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MULTITEMPORAL ANALYSIS IN SPRING AREAS IN THE URBAN ZONE OF IGUATEMI (MS)

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Abstract

Wetlands are ecosystems very important for preserving water and life, since they provide diverse ecosystem services. These environments are often associated with spring areas, with particular species and other very particular characteristics. This study aimed to analyze a wetland in an urban region of Iguatemi (MS), in relation to the kind of springs and the changes caused by anthropic actions in a period from 1985 to 2017. For this purpose, watershed delimitation techniques were carried out using SRTM radar images, as well as a multitemporal analysis from the photointerpretation of the reflectance of the spectral bands. For the analysis, free images were used, as well as free software. It was possible to confirm that the springs present in the area are of the perennial type, that is, they never dry out. In addition, the multitemporal analysis allowed to identify changes in the use of the area and, consequently, in the preservation of the wetland, with changes mainly generated by the commercial planting of eucalyptus. Considering the economic, social and ecological importance of wetlands, it is suggested to conserve this area.

Keywords: Geotechnologies; Wetland; QGIS.

ANÁLISE MULTITEMPORAL EM ÁREAS DE NASCENTE NA ZONA URBANA DE IGUATEMI (MS)

Resumo

Áreas úmidas são ecossistemas muito importantes para preservação da água e da vida, fornecendo diversos serviços ecossistêmicos. São ambientes frequentemente associados a áreas de nascentes, com espécies e outras características bastante particulares. Esse trabalho objetivou analisar as áreas úmidas na região urbana de Iguatemi (MS) quanto aos tipos de nascentes e as alterações sofridas pelas ações antrópicas durante o período de 1985 e 2017. Para tanto, foram realizadas técnicas de delimitação de bacia hidrográfica utilizando imagens de radar SRTM, bem como uma análise multitemporal a partir da fotointerpretação da refletância das bandas espectrais. Para as análises foram utilizadas imagens disponibilizadas gratuitamente, bem como softwares livres e gratuitos. Foi possível confirmar que as nascentes presentes na área são do tipo perene, ou seja, nunca secam. Além disso, as análises multitemporais permitiram identificar alterações no uso da área e consequentemente na preservação da área úmida, com mudanças geradas principalmente pelo plantio comercial de eucalipto. Considerando a importância econômica, social e ecológica das áreas úmidas, sugere-se a conservação dessa área.

Palavras-chave: Geotecnologias; área úmida; QGIS

ANÁLISIS MULTITEMPORAL EN ÁREAS DE MANANTIALES EN LA ZONA URBANA DE IGUATEMI (MS)

Resumen

Los humedales son ecosistemas muy importantes para preservar el agua y la vida, que brindan diversos servicios ecosistémicos. Son ambientes a menudo asociados con áreas de manantiales, con especies y otras características muy particulares. Este trabajo tuvo como objetivo analizar los humedales en la región urbana de Iguatemi (MS) con respecto a los tipos de manantiales y los cambios sufridos por las acciones antrópicas durante el período de 1985 y 2017. Para este propósito, se utilizaron técnicas para delimitar la cuenca hidrográfica utilizando imágenes de radar

SRTM, así como un análisis multitemporal a partir de la fotointerpretación de la reflectancia de las bandas espectrales. Los análisis utilizaron imágenes disponibles de forma gratuita, así como software gratuito. Fue posible confirmar que los manantiales presentes en el área son de tipo perenne, es decir, nunca se secan. Además, los análisis multitemporales permitieron identificar cambios en el uso del área y, en consecuencia, en la preservación del área húmeda, con cambios generados principalmente por la plantación comercial de eucaliptos. Considerando la importancia económica, social y ecológica de los humedales, se sugiere la conservación de esta área.

Palabras-clave: Geotecnologías; humedales; QGIS

1. INTRODUCTION

According to the Ramsar Convention (IUCN, 1971), wetlands (WLs) include areas of swamps, marshes, peat bogs, among others, of natural or artificial origin, that are permanent or temporary, with running or stagnant water, and may present fresh, salty or brackish water, including marine areas up to six meters deep at low tide. Thus, WLs are ecosystems that present plant and animal communities that are adapted to their unique water dynamics (JUNK et al., 2013).

WLs are environments that provide important ecosystem and ecological services, and are fundamental for maintaining flora and fauna species, as well as for human well-being (MMA, 2020). Such environments are often associated with river/stream springs, in addition, they function as hydrological buffers in landscapes, reduce flooding events or drought peaks, are important for storing and cleaning water, provide groundwater through infiltration, supply the water table, act in carbon storage and regulate biogeochemical cycles, present complex plant and animal communities and can house traditional human populations; all of which support their ecological, economic and social importance (JUNK et al., 2014; NUNES DA CUNHA; JUNK, 2014).

These ecosystems are among those that are most threatened by human destruction worldwide (JUNK et al., 2014). With the intense expansion of urban areas, WLs are often integrated and affected, suffering intense changes caused by the use of the areas surrounding them. Thus, given their huge importance in maintaining water and life, it is extremely important to understand the changes that urban WLs, or surrounding areas, experience in order to determine preservation/maintenance actions.

In this context, techniques that combine Remote Sensing and Geographic Information Systems (GIS) are easy and accurate ways to estimate the dynamic changes in land cover in an area (RAWAT; KUMAR, 2015; DOURADO et al., 2019). In turn, multitemporal analyses allow scenes from one location to be studied for a period of time, showing the changes that take place during such period (TORRES et al., 2011). Analyzes that evaluate changes in area usage during certain time periods are widely used to understand changes caused by anthropic actions (e.g. PARANHOS FILHO et al., 2014; PERES et al., 2016; MIRANDA; PARANHOS FILHO; POTT, 2018; SILVA; DALMAS; PARANHOS FILHO, 2018; DOURADO et al., 2019).

Thus, this study aimed to analyze a WL in the urban region of Iguatemi, MS, to investigate whether the springs found in this WL are perennial or intermittent, as well as to perform a multitemporal analysis and verify the changes in area usage between 1985 and 2017.

2. METHODS

2.1. Study area

The study area is located in the Iguatemi Municipality, southwestern Mato Grosso do Sul State, approximately 460 km from the capital, Campo Grande (Figure 1). According to Köppen classification, the climate of this region is Cfa, which is subtropical with hot summers (ALVARES et al., 2013). The vegetation in the region consists of Semideciduous Seasonal Forest (VELOSO; RANGEL FILHO; LIMA, 1991), with some areas influenced by *Cerrado* and presents Red Latosol type soil (ZEE/MS, 2015).

