GIS APPLIED IN THE ANALYSIS OF DISTRIBUTION OF VEGETATION IN SEMIARID REGION[1]

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A B S T R A C T

This work evaluated the distribution of vegetation in slope classes as subsidy analysis of degradation of the municipality of Soledade through the use of GIS and remote sensing techniques using algebraic language and modeling. We used Landsat TM-5 to generate the IVDN images and SRTM to generate the map of slope. As a result we obtained maps of vegetation and the distribution map of vegetation in slope. It can be concluded that there was a recovery of the local vegetation, as the class of sparse vegetation, dense transition and found an increase of 20.53% 33.46% and 6.06% respectively, the vegetation classes are distributed in their most classes of nil slope and mild totaling 530.16 km2 accounting for 94.53% of the total area, and slope classes moderate, strong, very strong and extremely strong totaling 3.7 km2 and Litholic Neosols occur in eutrophic soils.

Keywords: Geotechnology, GIS, Algebraic language, Environmental degradation.

Introduction

The Caatinga is an exclusively Brazilian biome that covers much of the area of semi-arid climate of northeastern Brazil (BRASIL, 2005). The Caatinga biome is characterized by having a wide variety of landscapes. The study of these landscapes has been improving, but still needs further detail (Carvalho and Freitas, 2005).

Inappropriate use of natural resources contributes to the degradation of the caatinga biome and relates to the absence of a culture of occupation of spaces, disregarding the richness and diversity of the ecosystem characteristics (Sousa et al., 2007; Mantovani et al., 1989; Guimarães, 2009).

Various techniques have been studied in order to determine quantitatively and

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qualitatively the state of vegetation from satellite images. These indexes generated from remote sensing data is an important strategy for monitoring natural changes, or man-made in the ecosystems. These indices have been used in the estimation of various parameters of vegetation (Holben et al., 1980; Baret and Guyot, 1991; Costa Filho et al., 2007) as, for example, the amount of green biomass (Tucker, 1979; Elvidge and Lyon, 1985).

Although there are many vegetation indices, the most used and known is currently termed the index of the normalized difference vegetation, or simply NDVI. The result of the NDVI is an image with a smaller number of information and noises, but with high enhancement of photosynthetically active vegetation, which allows monitoring the density and state of force, the vegetation on the land surface (Costa Filho et al., 2007; Martins et al., 2009) and as Madeira Netto (2001), their extensive use is largely due to the construction of global databases. According Ideão (2009) this index is used to identify the presence of vegetation on the surface, which allows to characterize their spatial distribution (Folhes, 2007).

The land slope is an important parameter to evaluate land and an easily

identified and given attribute (Francisco, 2010). For the representation of a real surface is essential to designing and creating a digital model that can be represented by a grid of points (Araújo et al., 2008).

Through the digital terrain model can generate slope maps used to represent the shape of the terrain (Francisco, 2010). A numerical model (DEM) is a mathematical representation of the spatial distribution of a particular trait linked to a real surface (Araújo et al., 2008).

A tool that enables you to perform spatial analysis using map algebra is the GIS is a Spatial Language for Algebraic (LEGAL) of SPRING, which is a query language and spatial manipulation which performs mathematical operations and allow you to perform crosses between two or more plans information (Câmara et al., 1996a).

This work aims to evaluate the distribution of vegetation in slope classes.

Materials and Methods

The municipality of Soledad located in Paraíba state has an area of 560.06 km² and is inserted in the Agreste Paraibano, bordering the municipalities of São Vicente do Seridó, Olivedos, Gurjão, Pocinhos, Boa Vista and Juazeirinho (Figure 1).

Figure 1. Localization of the study area.

Fonte: Adaptado de IBGE (2009); AESA (2011).

According to Köppen climate of the study area is considered the type Bsh - hot semiarid, with rainfall predominantly below 600 mm.yr^{-1}. In this region the rains in the region are influenced by the masses of Atlantic Southeast and North (Francisco, 2010). Throughout the area, the vegetation is a caatinga type hyperxerophilic. It is a traditionally pastoral region, which is predominantly goat rearing. Formerly with significant cotton production and currently cultivates palm and food crops (Francisco, 2010).

According PARAÍBA (2006) and the Reclassification of profiles conducted by Campos and Queiroz (2006) occur mainly four classes of soils in the study area, the Luvisols chromic orthic typical, the Planossol Natrich orthic typical, the Quartzarenich orthic typical, and Litholic Neosols eutrophic (Figure 2).

