

GEOTECHNOLOGIES APPLIED TO THE EVALUATION OF SUGARCANE DYNAMICS IN THE BUGRES RIVER BASIN, MATO GROSSO STATE - BRAZIL

Sandra Mara Alves da Silva NEVES¹

Iara Silveira do NASCIMENTO²

Jesã Pereira KREITLOW¹

Edinéia Aparecida dos Santos GALVANIN³

Ronaldo José NEVES¹

Carla Bernadete Madureira CRUZ²

Abstract

The expansion of the productive activities in plateau sections of the Upper Paraguai River Basin (BAP) can potentially impact the abiotic and biotic systems of the Pantanal. The objective of this study is to investigate the dynamics of sugarcane plantation in the Bugres river basin, Mato Grosso state. The methodological procedures followed are based on the generation of data from satellite images and processing in a GIS. In 1990 sugarcane occupied, in the area under study, 137.44 Km² increasing to 981.11 Km² with an expansion of 613.84%, preferentially in North-Northeast direction. Sugarcane occupied areas of Sub-montane Semi-Deciduous Seasonal Forests, Alluvial Forests and Livestock farms, not advancing over Urban Areas and Areas of Permanent Protection, the so-called "APP's". The declivity is an impeditive factor to increase sugar cane plantations in BAP, wherein it was established in sectors of flat to light undulated relief. As far as soils are concerned, plantations predominate on Oxisols. It was verified that the undulated relief is correlated with the proximal variables: roads, drainage and Indian lands. It was concluded that the good physical soil conditions and flat to light undulated terrain, favored the sugarcane plantation which, under such conditions, presents no restrictions to mechanization.

Keywords: Remote sensing. Image processing. Wetlands. Pantanal. Environmental conservation.

¹ University of the State of Mato Grosso (UNEMAT). *Stricto sensu* Graduate Program in Environment and Agricultural Production Systems and Geography. Laboratory of Geotechnologies. Av. Santos Dumont, s/n. Bairro: Santos Dumont. CEP: 78200-000 Cáceres/MT, Brasil. E-mails: {ssneves, rjneves}@unemat.br; jesapk1@hotmail.com.

² Federal University of Rio de Janeiro (UFRJ). *Stricto sensu* Graduate Program in Geography. Av. Brigadeiro Trompowski, s/n. Caixa Postal 68537. CEP: 21945-970 Rio de Janeiro/RJ, Brasil. E-mails: {iarasn.geo, carlamad}@gmail.com.

³ University of the State of Mato Grosso (UNEMAT). *Stricto sensu* Graduate Program in Environment and Agricultural Production Systems. Rua A, s/n. Bairro: Cohab São Raimundo. CEP: 78390-000 Barra do Bugres/MT, Brasil. E-mails: galvaninbbg@unemat.br.

Resumo

Geotecnologias aplicadas na avaliação da dinâmica da cana-de-açúcar na bacia do rio do Bugres, Mato Grosso-Brasil

A expansão das atividades produtivas nas áreas de planalto da Bacia do Alto Paraguai tem potencial para impactar os sistemas abióticos e bióticos do Pantanal. Objetivou-se investigar a dinâmica da cana-de-açúcar na bacia hidrográfica do rio do Bugres, Mato Grosso. Os procedimentos metodológicos foram baseados na geração de dados através de imagens orbitais e processamento em Sistema de Informação Geográfica. Em 1990 a cana de açúcar ocupava na área de estudo 137,44km² passando para 981,11 km², configurando uma expansão de 613,84%, preferencialmente na direção Norte-Nordeste. A cana ocupou áreas de Floresta estacional semidecidual sub-montana, Aluvial e de Pecuária, não avançando sobre as áreas urbanas e Áreas de Preservação Permanente. A declividade é um fator impeditivo de ampliação do cultivo de cana na bacia, tendo a cana se estabelecido em áreas de relevo plano e suave ondulado. No tocante aos solos houve predominância do cultivo nos Latossolos. Verificou-se que o relevo suave está correlacionado com as variáveis proximais estradas, hidrografia e terras indígenas. Concluiu-se que as boas condições físicas do solo aliadas ao relevo plano ou suave ondulado, que é o caso da área de estudo, favoreceram sua utilização o cultivo da cana-de-açúcar que nessa situação não apresenta restrição a mecanização.

Palavras-chave: Sensoriamento remoto. Processamento de imagens. Áreas úmidas. Pantanal. Conservação ambiental.

INTRODUCTION

Brazil is worldwide one of the largest sugarcane producers. Due to its environmental conditions, in almost the entire country, especially between latitudes S 8° to S 24°, sugarcane has favorable growth conditions. Project CANASAT data from 2012 (INPE, 2014) pointed out that from 2,879.47 Km² of the area planted with it in Mato Grosso state, 1,999.43 Km² (69.43%) are located within BAP where the following sugar mills are located: Jaciara (municipality of Jaciara), Barracol (municipality of Barra do Bugres) and Itamarati (municipality of Nova Olímpia); and the COOPERB ethanol distillery (municipality of Mirassol D'Oeste).

