the expansion of pasture.

Keywords: Soils. Pantanal. Remote Sensing. Deforestation. Land use.

Resumo

A intensidade das ações antrópicas nas sub-bacias hidrográficas do rio Diamantino, Mato Grosso/Brasil

O objetivo deste trabalho é quantificar e analisar o nível de transformação antrópica e suas relações com o uso e cobertura da terra e com os tipos de solos nas sub-bacias do Rio Diamantino – Mato Grosso. Foram utilizadas imagens do satélite Landsat-5 e Landsat-8, as quais foram processadas e classificadas no software Spring. As classes temáticas foram quantificadas no software ARCgis. O grau de antropização foi verificado por meio do Índice de Transformação Antrópica. Foram quantificados os tipos de solo da bacia, por meio do recorte do Mapa de solos do estado de Mato Grosso através da mascara de estudo no software ARCgis. Dentre as classes mapeadas a pastagem apresentou expansão significativa nos últimos 20 anos, em detrimento da supressão da vegetação natural em todas as sub-bacias. Os solos do tipo Latossolo Vermelho e Latossolo Vermelho-Amarelo destacam-se com maior área nas sub-bacia do rio Diamantino. Por meio do cálculo do Índice de Transformação Antrópico observou-se que os valores do nível de transformação antrópica têm aumentado nas sub-bacias do Rio Diamantino. Todas as sub-bacias foram classificadas como pouco degradada em 1993, passando para regular em 2013. Neste estudo o principal fator que tem favorecido o aumento dos valores do índice de transformação antrópica foi à expansão da pastagem.

Palavras-chave: Solos. Pantanal. Sensoriamento Remoto. Desmatamento, Uso da terra.

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INTRODUCTION

Humans have transformed the natural environment since their existence on Earth. However, over time, there was a significant change on the way on how man relates to his environment, resulting in an often cluttered model of occupation, leading to several environmental problems (Gonçalves, 2008) such as destruction of forests, impoverishment of genetic biodiversity, soil erosion, and contamination of water resources (BALSAN, 2006).

The Diamantino river is located at the Upper Paraguai River Basin (CASARIN, 2007), where the Paraguay River is the main source, which converges to an important ecosystem, the Pantanal of Mato Grosso, whose source is located in the municipality of Diamantino.

The municipality of Diamantino was initially occupied in 1728 by pioneers from São Paulo. The migration to this region was driven by the discovery of gold and diamonds in the cities of Alto Paraguay and Diamantino (ZOLINGER, 2002; LIRA, 2011). Over time, the mineral extraction became no longer the main source of income from this municipality. According to SEPLAN (2005), in 2002, approximately 52.62% from of the gross value produced in this region, originated from agriculture.

Given the importance of the Diamantino river as an important tributary to the Paraguai river, only few studies reported the land use in the Diamantino river basin. Casarin (2007) analyzed the main vectors for environmental degradation in the Paraguai/Diamantino basin: the active sites of mining, disturbing the sediments on the river banks and contaminating the water with mercury, destroying the riparian forests and steep slopes, compromising the flow and quality of water and increasing soil erosion. In this context, the preservation of water sources, especially of freshwater, is of paramount importance, because it allows the equilibrium of the Pantanal ecosystem.

The analysis of land use and land cover in a time span can be performed using the geo technologies (Remote sensing, GIS and GPS) which allow an integrated environmental analysis, to understand the problems related to the changes of the natural environment in space (SANTOS et al., 2012).

The Anthropic Transformation Index (ITA), proposed by Lémechev (1982), was adapted satisfactorily to geo-processing and environmental monitoring. The quantification of environmental change through ITA considers the land use as a variable and it has several advantages to identify and indicate the most modified areas, supporting decision-making for environmental preservation.

Thus, this study allows the monitoring and identification of priority areas for environmental preservation (ANACLETO et al., 2005). The objective of this study is to quantify and analyze the level of anthropic transformation and its relationship with land use/land cover and with the soil types in the Diamantino river sub-basin, Mato Grosso State.

MATERIALS AND METHODS

Study area

The Diamantino river basin (BHRD) is located in the center North of Mato Grosso State, between geographical coordinates S 14°16’30" to S 14°28’30" and W 56°22’30" to W 56°32’30". With an area of approximately 17,741.87 ha, it includes the municipalities of Diamantino and Alto Paraguai. The BHRD is well-drained, but its streams are small. It is divided in four sub-basins: Diamantino Spring river sub-basin (SBRDN) with 8,313.05 ha, Frei Manuel Stream (SBCFM) with 4,983.68 ha, the Ribeirão Buriti sub-basin (SBRB) with 2,828.10 ha, and Diamantino river outfall (SBRDF) with 1,617.05 ha (Figure 1).

