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ANALYSIS OF THE PROCESS OF ENVIRONMENTAL DEGRADATION OF AREAS OF SWAMP IN THE REGION NORTH OF MINAS GERAIS FROM TEMPORAL SERIES OF IMAGES

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Abstract

Environmental studies to characterize the process of environmental degradation of different ecosystems are extremely complex. In recent years, satellite images have become a great ally in these types of study, since they have the advantage of allowing the joint analysis of different variables, especially when associated with the temporal series. In this perspective, the study aimed to analyze the process of environmental degradation in areas of meadows, at the southern end of the basin of the Urucuia river, situated in the North of the state of Minas Gerais, from LANDSAT-5/TM images. Characterized by a transition region between the biomes savanna and caatinga, areas of meadows suffer strong anthropogenic pressures that are promoting major disturbances and disfiguration of the entire ecosystem. For the analysis were studied images of months more dry (July and August) for the years 1984, 1990, 2000 and 2010. The areas of meadows have been identified and mapped and then there was an automatic segmentation and analysis of the NDVI (Normalized Difference Vegetation Index) to study the dynamics of this environment. The results showed that during the period analyzed, these areas fell by around 9.61 times, mainly due to silting. The NDVI showed behavior similar to those observed in areas of paths, i.e. there was a change on the surface of the water for values corresponding to areas of exposed soil in the advanced stage of deterioration. The greatest period of degradation was observed between the decades of 1980's and 1990's with reduction in these areas around 88.29 %.

Keywords: Environmental modeling, NDVI, anthropogenic actions.

Introduction

In the Northern region of the state of Minas Gerais the savanna biome represents the greatest treasure of natural heritage, and the anthropic activities are its main instrument of environmental degradation, since this biome is still seen as available land and fuel reserve. Environments more sensitive as subecossistema of savanna, paths present a great ecological significance especially in the lowest areas which when formed by interconnected ponds are also called Swamp. Second Aguiar & Camargo (2004) the paths,

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typical environments of the savanna are located near the springs and act as drainage ways, contributing to the continued existence and regularity of water courses, since that act as collecting basins. However, with the economic development and agricultural expansion, these areas have been experiencing a series of degradation over time causing a rapid deterioration of these environments and so the need to understand the temporal dynamics of this process. In this context the basin of the Urucuia river which covers the Northern region of Minas Gerais is of great importance, because it is one of the basins of the middle São Francisco that has expressive contribution socio-environmental and economic. In the extreme south of the basin is large areas of swamp that form an environment with characteristics quite particular and even studied very little, but it is essential to the revitalization of the São Francisco River.

The area form a kind of Swamp because the marginal lagoons that makes an environment very conducive to procreation of fish of the São Francisco River. These areas present characteristics quite peculiar, especially as to its geographical location, as they are inserted in regions of transition between the biomes savanna and caatinga, surrounded by subecossistema paths. However with the strong anthropic intervention these areas suffer from strong changes in the scheme of flood being perceived mainly by decrease of flooded areas over the years. Second Melack & Hess (2004) information about the location, extent and other basic features that characterize the area, are scarce in the literature, mainly due to the difficulty of monitoring of those areas. In this context, the monitoring itself is of fundamental importance, since, changes in the schemes of floods cause changes in plant cover, which, therefore, change the whole ecosystem. The orbital remote sensing becomes an important tool in this process, since it provides a better assessment, management, management, and management of natural resources, such as water, soil and vegetation. The satellite images allow the generation of maps that show the conditions that the system is submitted to the course of time, provided that they are carried out analyzes temporal. Another important issue concerns the analysis of these environments that normally considers only the two extreme phases (flood and ebb tides), which has just disregarding a great diversity of scenarios intermediaries, with ecological implications distinct. From time series of satellite images is possible to perform analyzes between intermediate levels and correlating the data of different times and by establishing direct relations with different variables. In this perspective, the study aimed to analyze the process of environmental degradation of the areas of meadows on the south end of the basin of the Urucuia river through temporal series of LANDSAT-5/TM images in four different time periods: 1984, 1990, 2000 and 2010, corresponding to a period of twenty-six years. To characterize and quantify the changes in the area were analyzed NDVI images, corresponding to the years analyzed. This will serve as a subsidy for the development of research in the region, and the results generated can be used in search of mitigating actions and decision making processes.