Figure 2. Soil map of the study area. Font: Adapted from PARAÍBA (2006).

The relief of the study area (Figure 3) presents distributed with null slope and slight, with some small areas with very strong strong slope.
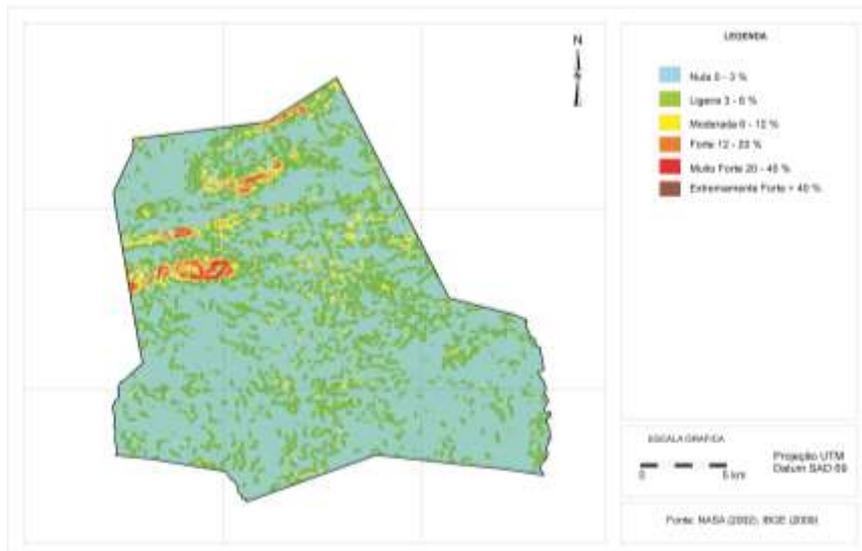
Figure 3. Map slope of the study area. Font: Adapted from NASA (2002); IBGE (2009).

The methodology of this work, in the field were identified and georeferenced areas of interest and carried out a description of the local vegetation.

Were acquired images of bands 5, 4 and 3 (R, G and B) of LANDSAT-5 TM through the National Institute for Space Research (INPE) the dates of the dates 25/11/1996, 29/10/2009 orbit 215, point 65. The images were selected based on characteristic periods of availability and lack of moisture by allowing the separation of the areas occupied by those coverage where coverage is not present and allow the contrast between different types of vegetation, soils, and allow differentiation of water bodies and identify possible changes in vegetation structure.

For the processing of the images was created in SPRING 5.1.5 a database with the projection / datum UTM / SAD-69. To assist the georeferencing was importing a digital archive of drainage obtained in AESA (2011), a file of the soil map (PARAÍBA, 2006) and an archive of municipalities to IBGE (2009).

The import was performed in bands 3, 4 and 5 of the study area for the Impima module and transformed to GRIB format and saved to file. After were imported to the database and performed their geometric correction using the polynomial method of first order, taking as a basis the digital coordinates of control points of the drainage network distributed throughout the area.

For better process cropping areas on

the basis of the limits of the municipality was conducted.

To calculate the reflectance and the transformation of ND values that are between 0 and 255, for NDVI values, which are between -1 and 1, we used the ERDAS Imagine 8.5 program and subprogram Model Maker, with the objective of facilitate the transformation of digital image numbers of the satellite values of physical meaning - reflectance. Requiring only enter certain information relating to the image sensor, image data, solar elevation angle as shown in Table 1 and applied to image atmospheric correction.

Table 1. Description of the bands of LANDSAT-5 with corresponding ranges of wavelengths, calibration coefficients and spectral irradiances at the top of the atmosphere

Bands	Wavelengths (μm)	Calibration coefficients $(Wm^{-2}sr^{-1}\mu m^{-1})$		Spectral Irradiance at the Top of Atmosphere $(Wm^{-2}\mu m^{-1})$
		a	**b**	
1 (blue)	0,45 – 0,52	-1,52	193,0	1957
2 (green)	0,52 – 0,60	-2,84	365,0	1826
3 (red)	0,63 – 0,69	-1,17	264,0	1554
4 (IV-near)	0,76 – 0,79	-1,51	221,0	1036
5 (IV-medium)	1,55 – 1,75	-0,37	30,2	215,0
6 (IV- thermal)	10,4 – 12,5	1,2378	15,303	-
7 (IV-medium)	2,08 – 2,35	-0,15	16,5	80,67

Font: Allen et al. (2002).