The study area consists of a WL in an urban area and a portion of the Sacarón Stream, located near residential, commercial and highway margin areas. This stream lies within the Sacarón stream watershed, which is a main tributary of the Iguatemi River. The soil in this WL is hydromorphic, black-gray Gleisoil (SANTOS et al., 2018), with different levels of soaking and typical herbaceous WL vegetation. This area covers part of two properties: a small farm (148,924 m²) and a lumber company (26,000 m²). For comparison, other WLs that are protected in the area of the Third Squadron of the Brazilian Army, within Iguatemi, MS, were also analyzed. These areas were visited in March 2018 to confirm information.

2.2. Data collection

Landsat (Land Remote Sensing Satellite) images collected with the following sensors were used: Landsat 5, Thematic Mapper (TM) sensor, Landsat 8, Operational Land Imager (OLI) sensor, and Sentinel-2B GMES Program (Global Monitoring for Environment and Security), MultiSpectral Instrument (MSI) sensor. Landsat mission satellites feature multispectral images and 30-meter spatial resolution, with Landsat 5 operating from 1984 to 2011 and Landsat 8 operating from 2013. Since images of the Sentinel-2B mission have been available since 2017 and have a higher spatial resolution of 10 and 20 meters, the features in images could be observed with greater detail. We chose to use Landsat images because they are free to access and are available from 1984, allowing a multitemporal analysis to be performed and recording changes that have occurred in the area over time.

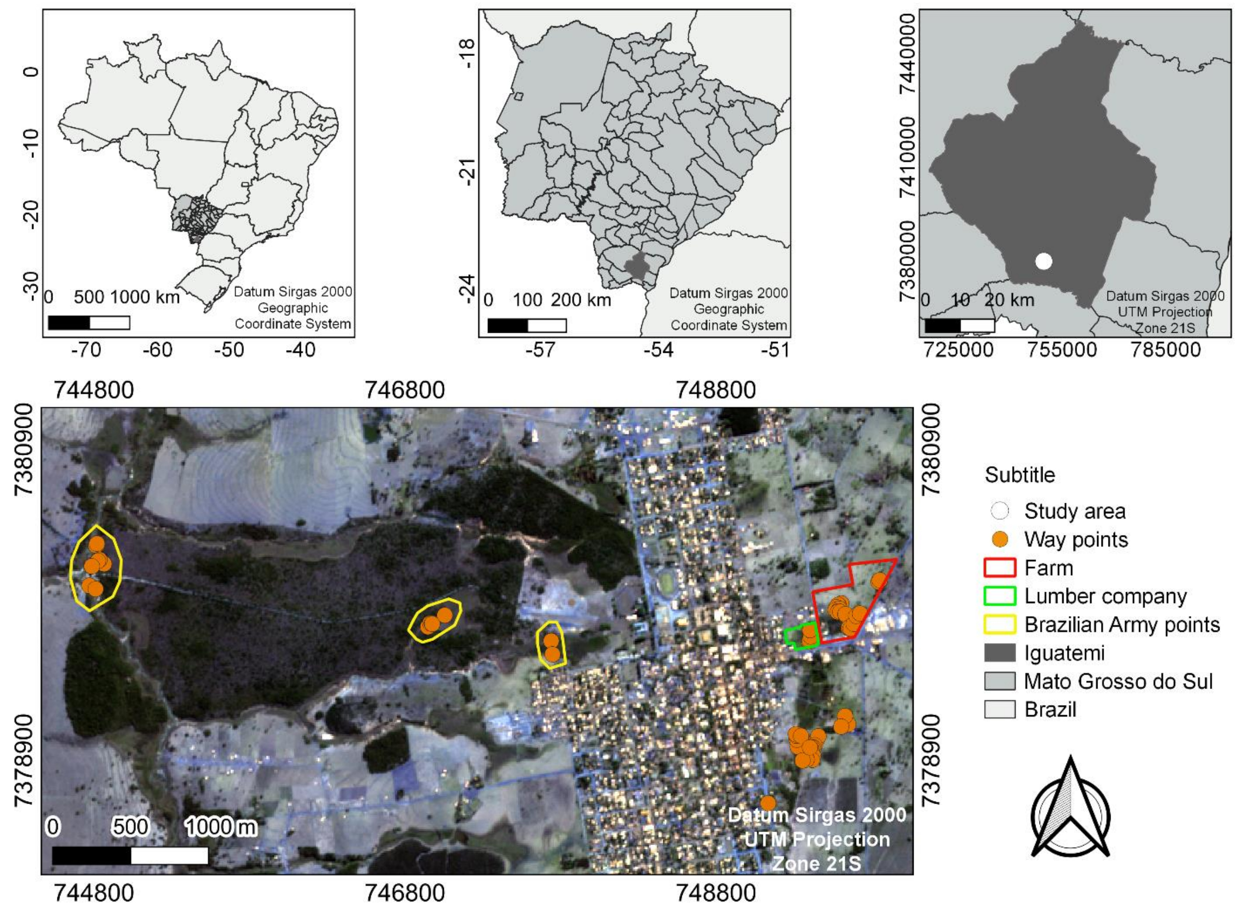

Figure 1 – Study area located in the Iguatemi, Municipality southwestern Mato Grosso do Sul State. Image: Sentinel-2B, date: August 4, 2017.

The images were obtained according to the availability of scenes for each year of interest and considering the absence of clouds and failures in the scenes. The scenes were selected on the Earth Explorer website (United States Geological Survey, USGS, 2018a). These on-demand products are georeferenced with atmospheric correction, reflectance data and atmospheric correction calculations and are available on the USGS website (2018b).

Images from August and September (dry season) of 1985 to 2017 were selected, as shown in Table 1.

The data was exported to the QGIS. free and open source software (QGIS DEVELOPMENT TEAM, 2016), and the scenes were redesigned using Universal Transverse Mercator (UTM), Geographic Coordinate System SIRGAS 2000, zone 21S, when necessary.

Table 1 – Information on the selected scenes for the analysis of wetland data in the Iguatemi Municipality, MS. Images obtained on the Earth Explorer website, referenced as: 1985 (USGS, 2018c); 1990 (USGS, 2018d); 2000 (USGS, 2018e); 2007 (USGS, 2018f); 2008 (USGS, 2018g); 2011 (USGS, 2018h); 2013 (USGS, 2018i); 2017 (USGS, 2018j).

Satellite	Sensor	Date	Orbit/point
Landsat 5	TM	08/22/1985	224/076
		08/04/1990	224/076
		08/15/2000	224/076
		09/04/2007	224/076
		08/21/2008	224/076
		09/15//2011	224/076
Landsat 8	OLI	09/04/2013	224/076
Sentinel-2B	MSI	08/04/2017	T134209

2.3. Watershed delimitation

In order to identify which hydrographic basins the WLs belong to; the watershed delimitation technique was performed. For this, images of the Shuttle Radar Topography Mission (SRTM) were used, consisting of radar images with information about Earth's elevation. Images of Mato Grosso do Sul obtained from the USGS website were used (USGS, 2018k). The watersheds and then the drainage of the rivers were delimited using the GRASS tool (GRASS DEVELOPMENT TEAM, 2016) in the QGIS software (QGIS DEVELOPMENT TEAM, 2016).

