THE INTENSITY OF ANTHROPOGENIC TRANSFORMATIONS IN THE BRAZILIAN LEGAL AMAZON AREA – MATO GROSSO/BRAZIL

A INTENSIDADE DA TRANSFORMAÇÃO ANTROPOGÊNCIA E M UMA ÁREA DA AMAZÔNIA LEGAL – MATO GROSSO/BRASIL

LA INTENSIDAD DE LA TRANSFORMACIÓN ANTROPOGÉNICA EN UN ÁREA DE LA AMAZONÍA LEGAL – MATO GROSSO/BRASIL

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ABSTRACT: This study analyzed the intensity of anthropogenic transformations occurred in the Sangue river sub-basins of Brazilian Legal Amazon, Mato Grosso State. The Thematic Mapper images onboard Landsat 5 satellite were geo-referenced, classified and processed using the Remote Sensing Image Processing System (SPRING) software and the thematic classes were quantified using ArcGis software. The degree of human disturbance was verified considering the Anthropogenic Transformation Index. Five land use/land cover classes were mapped, natural vegetation, water bodies, agriculture, pasture and other anthropogenic uses. Using the Anthropogenic Transformation Index, it was found out that there was an increase in the degree of anthropogenic changes over the years in the sub-basins studied, caused mainly by the increase in pasture, agriculture and other anthropogenic uses related to the reduction of natural vegetation.

Keywords: Deforestation. Geotechnology. Land use. Agriculture.

RESUMO: Este estudo analisou a intensidade da transformação antropogências ocorrida na bacia do rio do Sangue, na Amazônia legal brasileira, estado de Mato Grosso. As imagens do Landsat 5 foram georreferenciadas, classificadas e processadas no *software* Spring e as classes temáticas quantificadas no *software* ArcGis. O grau de antropização foi verificado através do Índice de Transformação Antrópica. Foram mapeadas cinco classes de uso e cobertura da terra, a vegetação natural, massas d'água, agricultura, pastagem e outros usos antrópicos. Por meio do Índice de Transformação Antrópica, verificou-se um aumento do grau de antropização ao longo dos anos nas sub-bacias, causado

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principalmente pela intensificação da pastagem, agricultura e outros usos antropogênicos relacionados a redução da vegetação natural.

Palavras-chave: Desmatamento. Geotecnologia. Uso da terra. Agricultura.

RESUMEN: Este estudio analizó la intensidad de las transformaciones antropogénicas ocurridas en las subcuencas del río Sangue de la Amazonía Legal brasileña, estado de Mato Grosso. Las imágenes de Thematic Mapper a bordo del satélite Landsat 5 fueron georreferenciadas, clasificadas y procesadas utilizando el software del Sistema de procesamiento de imágenes de detección remota SPRING y las clases temáticas se cuantificaron utilizando el software ArcGis. El grado de perturbación humana se verificó teniendo en cuenta el índice de transformación antropogénica. Se mapearon cinco clases de uso del suelo / cobertura del suelo, vegetación natural, cuerpos de agua, agricultura, pastos y otros usos antropogénicos. Utilizando el Índice de Transformación Antropogénica, se descubrió que hubo un aumento en el grado de cambios antropogénicos a lo largo de los años en las subcuencas estudiadas, causado principalmente por el aumento de los pastos, la agricultura y otros usos antropogénicos relacionados con la reducción de los recursos naturales. vegetación.

Palabras Clave: Deforestación. Geotecnología. Uso del suelo. Agricultura.

1 INTRODUCTION

The Mato Grosso state holds major rivers, which contribute to the Paraguay, Amazon, Araguaia and Tocantins basins. The Sangue river belongs to the Amazon river basin and is considered one of the main tributaries to the sub-basin of Juruena river (BATISTA *et al*., 2012). It has a great potential for generating electricity according to Fearnside (2015).

A river basin is a portion of land drained by a drainage system consisting of a main river and its tributaries controlled in a geographic space by a watershed (CARVALHO; BRUMATTI; DIAS, 2012). The adoption of river basin as the unit for environmental management and planning is a trend in many countries and has gained momentum in Brazil, with the regulation of the National Water Resources Policy (Law Nr. 9433 of 1997) (BRASIL, 1997). This legislation provides for the creation of committees and basin agencies and the participation of civil organizations in environmental planning and preparation of Master Plans for river basins.