2. Material and Methods

2.1 Study Area

The study area is located in the extreme north of Minas Gerais along the Urucuia river that covers several areas of ecological interest being considered one important nurseries for fish of the Sao Francisco river along with the River cornets. The River Basin of the Rio Urucuia has an area of 25.038,35 km² almost in total in the state of Minas Gerais with an estimated population of 93.850 in habitants. The basin covers in a total of 12 municipalities and the municipality with greater influence in the studied area are; Pintopolis, São Romão, Urucuia and Januária. The cut out studied and characterized by an environment formed by meadows located in areas of paths in the regions most low that form a kind of swamp due to a series of marginal lakes of Urucuia river. This complex of oxbow interconnects in the period of rainfall which occurs the piracema of part of the fish of the São Francisco river. The spatial area analyzed has the following geographic coordinates: 15° 32' 48.33" to 15º 44' 9.84" south latitude and 44° 43' 39.68" to 44° 33' 34.92" west longitude. According to the Map of vegetal cover Brazil IBGE (2004) the region a complex between the savanna and Caatinga biomes, predominantly the first with their variations IGA (2006). The monthly precipitation and annually in the region is 4 and 1,057 mm. The months of highest rainfall, november to march, totaling 91% of the total annual precipitation, the driest months are between april and october being the most critical the months of june to august. The average annual temperature is around 28°C; in the colder months, June and July, the average temperature around 24°C; in the hottest month, October, the average is 33°C. To analyze these events were used as reference meteorological data of the municipality of Januária supplied by INMET (National Institute of Meteorology). The soils of the region are predominant of sandy texture with a high rate of soil loss (Table 01), therefore very susceptible to erosion processes that subsequently ends up culminating in silting of lower areas and sensitive as the area in question.

2.2 Selection and georeferenced images of LANDSAT-5/TM

To analyze the process of degradation of the areas of meadows along the temporal series, were used images from LANDSAT-5/TM satellite, of 07/28/1984, 08/12/1990, 08/24/2000 and 08/24/2010, corresponding to the driest time of the region. The images, acquired from the National Institute for Space Research/INPE, were selected by eliminating

Table 01. Comparison of the soil loss for the Basin of the Urucuia river between 1987 and 2007.

Soil Loss Rate (t/ha.year)	Classes of Interpretation	Area (km^2) 1987	Area(%) 1987	Area (km^2) 2007	Area (%) 2007
<15	Zero a Moderate	20.635,91	81.84	16.669,41	68.87
15,1 - 15	Mean	2.338,31	9.7	3.177,88	15.8
50,1 - 120	Mean a Strong	1.578,80	6.3	3.281,47	11.36
>120,1	Strong a Very Strong	652,69	2.59	2.086,01	3.97

Source: Adapted from CARVALHO (1994)

possible interference of clouds and differences in lighting of the scenes. The georeferencing of images was performed by taking as reference images GeoCover of Nasa (2001) whereas 30 points distributed spatially in the scene of Path/Row 219/72. The digital processing of images was performed in software ENVI (Environment for Visualizing Images) version 4.2.

2.3 Radiometric Correction and Atmospheric images

Has been performed radiometric and atmospheric corrections for bands 3, 4 LANDSAT-5/TM images. The refletance and radiance are calculated by Equations 1 and 2, respectively.

$$Lrad = Li,\min + \left(\frac{Li,\max - Li,\min}{255} \right) \times NCi \quad (1)$$

Were: L*rad* and the spectral radiance in band i in Wm-2sr-1 µm-1 ;*Li*,max and L*i*,min values of radiance maximum and minimum in band i, respectively, and *NCi* the level of ash in band i.

$$P\lambda i = \frac{\pi \times Li}{Ki \times L \times \cos Z \times dr} \quad (2)$$

Were, L*i* and the spectral radiance of each band (Wm *i* $L\lambda^{-2}sr^{-1}\mu m^{-1}$); K*i* and the solar irradiance of spectral band at the top of the atmosphere (Wm *i* $K\lambda^{-2}\mu m^{-1}$); *Z* and the overhead angle solar; *dr*, and the square of the ratio between the average distance earth sun (r0) and the distance earth-sun (r_0) in a given day of the year (DJ). For the atmospheric correction, the values of irradiance measurements were converted to a by the method of (Dark Object Subtraction), using the histogram of band 1, as reference for the selection the pixel darker second methodology proposed by (Gürtler et al., 2005). The atmospheric correction allows mitigate the combined effects of absorption, scattering and atmospheric, caused by the presence of various gases, water vapor and particles that interact with the electromagnetic radiation as (Rodrigues et al., 2010).

