Study of the Floodflow Dynamics in the Pantanal of Cáceres/MT

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Abstract: The Brazilian Constitution lists some biomes and ecosystems considered as national patrimony, among which the Pantanal Matogrossense is inserted, legally establishing conditions that ensure the preservation of the environment, including the use of its natural resources (Article 225, § 4). In this context, the research proposes to analyze the dynamics of the floodflow in the Pantanal of Cáceres/MT and aims to contribute a methodology to obtain results that can support the planning, management, and monitoring of natural resources, as well as providing important information for agriculture, geology, hydrology, and ecological models. In this research, images from the MODIS sensor from the year 2015, with a resolution of 250 m, were used for the application of the methodology. The software ArcGis and Matlab were used for the image processing. The normalized difference water index obtained through 500 m resolution MODIS images was used as a priori analysis of the regions with water and without water, after a threshold was defined for all of the images and the processing was done to obtain the matrix with days with water and without water in the studied area. The results obtained provide a classification for the floodflow, the quality parameters derived using study area show that the proposed method performed better with classes < 30 (96%) and 180 - 270 (90%) of 4% and 10% of false positives, respectively.

1 INTRODUCTION

The Pantanal is a large wetland composed of several types of vegetation (landscape units) that make up a complex set of habitats with multiple functions. These systems depend on the pulse of flood and the interaction of these environments. Biodiversity maintenance needs these habitats. Similarly, this immense floodplain maintains a relationship of interdependence with the ecosystems located around the Pantanal, considering, in this context, the impacts caused by human intervention in the highlands surrounding the wetlands (Wantzen et al., 2008; Silva and Girard, 2004).

The Pantanal of Cáceres, as a subregion of the Mato Grosso Pantanal, corresponds to an extensive area of accumulation with a very flat topography that is frequently subjected to floods, whose drainage network is controlled by the Paraguai River (Brasil, 1997).

Some studies have concluded that the floods of area are due to the volume of water brought by the network of tributaries of the Paraguai River, together with the weak slope and soil type rather than the rainfall. The Pantanal vegetation consists of a variety of species adapted to the dynamics defined by the flood pulses.

According to Adamoli (2005), the Pantanal is a biome that frequently undergoes alteration in its vegetation cover. This factor is due to the differentiated dynamics, caused by the double seasonality and alterations in the flood regime, which changes the structure and floral composition, making the humid areas more sensitive to anthropic processes (Bove et al., 2003).

Due to this distinct characteristic, flooded areas require monitoring to verify the change in vegetation. Santos et al., (2009) emphasize that the most efficient way to promote the monitoring of these areas is through Geographic Information System (GIS) and

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geoprocessing that makes it possible to have precise evaluations, aiding in the analysis of the spatio-temporal modifications. Due to the synoptic view, mapping and repetitive coverage through remote sensing images is a viable source of information at regional and global scales (Csaplovics, 1998; Foody, 2002).

In this context, high-spatial revisits with a moderate resolution image spectroradiometer (MODIS) have been used to monitor land use/land (LULC) cover, predict global changes, and to assist in the protection of our environment. In Song et al. (2011), an approach is proposed for the mapping of LULC in the Amur river basin using MODIS at 250m resolution, the normalized difference vegetation index (NDVI), land surface vegetation index (LSWI), and the reflectance time series data for 2001 and 2007.

Almeida et al. (2015) analyzed the spatio-temporal variability of the Pantanal vegetation cover by a principal component analysis applied to a complete annual dataset of filtered EVI2 images. PCA-based approach was able to capture the essentials of the phenological/environmental variability.

Gu et al. (2008) evaluated the relationship between satellite derived vegetation indices (normalized difference vegetation index–NDVI and normalized difference water index–NDWI) and soil moisture to understand how these indices respond to soil moisture fluctuations.

The most relevant aspect of this work is the exploration of methodologies to identify the floodflow dynamics in the Pantanal of Cáceres, which were formulated based on the analysis of the images of the annual time series of the MODIS system with 250 m resolution and the normalized difference water index (NDWI) of MODIS at 500 m resolution.

The scientific and technological relevance of the theme, in the context of the development of new methodologies for the efficient capture of cartographic information, is evidenced by the importance given to the theme by the International Society for Photogrammetry and Remote Sensing (ISPRS), where one of the terms of reference is the remote sensing of land use and coverage.