This tool uses the AT (least-cost search) algorithm described by Ehlschlaeger (1989).

2.4. Multitemporal analysis

The temporal analysis of the images was performed from the photointerpretation of the reflectance of the spectral bands, which are defined as the interval between two wavelengths in the electromagnetic spectrum. The spectral bands were stacked using the mosaic technique and later the false-color composition of the RGB channels was generated with the near infrared (NIR), medium infrared (SWIR1) bands and the visible red band (Red). Bands were chosen due to the spectral response of the targets of interest, which were vegetation, water depth and water bodies. Vegetation with photosynthetic vigor absorbs the wave of the electromagnetic red spectrum and reflects the infrared spectra. For water bodies, the reflectance is generally elevated in the spectral range corresponding to blue light and the others are gradually absorbed, whereas in the infrared spectrum light is fully absorbed (LILLESAND; KIEFER; CHIPMAN, 2004; NOVO; BARBOSA; LOBO, 2019). The spectral bands corresponding to these compositions are shown in Table 2.

Photointerpretation involves analyzing tonality, colors, textures, structure, pattern, shading, location, shape and size according to Fitz (2008) criteria, regarding the differences in spectral responses of each target.

Table 2 – Satellite, sensor, and the corresponding spectral bands for the RGB composition used for the images obtained.

Satellite/Sensor	Spectral bands of the RGB composition
Landsat 5/ TM	4-5-3
Landsat 8/ OLI	5-6-4
Sentinel-2B/ MSI	8-4-11

3. RESULTS

The delimitation of the hydrographic basin through radar images (SRTM) confirmed that the study area is a spring region of the Sacarón Stream, a tributary of the Iguatemi River (Figure 2). Moreover, from the multitemporal analyzes, it was clear that the springs found in this region are perennial (Figures 3 to 10).

The analysis of satellite images, along with the on-site visit, showed that the terrain lowers where the lake forms in this region. When analyzing the changes in area usage over the years, there was an increase in water concentration where the lake is located from 1985 to 1990 (Figure 3 and 4). Between 1990 and 2000, there was a decrease in the amount of water, as well as in the surrounding vegetation (Figure 4 and 5). In 2007, the vegetation was removed from the land around the lake and, between 2007 and 2011, eucalyptus (*Eucalyptus* sp.) was planted in the surrounding area and within the WL, reducing the water volume (Figures 6 to 8). In 2013, much of this plantation was removed (Figure 9), but the amount of water remained low. In the interval up until 2017, the amount of water increased again (Figure 10), and at the time of the on-site visit in 2018, the lake was full. In 1985, the lake area was probably 25,523 m^2 with the highest water volume in the center and only a thin blade of water at the edges. From 2008 to 2013, the water volume drastically reduced. The occupied area was approximately 7,332 m^2 in 2008, while in 2013 it increased to 10,444 m^2. Currently, it is a Permanent Preservation Area (APP) with 16,828 $m2^2$.

4. DISCUSSION

During visits, blackish-gray hydromorphic Gleisol soil that is characteristic of wetlands (JUNK et al. 2014) were found in WLs and *veredas* with higher clay concentrations in the subsurface layers (RAMOS et al., 2006; SOUSA et al., 2011; SANCHES et al., 2012; RAMOS et al., 2014).

In addition, the WL studied here is believed to be a *vereda* due to soil characteristics, soaking level and the occurrence of herbaceous vegetation typically found in wetlands, formed mainly by species of Poaceae, Cyperaceae, Asteraceae and Xyridaceae, which usually predominant in such areas (MOREIRA et al., 2015). However, further studies related to vegetation characterization are necessary to confirm such claim. *Veredas* are a type of WL that can be considered as a *Cerrado* biome phytophysiognomy, located in elongated and shallow depressions within the terrain (GUIMARÃES; ARAUJO; CORRÊA, 2002; NUNES DA CUNHA; PIEDADE; JUNK, 2014). This type of WL occurs in hydromorphic soils, which are saturated for most of the year, and generally occupies places near water bodies, such as valleys or flat areas (RIBEIRO; WALTER, 2008).

The springs observed in the WL are perennial, that is, they do not dry out during the dry season. Additionally, these springs are included within the headwaters of the Sacarón Stream, which is a main tributary of the Iguatemi River, within the Paraná River basin. In this case, the springs are diffuse, forming small springs throughout the terrain, which only soaks the soil with low flow, but accumulates water in the impermeable layer parallel to the lowest part of the terrain with high flow, resulting in the formation of a lake due to proximity to the surface (CALHEIROS et al., 2009; BARRETO; RIBEIRO; BORBA, 2010). Regarding the area in question, a lake is formed that is also influenced by the construction of the highway, which increases water damming.

There has been changes in area usage over the years, with periods of higher and lower water concentration, depending on the anthropic actions that took place in the area. From 2007 to 2012, eucalyptus trees were planted in the farm area and within the WL. During this period, the springs dried, but after eucalyptus trees were removed, water started to accumulate again in the area. However, during this same period, in adjacent areas, such as the farm area and army area downstream from the springs, we observed that the WLs had water depth, demonstrating that the springs did not dry up despite it being the dry season. Some studies suggest that eucalyptus planting may be a problem for maintaining water levels, since this species grows quickly and vigorously, therefore demanding high amounts of water (CALHEIROS et al., 2009; BARRETO; RIBEIRO; BORBA, 2010). Such anthropic actions that drastically affect WL characteristics and the preservation of springs, should be avoided to conserve these important areas. Furthermore, it is important to remember that these areas provide important ecosystem services (MMA, 2019) and the structure and function of these WLs have often been threatened by numerous anthropic interventions

(JUNK et al., 2014), reinforcing the urgency for policies that help preserve these important environments.