For the preparation and implementation of these plans, it is however essential to raise quickly and reliably quantitative information about the effect of human activities on the environment in short, medium and long term (ORTIZ; FREITAS, 2005).

The Sangue river is located in a region of Mato Grosso state with intensive agricultural and livestock production. Since these activities occupy the space, they end up reducing the natural vegetation, and in some cases even areas protected by Law, such as Permanent Preservation Areas (APPs) and an Indian Reservation Unit (FEARNSIDE, 2015). The reduction of natural vegetation causes several problems to the environment, such as imbalance in local populations of fauna and flora, disruptions in water flow, among others (ORTIZ; FREITAS, 2005). In this context, Remote Sensing techniques allow a rapid diagnosis on the expansion of human activities on the Earth's surface (CORREIA *et al.*, 2004).

The Anthropogenic Transformation Index (ITA) proposed by Lémechev (1982), modified by Mateo (1991), relies on the preparation of thematic maps from Geographic Information

System (GIS) to quantify the degree of landscape modification, during the assessment of environmental quality. This Index takes into account the area occupied by each land use and the weight determined by the degree of human disturbance assigned to each use, provides an overview of landscape transformation (GOUVEIA; GALVANIN; NEVES, 2013).

Using geo-processing techniques and the ITA, it is possible to identify the different impacts of the expansion from human activities and the pressures imposed by them on areas with natural vegetation in the river basin. So this study aims to evaluate the intensity of anthropogenic changes occurred in the sub-basins belonging to the Sangue river basin (BHRS) in Mato Grosso state.

2 MATERIAL AND METHODS

The Sangue river basin (BHRS) in Mato Grosso state is located between the coordinates of 11°0’00” and 15°0’00” south latitude and 59°0’00” and 57°0’00” west longitude, occupies an area of approximately 2,890,412.65 ha, consisting of nine sub-basins (river: Tenente Noronha, Cravari, creek Domingos, Treze-de-Maio, Benedito, Membeca, Sangue, Sucuruína and Sem Nome (Without Name), (this sub-basin is nameless because in the topographic maps the hydrography within the limits thereof have no name). They include the municipalities of Tangará da Serra, Campo Novo Parecis, Diamantino, Nova Marilândia, Nova Maringá, Brasnorte and Juara (Figure 1).

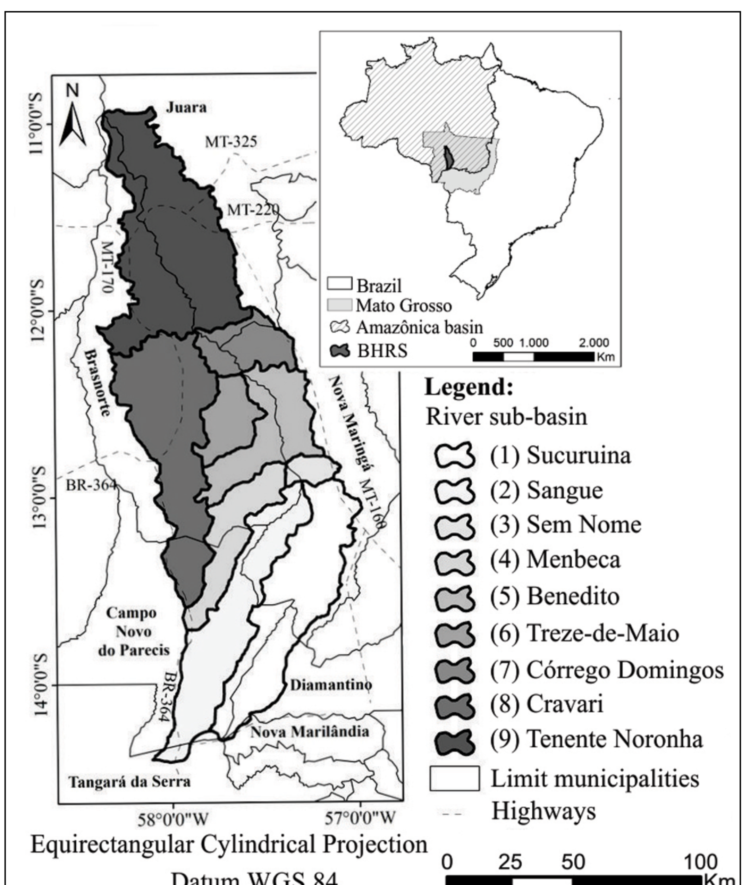

Figure 1. Location of the study area in the Amazon and Mato Grosso State – Brasil.