The Diamantino river rises on the slopes of Tapirapuã Mountain; the local characteristic vegetation is known as Cerradão [Wooded Savannah] (CASARIN, 2007). The climate is tropical, with a rainfall season from October to March and a dry one from April to September, average annual temperature is 24.4°C and annual rainfall 1,500 mm (DALLACORT et al., 2010).

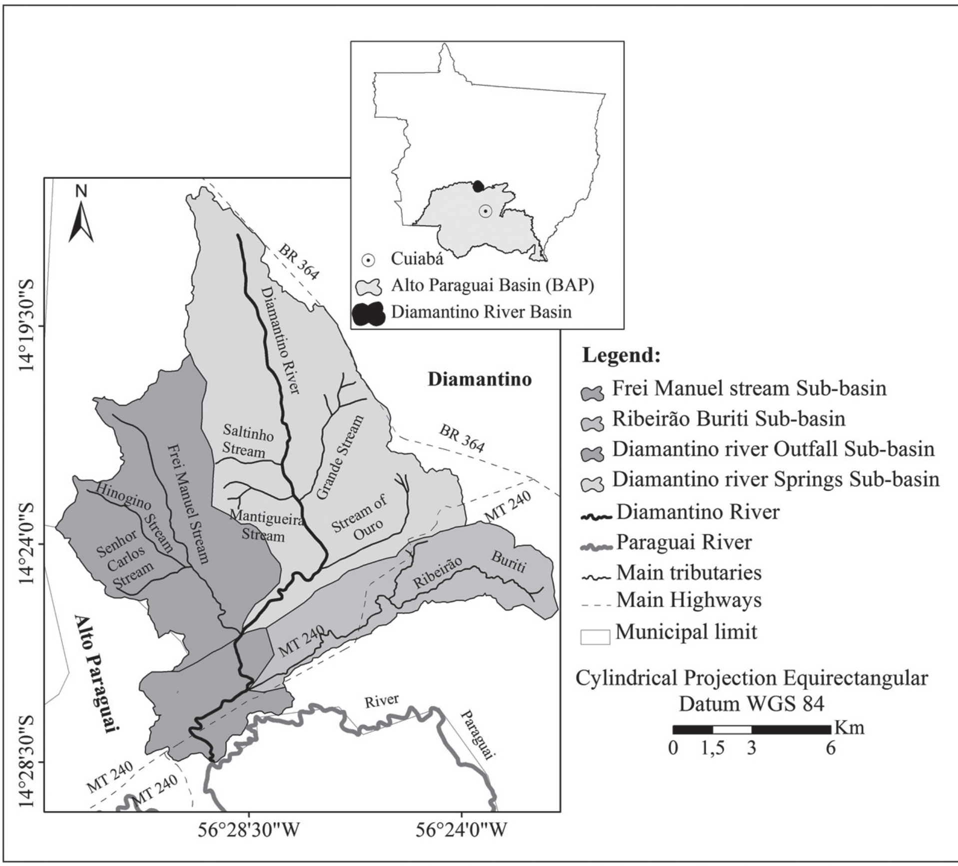

Figure 1 - Location map of Diamantino river sub-basin, Mato Grosso, Brazil

Methodological procedures

Initially the study area was visited during the dry season on June 20, 2014 to record photographically the characteristic features of the basin, in order to validate the classification of satellite images.

To delimit the sub-basins of the Diamantino river Basin (BHRD) a Digital Elevation Model (DEM) was used. It was based on data received from the Shuttle Radar Topography Mission (SRTM) obtained at the National Institute for Space Research (INPE), and processed with the ArcGis software (ESRI, 2007).

Later on, TM Landsat-5 images dated January and July 1993 and June 2003 were acquired from INPE for the temporal analysis of land use/land cover. An image from the Operational Land Imager sensor (OLI) aboard the Landsat 8, obtained from the website of the Earth Explorer from the United States Geological Survey (USGS) of July 2013 was also used. Both sensors have Orbit/Point 227/70, with a spatial resolution of 30 m and a revisit time of 16 days in the same area (COELHO; CORREIA, 2013).