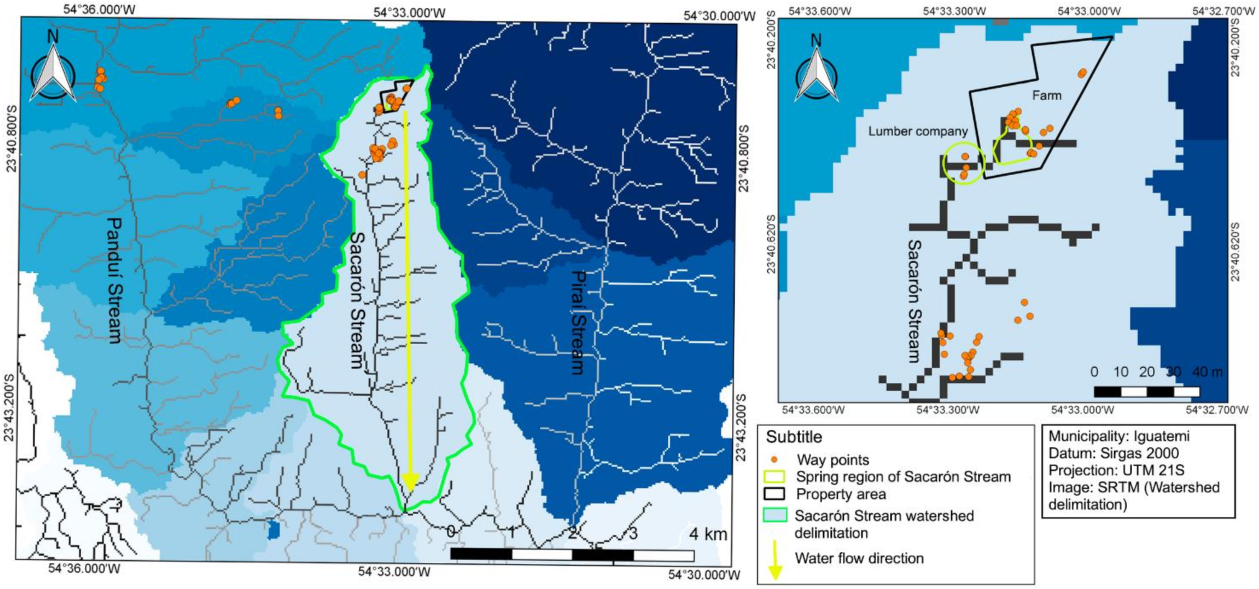

Figure 2 – Watershed delimitation using radar images (SRTM), showing that the springs found in the analyzed wetland belong to the head of the Sacarón Stream, a tributary of the Iguatemi River, Iguatemi Municipality, MS.

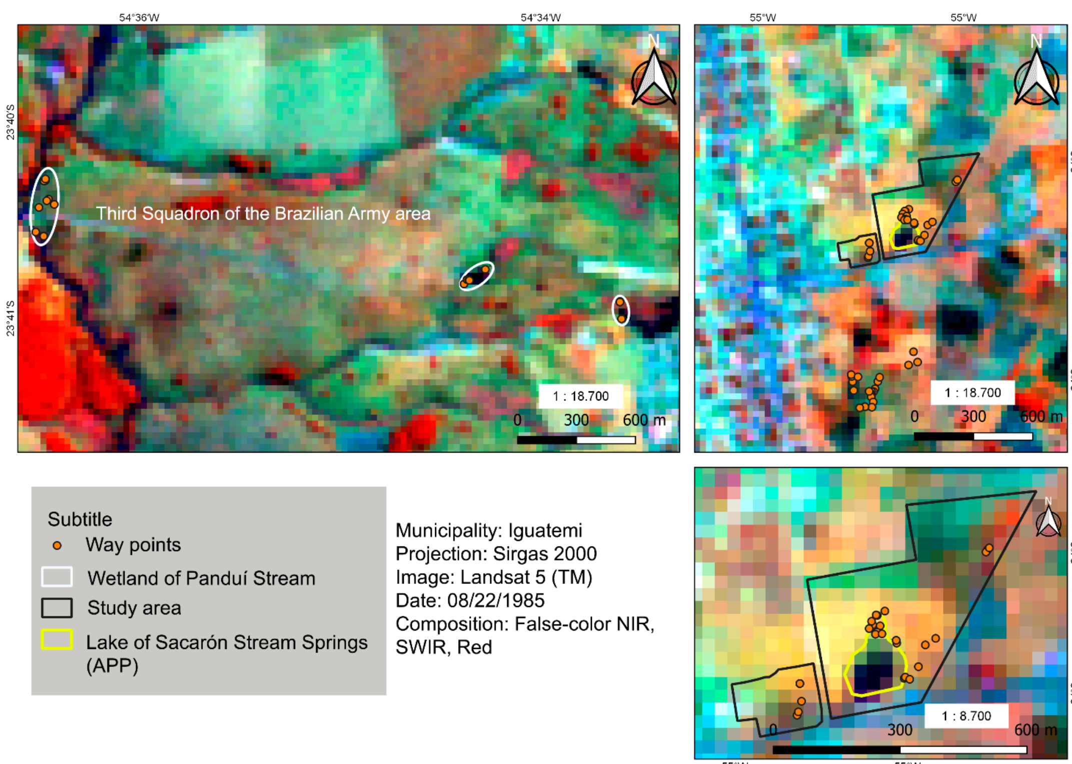

Figure 3 – Landsat 5 image from the year 1985 (USGS, 2018c), in a false-RGB color composition (4-5-3) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

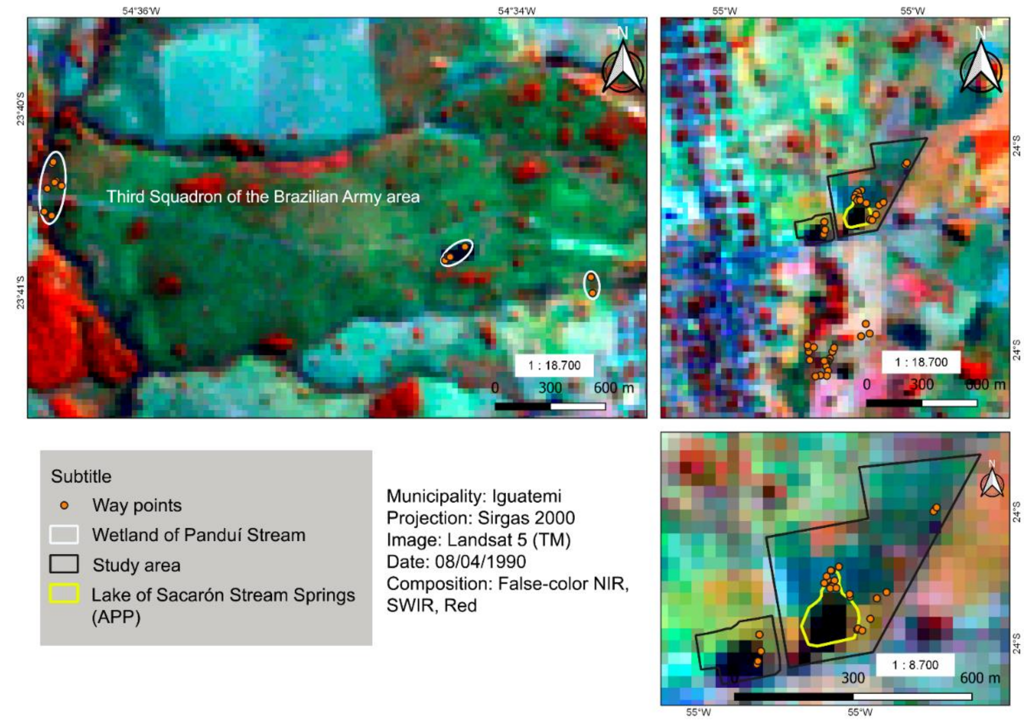

Figure 4 – Landsat 5 image from the year 1990 (USGS, 2018d), in a false-RGB color composition (4-5-3) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