2.4 Supervised Classification and Automatic Segmentation

From the images pre-processed were performed compositions color RGB-453 and then the classification non-supervised by k-means algorithm. The automatic segmentation was performed to delimit the areas of meadows of spatial area. The polygons resulting from the segmentation were quantified, to study the behavior of the advance of degraded areas throughout the series.

2.5 Calculating the NDVI

The NDVI was calculated by the equation (3). They were then selected 100 points randomly distributed in the areas of meadows, along the rivers tambourines and San Francisco, taking as reference the year of 1984, considered the initial period of evaluation of the process of environmental degradation. From the analysis of points of control was possible to assess the fluctuation in the NDVI values, and correlate them with the changes of coverage in the areas studied as a function of time.

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (3)$$

Were, ρ_{NIR} reflectance near infrared (band 4) and ρ_{RED} reflectance of red (band 3).

2.6 Statistical Analysis

The statistical analysis of the results was performed using a regression analysis used the computer program SAS (Statistical Analysis System) version 9.1.

3. Results and Discussion

Figure 1 represents the composition color RGB-453 and automatic segmentation of the areas of meadows, the initial period and end of the temporal series, respectively representing the 1984 and 2010. Figure 2 shows the total of degraded area versus % decrease in function of decades analyzed, is it possible to perceive that the period of greater degradation was between the 1984's and 1990's, with reduction of 1.147,64 hectares, i.e. 88.39% of flooded areas. From 1990's with the introduction of practical conservationist this process was reducing, with decreases of approximately 38.4% and 11.1%, respectively representing the years of 2000's and 2010's. Although it has been observed that reduction of assureds areas, it is important to emphasize that this process, is not only associated with the conservationist practices in the region necessarily, but a gradual reduction in flooded areas depending on the time of analysis.

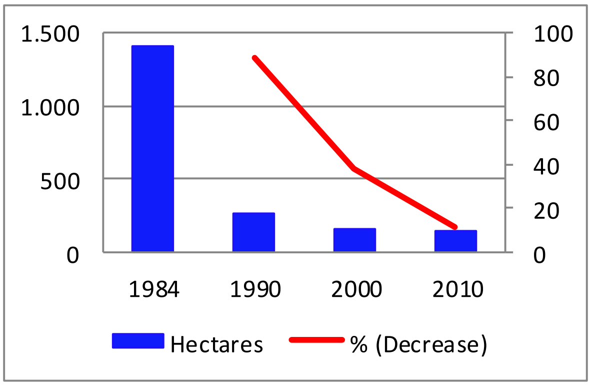


Figure 2. Degraded area in hectares (%) decrease of polygons of meadows in function of years analyzed, taking as reference 1984.

One of the activities that has grown in the region and the irrigation by central pivot, the period of greatest expansion was observed between the decades from 2000 to 2010 (Figure 3). The use of pivots next areas considered very sensitive to anthropogenic activities, were responsible for degradation process, and these systems located in the main area of procreation of fish of the São Francisco river. In the period there was an increase 390 hectares (Figure 3b), irrigated area.