The radiometric calibration step in which the digital number (DN) of each pixel of the image is converted into that represent the spectral radiance reflected solar energy per pixel per unit area, time, solid angle and wavelength, as the LANDSAT satellite (705 mi) level to bands 1, 2, 3, 4, 5 and 7; 6 for the band, that is the radiance energy emitted by each pixel, and the calibration is effected according to equation 1 (Markham and Baker, 1987).

$$L_{\lambda i} = a_i + \left(\frac{b_i - a_i}{255}\right) ND \quad (1)$$

Where: a and b are the minimum and maximum spectral radiance (Table 1); ND is the intensity of pixel (digital number - integer number 0-255); i corresponds bands (1, 2, 3, 4, 5, 6 and 7) satellite LANDSAT 5 - TM.

Step from the computation of the monochromatic reflectance of each band, defined as the ratio between the flux of solar radiation reflected and the flux of solar radiation, which according to equation 2 is obtained.

$$\rho_{\lambda i} = \frac{\pi . L_{\lambda i}}{k_{\lambda i} . \cos Z . d_r} \quad (2)$$

Where: is the spectral radiance of each band, is the spectral irradiance of each band at the top of the atmosphere (Table 1), Z is the solar zenith angle obtained in their catalog image

and is the square of the ratio between the average earth distance Earth-Sun (ro) and the Earth-Sun distance (r) at a given day of the year (DSA), which is given by equation 3.

$$d_r = 1 + 0,033\cos(DSA.2\pi/365) \quad (3)$$

Where: DSA is the sequential day of the year and the argument of the function cos in radians.

The average annual value is equal to 1.00 and it varies between 0.97 and 1.03, approximately. When the study area has little slope the cosine of the angle of incidence of solar radiation is obtained simply from the angle of elevation of the sun - E that is in the image header, equation 4.

$$\cos z = \cos(\frac{\pi}{2} - E) = sen(E) \quad (4)$$

Where: the argument of cos is in radian.

NDVI was obtained by the ratio between the reflectivity of the near-IR (ρ_{IV}) and red (ρ_V), the sum thereof, equation 5.

$$NDVI = \frac{\rho_{IV} - \rho_V}{\rho_{IV} + \rho_V} \quad (5)$$

Where: ρ_{IV} and ρ_V respectively, correspond bands 4 and 3 LANDSAT 5 - TM.

The NDVI is a sensitive indicator of the quantity and condition of vegetation. Their values range from -1 to +1 and surfaces with some vegetation NDVI varies between 0 and 1, since the water and clouds NDVI is generally less than zero.

For the classification of images was imported to the database of SPRING and elaborate in LEGAL subprogram the image classification using the data of the Table 2 using the methodology adapted from Lawrence and Landim (2004).

The classified images allows a quantification of different classes of vegetation, soil and water to the municipality.

Table 2. Values of NDVI used in selecting vegetation cover classes

Class	NDVI
Dense vegetation	> 0.35
Transitional vegetation	0.30 a 0.35
Sparse vegetation	0.25 a 0.30
Wispy vegetation	0.10 a 0.25
Exposed soil	0.0 a 0.10
Water	< 0.0

Font: Adaptad Chagas et al. (2008).

To elaborate the slope map was used a digital archive of SRTM (Shuttle Radar Topography Mission) of NASA, on the scale of 1: 500,000 of quadrant SB-24 and SB-ZB-24-ZD of the study area were generated and the contour with equidistance of 10 meters. Using the methodology of Francisco (2010) to generate the triangular grid level curves were used as the sample without breaklines and contours of tolerance of 50 points isoline tolerance between 100 and tolerance breaklines 50 and the lower edge of triangulation of 50 meters.

Then was performed slicing the triangular grid with its dimension values was performed yielding an information plan of

thematic category representing a particular aspect of the numerical model of terrain, being associated with a predefined thematic class in the conceptual scheme of the active database to generate the map. For   generating the slope map were established slices (Table 4) based on the values of slope in adjusted percentage of Ramalho Filho and Beek (1995) and used by Francisco (2010).

Table 4. Classes of slope

Limits Class (%)	Classes of Slope
0-3	Plan
3-6	Smooth Wavy
6-12	Moderately Wavy
12-20	Wavy
20-40	Strong Wavy
> 40	Mountainous

Fonte: Ramalho Filho & Beek (1995).