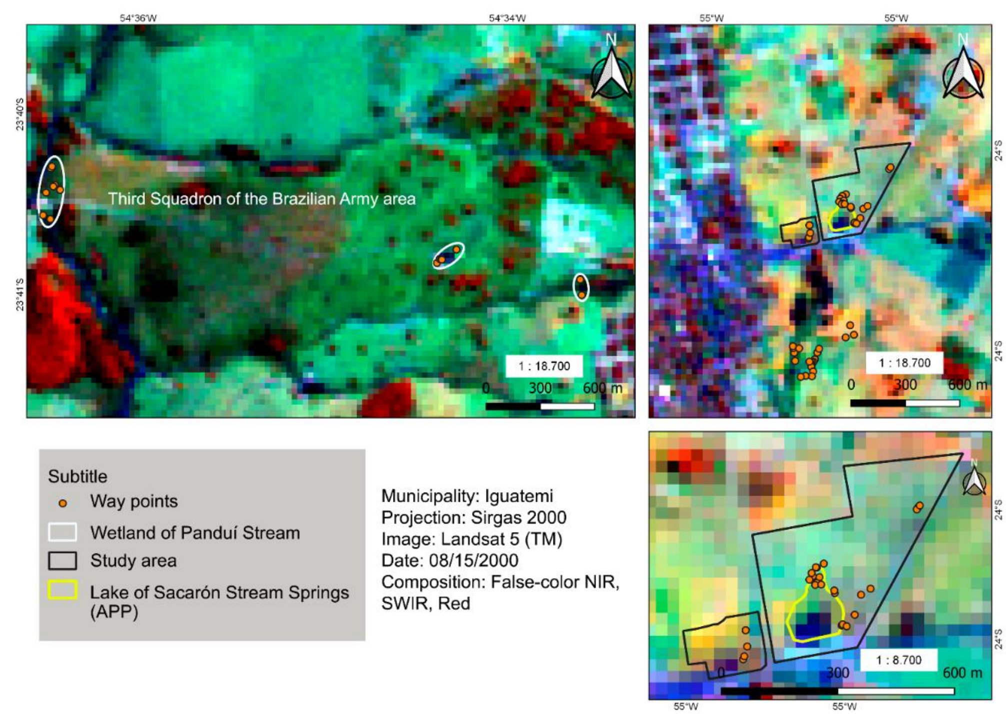

Figure 5 – Landsat 5 image from the year 2000 (USGS, 2018e), in a false-RGB color composition (4-5-3) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

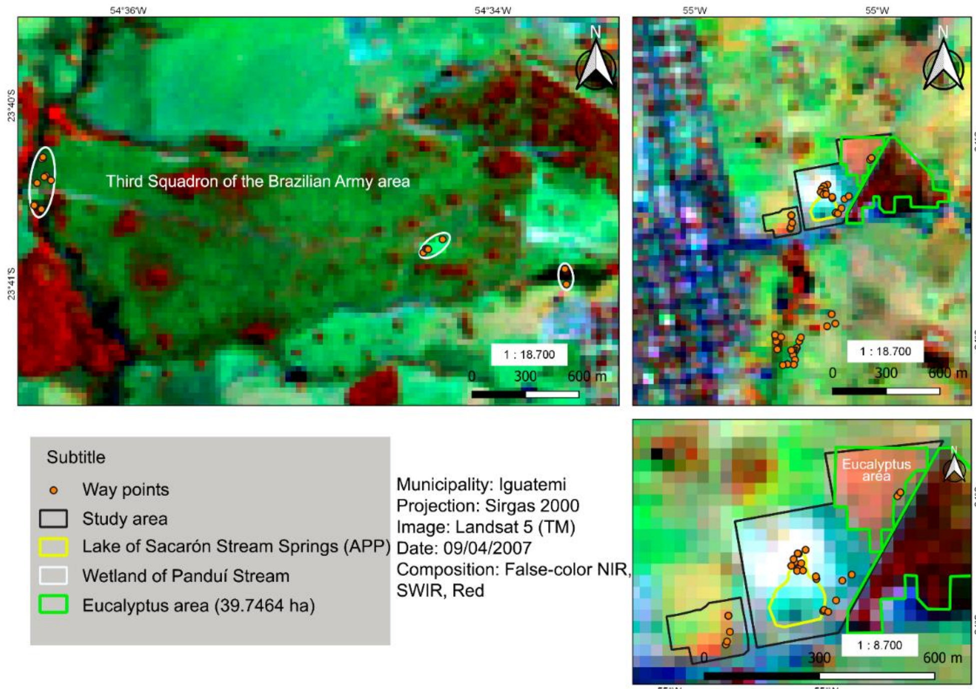

Figure 6 – Landsat 5 image from the year 2007 (USGS, 2018f), in a false-RGB color composition (4-5-3) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

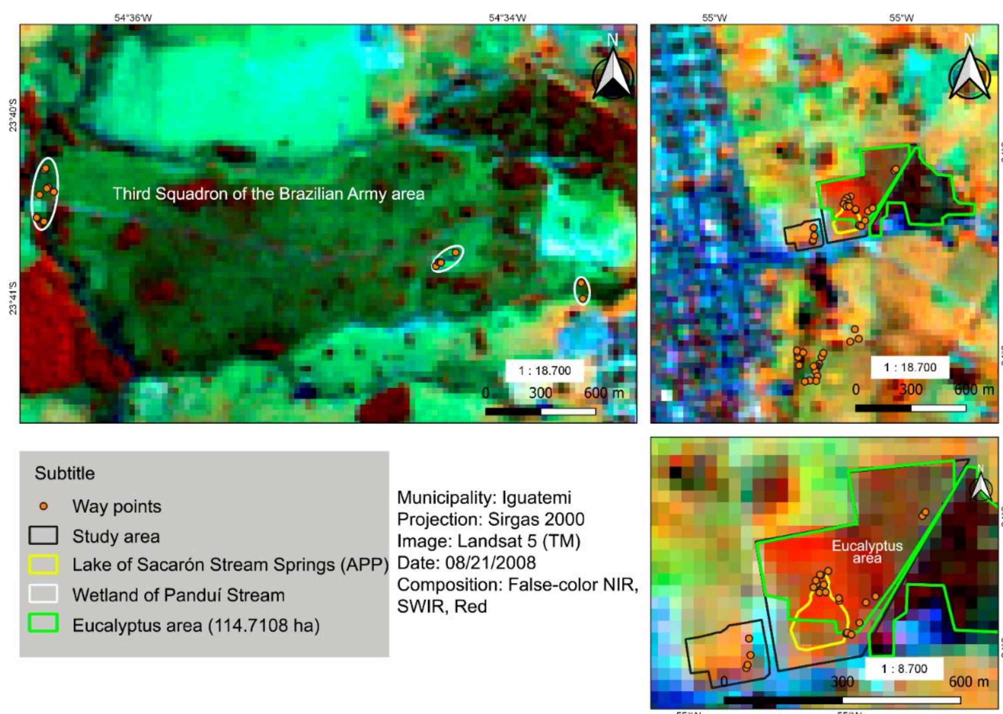

Figure 7 – Landsat 5 image from the year 2008 (USGS, 2018g), in a false-RGB color composition (4-5-3) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