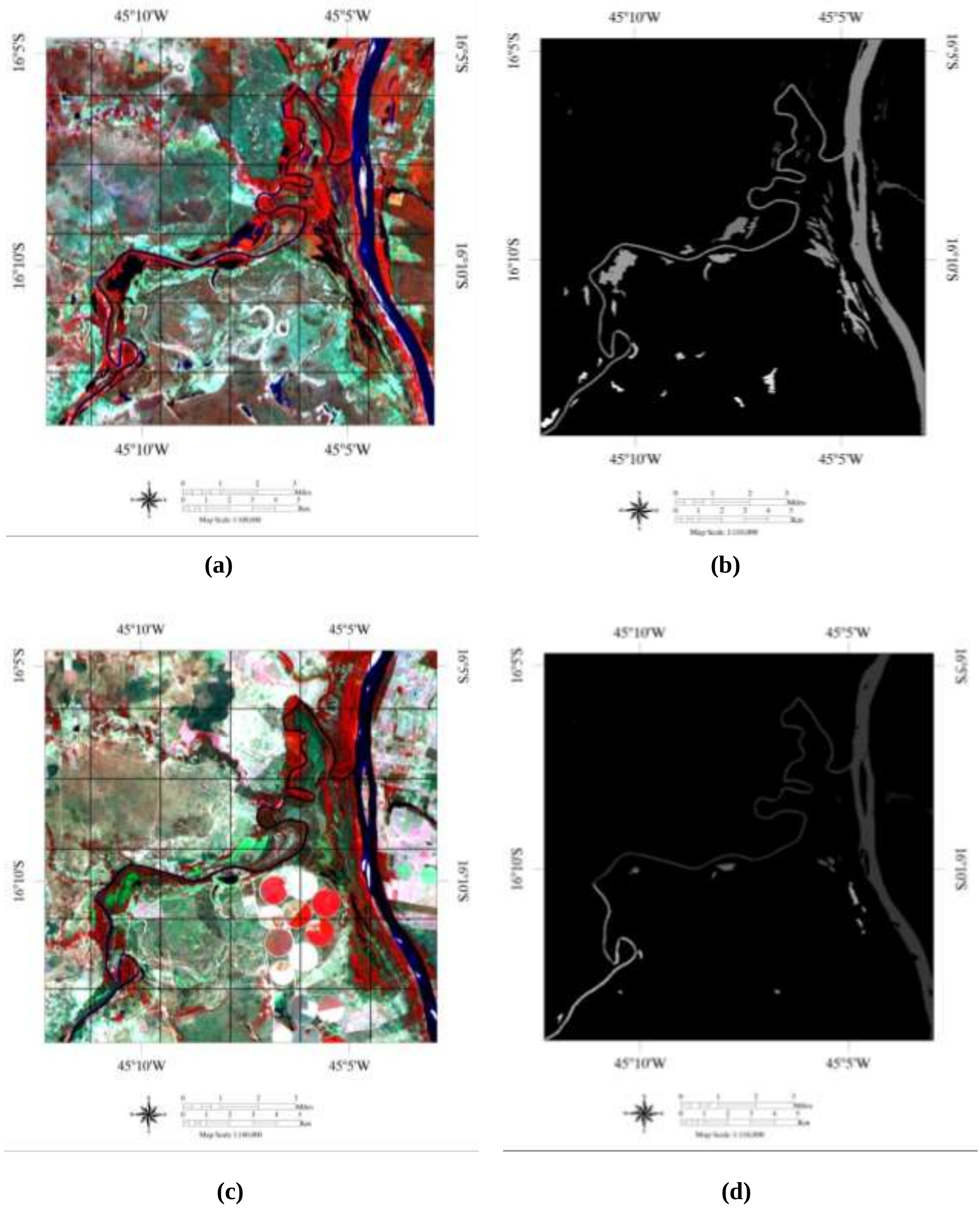
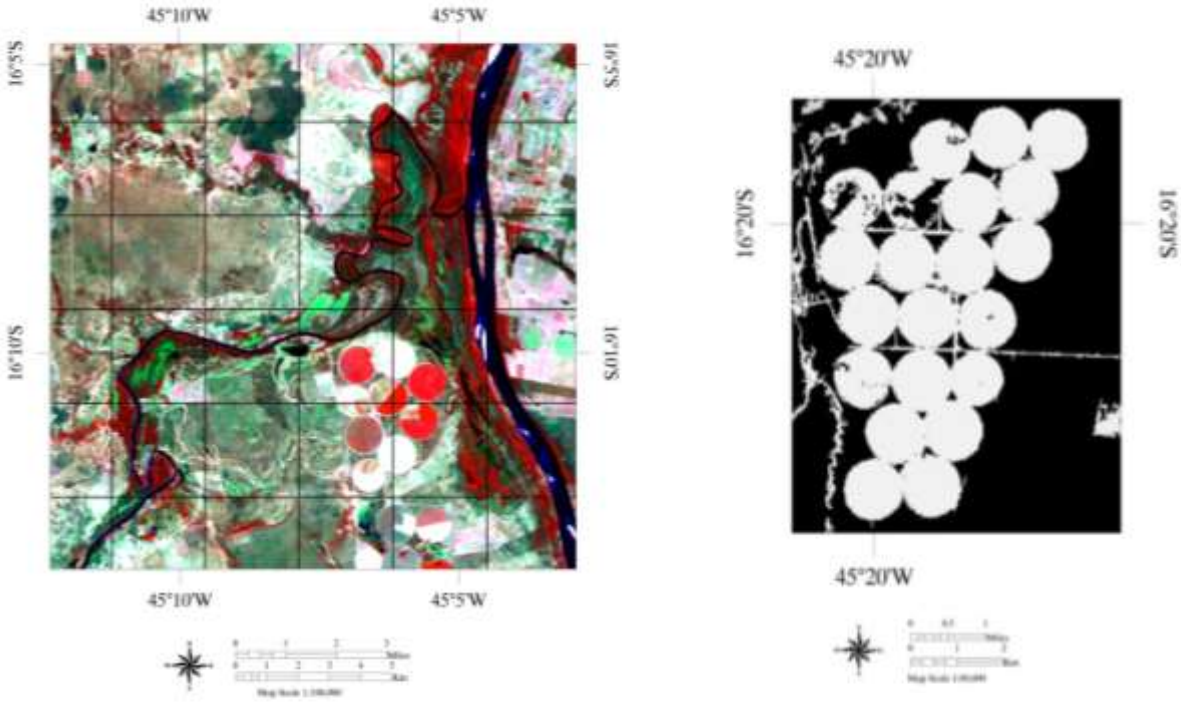