This paper is organized into four sections: the next section presents the proposed methodolgy, followed by the experimental results, discussion, and the main conclusions. Future prospectives are described in the last section.

2 MATERIALS AND METHODS

2.1 Study Area

The Pantanal of Cáceres is one of the subregions of the Mato Grosso Pantanal, which corresponds to approximately 9.01% of its territorial area (Silva and Abdon, 1998) and occupying 50.87% of the territorial area of the municipality of Cáceres, located in Mato Grosso. It is located in the upper Paraguai Basin (BAP) in the southwest region of the state of Mato Grosso (Figure 1).

It lies between the Paraguai river and the municipality of Corumbá/MS (north–south) and borders the Republic of Bolivia and the Poconé Pantanal (east–west) at the geographic coordinates 15°31’15’’ and 17°37’45’’ South latitude and 58°32’30’’ and 57°21’55’’ West Longitude. The Cáceres Pantanal area is 12,412.56 km^2, where 12,371 km^2 (99.66%) are located within the municipality of Cáceres (Neves, 2008).

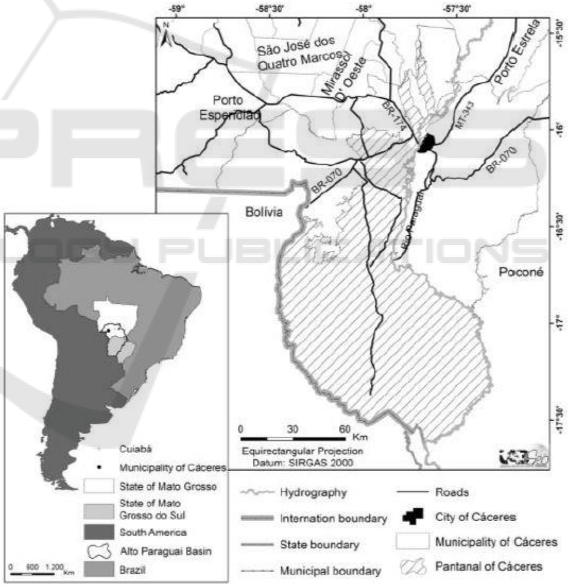

Figure 1: Location map of Pantanal of Cáceres, Mato Grosso, Brazil.

The study area represents an extensive flooded environment, described as an ancient sandy alluvial plain (Ab'Saber, 2006) with phyto-physiognomic aspects composed of different vegetal types such as: wooded savanna, forest savanna, and grass savanna (IBGE, 2012).

The annual average temperature is 22.6°C (Brasil, 2007). It presents a rainfall index of 1200 to 1500 mm annually (Neves et al., 2011) with an altitude varying between 90 and 200 meters (Radambrasil, 1982).

The soil of the region presents low fertility, mainly composed by Plintossolo (PL), Plantossolo (PT), and quartz sands (Quartzarenic Neosol), with the influence of hydromorphic processes (Fernandes et al., 2007; Embrapa, 2006).

2.2 Methodology

In this paper, we propose an analyze of the dynamics of the floodflow in the Pantanal of Cáceres/MT. Methodological steps are explained in detail in the Figure 2.

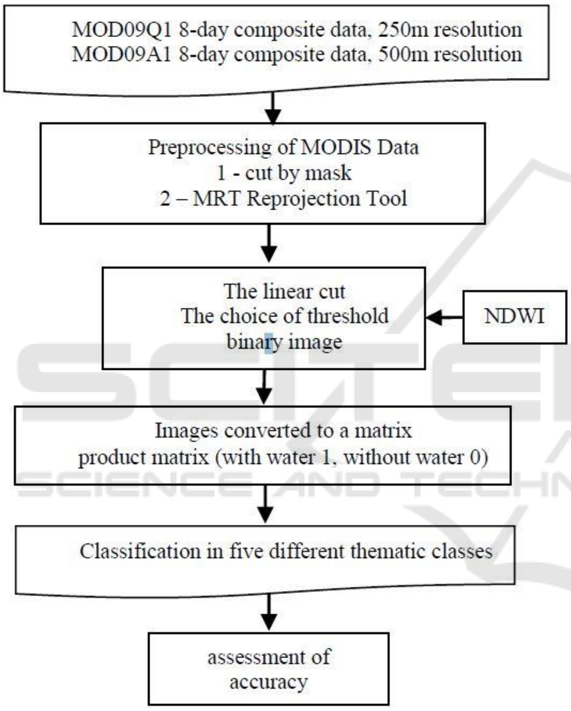

Figure 2: Flowchart of methodology.