After was created in LEGAL subprogram of SPRING an Algebraic Language to generate maps of vegetation distribution according to Table 5.

Table 5. Parameters composition LEGAL

Class	Null	Ligth	Moderate	Strong	Very Strong	Extremely Strong
Dense	D-N	D-L	D-M	D-F	D-MF	D-EF
Transitional	T-N	T-L	T-M	T-F	T-MF	T-EF
Sparse	E-N	E-L	E-M	E-F	E-MF	E-EF
Wispy	R-N	R-L	R-M	R-F	R-MF	R-EF
Exposed soil	S-N	S-L	S-M	S-F	S-MF	S-EF
Water	A-N	A-L	-	-	-	-

Results and discussion

On the vegetation map of 1996 (Figure 4) it is observed that the exposed soil class has an area of 13.93 km^2 representing 2.4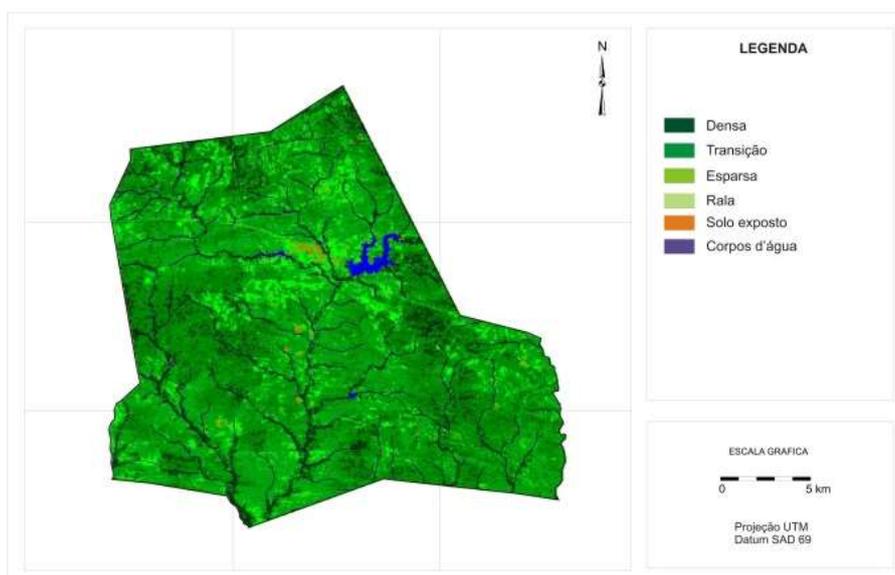8% of the total area, the class of wispy vegetation is 374.72 km^2 with 66 81%, the sparse class representing 18.36% 102.92 km^2, the class transition 41.15 km^2 equivalent to 7.34% and 27.99 km^2 dense class representing 4.99% of total area of 560.8 km^2.
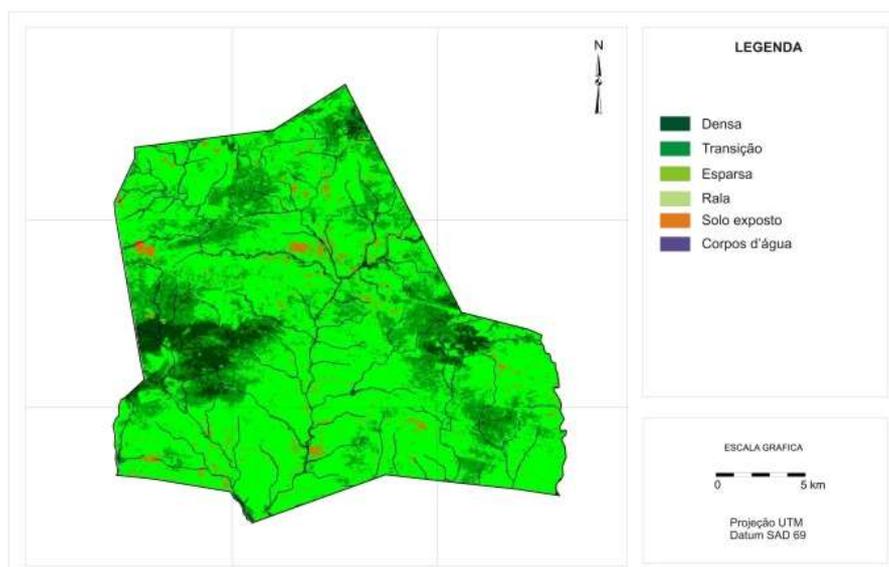
On the vegetation map of 2009 (Figure 5) it is observed that the bare soil class has an area of 4.34 km^2 representing 0.8% of total area, the class of wispy vegetation is 44.29 km^2 with 7, 91%, the sparse class 217.84 km^2 representing 38.89%, transition class 228.79 km^2 equivalent to 40.8% and 61.88 km^2 dense class representing 11.05% of total area.