Figure 1. Composition color RGB-453, from 1984 (a) and 2010 (c) and automatic segmentation of areas, from 1984 (b) and 2010 (d), of the areas of swamp.



(a) **(b)**

Figure 3. Composition color RGB-453 (a) and automatic segmentation (b) of a set of central pivots in 2010.

Despite an apparent improvement in the 90's, some activities considered potentially harmful to these environments are still in full activity. The central pivots have on average an area of 11.5 hectares, not having change in size during the analysis period occurring only the change of location and expansion throughout the decade. This fact may is associated with soil depletion after some time of intensive exploitation which implies in opening of new areas and abandonment of the old. This type of practice is still very common in the northern region of Minas Gerais. In addition to these activities that contributes to the process of degradation of swamp areas, the characteristics of the local soils that are in their majority sandy texture accelerates the process of silting of lower areas. The permanence of cultural practices that have survived over the centuries, in addition to practices such as burning, deforestation of the riparian vegetation and the drain of the waters of the paths for agricultural crops generate major environmental problems by changing the entire chain of the local flora and fauna. Adámoli (1995) emphasizes that the process of flooding represents one of the main features of swamp areas, being that this scheme and the ecological factor fundamental of the region and determines the main biotic and abiotic processes, as well as the specific compositions of landscape units. The consequences of the process of degradation are quite alarming and are directly related to the need for monitoring of those areas for which there is a decrease and/or mitigation of these anthropogenic actions. Therefore, we need more effort in getting to know these environments, due to its importance, uniqueness and mainly by large anthropic pressure that has been occurring and being intensified even in areas protected by law. For a more detailed study and analysis of the dynamics of the process of degradation of swamp areas were considered only the surfaces of water, and therefore not including areas of wetland forests and floating macrophytes, since these are detectable in the period of maximum flood Freitas & Novo (2005). However, as the objective of the study and analyze the dynamics of degradation and this process is characterized by the silting of swamp areas, makes the knowledge of the vegetation index and climate variables an indispensable tool for this analysis. Second Stockli (2004) vegetation responds to the standards space-time climate and operates by modifying the atmospheric layer adjacent the surface acting on the carbon cycle, hydrological and energy balance. Another relevant factor is due to the region is found in the area which covers the polygon of drought, which directly interferes in the formation and dynamics of the stratum plant especially when the process of degradation is accelerated. Especially from the 90's, some authors have examined the use of the NDVI for the region semiarid as an alternative to model and monitor the stage of degradation of the environment. In this context, to analyze the monthly average of precipitation and the maximum average temperature throughout the series (Figure 4) it is perceived that there was a greater uniformity of precipitation in 2000 for the other years. This behavior is not common, since the climate in the region is characterized by two stations quite distinct, the dry and the rainy season with irregular distribution between the months of September to April. This way this event type atypical can result in a series of changes in arrangements of some environments, as well as in the behavior of vegetation that is replaced by greater availability of water for more time. Table 2 presents the average variation in the values of NDVI, for 100 points distributed in the areas of meadows, in the period analyzed. We can observe that the NDVI values present spectral response similar to areas of exposed soil, with the exception of 2000, with an increase in the value of the index.