Significantly, the identification of land use/land cover classes for the years 2003 and 2013 was done using the database of the Vegetation Index and Enhanced Vegetation Index (EVI) time series, provided by the Remote Sensing Laboratory in Agriculture and Forest (LAF/INPE) from 2000. In order to distinguish between land use types, images from 1993 were necessary, apart from images of both dry and wet seasons. However scenes only of the 1993 dry season were used for mapping, avoiding the spectral confusion due to the cloud coverage in the scenes of the rainy season.

The images were processed and analyzed in the Geo-referenced Information Processing System (SPRING), version 5.1.8 (CAMARA et al., 1996), a database that was initially created using the UTM coordinate system, datum WGS84. Following, the record of Landsat 5 (1993 and 2003) was used, with GeoTIFF images in Geocover format, provided by NASA, bands 3, 4 and 5 (BGR), with 28.5 m spatial resolution, year 2001, in the display screen mode. It is emphasized that the 2013 images are registered and from these images bands 4, 5 and 6 (BGR) were used.

After analyzing the image and the methodology proposed by Silva et al. (2011) and IBGE (2008) modified, five classes of land use/land cover were defined, namely: Natural Vegetation (Forests, Savannas), Agriculture (all types of agriculture: temporary perennial, agro-forestry system), Water bodies (including lakes, rivers, lagoons), Pasture (all types of pasture) and Other Anthropic Uses (in this class urban sites, rural offices, and other engineering and mining sites were considered).

Next, a supervised classification was performed, with the training done by (this activity includes the identification of sample classes) the Bhattacharya classifier, with acceptance of 99%. After the classification process an assessment of accuracy was performed using the Kappa Index to check the reliability of the map generated with the SPRING software package (COHEN, 1960).

Finally, the Anthropic Transformation Index (ITA) was calculated for SBHRD. The ITA was proposed by Lémechev (1982) and modified by Mateo (1991) in order to quantify the anthropic pressure on some environmental components. The ITA was calculated from the map showing the classes of land use/ land cover as follows:

$$ITA = \Sigma\ (\%USO \times PESO)/100$$

where:

USO = percentage of areas of land use/land cover classes

PESO = weight assigned to different types of land use/land cover according to the degree of anthropic change. It ranges from 1 to 10, where 10 indicates the highest pressure.

Employing the Delphi method, a weight was assigned according to the type of land use class. This was done from the multidisciplinary perspective of several experts which established a consensus on the weight assigned to each land use class (SCHWENK; CRUZ, 2008). The weights for each land use class are shown in table 1.

Table 1 - ITA ranking with the weights assigned to each land use class

Land use classes	weight
Agriculture	7,3
Water bodies	2
Other anthropic uses	9,7
Pasture	6
Natural vegetation	1

According to Cruz et al. (1998), one type of classification for the basins, related to the anthropic load is given in quartiles: Little degraded (0 to 2.50); Regular (2.51 to 5.0); Degraded (5.1 to 7.50) and Very Strongly Degraded (7.51 to 10).

A Soils Map was elaborated up using the ArcGIS software, checking with the Mato Grosso State Soils Map as a reference, on the scale 1:250,000 (SEPLAN, 2001). This was done following the updated classification of the Brazilian System for Soil Classification (EMBRAPA, 2006) to quantify the soil type in each sub-basin.

RESULTS AND DISCUSSION

The preparation of the thematic maps from the area under study was an important step for the calculation of ITA. The accuracy of these maps was verified by the error matrix, using the Kappa Index (Table 2).

Some confusion was noted only in the spectral classification performed for the year 2003. The results show a spectral confusion at the Pasture class. In this case, from the 13,041 pixels listed for this class, 65 pixels, i.e. 0.50%, which should have been attributed to the class Pasture were erroneously attributed to the class Natural Vegetation. There was also spectral confusion among classes Other Anthropic Uses and Pasture, where from the 1,445 pixels collected for this class, 12 pixels were erroneously attributed to class Pasture (0.83%).

For the years 1993 and 2013 no spectral confusion was observed. The Kappa Index values in this study (Table 2) are considered Excellent (K> 0.8) by Fonseca (2000) and Manel et al. (2001) indicating that the resulting classification is a true representation of the land use in the basin.

Table 2 - Results of the classification, the Kappa error estimator in BHRD

	1993	2003	2013
Global accuracy (%)	100	99.92	100
Kappa Index (%)	100	99.73	100

The Landsat satellite images and field surveys allowed the identification, mapping and quantification of five main land use classes in SBHRD (Figure 2).