The Sugarcane Agro-Ecologic Zoning (ZAE) (BRASIL, 2012) elaborated with digital processing techniques, is the instrument indicated by the Brazilian national policy to direct the production of sugarcane. This document came out from the strategic need to evaluate, and to indicate spatially the land potential for the expansion of plantations under dry-land conditions (without full irrigation). The geotechnologies are important to order this economic activity, since to execute zonings presently, the GIS is used to process thematic and cartographic information. Both remote sensing and GIS have been indispensable for monitoring sugarcane plantations by governmental institutions and for scientific research (RUDORFF *et al.* 2010; SOUZA, 2010; PESSOA *et al.*, 2013; SANTOS *et al.*, 2013).

This investigation at the Bugres river basin is important due to the importance of this river for the environmental system of BAP, where the biome and the floodplain of the Pantanal and the largest sugarcane plantations are located. Furthermore this river is used for the water supply of the city Barra do Bugres. So the conservation of environmental components of this river basin as well as the control of the quantity and quality of its water is of interest for the local residents, because they would be the

most injured in case of degradation, pollution and contamination of the natural resources from this area (FAVA *et al.*, 2012). In the above mentioned context, the objective of this paper is to investigate the dynamics of s plantations in the Bugres river basin, in the period 1990-2014, using geotechnologies.

MATERIAL AND METHODS

Study Area

The Bugres river basin (BHRB) is one of the units from the Upper Paraguai River Basin (BAP), in the Mato Grosso state (Figure 1). BHRB has a territorial extension of 2,269.77 km² distributed between the following municipalities: Santo Afonso (4.7 Km²), Arenápolis (181.6 Km²), Denise (1,138.52 Km²), Tangará da Serra (6.4 Km²), Nova Olímpia (470.77 Km²) and Barra do Bugres (467.8 Km²).

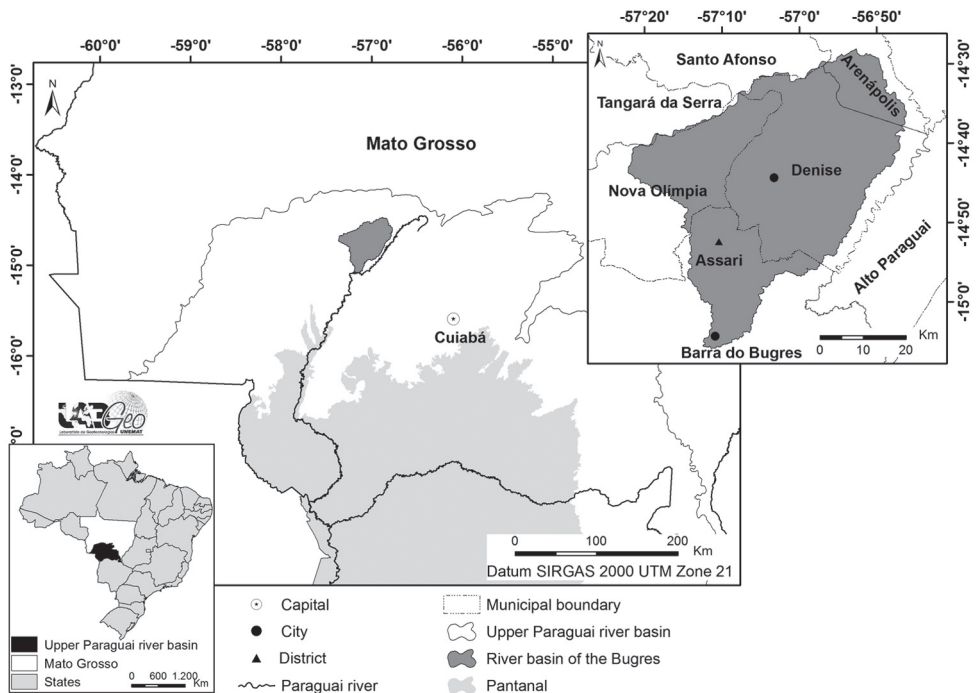


Figure 1 - Study area within BAP, in Mato Grosso state

Source: the authors, 2015.

According to EMBRAPA (2008), the predominant climate at the basin is of Tropical type with a rainfall regime constituted by a rainy season (October to March) and a dry season (April to September).

Methodological procedures

For the map generation, bands 3, 4 and 5 of satellites LANDSAT 5 and 8, TM sensor and OLI (Operational Land Imager) respectively, Orbit/Point 227/70, with 30 m spatial resolution, were used. The images were obtained from INPE (National Institute for Space Research, Brazil) and USGS (United States Geological Survey) respectively.

The scenes selected are from the dry period, thus allowing distinguishing those areas occupied by sugarcane plantations from natural vegetation and other land uses.