The Sangue river sub-basins (SBHRS) have, in general, two types of vegetation: Seasonal forest and Savanna, contained in the biomes Amazon and *Cerrado*. The climate is tropical with two distinct seasons: from October to March (rainy) and from April to September (dry). The average annual temperature and rainfall are 24.4°C and 1,500mm, respectively (DALLACORT *et al*., 2010).

An initial visit to the study area was done during the dry season in August 5th and 6th 2013, for photographic recording of the existing features and collection of Ground Control Points (GCPs), to support the classification of satellite images.

Afterwards the Sangue river sub-basins were delimited by topographic data of the Digital Elevation Model (DEM) in raster format, obtained in the geo-morphometric Brazilian database, from TOPODATA Project, provided by the National Institute for Space Research (INPE). For the analysis of spatial-temporal land use, LANDSAT-TM 5 satellite images with 30 m resolution were obtained from INPE's image catalogue. Image localization (Orbit/Point): 70 227/69, 228/68, 69 and 70, bands 5, 4 and 3, RGB composition, respectively. The images were taken in July and November 1990, July 2000 and June 2010.

The images were processed and analyzed in the Processing System for Geo-referenced Information (SPRING), version 4.1.8. at INPE (CAMARA *et al*., 1996). Initially a database was created, using the coordinate system of Universal Transverse Mercator (UTM), datum World Geodetic System (WGS 84). Sequentially the geo-referencing of LANDSAT images was made using GeoCover images available in the LANDSAT website.

Afterwards a mosaic of five scenes for each year was made and the area under study was cut through map algebra, using a mask of SBHRS in vector format. Following, the segmentation of the mosaic images was made using the region growth algorithm to group spectrally similar pixels, forming homogeneous regions.

Therefore, tests were performed with the similarity and area values to find the best combination. The similarity values 8 and area 16 showed the best result to group two spectrally similar regions into a single region and the best result in the individualization between regions by the number of pixels, such as in the study from Vasconcelos and Novo (2004).

The scenes from Sangue river basin presented many clouds during the rainy season, which caused a strong spectral confusion between land use/land cover classes, and also the predominance of the deciduous vegetation in the region, which makes it difficult to discriminate this natural vegetation type during the dry period, with other uses (agriculture and pasture, for example) (FELFILI; CARVALHO; HAIDAR, 2005).

So the distinction between the classes was carried out through time series of the Enhanced Vegetation Index (EVI), provided by the Remote Sensing Laboratory for Agriculture and Forestry (LAF/INPE), making it possible to distinguish the different types of vegetation occurring in certain regions (FREITAS *et al*., 2011).

The EVI time series however subsidized only the classification for the years 2000 and 2010, since there were no previous time series to 2000 (FREITAS *et al*., 2011). To perform the classification for the year 1990, in addition to scenes from the dry season, images from the rainy season were used to allow the distinction between land use classes.

The land use/land cover classes were defined, analyzing the image and methodology used by Silva *et al.* (2011). In our study 5 classes were considered, namely: Natural vegetation (Forests and Savannas), Agriculture (including temporary and agro-forestry-pastoral perennial system), Water bodies (Lakes, rivers and ponds), Pasture (all types of pasture including intensive, semi-intensive and extensive) and other anthropogenic uses, such as urban areas, headquarters of farms and engineering works, such as hydro-electric power).

Following, a supervised classification of the dry period images, using the classifier of Bhattacharrya regions with an acceptance of 99.9% was made (XAUD; EPIPHANIO, 2014).

At the end of the classification process, an assessment of the accuracy using the Kappa index was performed to verify the reliability of the resulting map. This index is the ratio of the sum from the main diagonal of the error matrix and the sum of all the elements of this matrix, represented by the total sample number, with reference to the total number of classes, considering the proportion of correctly classified samples (COHEN, 1960).

The classifications generated with SPRING were transformed to thematic classes, modified from matrix to vector and exported. These vector files were processed in ArcGIS software, version 9.2 (ESRI, 2007), for cartographic editing and quantification of the land use/land cover classes, using the attribute calculator.