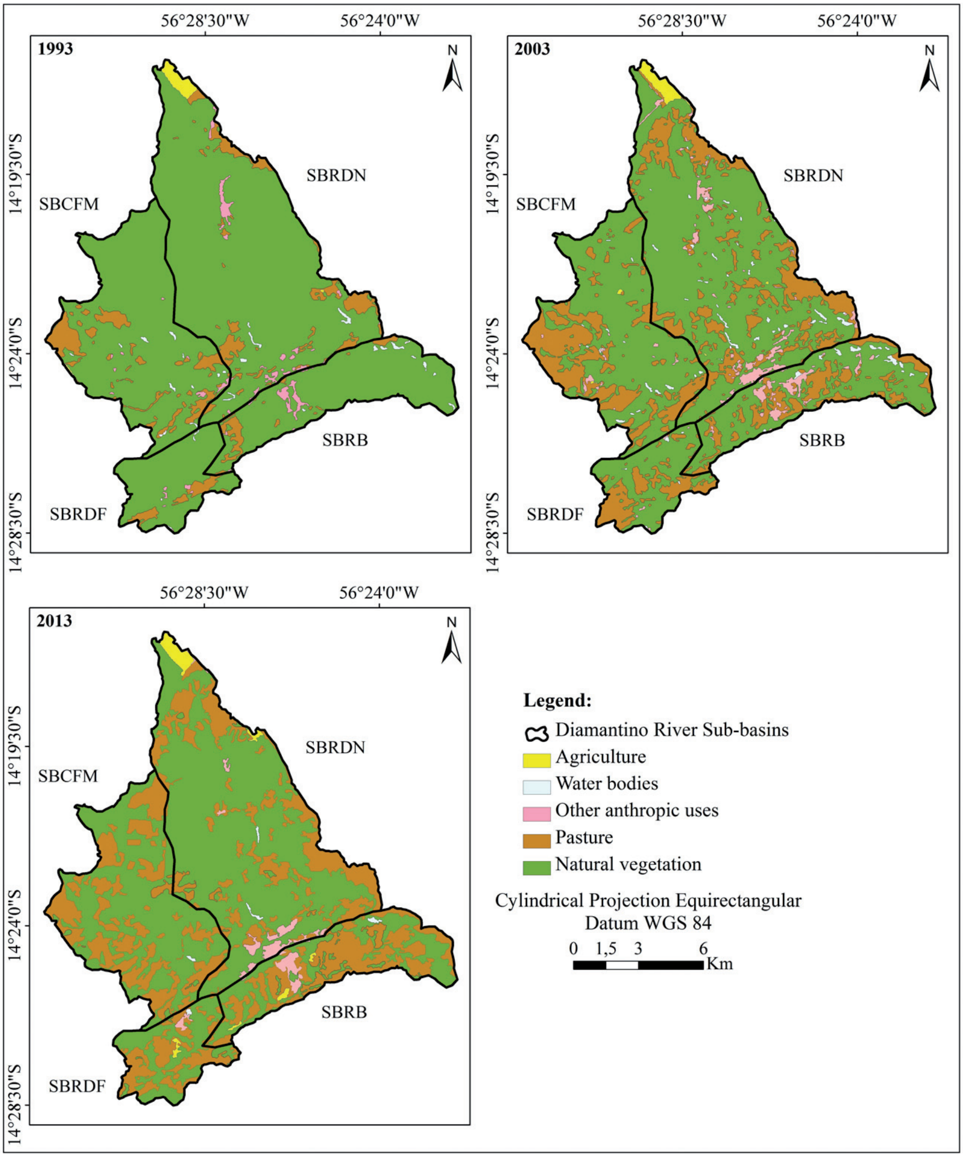

Figure 2 - Distribution of thematic classes of land use in SBHRD in 1993, 2003, and 2013

The quantitative results of the thematic classes and of ITA for each sub-basin considered per year are shown in table 3. Agriculture is localized mainly in SBRDN

(Figure 2), with an area increase of 0.26% from 1993 to 2003 and of 0.04% from 2003 to 2013 (Table 3).