In the first stage of the methodology, 46 MODIS product Q1 images were selected with a spatial resolution of 250 m on the Terra platform, available in the EOS Data Gateway (NASA, 2007) portal, in an 8-day composition, referring to the months of January to December 2015.

The choice of the 8-day composition in this work is due to the reduction of the number of images with clouds and the effects of bidirectional reflectance and atmosphere reflectance (Martinez et al., 2009; Villar et al., 2012).

In this stage, the study area was cut by mask of the area using the shapefile extension. The linear cut with one standard deviation was used as a parameter for the choice of threshold. The thresholds were chosen in the software ArcGis, version 9.2 (ESRI, 2007).

The NDWI images of the MODIS product A1 with a spatial resolution of 500 m from the months of January and July of 2015 was used to subsidize the choice of threshold. The NDWI was calculated according to Gao (1995).

Larger thresholds were tested, however, they eventually underestimated the delimitation of the areas with water, causing the grouping of areas with differentiated responses. The use of one standard deviation was an empirical choice but provided a plausible result for determining the threshold to be used in all study images.

It is worth noting that the months of the dry season are May–October, with July being the month with the lowest total rainfall. The months of the rainy season are November–April, when 76% of the annual total rainfall occurs, with January being the wettest month.

The resulting image was classified in a binary image (with water values being 1 and not water being 0) and exported to Matlab software.

In the second step of the methodology, the images were imported into the Matlab software, in which all images were converted to a matrix, and to performed the sum of the values of the pixels with water (value of 1) and without water (value of 0) and the after the product matrix was generated, resulting from the matrix sum multiplied by the composition of the MODIS images (8 days).

This gave a matrix with values of days with water varying from 0 (not one day with water) to 365 (every day with water). At the end of the compilation process in the Matlab software, the georeferenced product image and a classification of the days with water in the study area were imported into ArcgGis.

For the classification, five different thematic classes were defined, including the days with water: <30 (nonflooded or rarely flooded—automatic landscapes), 30–90 (occasionally flooded), 90–180 (seasonally flooded), 180–270 (frequently flooded), >270 (permanently flooded–hydromorphic landscapes).

Visits were made to the study area during the dry period, in November 2015, to record photographs of the existing landscapes in the region (attached in Figure 1) and collect land control points (PCTs) to subsidize the classification of satellite images.

After the classification process an assessment of accuracy was performed using the Khat statistic to check the reliability of the map generated (Congalton (1991). The producer's accuracy refers to the total number of correct pixels in a class divided by the total number of pixels of that class as derived from the reference data (i.e., the column total). The user's accuracy is the total number of correct pixels in a class divided by the total number of pixels that were classified in that class (i.e., the row total).

For the generation of the confusion matrix, the classification generated in ArcGIS were converted to the feature class, through the Raster to Polygon tool.

In the ArcGIS, 150 (hundred and fifty) points were created randomly, distributed in the each class.

In the ArcMap application, the Esri Image Service (World Imagery) was used for point validation.

3 RESULTS

In order to aid in the detection of variations in water availability in the environment, the NDWI was used (Figure 3) which, according to Gao (1995), is more sensitive to variations because the values of reflectances corresponding to the average infrared region are used.

However, with a resolution of 500 m, this product was used to subsidize the choice of a linear cut threshold for the histogram of the MODIS images at 250 m, considering that the study was carried out on a regional scale.

The NDWI of the months with the highest (January) and lowest (July) total rainfall was analyzed and verified by the histograms that in the month of July (driest period), a greater distribution of the values occurs. In the month of January (the rainy season) it is possible to verify a higher concentration of the values. The same behavior can be verified in MODIS images at 250 m. This analysis assisted in the final classification of the floodflow dynamics.

Figures (4) and (5) show the frequency histograms of the MODIS images at 250 m from January and July, respectively, and the linear cut with the threshold of a standard deviation.

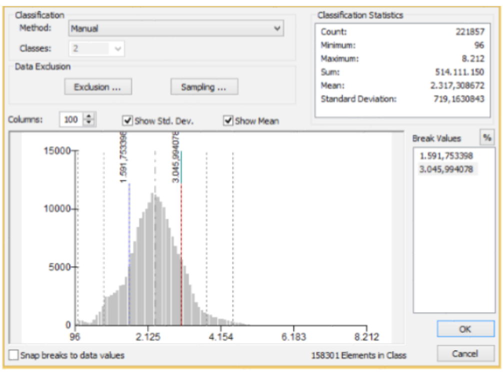

Figure 4: Image histogram of January 2015.