In order to quantify the human pressure on SBHRS the ITA proposed by Lémechev (1982) and modified by Mateo (1991), was used, which is expressed by equation 1.

$$\mathrm{ITA} = \sum \left(\%\,\mathrm{USO} \times \mathrm{PESO}\right) / 100 \qquad (1)$$

where:

USO = area percentage of land use/land cover class,

PESO = weight given to different types of use and coverage in the level of anthropogenic change. It ranges from 1 to 10; where 10 indicate the highest pressures.

Therefore, the attribution of values for the weight in each class of land use and vegetation cover that contributes to the transformation of the landscape, is realized by the systematic consultation called “Delphi”, which allows the establishment of the consensus on how to quantify the degree of modification of the landscape (SCHWENK; CRUZ, 2008).

In this way, the weight values were attributed through the discussion between the authors and the researchers members of the Laboratory of Geomatics of the University of Mato Grosso (UNEMAT), Barra do Bugres Campus, in view of the knowledge they have about the study area. Corroborating thus with Mateo (1984) that mentions that each class presents a weight attributed in function of the knowledge that the author has about them in relation to the degree of anthropization. The weights of each land use class are set forth in Table 1.

Table 1. ITA classification with weights for each land use class

Land use Classes	Weight
Agriculture	7.3
Water bodies	2
Other anthropogenic uses	9.7
Pasture	5
Natural vegetation	1

The transposition of quantitatively measured values into qualitative classes occurred through the adoption of the quartiles method used by Cruz *et al*. (1998): Little degraded (0 to 2.5); Regular (2.5 to 5); Degraded (5 to 7.5) and Very degraded (7.5 to 10).

3 RESULTS AND DISCUSSION

The proposal from Lémechev (1982), to quantify the degree of environmental transformation was adapted satisfactorily to geo-processing and environmental monitoring. Since this technique has many advantages to identify and indicate areas with high human disturbance, taking into account the land use as variable. Thus, the generation of use and land cover map is an important step in the calculation of the ITA (Figure 2).