Table 2. Average variation in the values of NDVI in the period analyzed.

Year	*observation*	*Mean NDVI*	*Coefficient of Variation*
1984	100	0.28	107.51
1990	100	0.30	111.29
2000	100	0.53	32.50
2010	100	0.35	44.70

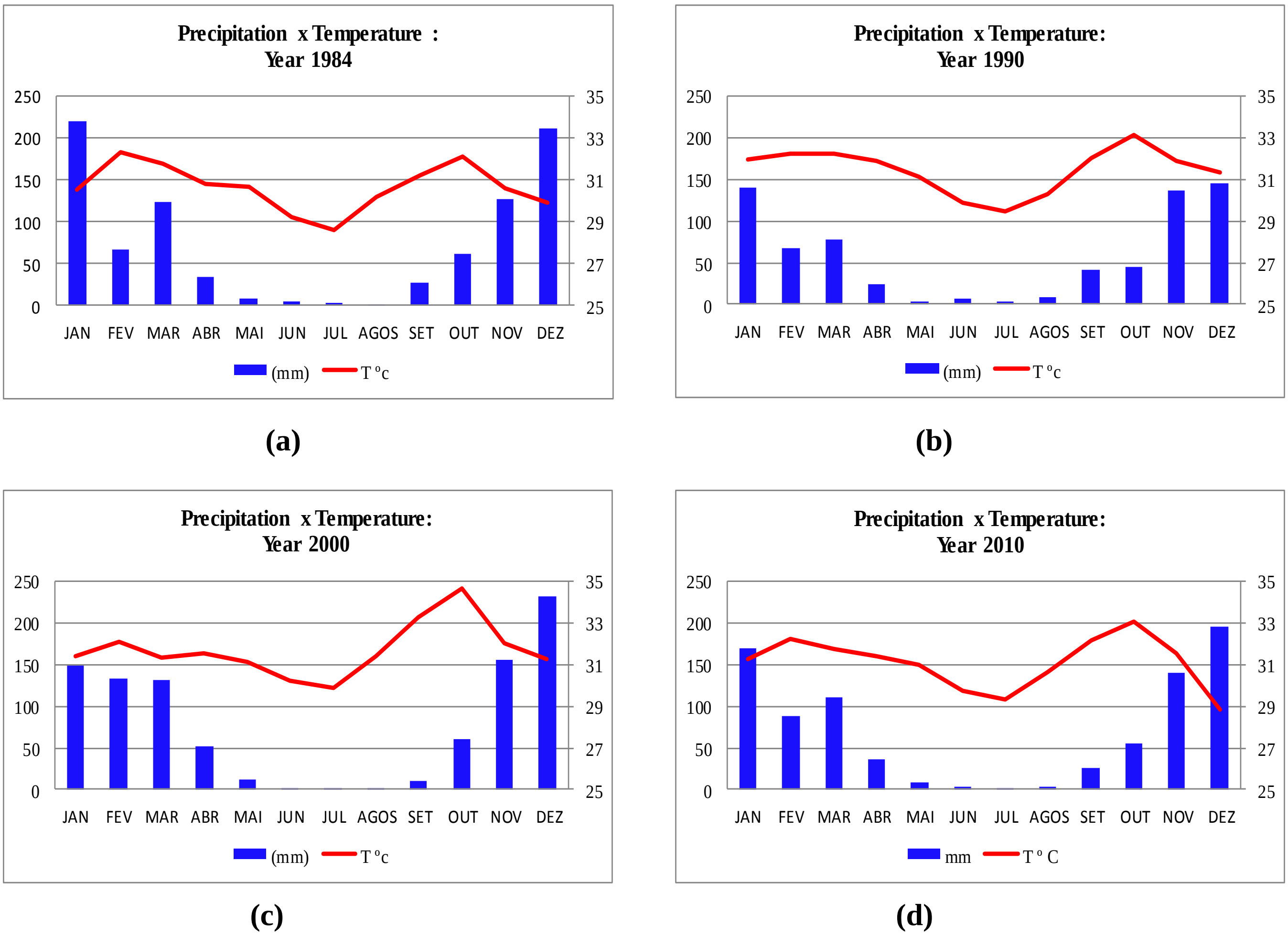


Figure 4. Graph of monthly average of rainfall and average maximum temperatures for their four years of the series.