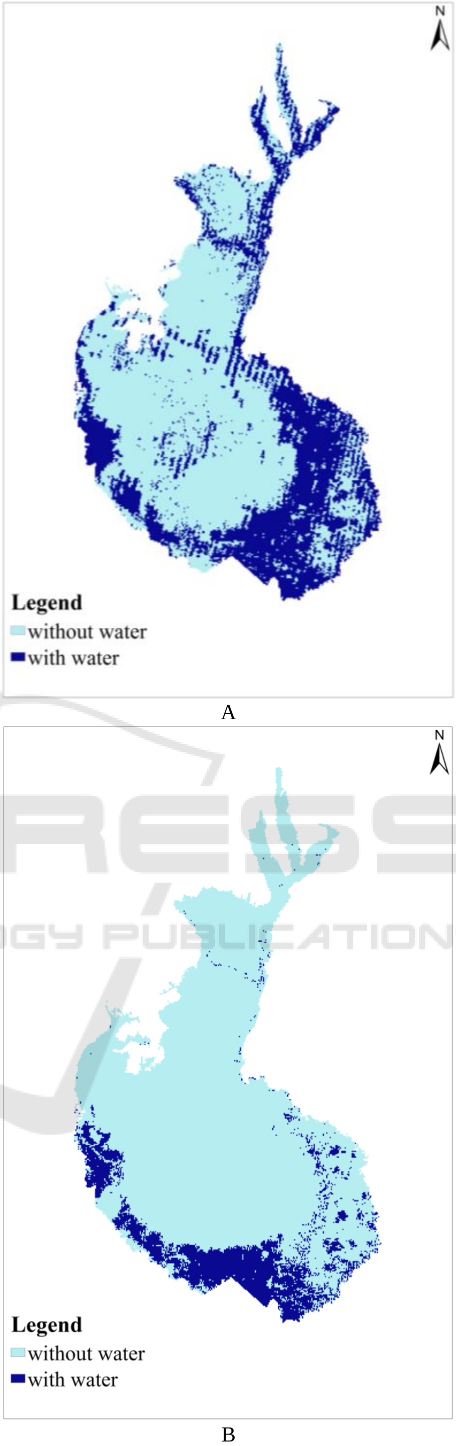

Figure 3: NDWI images. A) NDWI image of January 2015 and; B) NDWI image of July 2015.

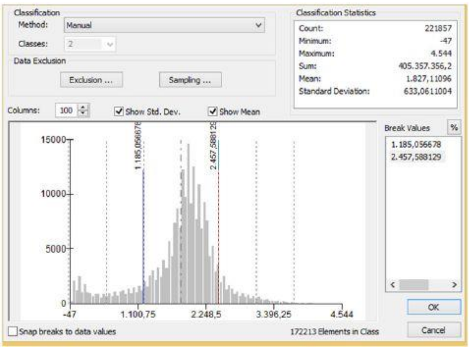

Figure 5: Image histogram of July 2015.

The classes that represent the floodflow in the Pantanal of Cáceres / MT are presented in figure 6.

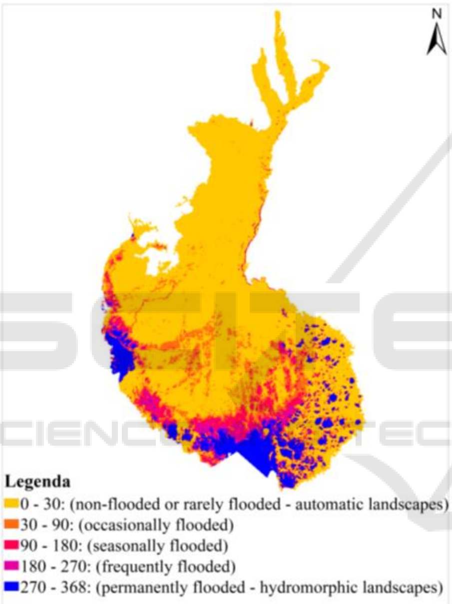

Figure 6: Classification of the floodflow in the Pantanal of Cáceres / MT.