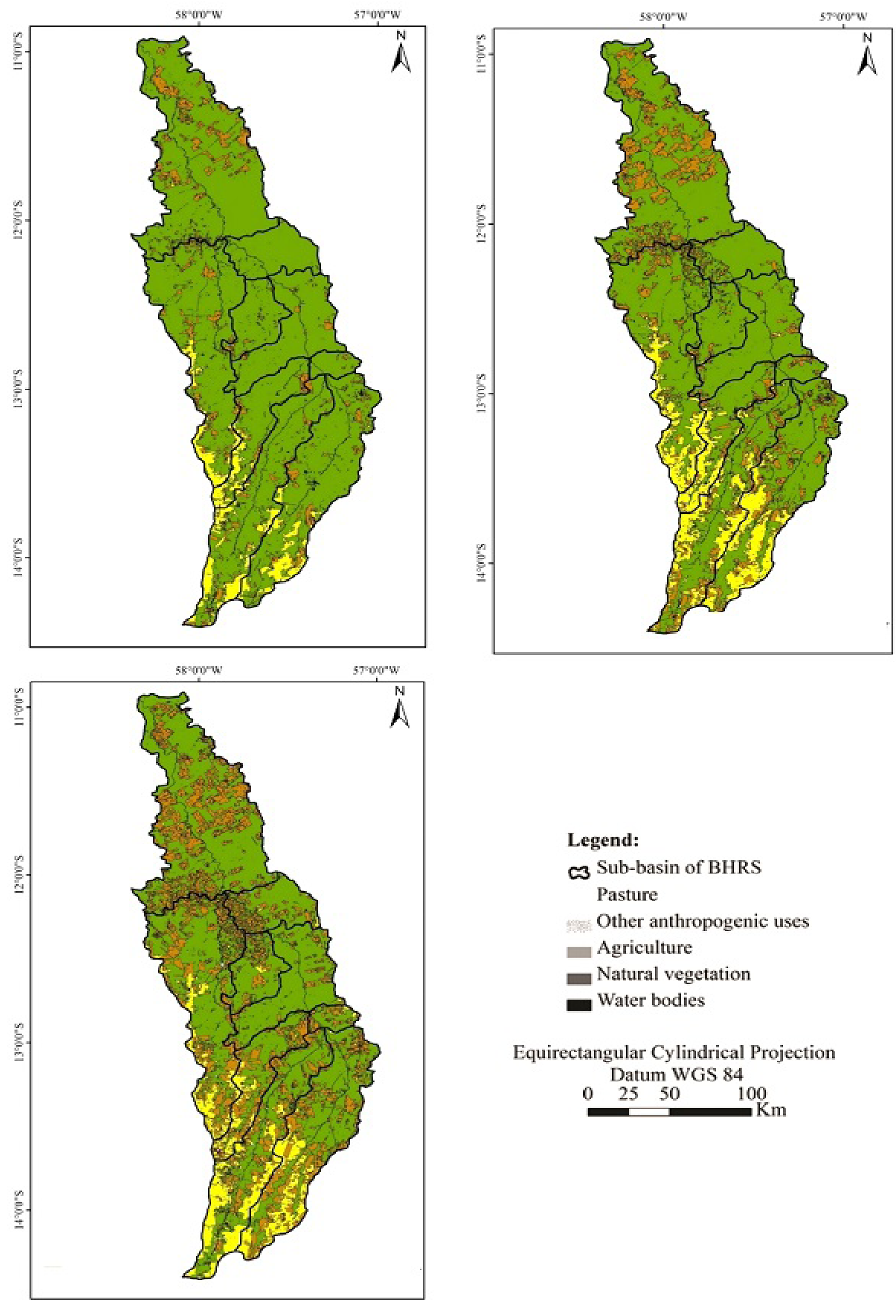

Figure 2. Distribution of thematic classes Land use/Land cover in Sangue river sub-basins for the years 1990 (a), 2000 (b) and 2010 (c).

The classification of BHRS sub-basins reveals that agriculture has expanded from the southern and southwestern region to the west and north of BHRS. This dynamic expansion of human activities, especially the extensive agriculture (soy, corn, sugarcane, cotton), of the south to the north of Mato Grosso State towards the States of Pará and Amazonas, are also evidenced by Fearnside (2006).

The dynamics of occupation in the Amazon region, according to Arima, Barreto and Brito (2005), occurs in three phases. Initially there is timber extraction. In the second stage, the deforested area is planted with pasture, because this activity is economically more viable due to the low initial investment for its implementation than other activities, such as agriculture. Only in a third phase the grazing areas are used for agriculture.

Environmental problems caused by extensive and irregular land use have been strongly influenced by land speculation, by governmental investment in the deployment of railways, waterways and highways. Tax subsidies and credits to private investments in the region made the implementation of agricultural activities profitable, which initially were unviable, thus increasing the interest in the region. This caused, in the last three decades, the intensification of the deforestation process (MORAN *et al*., 1996; ARIMA; BARRETO; BRITO, 2005).

The quantitative results of the area from each class, in relative values (%) of land use and the ITA calculated for each sub-basin are shown in Table 2. From the classification of sub-basins using the ITA calculus, it was possible to generate the thematic map shown in Figure 3.

In 1990 only sub-basin 2 was in the regular condition and the others were little degraded (Figure 3a and Table 2). In 2000, the sub-basins 8 and 4 were included in the Regular level along with the sub-basin 2, which remained in this level of human disturbance. Sub-basins 1, 3, 5, 6, 7, and 9 remained as little degraded (Figure 3b and Table 2).

However, in 2010 only sub-basins 5, 6 and 7 kept the level of little degraded, sub-basin 4 got the degraded level and the other ones got the Regular degree (Figure 3c). None of the sub-basins got the degree very Degraded (ITA between 7.5 and 10) for the time analyzed (Table 2).

Table 2. Results of Land Use classes and ITA for each sub-basin of Rio do Sangue watershed, Mato Grosso State, Brazil, for 1990, 2000 and 2010. Legend: Agriculture (A), Water body (WB), Other anthropogenic uses (OAU), Pasture (P) and Natural Vegetation (NV).