For the selection of dates from images, the crop year for semi-perennial cultures was considered. This period includes the soil preparation, plantation and harvesting which, in this region, according to Ordinance Nr. 40/2009 (BRASIL, 2009), occurs from July 1st from one year until June 30th of the following year. The images of crop years selected, date from July 8th 1990-July 27th 1991; July 19th 1994-August 7th 1995; July 19th 2000-July 30th 2001; August 15th 2004-July 1st 2005; July 31st 2010-June 16th 2011 and June 24th 2014.

For the thematic classifications of the sugarcane plantations within the basin, the SPRING software package, version 5.2.7 from INPE was used. The image processing consisted of two steps, namely: 1st – the geo-referenced scenes (Geocover) available at the site from NASA were inserted in the geographic databank from SPRING by importation and geo-reference (registration), mode screen-by-screen, obtaining the coordinates from the Geocover reference images, whose average error of the control points was 0.400 . Afterwards they were imported to the databank. This procedure was not executed on LANDSAT 8 image from 2014, because it was geo-referenced; 2nd – In order to optimize digital processing, only those areas occupied by sugarcane in the basin were classified. The procedures adopted were: segmentation, which used the algorithm from Region Growth with the definition of following parameters: Similarity 10 and Area 10 for LANDSAT 5 images and Similarity 300 and Area 300 for LANDSAT 8; Attribute extraction aiming to determine parameters of the polygons created; Training with polygon sample selection with sugarcane at different growth stages; Classification, whose cluster of spectrally homogeneous classes occurred with the classifier Bhattacharya, acceptance threshold 99.9%; Generation of sugarcane maps by conversion Matrix-Vector, and finally the vector files generated were exported at the extension Shapefile, so that in ArcGIS, version 9.2, from ESRI, layouts of maps and quantification of sugarcane areas could be generated. For the validation of the products generated, field surveys were done in October 24th 2011, during the classification phase, when 8 places were visited, with coordinate registration by Global Navigation Satellite System (GNSS), Garmin model 60, and pictures from cultures by a digital camera. For those data generated from years 2000, 2001, 2004 and 2005, the temporal series of the EVI2 MODIS filtered data were used, available at the website www.dsr.inpe.br/laf/series, whence considering the following information: viewing angle of the sensor, reflectance of spectral band and observation date from the pixel (FREITAS *et al.*, 2011).

The spatial standard of sugarcane from 1990 to 2014 was obtained by the analysis of the following parameters: orientation of the growth from the cultivated area within the basin, expansion of the culture within BHRB, progression of the culture over other forms of land use/land cover and evaluation of the expansion by municipality. In order to analyze the orientation (direction) of the sugarcane expansion in the BHRB, the positioning in the center of the basin (cardinal and collateral points) was considered. The evaluation of the progression from the culture was made with the Intersect tool in ArcGIS, considering each sugarcane layer in the period 1990 to 2001, together with the layer generated at Projeto Radambrasil (BRASIL, 1982). For the period 2004 to 2014 the vegetation layer of Project PROBIO (BRASIL, 2014) was used. For the quantification of the spatial dynamics from sugarcane by municipality, each annual

layer was related to the municipality layer by Intersect (ArcGIS), resulting in layers for each of these administrative units.

In ArcGIS the proximal variables (altimetry, drainage, slope, roads, Indian lands and soil) which could influence the expansion of sugarcane in the basin were made operational following the procedures mentioned below:

- **Altimetry:** the DEM (Digital Elevation Model) scenes originated from the geomorphometric databank TOPODATA (VALERIANO, 2005). The resolution of data generated by the SRTM (Shuttle Radar Topography Mission), C band, was improved from 3" to 1" (~30m). The images were prepared as mosaics, masked for the area under study, and stored in the BHRB file. Afterwards the conversion was made from projection WGS 84 to SIRGAS 2000 UTM 21 S, through the module ArcToolbox from ArcGIS. The SRTM image of the basin was sliced, using function Classify, with definition of following class intervals, in meters: 150-250, 250,1-350, 350,1-450 and 1-550. The intersection between the altimetry map with those of sugarcane (annually) was made, obtaining the area planted with sugarcane for altimetry class.
- **Declivity:** through the extension Spatial Analyst, the processing phases of the SRTM image were made, according to a methodology proposed by Fornelos & Neves (2007). The file generated was reclassified in six classes in accordance with IBGE (2007). The raster file was converted to vector, using tool Raster to Polygon, to calculate the areas planted yearly with sugarcane by declivity classes.
- **Roads:** from the geo-processing tool Multiple Ring Buffer, buffers were generated for the following distances: 0-50, 50, 1-100, 100, 1-200, 400, 1-800, 800,1-1000 and >1000,1 in the surroundings of BHRB.
- **Drainage:** from the Drainage an Permanent Protection Area (APP) was generated using the tool Buffer, with 30 m distance. In sequence, using the file Buffer with 30 m, the Multiple Ring Buffer tool was applied, to generate influence areas, adopting the following distances in meters: 100, 200, 300, 400, >=500. The cartographic product generated was intersected with each sugarcane map investigated.
- **Indian lands:** in the surroundings of each Indian area, using the Multiple Ring Buffer tool, the following distances were created: 1000, 2000, 3000, 4000 and >= 5000.
- **Soil:** the intersection was made on the Soils map, whose vector file (.shp) was obtained from the Secretary for Planning of Mato Grosso State - SEPLAN (MATO GROSSO, 2011), combining it with those of sugarcane for each year evaluated, and in sequence measuring the total sugarcane area of each year on the different soil types.