Table 1 shows the results of the quality parameters obtained for the five thematic classes. Four main columns are shown in Table 1: column 1 identifies the thematic classes; column 2 shows the user's accuracy (number of false positives); column 3 shows the producer's accuracy (number of false negatives); and column 4 shows the KHAT accuracy is a KHAT statistic (an estimate of KAPPA).

The quality parameters derived using study area show that the proposed method performed better with classes < 30 (96%) and 180 - 270 (90%) of 4% and 10% of false positives, respectively. In the class of 30 - 90 was obtained (30% of false positives). Because this area is occasionally flooded and this fact difficult the classification.

Table 1: Quality parameters.

	User's accuracy (%)	Producer's accuracy (%)	Khat accuracy
< 30	96	80	0,82
30 - 90	70	87	
90 - 180	86	78	
180 - 270	90	87	
> 270	83	96	

In the table 1, class > 270 present 4% of false negatives and class 90 – 180 presented 22% of false negatives. Less than ideal results, in terms of false negatives. In conclusion, the method performance for this experiment can be considered satisfactory.

The result obtained in this work is essential for the monitoring of the impacts caused by excess or lack of water, as well as the definition of the environments of the Pantanal of Cáceres.

4 CONCLUSIONS

The results generated in this work showed the areas with and without water and resulted in defining the thematic classes of the floodflow of the Pantanal of Cáceres / MT, Brazil. For that, a methodology was developed using an annual time series of images of the MODIS Q1 and A1 sensor for the year 2015.

Results from this study indicate that the floodflow can be mapped into thematic classes, according to five flood distinctions.

To evaluate the proposed method, the analysis were conducted involving sample of classified classes. In general, the method showed a satisfactory performance, few false positives occurred and few false negatives were verified.

The main challenge of this work was to obtain a single threshold for the entire series of images from the year 2015.

As future work will be performed, some statistical analyses will be performed to evaluate the results obtained by the temporal profile of the floodflow.

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REFERENCES

Ab'Saber, A. N. *Brasil, Paisagens de Exceção: o litoral e o Pantanal Mato-Grossense: patrimônio básico*. Editora Ateliê. Cotia S.P., p.57-59, 2006.

Adamoli, J. Zoneamento ecológico do Pantanal baseado no regime de inundações. In: *Encontro Sobre Sensoriamento Remoto Aplicado a Estudos no Pantanal*, 1., 1995, Corumbá. Anais. São José dos Campos: Inpe, p.15-17, 2005.

Almeida, T. I. R.; Penatti, N. C.; Ferreira, L. G.; Arantes, A. E.; Amaral, C. H. Principal component analysis applied to a time series of MODIS images: the spatio-temporal variability of the Pantanal wetland, Brazil. *Wetlands Ecology Management*, vol. 23, p. 737-748. 2015.

Bove, C. P.; Gil, A. S. B.; Moreira, C. B.; Anjos, R. F. B. Hidrófitas fanerogâmicas de ecossistemas aquáticos temporários da planície costeira do Estado do Rio de Janeiro, Brasil. *Acta Bot. Bras*., v.17, n.1, p. 119-135, 2003.

BRASIL. Ministério do Meio Ambiente. Biomas. Pantanal: Fauna e Flora. 2007. Disponível em:< http://www.mma.gov.br/biomas/pantanal#footer>. Acesso em: jan. 2015.

BRASIL. Ministérios do Meio Ambiente, dos Recursos Hidricos e da Amazônia Legal. *Plano de Conservação da Bacia do Alto Paraguai (Pantanal) – PCBAP*. Diagnóstico dos meios físicos e bióticos: meio biótico. Brasília, DF: MMA, v. 2, t. 3. p. 3-68, 1997.

Congalton, R. G. A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*. n. 37, 35-46, 1991.

Csaplovics, E. High Resolution space imagery for regional environmental monitoring — status quo and future trends. *International Archives of Photogrammetry and Remote Sensing*, 32(7), 211-216, 1998.

EMBRAPA. Centro Nacional de Pesquisa de Solos (Rio de Janeiro, RJ). *Sistema Brasileiro de Classificação de solos*. 2. ed. – Rio de Janeiro : EMBRAPA-SPI, 2006.

ESRI. *ArcGIS Desktop: release 9.2*. Redlands, CA: Environmental Systems Research Institute, 2007.