Figure 5. Vegetation map of 2009.

In Table 6 we can observe the distribution of vegetation classes. Comparing the areas of 1996 from 2009, an increase in the sparse class of 20.53% of the total area, the transition class an increase of 33.46% and the class of dense vegetation observed an increase of 6.06%. Classes of wispy vegetation and exposed soil areas there was a decrease of 58.9% and 1.68% respectively.

This increase in classes of vegetation areas, which is observed in this work, is the result of the abandonment of agriculture in the region caused by lack of incentives and public funding, abandonment of agricultural practices in rural areas and migration to urban centers.
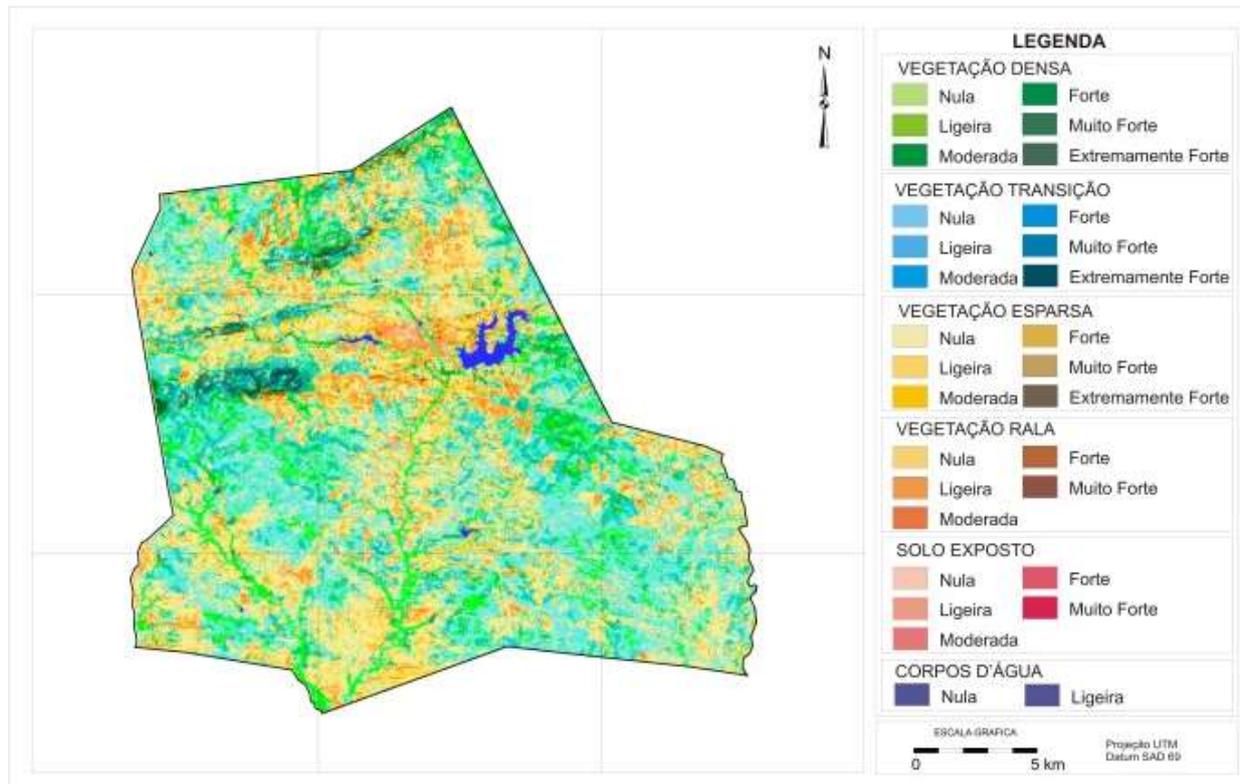
In the distribution of vegetation for slope map (Figure 6), it is observed that the vegetation classes are distributed mostly in the null classes with 382.01 km^2 and 148.15 km^2 with slight, totaling 530.16 km^2, 94.53% of the total area (Table 7). This distribution agrees with the topography of the study area that is mostly plane (Figure 3). In classes of moderate slope, strong, very strong and