Table 3 - Classes use and land cover mapped the images of Landsat satellite in SBHRD

Sub-Basin	Classes	Area (%) 1993	Area (%) 2003	Area (%) 2013	Weight	Calculation of ITA 1993	Calculation of ITA 2003	Calculation of ITA 2013
Frei Manuel Stream (SBCFM)	Agriculture	0.11	0.17	0	7.3	0.01	0.01	0.00
	Water masses	0.60	0.76	0.12	2	0.01	0.02	0.002
	Other anthropogenic uses	0.61	0.71	0	9.7	0.06	0.07	0.00
	Pasture	11.85	29.60	38.79	6	0.71	1.78	2.33
	Natural vegetation	86.83	68.77	61.09	1	0.87	0.69	0.61
	Total	100	100	100	---	1.66	2.56	2.94
Ribeirão Buriti (SBRB)	Agriculture	0	0	1.11	7.3	0.00	0.00	0.08
	Water masses	1.02	2.04	0.38	2	0.02	0.04	0.01
	Other anthropogenic uses	3.03	3.74	3.95	9.7	0.29	0.36	0.38
	Pasture	6.08	29.39	51.89	6	0.36	1.76	3.11
	Natural vegetation	89.88	64.83	42.67	1	0.90	0.65	0.43
	Total	100	100	100	---	1.58	2.82	4.01
Diamantino river Outfall (SBRDF)	Agriculture	0	0	1.20	7.3	0.00	0.00	0.09
	Water masses	0.39	0.57	0.37	2	0.01	0.01	0.01
	Other anthropogenic uses	0.94	0.57	1.47	9.7	0.09	0.06	0.14
	Pasture	9.15	32.71	43.26	6	0.55	1.96	2.60
	Natural vegetation	89.52	66.14	53.70	1	0.90	0.66	0.54
	Total	100	100	100	---	1.54	2.69	3.37
Diamantino river Springs (SBRDN)	Agriculture	1.47	1.73	1.77	7.3	0.11	0.13	0.13
	Water masses	0.46	1.08	0.22	2	0.01	0.02	0.00
	Other anthropogenic uses	1.81	2.50	2.54	9.7	0.18	0.24	0.25
	Pasture	7.26	22.15	23.68	6	0.44	1.33	1.42
	Natural vegetation	89.00	72.54	71.80	1	0.89	0.73	0.72
	Total	100	100	100	---	1.62	2.44	2.52

The water masses, represented mainly by the Diamantino river, Ribeirão creek, Frei Manuel stream and natural as well as artificial ponds, showed an area reduction in the past 20 years at all sub-basins, with the SBRB showing the greatest areal reduction of this class in the time analyzed (0.64%).

According to Casarin (2007) and Casarin et al. (2008), in the Diamantino river sub-basin (SBCFM, SBRB, SBRDF, and SBRDN) there was an elevation in the amount of mercury contaminating the rivers and lakes. The author also found out that the water quality of the main sub-basin rivers were of Class III, according to the provisions of Resolution Nr. 357/2005 from CONAMA, attributing the contamination of water and bottom sediments mainly by mercury. The high mercury levels are due to the intensive mineral extraction (gold and diamonds) activity, which existed in these rivers in the past. It should be noted that mercury in high levels is toxic to biological organisms. This element comes into the first trophic degree, passing through various levels of the food chain and finally reaching humans.

The Natural Vegetation in the period analyzed was composed mainly by Permanent Preservation Areas (PPAs) along the water bodies (Figure 2). The SBRDN had the highest Natural Vegetation area in 2013 as compared to other classes. However at all sub-basins the area of Natural Vegetation was reduced and more intensely in the SBRB sub-basins (47.21%) and at SBRDF (35.82%), followed by SBCFM sub-basins with a reduction of 25.74% and 17.21% at SBRDN.

In this sense, Pessoa et al. (2013) reported changes in all thematic classes over the last 20 years in the Middle Paraguai River/Mato Grosso State inter-basin. These authors indicated conflicts of land use, especially in the riparian forest areas, which may consequently influence negatively the conservation of the inter-basin and the Pantanal of Mato Grosso.

The class Other Anthropic Uses includes the urban area of the Diamantino municipality, located in SBRDN and SBRB (Figure 2), the mining areas, and the resorts. This class presented an area reduction of 0.61% only in the SBCFM between 1993 and 2013. Pasture is located mainly in SBCFM; however all sub-basins showed an increase in this class during the 20 years of analysis, but the greatest increase was in SBRB (45.81%) and the lowest one in SBRDN (16.21%).