The data of proximal variables were submitted to the Kolmogorov-Smirnov adherence test ($\alpha = 5\%$) to verify its normality. Because of this, all variables were analyzed by the non-parametric correlation matrix from Spearman, using the statistical program MINITAB version 16.

The Spearman correlation coefficient, named after the greek letter ρ (rho), is a non-parametric correlation measure based on posts and was introduced by Spearman in 1904 (SIEGEL, 2006). The estimates of Spearman's correlation coefficients among values of proximal variables are listed at table 1. The p values obtained in the table refer to Pearson's linear correlation coefficient applied to data posts. These values define if two variables are correlated or not from the statistical point of view. In general, if this value is lower than 0.05, the correlation among the variables is significant.

For the definition of the legend colors at the cartographic representations, the same pattern adopted by Projeto Radambrasil (BRASIL, 1982) and PROBIO (BRASIL,

2014) was considered for Vegetation, from SEPLAN for soils (MATO GROSSO, 2011) and from the Technical Soils Manual (BRASIL, 2007) for the relief.

RESULTS AND DISCUSSION

The sugarcane expansion in the Bugres river basin, presented the following standard referring to its direction: in 1990 and 1991 W-SW, in 1994 and 1995 NE-E and in 2000 to 2014, N-NE. This pattern was possibly influenced by the soil type (Oxisols), the relief (flat to light undulated) which are the characteristics that favor this economic activity because it implies on less production costs, soil management and mechanization of production.

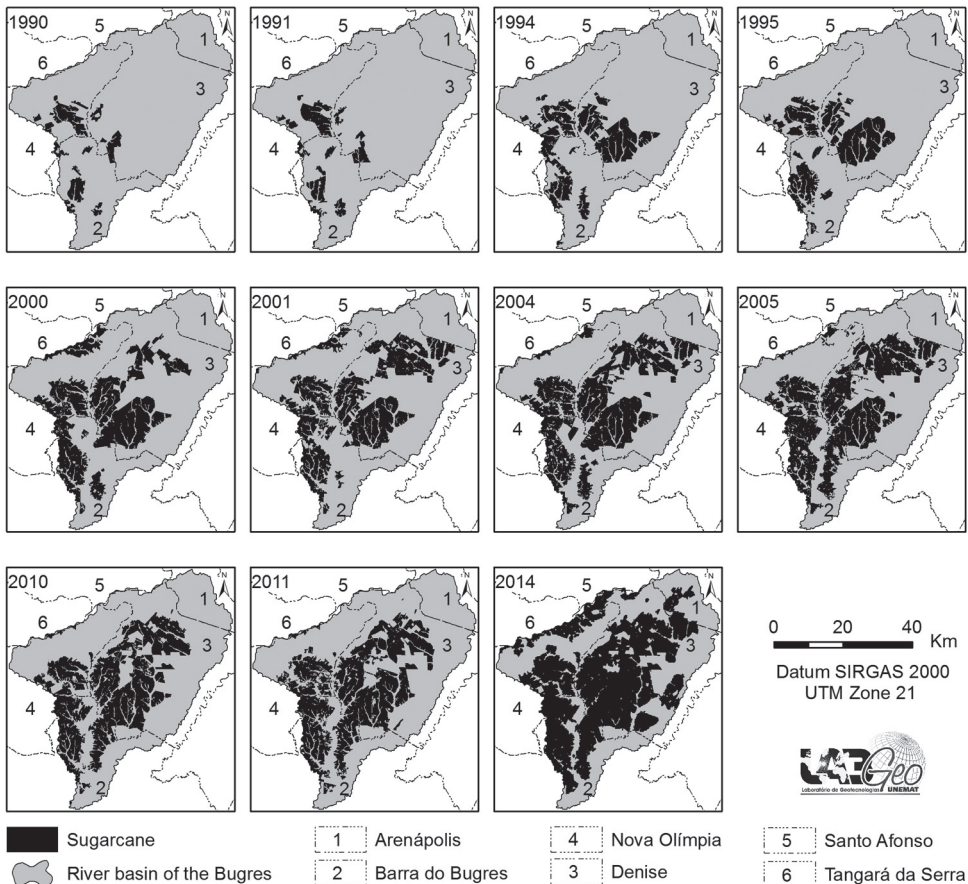


Figure 2 - Expansion of sugarcane within BHRB in the period 1990 to 2014 in the municipalities

Source: the authors, 2015.