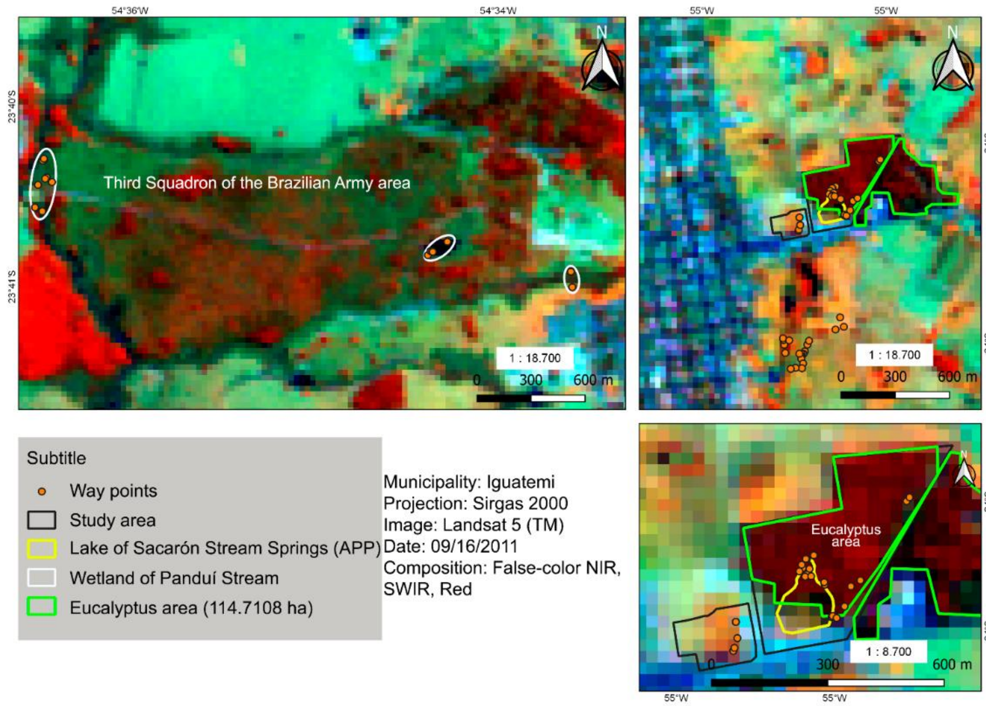

Figure 8 – Landsat 5 image from the year 2011 (USGS, 2018h), in a false-RGB color composition (4-5-3) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

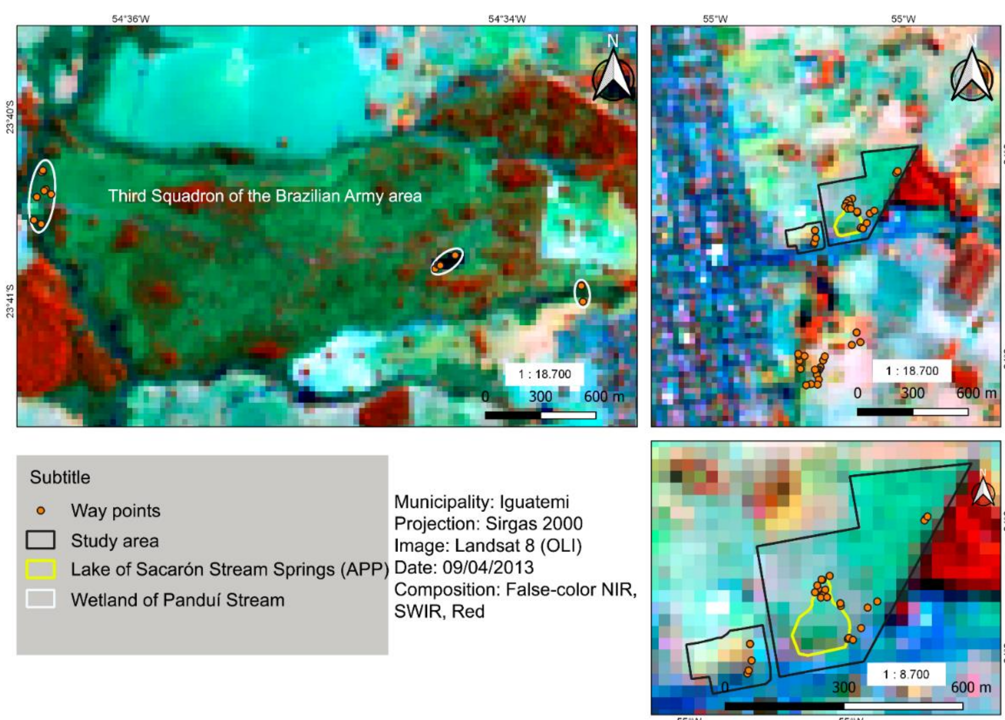

Figure 9 – Landsat 8 image from the year 2013 (USGS, 2018i), in a false-RGB color composition (5-6-4) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