Casarin (2007) reports on a survey performed in 2003 at the Paraguai/ Diamantino Basin, highlighting the main human activities such as livestock, agriculture, and mineral extraction, which is in agreement with the results of the present study. These activities can cause contamination of water bodies by pesticides, herbicides, mercury from illegal mining, and solid waste from cities and land degradation (Alho, 2011). In this context, Margulis (2003) showed that, initially the Savannah areas were converted to pasture, which could be used subsequently for agriculture.

As for the anthropic transformation level shown at table 3, a thematic map of the ITA classification from the sub-basins was elaborated (Figure 3).

All the Diamantino river sub-basins were classified as slightly degraded in 1993 (Table 3 and Figure 3). However in 2003, the SBCFM, SBRB, and SBRDF showed the regular level, with SBRDN remaining slightly lower. In 2013, the SBRDN also showed the normal level along with the other sub-basins, which remained in this state (Table 3 and Figure 3). Thus, it was found that the values of the Anthropic Transformation Index have increased over the years, although no sub-basin became Degraded or Very Degraded. In this study, the main factor that favored the increase of the Anthropic Transformation Index values was the expansion of Pasture.

Gouveia et al. (2013) verified that there was an increase from the “Regular” ITA level (4.75) in 1984 to the “Degraded” level (5.88) in 2011 at the Bezerro Vermelho stream basin in Tangará da Serra, Mato Grosso State, mainly due to the activities associated to the expansion of agriculture and the consequent reduction of Natural Vegetation.

The destruction of Natural Vegetation affects considerably the environment, with the reduction of water resources, loss of soil fertility, intensification of desertification processes, soil compaction, and the elimination of species (fauna and flora) which have not yet been cataloged, as for their economic, ecologic, medical potential, and for still unknown uses (SANTOS, 2009).