In Figure (5) illustrates the temporal dynamics of the values of NDVI, described above. In 2000 there was a large increase in NDVI reaching to exit fully the trend line, that means a great advance of vegetation in these areas during this period. This behavior can be explained by the response of rainfall indices, which according to Figure 4, more uniform in the rainy season.

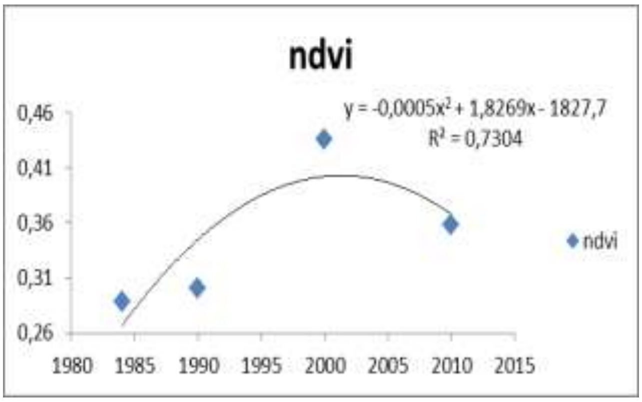
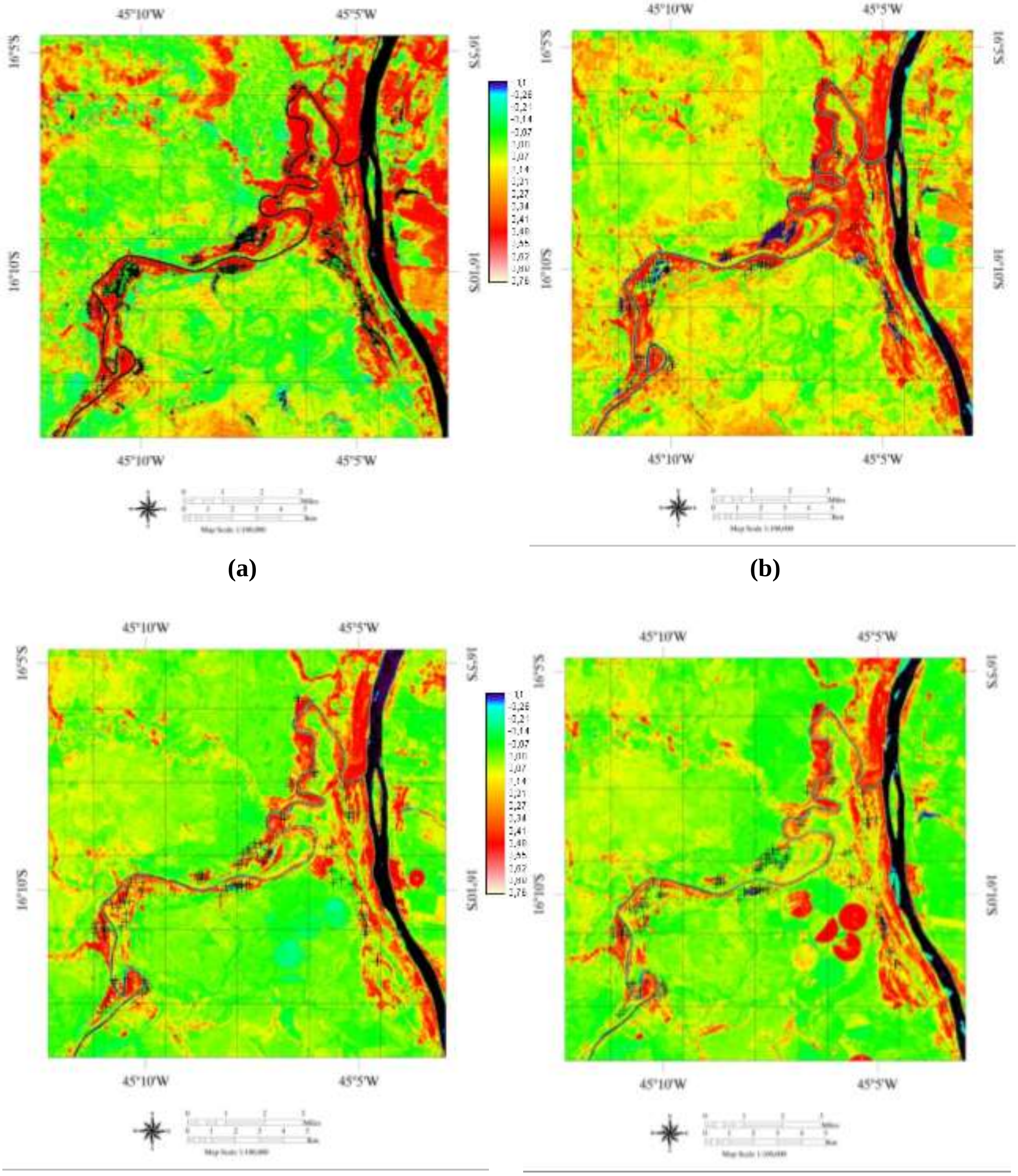