In the area under study, totaling 2,269.77 Km², sugarcane occupied in 1990, 137.44 Km², (6.06%) and in 2014, 981.11 Km² (43.23%). In 24 years there was an area increase of 613.84% (Figure 2). This is probably due to governmental incentives for alternatives to fossil fuels after the oil crisis and the Brazilian sugar agro-industry. A contribution to this effort was the creation, in the 70's and 80's, of the National Alcohol Program – PROALCOOL (PAULILLO *et al.*, 2007). This program funded the installation of alcohol distilleries close to the sugar plants. The program suffered under a period of uncertainties during the 1990's, but the alcohol fuel in Brazil strengthened due to new market perspectives, with the manufacture of the so-called "Flex fuel" vehicle (LEME, 2004; SANTOS *et al.*, 2013; PESSOA *et al.*, 2013a). Another factor which favored the increase of the planted area within the basin was the installation of two sugar mills in the cities Nova Olímpia and Barra do Bugres in the 1980's (CASARIN *et al.*, 2008; PESSOA *et al.*, 2013b).

Table 1 - Dynamics of sugarcane in the basin under study, by municipalities

Municipality	Arenápolis		Barra do Bugres		Denise		Nova Olímpia		Santo Afonso		Tangará da Serra		Total sugarcane area in BHRB	
	(km ²)													
	181.60		467.80		1.138.52		470.77		4.70		6.40		2,269.77	
Years	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%
1990	-	-	50.91	10.88	25.23	2.22	61.30	13.02	-	-	-	-	137.44	6.06
1991	-	-	58.26	12.45	24.98	2.19	64.07	13.61	-	-	-	-	147.31	6.49
1994	-	-	84.17	17.99	164.52	14.45	82.00	17.42	-	-	-	-	330.69	14.57
1995	-	-	93.79	20.05	180.76	15.88	76.43	16.24	-	-	-	-	350.98	15.46
2000	-	-	150.38	32.15	305.1	26.80	143.93	30.57	-	-	4.54	70.94	603.95	26.61
2001	-	-	125.21	26.77	379.06	33.29	124.15	26.37	-	-	2.54	39.69	630.96	27.80
2004	-	-	172.43	36.86	407.55	35.80	126.33	26.83	-	-	2.38	37.19	708.69	31.22
2005	-	-	206.45	44.13	416.77	36.61	124.41	26.43	-	-	1.66	25.94	749.29	33.01
2010	-	-	189.39	40.49	412.04	36.19	101.85	21.63	-	-	2.12	33.13	705.40	31.08
2011	-	-	198.20	42.37	416.00	36.54	114.90	24.41	-	-	2.10	32.81	731.20	32.21
2014	29.11	16.03	214.53	45.86	563.40	49.49	173.22	36.80	0.83	17.61	0.02	-99.66	981.11	43.23

From 1990 to 2005 this culture had a constant growth, and in 2005 it presented most expansion within the basin, corresponding to an enlargement of 445.17%. In 2010 the growth rhythm was interrupted, with a reduction of expansion to 31.93%, a resumption of increase at 18.77% in 2011 and 181.83% in 2014 (Figure 2). The increase of the cultivated area was possibly boosted by the sugar prices, which were high in the decades of 1990 and 2000 (LEME, 2004). The pattern on the evolution of the sugarcane planted area in the basin follows the patterns of the Mato Grosso state (UNICA, 2014a; 2014b).

The analysis of the sugarcane expansion at BHRB by municipality evidenced that only in 2014 this culture was introduced in parts of the basin located in Arenápolis and Santo Afonso, totaling 29.93 Km² (Table 1).

In 1990 sugarcane occupied a few square kilometers of the 467.80 Km² from the municipality Barra do Bugres, expanding during the period of analysis, with an apex in 2014, when it presented the greatest expansion (Figure 2 and Table 1). Since the introduction of sugarcane in the basin and in this municipality, it increased there by 321.39%.

The greatest territorial extension of the basin under study was in the municipality of Denise (1,138.52 Km²), wherein in 1990 a few square kilometers were covered by sugarcane, but in 2014 it covered almost half of this area, which corresponds to an

expansion of 2,133.07%, when evaluating the period since its insertion in the basin (Figure 2 and Table 1).

The area of the basin on the territory of Nova Olímpia corresponds to 470.77 Km² and in 1990 sugarcane was little representative, but in 2014 it occupied 1/3 of its extension, presenting an expansion of 182.58% in 24 years. This percentage of expansion, when compared with that one from Barra do Bugres, was less 138.80%. This can be attributed to the type of soils (Udorthent) and to the relief (slope >20%), which are deterrents for the expansion of the culture. Sugarcane was introduced in the area under study, located in the municipalities of Santo Afonso and Arenópolis after 2011.

Plantations of sugarcane in the municipality of Tangará da Serra (6.4 Km²) occurred in 2000, corresponding to 70.94%. In 2014 there was a reduction of 99.66%, possibly influenced by better prices for soybeans and due to the crisis in the sugar and alcohol sector.

The increase of the sugarcane planted area in the period analyzed, implied on the advancement of this culture over other land uses and vegetation formations. So, the references are: for the analysis in the period 1990 – 2001, the land use/land cover map of 1982 (BRASIL, 1982), and for the period 2004 – 2014, the map from 2002 (BRASIL, 2007), as observed on figure 3.