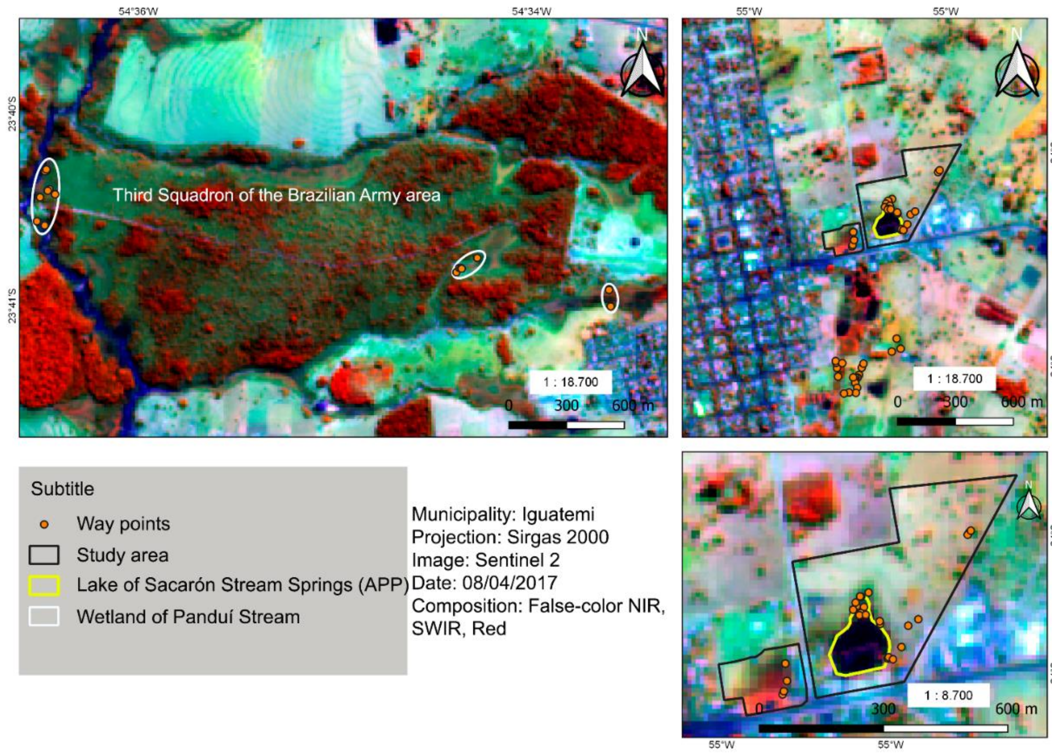

Figure 10 – Sentinel-2B image from the year 2017 (USGS, 2018j), in a false-RGB color composition (8-4-11) showing the crossing points during the on-site visit, the delimitation of the wetland region where the springs occurs and the delimitation of the farm and lumber company, as well as the image of the Brazilian Army Area, Iguatemi Municipality, MS.

5. FINAL CONSIDERATIONS

Thus, the studied area presents perennial springs, confirming that this is a permanent wetland, which corroborates the other characteristics observed, e.g., predominant herbaceous species and the hydromorphic soil. It was also clear that the area was affected/influenced by how the WL and its surrounding areas were used, with decreased water concentration primarily during eucalyptus planting. Given the importance of WLs and aiming to preserve springs, it is important to emphasize the need to conserve this area.

6. REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G.. Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift,* v. 22, n. 6, p. 711-728, 2013.

BARRETO, S. R.; RIBEIRO, S. A.; BORBA, M. P. *Nascentes do Brasil - Estratégias para a proteção de cabeceiras em bacias hidrográficas.* São Paulo: WWF-Brasil/Imprensa Oficial do Estado de São Paulo, 2010. 140 p.

CALHEIROS, R. O.; TABAI, F. C. V.; BOSQUILIA, S. V.; CALAMARI, M.. *Preservação e recuperação das nascentes de água e de vida. Cadernos da Mata Ciliar / Secretaria de Estado do Meio Ambiente, Departamento de Proteção da Biodiversidade. - N 1 (2009)* - São Paulo: SMA, 2009. 35 p.

DOURADO, G. F.; MOTTA, J. S.; PARANHOS FILHO, A. C.; SCOTT, D. F.; GABAS, S. G.. The Use of Remote Sensing Indices for Land Cover Change Detection. *Anuário do Instituto de Geociências,* v. 42, n. 2, p. 72-85, 2019.

EHLSCHLAEGER, C. R.. Using the A^T search algorithm to develop hydrologic models from digital elevation data. *In Proceedings of the international geographic information system (IGIS) symposium.* Baltimore, MD, 1989. p. 275-281.

FITZ, P. R.. *Geoprocessamento sem complicação.* São Paulo: Oficina de Textos, 2008. 160 p.

GRASS DEVELOPMENT TEAM. GRASS GIS - Bringing advanced geospatial technologies to the world. *In GRASS GIS.* Disponível em: https://grass.osgeo.org/. Acesso em: 13/08/2018.

GUIMARÃES, A. J. M.; ARAÚJO, G. M. D. E.; CORRÊA, G. F.. Estrutura fitossociológica em área natural e antropizada de uma vereda em Uberlândia, MG. *Acta Botanica Brasilica,* v. 16, n. 3, p. 317-329, 2002.

IUCN - International Union for Conservation of Nature. **The** *Ramsar Conference: Final act of the international* *conference on the conservation of wetlands and waterfowl, Annex 1.* Special Supplement to IUCN, Bulletin 2, 1971. 4 p.

JUNK, W. J.; PIEDADE, M. T. F.; LOURIVAL, R.; WITTMANN, F.; KANDUS, P.; LACERDA, L. D.; BOZELLI, R. L; ESTEVES, F. A.; CUNHA, C. N.; MALTCHIK, L.; SCHÖNGART, J.; SCHAEFFER-NOVELLI, Y.; AGOSTINHO, A. A.. Brazilian wetlands: their definition, delineation, and classification, for research, sustainable management, and protection. *Aquatic Conservation: Marine and Freshwater Ecosystems,* v. 24, n. 1, p. 5-22, 2013.

JUNK, W. J.; PIEDADE, M. T. F.; LOURIVAL, R.; WITTMANN, F.; KANDUS, P.; LACERDA, L. D.; BOZELLI, R. L.; ESTEVES, F. A.; NUNES DA CUNHA, C.; MALTCHIK, L.; SCHÖNGART, J.; SCHAEFFER-NOVELLI, Y.; AGOSTINHO, A. A.; NÓBREGA, R. L. B.; CAMARGO, E.. Parte I: Definição e Classificação das Áreas Úmidas (AUs) brasileiras: Base Científica para uma Nova Política de Proteção e Manejo Sustentável. *In Classificação e delineamento das áreas úmidas brasileiras e de seus macrohabitats.* Cuiabá: EdUFMT, 2014. p. 13-82.

LILLESAND, T.; KIEFER, R. W.; CHIPMAN, J. *Remote sensing and image interpretation.* Nova Jersey: John Wiley & Sons, 2015. 763 p.

MIRANDA, C. S.; PARANHOS FILHO, A. C.; POTT, A.. Changes in vegetation cover of the Pantanal wetland detected by Vegetation Index: a strategy for conservation. *Biota Neotropica,* v. 18, n. 1, e20160297, 2018.

MMA - Ministério do Meio Ambiente Áreas Úmidas - Convenção de Ramsar**.** *In Ministério do Meio Ambiente.* Disponível em: https://www.mma.gov.br/biodiversidade/biodiversidade-aquatica/zonas-umidas-convencao-de-ramsar.html Acesso em: 10/01/2020.

MOREIRA, S. N.; EISENLOHR, P. V.; POTT, A.; POTT, V. J.; OLIVEIRA-FILHO, A. T.. Similar vegetation structure in protected and non-protected wetlands in Central Brazil: conservation significance. *Environmental Conservation,* v. 42, n. 4, p. 356-362, 2015.