Table 6. Classes and areas of vegetation

Classes of vegetation	NDVI			
	1996 (km^2)	%	2009 (km^2)	%
Dense	27.99	4.99	61.88	11.05
Transitional	41.15	7.34	228.79	40.80
Esparse	102.92	18.36	217.84	38.89
Wispy	374.72	66.81	44.29	7.91
Exposed soil	13.93	2.48	4.34	0.80
Water	0.09	0.02	3.66	0.55
Total Area	560.80	100	560.8	100

extremely strong totals an area of 30.64 km^2 representing 5.47% of the total area.

Figure 6. Distribution map of vegetation in the study area.

Table 7. Distribution of vegetation for slope

Classes	Null (km^2)	Ligth (km^2)	Moderate (km^2)	Strong (km^2)	Very Strong (km^2)	Extremely Strong (km^2)	Total (km^2)
Dense	43.06	15.04	2.62	0.63	0.44	0.01	61.8
Transitional	154.82	58.96	9.74	2.96	2.04	0.11	228.63
Esparse	147.92	59.7	8.36	1.06	0.61	0.03	217.68
Wispy	29.98	12.4	1.68	0.11	0.09	0	44.26
Exposed soil	2.75	1.19	0.14	0.01	0	0	4.09
Water	3.48	0.86					4.34
Total	382.01	148.15	22.54	4.77	3.18	0.15	560.8

In class (D-N) Dense vegetation is mostly distributed in the null class with 43,06 km^2, which as noted in fieldwork, occur the Algoraba (*Prosopis juliflora* (sw) DC) and other native species such as Jurema (*Mimosa tenuiflora* (willd.) Poir) and Aroeira (*M. Urundeuva Allemão*), located in the drainage and the banks of streams in moist soils throughout much of the year, providing better conditions for the permanence of species in the area. In the class (D-L) of slight slope dense vegetation is an area of 15.04 km^2 and classes (DM) moderate, (DF) strong, (D-MF) and very strong (D-EF) is extremely strong If distributed with a total of 3.7 km^2.

These distributions of vegetation in these classes are given mainly in shallower soils

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with steeper slope, the Entisols eutrophic (Figure 2) without agricultural use.

It can be observed in Figure 7, the dense native vegetation occurring in a strong and extremely strong slope, contrasting what, in most cases, be expected in a field study. The common is that, in most cases, the areas with steeper relief have a higher degradation due to a lack or low occurrence of vegetation cover.

Figure 7. Dense vegetation in relief with strong and extremely strong slope.

It can be observed in Figure 8 in place of the soft wavy relief plan a sparse vegetation/wispy with finding the occurrence of erosion.

Figure 8. Sparse/wispy vegetation in relief with a slight slope to zero.

In Figure 9, we observe the occurrence of dense vegetation, with the main event to Algaroba, exotic species of the study area, in this area of alluvium, with an emphasis on slope null and low degradation.

Figure 9. Dense vegetation in relief with slope null.

In Figure 10, there is dense vegetation in the background, with the main event to Algaroba, in this area of alluvium, with relief of the slight slope null.

Figure 10. Dense vegetation on the slight slope null.

In Figure 11, we can observe the occurrence of dense vegetation, native, with the presence of Jurema, Aroeira Umburana (*Amburana cearensi*.), Umbuzeiro (*Spondias tuberosa*), Catingueira (*Caesalpinia pyramidalis*), Pereiro (*Aspidosperma pyrifolium*), Cumaru (*Dipteryx odorata*) and cactaceas in null slope.

Figure 11. Dense vegetation in relief with null slope.

The vegetation class Transition is distributed in class (T-N) null slope with 154.82 km^2 in class (T-L) of a slight slope vegetation is an area of 58.96 km^2 and classes (TM) moderate, (T-F) heavy (T-MF) and very strong (T-FE) extremely strong it is distributed for a total of 14.85 km^2.

In this class of vegetation, highlights are the native species, among them the Pinhão Bravo (*Jatropha curcas*), Aroeira, Juazeiro (*Ziziphus joazeiro Mart.; Rhamnaceae*), Jurema and cactaceas (Figure 12), in the area of relief slight slope .