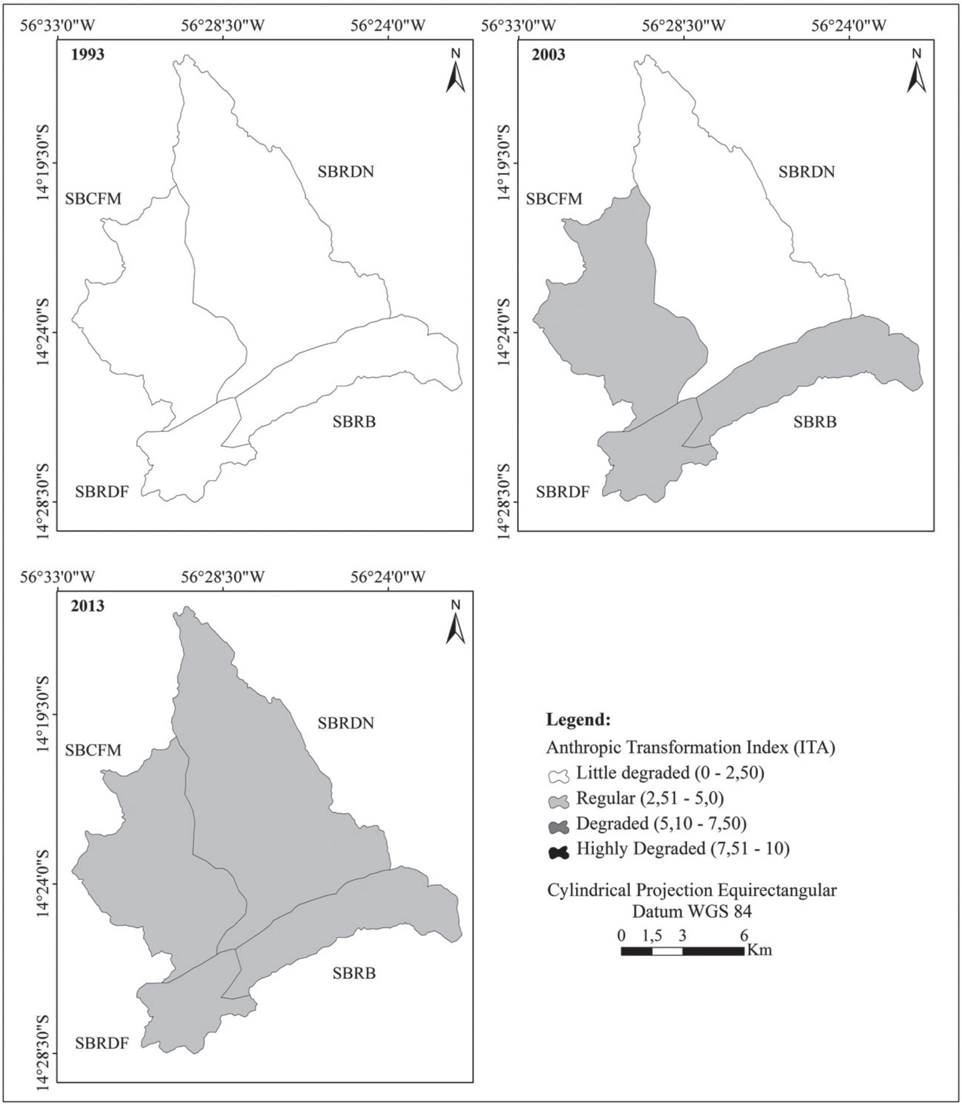

Figure 3 - Anthropic Transformation Index in SBHRD

Alho (2011) informs on other negative environmental effects, such as contamination by pesticides and herbicides, mercury from illegal mining, solid waste from urban areas, poaching, wildlife trade, soil degradation, lack of awareness for environmental preservation, and the inefficiency of government agencies to monitor and enforce the legislation.

It must be highlighted that it is extremely important to monitor the advancement of deforestation in SBHRD even in the present low degraded state, which can be increased over a period of time, as shown by Perez and Carvalho (2012) for the Micro-basin of Ipê Stream in São Paulo State, where changes in the Anthropic Transformation Level changed from "Degraded" to "Very Degraded" in just 9 years, from 2002 to 2011.

Human activities in the environment are influenced by several factors related to the characteristics of the environment, such as soil, relief, and/or human actions involved in the development. Among the environmental characteristics, the type of soil is the most important feature, which can become a standoff/facilitator for the implantation of a particular activity.

Thus, checking the soil characteristics from a region is of paramount importance to understand the dynamics of human actions in the natural environment. The results from the analysis of the soil types in each sub-basin are shown in figure 4 and table 4.

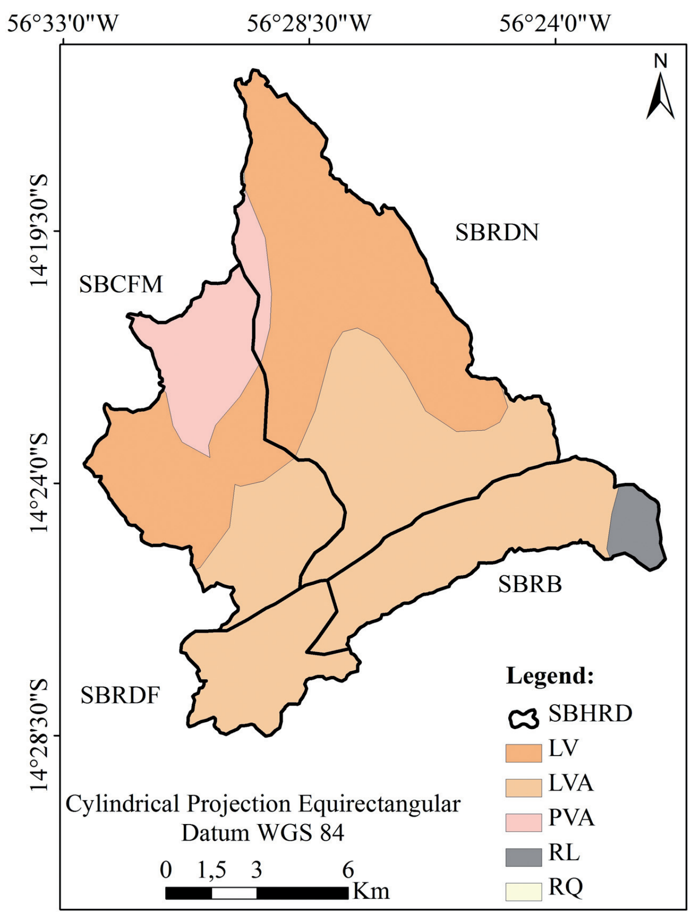

Figura 4 - Distribuition of the soils type present in the SBHRD, LVA: Oxisol; LV Rhodic; PVA: Red Yellow Argisol; RL: Neossolo Lytic; RQ: Neosssolo Quartizaremico

Table 4 - Relation of soil type in each sub-basin of the river Diamantino, Mato Grosso

Sub-basins	Types				
	LVA	LV	PVA	RL	RQ
Frei Manuel	1.464,7	2.114,9	1.404,08	0	0
Ribeirao Buriti	2.453,84	0	0	374,26	0
Diamantino river outfall	1.617,05	0	0	0	0
Rio Diamantino Springs	3.228,65	4.731,95	346,73	0	5,72
Total	8.764,23	6.846,84	1.750,81	374,26	5,72

Legend: LVA: Oxisol; LV Rhodic; PVA: Red Yellow Argisol; RL: Neossolo Lytic; RQ: Neosssolo Quartizaremico.