In the basin the Sub-montane Semi-Deciduous Seasonal Forest totaled an area of 589.13 Km². In 2001 the substitution amount was of 31.27%. The greatest expansion of sugarcane within this vegetation formation was registered in 2000 with 40.81%.

The Tall Wooded Savanna with Riparian Forest occupied in 1990 181.84 Km² without any advancement of sugarcane over this formation. In 2001 however, sugarcane occupied 14.71% of this formation, whose greatest increase was in 2000, corresponding to 18.46%. The Alluvial Semi-Deciduous Forest then occupied 25.75 Km² and in 1990 sugarcane occupied 4.78%, reaching 25.09% in 2001. In 1995 this culture occupied the largest area within this vegetation formation, reaching 28.97%.

The land use in the basin during 1982 was restricted to pasture, totaling 1,472.10 Km² (64.85%). In 1990 the pasture percentage decreased to 7.30% due to sugarcane expansion, but keeping a growth rhythm. In 2001 it corresponded to 31.09% in this land use class (Figure 3).

In 2004 the class Agriculture + Livestock was identified, which corresponded to 284.37 Km², and 68.86% of this amount was sugarcane. The greatest advance of sugarcane in this class occurred in 2005 when it attained 72.84%, however in the last year under analysis it occupied 72.29% of the space used for Agriculture + Livestock in the basin (Figure 3).

Classes Livestock with Secondary Vegetation (1,261.13 Km²), Livestock with Tall Wooded Savanna (22.40 Km²) and Livestock (19.40 Km²), for purposes of analysis, were grouped under the denomination of dominant class "Livestock with Secondary Vegetation", totaling so 1,302.93 Km². For the expansion of Livestock in 2004, 35.90% of Livestock were suppressed, reaching de largest area in this class during 2014, when sugarcane advanced 54.44% of the class considered.

The transition area between Savanna and Semi-Deciduous Seasonal Forest (Ecotone) totaled 131.42 Km² in the basin, being constituted by Tall Wooded Savanna with Livestock in 89.88 Km² and Semi-Deciduous Seasonal Forest of Lowlands with 2.91Km². Both vegetation formations were not occupied by sugarcane in the period studied (Figure 3).

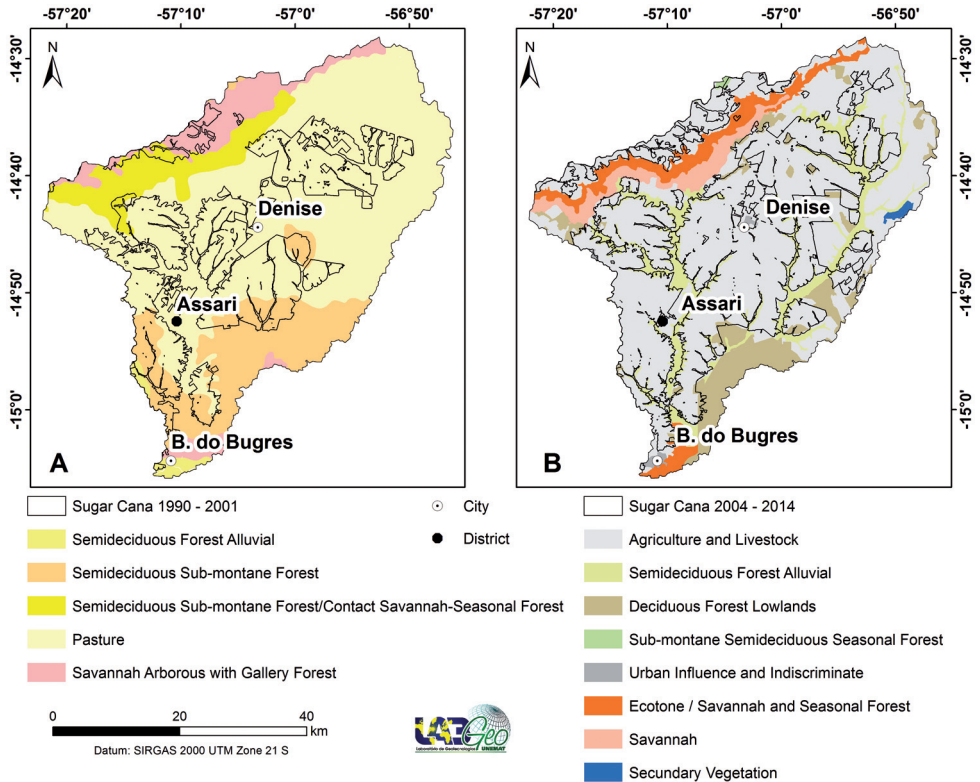


Figure 3 - Distribution of sugarcane in the period 1990 to 2001 (A) and in the period 2004 to 2014(B)

Source: the authors, 2015.