Fernandes, F. A.; Fernandes, A. H. B. M.; Soares, M. T. S; Pellegrin, L. A.; Lima, I. B. T. de. *Atualização do mapa de solos da planície pantaneira para o Sistema Brasileiro de Classificação de Solos*. Corumbá: Embrapa Pantanal, 2007.

Foody, G. M. Status of Land Cover Classification Accuracy Assessment, *Remote Sensing of Environment*, 80, 185-201, 2002.

Gao, B.C. A normalized difference water index for remote sensing of vegetation liquid water from space, in SPIE's *1995 Symposium on OE / Aerospace Sensing and Dual Use Photonics*, Vol. 2480, Orlando, FL, 1995.

Gu, Y.; Hunt E.; Wardlow, B.; Basara, J.; Brown, J. F.; Verdin, J. P. Evaluation of MODIS NDVI and NDWI for vegetation drought monitoring using Oklahoma Mesonet soil moisture data. *Geophysical Research Letters*, vol. 35, p. 1-5, 2008.

IBGE- Instituto Brasileiro de Geografia e Estatística. *Manual Técnico da Vegetação Brasileira*. Ed. 2. 2012.

Martinez, J. M.; Guyot, J. L., Filizola, N., Sondag, F. Increase in suspended sediment discharge of the Amazon River assessed by monitoring network and satellite data. *Catena*, v.79. p.257-264. 2009.

NASA. National Aeronautics and Space Administration. Earth observing system data gateway. Disponível em: <http:// edcimswww.cr.usgs.gov/pub/imswelcome/>. Acesso em: 15 out. 2007.

Neves, S. M. A. S.; Cruz, C. B. M.; Neves, R. J. Operacionalização de propostas de Zoneamento Turistico do Pantanal de Cáceres/MT, com suporte nas geotecnologias. *Ciência Geográfica*, v. 18, n., p. 76-86, 2008.

Neves, S. M. A. S.; Nunes, M. C. M.; Neves, R. J. Caracterização das condições climáticas de Cáceres/MT Brasil, no período de 1971 a 2009: subsídios às atividades agropecuárias e turísticas municipais. *Boletim Goiano de Geografia*, v. 31, n. 2, p. 55-68, 2011.

Radam-Brasil. *Projeto RADAMBRASIL: Levantamento de Recursos Naturais* Vol. 27 - Corumbá. Rio de Janeiro: Ministério das Minas e Energia, 1982.

Santos, J. S.; Pereira, G.; Shimabukuru, Y. E.; Rudorff, B. F. T. Identificação de áreas alagadas no Bioma Pantanal - Brasil -utilizando dados multitemporais TERRA/MODIS. GEOGRAFIA, Rio Claro, v. 34, Número Especial, p. 745-755, dez., 2009.

Silva, J.S.V.; Abdon, M.M.; Delimitação do Pantanal brasileiro e suas sub-regiões. *Pesquisa Agropecuária Brasileira*, Brasília, v.33, Número Especial, p.1703-1711, out.,1998.

Silva, C.J.; Girard. P New challenges in the management of the Brazilian Pantanal and catchment area. Wetlands *Ecology and Management*, 12: 553-561, 2004.

Song, K.; Wang, Z.; Liu, Q.; Liu, D.; Ermoshin, V. V.; Ganzei, S. S.; Zhang, B.; Ren, C.; Zeng, L.; Du, J. Land use/land cover (LULC) classification with MODIS time series data and validation in the Amur River Basin. *Geography and Natural Resources*, Vol. 32, Issue 1, p. 9–15, 2011.

Villar, R. E.; Martinez, J. M.; Guyot, J. L.; Fraizy, P.; Armijos, E.; Crave, A.; Bazán, H.; Vauchel, P.; Lavado, W. The integration of field measurements and satellite observations to determine river solid loads in poorly monitored basins. *Journal of Hydrology*, v.44, p.45-54. 2012.

Wantzen, K. M.; Cunha, C. N.; Junk, W. J.; Girard, P.; Rossetto, O. C.; Penha, J. M.; Couto, E. G.; Becker, M.; Priante, G.; Tomas, W. M.; Santos, S. A.; Marta, J.; Domingos, I.; Sonoda, F.; Curvo, M.; Callil, C. T. Towards a sustainable management concept for ecosystem services of the Pantanal wetland. *Ecohydrology & Hydrobiology*, 8: P. 115-138, 2008.