Figure 5. Statistical analysis of the points of NDVI acquired throughout the series.

Already for the year 2010 the NDVI showed a decline, being in range that can be considered as the predominance of exposed soils with low vegetation. This behavior is seen as an advanced state of decay and may is associated with the advance of vegetal substrate for within these areas, because the lowering of groundwater great location caused by the silting. As commented by Meirelles et al. (2004) the trampling of the cattle, in the paths, cause the compaction of the soil, causing the decrease in the rate of water infiltration, deficit in recharge aquifers feeders of perennial sources downstream, lowering in the aquifer and reduction of flow the springs. Figure 6 shows the NDVI in the whole series analyzed where you can check the variation and the dynamics of their values also changes in coverage and use of the soil.

As the area in question is located in environment formed by vast paths in an advanced stage of disruption because these practices, the training of plant substratum differentiated in the areas of swamp is associated with the loss of soil moisture appearing as well an environment more conducive to species more resistant and more rustic and/or adapted to these conditions, influencing the response of the index. The NDVI proved to be favorable to the type of study proposed, because among other usefulness, allowed us to identify and characterize areas natural powers of erosion for future studies on the implementation of conservation practices for the prevention of siltation, one of the main reasons of degradation of the areas of meadows. The areas of meadows of Urucuia river or Swamp as it is called in the region is considered environment unique in the state that needs a protection provided by refuge enough for its preservation, the main loss with this degradation and biodiversity decline. These environmental impacts caused in all extension to extension of the basin directly reflect in the areas of meadows mainly due to the degradation of the paths and riparian vegetation. From the study and results obtained in this work we can perceive the importance of creating projects for monitoring more effective of these environments. Without doubt, there is a great need for multidisciplinary studies in these areas that are known to the special features of these environments of great social importance and environmental for the northern region of Minas Gerais.



(a) **(b)**

(c) **(d)**

Figure 6. Image NDVI from 1984 (a), 1990 (b), 2000 (c) and 2010 (d) of the areas of meadows in the north of Minas Gerais.

4. Conclusions

The results demonstrated that in the period analyzed, there were a significant decrease in swamp areas. This fact may is associated with the lack of monitoring more rigorous of these natural environments along the temporal series analyzed. The use of LANDSAT-5/TM images for the quantification of the dynamics of decrease in areas of swamps proved to be a fundamental tool, which can help positively future processes of decision-making concerning the introduction of mitigating actions for preservation of these areas. With the work it is clear that it is necessary that actions for restoration and conservation are developed based on the recognition and diagnosis of possible problem, acquired from environmental studies.

5. Acknowledgements

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