River sub-basin	Land use classes (%)					ITA
	A	WB	OAU	P	NV	
1990						
(1) Sucuruína	7,87	0,45	0,15	7,22	84,29	1,803
(2) Sangue	24,01	0,38	0,19	9,63	65,78	2,918
(3) Sem Nome	0,04	0,57	0,00	5,78	93,59	1,24
(4) Membeca	16,11	0,27	0,09	9,65	73,85	2,412
(5) Benedito	0,15	0,72	0,01	2,57	96,52	1,122
(6) Treze-de-Maio	0,06	1,34	0,01	1,74	96,82	1,089
(7) Córrego Domingos	0,01	1,05	0,02	0,59	98,32	1,037
(8) Cravari	7,29	0,57	0,09	8,87	83,15	1,83
(9) Tenente Noronha	0,05	0,27	0,06	11,57	88,03	1,475
2000						
(1) Sucuruína	8,61	0,49	0,21	19,02	71,66	2,327
(2) Sangue	45,64	0,67	0,18	20,1	33,4	4,703
(3) Sem Nome	3,78	1,30	0,05	13,57	81,28	1,799
(4) Membeca	42,35	0,44	0,43	9,80	46,96	4,103
(5) Benedito	1,14	0,45	0,04	3,41	94,96	1,216
(6) Treze-de-Maio	1,01	0,51	0,04	3,25	95,18	1,202
(7) Córrego Domingos	0,41	1,17	0,06	1,58	96,77	1,106
(8) Cravari	15,49	0,53	0,13	13,97	69,85	2,556
(9) Tenente Noronha	0,15	0,30	0,07	24,32	75,14	1,993
2010						
(1) Sucuruína	31,22	0,34	0,14	25,98	42,31	4,022
(2) Sangue	42,15	0,26	0,16	20,11	37,32	4,5
(3) Sem Nome	13,04	0,83	0,29	22,23	63,6	2,744
(4) Membeca	64,86	0,53	0,62	4,39	29,6	5,322
(5) Benedito	2,43	0,64	0,09	7,96	88,87	1,5
(6) Treze-de-Maio	4,21	0,38	0,11	8,33	86,96	1,612
(7) Córrego Domingos	2,45	1,30	0,16	8,76	87,32	1,532
(8) Cravari	14,65	0,85	0,16	30,2	54,07	3,16
(9) Tenente Noronha	1,54	0,40	0,11	36,48	61,46	2,57