In those areas of Alluvial Semi-Deciduous Seasonal Forest (0.48 Km²) and Alluvial Semi-Deciduous Seasonal Forest with Pioneer Formations (239.23 Km²), which together come up to 239.71 Km², were suppressed by 20.24% in 2014 for sugarcane plantation, which corresponds to the year with most suppression of this vegetation formation during the period evaluated. Changes at the environmental legislation possibly influenced the increase of the occupied area by sugarcane in this class.

The vegetation formations Semi-Deciduous Seasonal Forest of Lowlands (95.28 Km²), Semi-Deciduous Seasonal Forest of Lowlands with Secondary Vegetation (108.14 Km²) and Secondary Vegetation with Semi-Deciduous Seasonal Forest of Lowlands (6.30 Km²) were united under the denomination of the class with the largest area. So the class Semi-Deciduous Seasonal Forest of Lowlands with Secondary Vegetation presented an area of 209.72 Km² from which in 2004 sugarcane substituted 6.07% and in 2014 9.77%

In the basin the urban areas of Barra do Bugres, Assari and Denise in the map of Projeto Radambrasil (BRASIL, 1982) were not represented, and in the PROBIO map (BRASIL, 2007) its area was underestimated, totaling only 8.90 Km². It was verified that this class presented confusion during classification, and in Denise it was mapped

as "Agriculture + Livestock" and in Barra do Bugres as "Non-discriminated areas". Sugarcane did not advance over the class Urban Influence in none of the years studied, as mentioned in the ZAE-Cana document (BRASIL, 2009).

In the period 1990 to 2014 it was verified that sugarcane plantations did not present land use conflict with the APPs, which could plight the environmental integrity of the water resources and agriculture activity, considering that this is the economic activity with the highest water consumption (MASCARENHAS *et al.*, 2009), although it advanced over formations of Alluvial Semi-Deciduous Seasonal Forest and Alluvial Semi-Deciduous Seasonal Forest with Pioneer Formations.

The maintenance of the APPs along the margins of water courses is indispensable because they act as a filter impeding the contamination of the water by agro-chemicals, it contributes for water retention in the soil and sub-soil, it helps in the contention of erosion processes and silting of the drainage net, benefitting the conservation of the biodiversity (RESENDE, 1995).

In the Bugres river basin relief classes flat (1,272.96 Km²) and light undulated (854.20 Km²) predominate, which totalize 56.08% and 37.63% respectively (Figure 4). In the other areas, which totalize 142.8 Km² (6.28%) the following classes occur: undulated (61.35 Km²), strongly undulated (35.44 Km²), mountain (28.14 Km²) and steep (17.68 Km²).

It was verified that the declivity is an impeditive factor for the expansion of sugarcane cultivation in the BHRB, because it occupied and expanded in areas with flat to light undulated terrain with no impediment for its mechanization (RODRIGUES & SAAB, 2007; GUIMARÃES *et al.*, 2008).

The largest volume of sugarcane planted in the period from 1990 to 2014 was on Oxisols (Figure 4), as follows: Udox (1,671.35 Km²), the so-called "Purple Oxisol" (157.46 Km²) and the "Dark Red Oxisol" (113.19 Km²), totalizing within the basin 1,942.00 Km² (85.56%). On this soil type in 1990 sugarcane covered 134.69 Km² and in 2014 949.59 Km². According to Embrapa (2006), the characteristics of Oxisols are: deep to very deep, well drained, with medium to clay texture, with low base saturation (distrophic), high agricultural capacity, presenting more resistance to its use. It presents good physical conditions with flat or light undulated, which occurs at BHRB. This favors its use for the plantation of several cultures adapted to the climate of the region, such as sugarcane which, under these conditions, does not present a restriction for the use of machines for its production.

The other soil types within the basin: Quartz Sands (58.63 Km²), Red-Yellow Podzol (214.91 Km²), Alluvial soils (7.6 Km²) and Udorthent (25.27 Km²), the so-called Brazilian "Terra Roxa" (7.31 Km²), corresponds to 14.44%, covered by few to no sugarcane, probably due to the type of relief (undulated to steep), legal restrictions (in APPs) and the unfavorable characteristics presented by some soil types within the basin. Among the soil types "Terra Roxa" presents the most favorable conditions for livestock use, but because it is situated on mountain and steep relief, it was not occupied by sugarcane in the period investigated. The matrix formed by the results of the multiple correlation coefficient between the proximal variables is presented at table 2, which illustrates the Spearman correlation values followed by values of the P test, respectively.