NOVO, E. M. L. M.; BARBOSA, C. C. F.; LOBO, F. L.. Comportamento espectral dos ambientes aquáticos. *In Reflectância dos materiais terrestres, análise e interpretação.* São Paulo: Oficina de Texto, 2019. P. 225-245.

NUNES DA CUNHA, C.; JUNK, W. J.. Parte II: A Classificação dos Macrohabitats do Pantanal Mato-grossense. *In Classificação e delineamento das áreas úmidas brasileiras e de seus macrohabitats.* Cuiabá: EdUFMT, 2014. p. 83-130.

NUNES DA CUNHA, C.; PIEDADE, M. T. F.; JUNK, W. J.. *Classificação e delineamento das áreas úmidas brasileiras e de seus macrohabitats.* Cuiabá: EdUFMT, 2014. 165 p.

PARANHOS FILHO, A.; MOREIRA, E.; OLIVEIRA, A.; PAGOTTO, T.; MIOTO, C.. Análise da variação da cobertura do solo no Pantanal de 2003 a 2010 através de sensoriamento remoto. *Engenharia Sanitária e Ambiental,* v. 1, n. 1, p. 69-76, 2014.

PERES, P. N.; MIOTO, C. L.; MARCATO JUNIOR, J.; PARANHOS FILHO, A. C.. Variação da Cobertura do Solo no Pantanal de 2000 a 2015 por Sensoriamento Remoto com Software e Dados Gratuitos. *Anuário do Instituto de Geociências,* v. 39, n. 2, p. 116-123, 2016.

QGIS - DEVELOPMENT TEAM (2016). Um Sistema de Informação Geográfica livre e aberto. *In QGIS.* Disponível em: https://www.qgis.org/pt_BR/site/. Acesso em: 13/08/2018.

RAMOS, M. V. V.; CURI, N.; MOTTA, P. E. F.; VITORINO, A. C. T.; FERREIRA, M. M.; SILVA, M. L. N.. Veredas do Triângulo Mineiro: solos, água e uso. *Ciência e Agrotecnologia,* v. 30, n. 2, p. 283-293, 2006.

RAMOS, M. V. V.; HARIDASAN, M.; ARAÚJO, G. M.. Caracterização dos Solos e da Estrutura Fitossociológica da Vegetação de Veredas da Chapada no Triângulo Mineiro. *Fronteiras: Journal of Social, Technological and Environmental Science,* v. 3, p. 180-210, 2014.

RAWAT, J. S.; KUMAR, M.. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science,* v. 18, n. 1, p. 77-84, 2015.

RIBEIRO, J. F.; WALTER, B. M. T.. As principais fitofisionomias do Bioma Cerrado. *In Cerrado: ecologia e flora.* Planaltina: Embrapa Cerrados, 2008. p. 152-212.

SANCHES, R. A.; ROSSETE, A. N.; REZENDE, A. C. P.; ALVES, H. Q.; VILLAS-BÔAS, A.. Subsídios para a proteção de áreas úmidas da bacia do rio Xingu (Mato Grosso, Brasil). *Revista Árvore,* v. 36, p. 489-498, 2012.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAUJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F.. *Sistema Brasileiro de Classificação de Solos.* Brasília, DF: Embrapa, 2018. 356 p.

SILVA, A. A. M.; DALMAS, F. B.; PARANHOS FILHO, A. C.. Análise multitemporal do crescimento do Munícipio de Amambai-MS. *Revista Geociências-UNG-Ser,* v. 17, n. 1, p. 6-13, 2019.

SOUSA, R. F. D.; NASCIMENTO, J. L. D.; BRASIL, E. P. F.; LEANDRO, W. M.; CAMPOS, A. B. D.. Matéria orgânica e textura do solo em veredas conservadas e antropizadas no bioma Cerrado. *Revista Brasileira de Engenharia Agrícola e Ambiental,* v. 15, n. 8, p. 861–866, 2011.

TORRES, D. R. *Análise multitemporal do uso da terra e cobertura florestal com dados dos satélites Landsat e Alos.* Dissertação de Mestrado apresentado ao Programa de Pós-Graduação em Engenharia Florestal, Centro de Ciências Rurais, Universidade Federal de Santa Maria, Santa Maria, 2011, 96 p.

USGS - United States Geological Survey. Earth Explorer – Home. *In USGS science for a changing world*. Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. a.

USGS - United States Geological Survey. USGS EROS Archive - Landsat Archives - Landsat 8 OLI/TIRS Level-2 Data Products - Surface Reflectance. *In USGS science for a changing world.* Disponível em: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archives-landsat-8-olitirs-level-2-data-products?qt-science_center_objects=0#qt-science_center_objects. Acesso em: 13/08/2018. b.

USGS - United States Geological Survey. Imagens Landsat 5. Órbita 224, ponto 076. Data de passagem 22 de agosto de 1985. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. c.

USGS - United States Geological Survey. Imagens Landsat 5. Órbita 224, ponto 076. Data de passagem 04 de agosto de 1990. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. d.

USGS - United States Geological Survey. Imagens Landsat 5. Órbita 224, ponto 076. Data de passagem 15 de agosto de 2000. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. e.

USGS - United States Geological Survey. Imagens Landsat 5. Órbita 224, ponto 076. Data de passagem 04 de setembro de 2007. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. f.

USGS - United States Geological Survey. Imagens Landsat 5. Órbita 224, ponto 076. Data de passagem 21 de agosto de 2008. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. g.

USGS - United States Geological Survey. Imagens Landsat 5. Órbita 224, ponto 076. Data de passagem 15 de setembro de 2011. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. h.

USGS - United States Geological Survey. Imagens Landsat 7. Órbita 224, ponto 076. Data de passagem 04 de setembro de 2013. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. i.

USGS - United States Geological Survey. Imagens Sentinel 2B. T134209 Data de passagem 04 de agosto de 2017. *In USGS science for a changing world.* Disponível em: https://earthexplorer.usgs.gov/. Acesso em: 13/08/2018. j.

USGS - United States Geological Survey. Shuttle Radar Topography Mission – SRTM. *In USGS science for a changing world.* Disponível em: http://srtm.usgs.gov/data/obtainingdata.html. Acesso em: 13/08/2018. k.

VELOSO, R. B; RANGEL FILHO, A. L. R.; LIMA, J. C. A.. *Classificação da vegetação brasileira, adaptada a um sistema universal*. Rio de Janeiro: IBGE, 1991. 124 p.

ZEE/MS. *Zoneamento Ecológico-Econômico do Estado de Mato Grosso do Sul. Segunda Aproximação. Elementos para construção da sustentabilidade do território sul-matogrossene.* Campo Grande, 2015. 199 p.

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