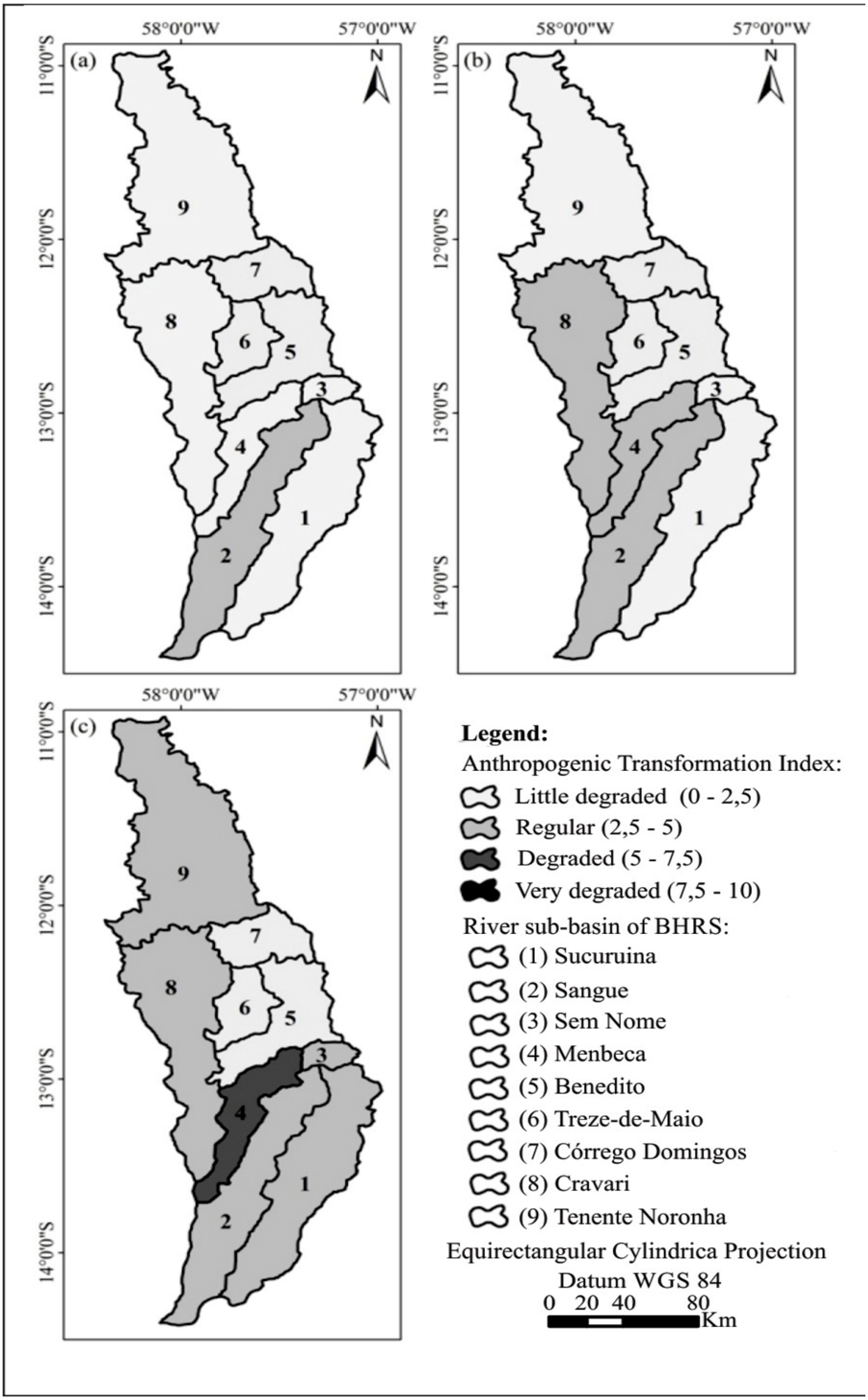

Figure 3. Anthropogenic Transformation Index for the Sangue river sub-basins for the years 1990 (a), 2000 (b) and 2011 (c).

The main factors that contributed to the increase in the level of anthropogenic transformation, over time, was the increase in the area of human activities, with agriculture and livestock. Agriculture was the most representative class in the sub-basins (1, 2 and 3) present in the southwestern part of BHRS. Livestock had to be more relevant in the sub-basins 8 and 9 located further north of BHRS.

We must stick to the results observed for the BHRS sub-basins, to prevent in the coming years, that the anthropogenic transformation reaches high levels, because in a short period of time the degree of disturbance can increase, as shown in a work by Perez and Carvalho (2012), for the Ipê river basin in São Paulo State, where the degree of anthropogenic transformation changed from "Degraded" to "Very degraded" during just nine years of study, from 2002 to 2011. Changing the availability of native vegetation and the garbage dump in the stream, contributing to the proliferation of vectors of diseases.

The landscape modification and inadequate land occupation lead to consequences extremely worrying, such as reduced water resources availability, loss of soil fertility, intensification of desertification processes, soil compaction and species elimination (fauna and flora) which were not catalogued. These changes are neglected by public administrations and by the population itself, and it is forgotten that the human being depends on the resources of the land for survival, food production and clothing - thus, conservation of at least the areas protected by the law is necessary (EZEAKUI; DAVIDSON, 2008).

Although in this work there were no studies on the impact from the removal of natural vegetation on the water bodies, flora and fauna, the results found in our work indicate that Sub-basin 4, classified as "Degraded", presents some disturbance, as a result of intense transformation. The higher the degradation degree, the greater is the possibility of ecological landscape imbalance.

In this sense Cruz *et al.* (1998) found that there is a positive relationship between the degree of human disturbance of the sub-basins draining to Guanabara Bay, Rio de Janeiro State, and water contamination. The sub-basins with a high ITA level were those which presented contamination of the water surface by fecal coli and total phosphorous. A detailed investigation in this perspective is necessary, which is important for the population health.

The government of Mato Grosso State foresees a plan for the prevention and control of deforestation and forest fires through an integrated set of programs in three areas: planning of land use, monitoring, and encouraging the development of sustainable activities (FEARNSIDE, 2002).

Although many actions from the plan have not been implemented, the environmental record of rural properties, according to Strassburg *et al*. (2014), is a major breakthrough for the environmental suitability of the uneven areas regarding legislation, as well as the establishment of governmental development plans for land use.

CONCLUSIONS

It was observed that the area of natural vegetation was reduced and that other classes presented an increase of occupation in the Sangue river sub-basins, during the years analyzed.

The ITA has increased over the years in the Sangue river sub-basins, but no sub-basin reached a very degraded state.

Since there are few studies in this region, it is necessary to conduct other studies to understand the consequences from the result of the Anthropogenic Transformation Index in the environment, such as water quality, enabling the development of conservation plans and recovery of sub-basin areas.

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