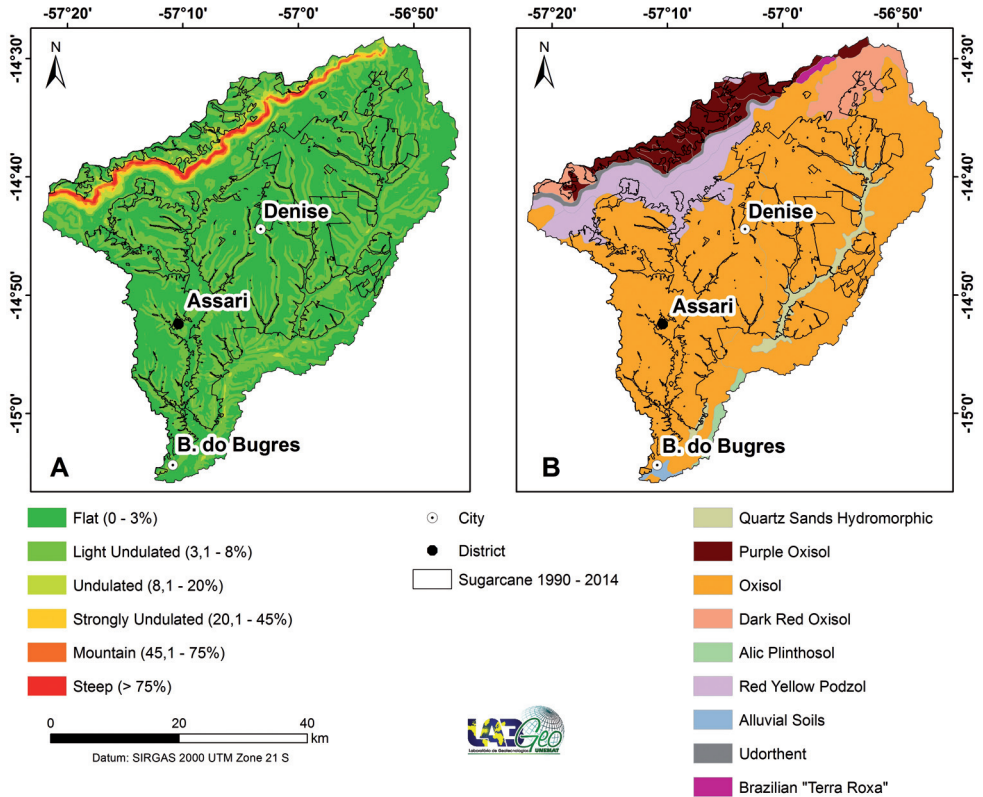


Figure 4 - A) Relief classes and B) Soil types in the Bugres River basin (BHRB)

Source: the authors, 2015.

Table 2 - Spearman correlation matrix for proximal variables

	Altimetry		Declivity		Roads		Drainage		Indian lands	
	150-250	450,1-550	0-3	>20,1	0-50	>1000,1	30-100	>500	1000	>=5000
150-250	1.000									
450,1-550	0.714*	1.000								
0-3	1.000*	0.714*	1.000							
>20,1	0.570**	0.910*	0.570**	1.000						
0-50	0.955*	0.667*	0.955*	0.461**	1.000					
>1000,1	0.982*	0.690*	0.982*	0.516**	0.982*	1.000				
30-100	0.800*	0.602*	0.800*	0.501**	0.755*	0.782*	1.000			
>500	1.000*	0.714*	1.000*	0.570**	0.955*	0.982*	0.800*	1.000		
1000	0.582**	0.424**	0.582**	0.402**	0.627*	0.609**	0.773*	0.582**	1.000	
>=5000	0.970*	0.668*	0.970*	0.462**	0.989*	0.980*	0.761*	0.970*	0.624*	1.000

* Significant to 5% Probability ** Not significant

According with the results presented in the Correlation Matrix, the 5 proximal variables used in the basin investigated present a high correlation with at least two other variables. Most correlation coefficients are statistically significant, according to the Significance P Test.

The variable declivity presents a high positive correlation with roads in the interval 0 to 3, corresponding to those most favorable areas for agriculture activities (flat and lowlands with easy access), on the contrary of areas with higher declivity and altitude, where there is no correlation among these variables. According to Politano *et al.* (1989), the roads localized in rural properties used for the flow of agricultural production, are constructed preferentially at the same altimetry quota to avoid the formation of ravines which would affect the safety of the movement from agricultural machines, favoring erosion.

The declivity in the interval (> 20) referring to strongly undulated, mountain and steep relief, does not present any correlation with a proximal variable. There is a strong correlation between the drainage in the interval (> 500), with Indian lands in the interval (≥ 5000). This is due to the fact that Indian lands (Umutina) are localized between the rivers Bugres and Paraguai.

CONCLUSIONS

In the period 1990 to 2014 the areas planted with sugarcane in the Bugres river basin oscillated, keeping nevertheless a growth pattern, preferentially directed to North - Northeast.

The analysis of the sugarcane dynamics in relation to the Vegetation category allowed the conclusion that the expansion of this culture contributed for the partial suppression of the Sub-Montane Semi-Deciduous Forests. In the classes of human use, sugarcane expanded in detriment to Livestock. And finally it did not advance over urban areas and APPs.

Regarding Relief, the declivity is an impeditive factor for sugarcane plantation in the BHRB, which was established on areas with flat to light undulated relief. Referring to soils, there was a predominance for plantations on Oxisols (Udox, Purple Oxisol and Dark Red Udox).

In the quantitative analysis, the correlation performed for the proximal variables demonstrate a strong relation between flat terrain, the roads, drainage and Indian lands. However there was no correlation between proximal variables, strongly undulated, mountain and steep relief.

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