The Oxisol is the most representative soil in SBRDN and SBRB with 18.20% and 13, 83%, respectively, and in a smaller area in SBRDF (9.11%) and SBFM (8.25%); thus, this soil type is present mainly in the southern part of the Diamantino river basin (Table 4).

The Rhodic occurs mainly in the north-central and western portion of BHRD, at SBFM (11.92%) and SBRDN (26.67%). The same sub-basins, presenting LV soil type, have also the soil Paleudult-yellow type. In the SBFM (7.91%) and SBRDN (1.95%), the PVA occurs mainly in the northwestern portion.

The Neossolos Litólicos are located in a small portion in the southwestern part of BHRD, comprising only a sub-basin in the SBRB (2.11%). The Neossolos Quartzarênicos are located exclusively in the SBRDN (0.03%), occupying a small portion in the northwestern part of BHRD (Figure 4).

SBRDF was the sub-basin with only one type of soil, the Red-Yellow Oxisol. According to Sousa and Lobato (2007), Oxisols are porous, deep, well-drained, and well permeable soils, even with high clay content they are usually situated on flat, smooth-rolling relief. However, this soil type has low fertility and high aluminum saturation, representing a problem for agricultural use. Thus, to obtain a good productivity on this soil type, it is necessary to use chemical fertilizers, organic matter, minerals taken from deposits of from free air (in the case of biological nitrogen fixation), and correction or liming (SPERA et al., 2000).

According to Coutinho (2005), Red and Red-Yellow Oxisols are one of the main soil types used in technical agriculture (for Soy, Wheat, Corn, and Cotton) and livestock; this factor may have favored the expansion of these activities in BHRD.

Argissolos are mineral soil types with a great diversity of properties (fertility) for agricultural use. This is a good soil suitable for both agricultural use and in the communal areas (SOUSA; LOBATO, 2007). The Neossolos Quartzarênicos are soils generally derived from sandy deposits. This type of soil has a low agricultural potential, and its continuous use can lead to rapid degradation, requiring proper management and intensive care to control erosion and fertilization for agricultural purposes (SOUSA; LOBATO, 2007).

RQ soils must be used carefully, especially in the SBRDN area with this soil type. Sousa and Lobato (2007) insist that RQ soils close to water sources must strictly be maintained without usage for the preservation of water resources, flora, and fauna in this area.

Thus, the main causes of Natural Vegetation decrease in Mato Grosso State, which can cause great environmental damage, are related to the soil characteristics at SBHRD that allowed the expansion of agriculture and livestock activities.

The preservation of SBHRD is of fundamental importance, because it is part of a major biome, the Pantanal, which provides ecological services such as the maintenance of biodiversity, landscape, fresh water supply, fishing, and nutrient cycling, contributing to the human life quality (GARLIC, 2011).

The present study contributes to understand the magnitude of land use and for the mitigation of its impact on risk areas. The results of this study can be incorporated into an action plan for the conservation of SBHRD and, consequently, of the Pantanal.

CONCLUSIONS

The methodology used in this study allowed identification and preparation for the thematic mapping of five land use classes in SBHRD (Natural Vegetation, Pasture, Agriculture, Water masses, and Other Anthropic Uses).

The pasture expanded significantly in the last 20 years at the expense of suppression from Natural Vegetation in all sub-basins. The soil types Rhodic and Oxisol occur widely in the Diamantino River sub-basins.

Calculation of ITA indicated that the values of Anthropic Processing increased in SBHRD. All sub-basins were classified as “Slightly degraded” in 1993. However, in 2003, SBCFM, SBRB, and SBRDF became part of the “Regular level”, only SBRDN remained as little degraded.

In 2013, SBRDN became part of the Regular level along with the other sub-basins, which remained in the normal state. Thus, it was found that the values of the Anthropic Transformation Index increased in a few years, although no sub-basin has reached a degraded state.

In this study, it was found out that the main factor favoring the increase of the Anthropic Transformation Index was the expansion of pasture. It is therefore important to seriously consider the results of the Anthropic Transformation Index, in order to avoid higher levels of it.

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