Figure 12. Vegetation transition in relief with slight slope.

For the class of Sparse vegetation is mostly distributed in class (E-N) null slope with 147.92 km^2 in class (E-L) mild slope vegetation is in an area of 59.7 km^2 and classes (E-M) moderate (E-F) strong, (E-MF) and very strong (E-EF) extremely strong it is distributed with a total of 70.45 km^2, which as noted in the fieldwork are the species of Marmeleiro (*Croton sonderianus Muell. Arg.*), Pereiro and Pinhão (*Podocarpus lambertii Klotz*) (Figure 13).

Figura 13. Vegetação esparsa em relevo com declividade ligeira.

According to Figure 14, the sparse vegetation occurs in relief with a null slope. In this form of relief-presents the greatest quantitative area of this vegetation class. On the ground observed the presence of stones in surface horizon and decaying organic matter. Are areas in regeneration. Species such as Marmeleiro (*Croton sonderianus Muell. Arg.*), Pereiro (*Aspidosperma pyrifolium Mart.*), Catingueira (*Caesalpinia pyramidalis*), Pinhão-Bravo (*Jatropha curcas*) and cactaceas are the main representatives of this vegetation class, as occurs in areas with slope slight.

Figure 14. Sparse vegetation in relief with null slope.

In vegetation class wispy is distributed in class (R-N) with null slope 29.98 km^2 in class (R-L) mild slope vegetation is an area of 12.4 km^2 and classes (R-M) moderate, (R-F) Strong (R-MF) and very strong (R-PE) extremely strong it is distributed with a total of 1.88 km^2.

The predominant species in this vegetation type are Marmeleiro and Pinhão-Bravo, besides the cactaceas. Observed in this class of vegetation and with a slight slope occurrence of many stones in the surface soil horizons (Figure 15).

Figure 15. Wispy vegetation on slight slope.

The class of exposed soil (S-N, S-L, S-M, S-F) has an area of 4.09 km^2 and water bodies (A-N, A-L) with 4.34 km^2.

It can be observed relief with slight to moderate slope, stoniness high in the surface horizon and the occurrence of exposed soil in area of extensive livestock (Figure 16).

Figure 16. Soil exposed in mild to moderate slope.

In Figure 17, we observe the occurrence of exposed soil at null slope with the occurrence of Barriguda or Paineira-Branca (*Ceiba glaziovii*) and Pinhão-Bravo. This is area of extensive livestock.

Figure 17. Exposed soil in null relief.

Conclusions

For this work we can conclude that:

1. With the use of GIS techniques, remote sensing and development of algebraic language can reach satisfactory results quickly and accurately.

2. Through the NDVI can be concluded that there was a recovery of the local vegetation, as the results show in the class of sparse and

dense vegetation transition there was an increase of 20.53%, 33.46% and 6.06% respectively.

3. The vegetation classes are distributed mostly in the classes of null slope and slight totaling 530.16 km^2 corresponding to 94.53% of the total area.

4. The slope classes moderate, strong, very strong and extremely strong totaling 3.7 km^2 and occur in Entisols soils eutrophic.

References

AESA. (2006). Agência Executiva de Gestão das Águas do Estado da Paraíba. Dados sobre perímetro e geoprocessamento. Disponível em: http://geo.aesa.pb.gov.br/. Acesso em: 10-05-2011.

Allen, R. G., Trezza, R., Tasumi M. (2002). Surface energy balance algorithms for land. *Advance training and user's manual*, 1.0, p.98.

Araújo, W. T.; Santos, R. L.; Lage, C. S. (2008). A modelagem digital de elevação como instrumento de análise da ocupação do sítio urbano. *Revista de Sistemas de Informação*, 1.

Baret, F.; Guyot, G. (1991). Potentials and limits of vegetation indices for LAI and APAR assessment. *Remote Sensing of Environment*, 35, p.161-173.

BRASIL. (2005). Ministério do Meio Ambiente, Secretaria de Recursos Hídricos. Programa de Ação Nacional de Combate à Desertificação e Mitigação dos Efeitos da Seca – PAN-Brasil. Brasília-DF, 213p.

Câmara, G.; Medeiros, C. B.; Casano-Va, M. A.; Hemerly, A.; Magalhães, G. Anatomia de Sistemas de Informação Geográfica. Escola de Computação. SBC, 1996.

Campos, M. C. C.; Queiroz, S. B. (2006). Reclassificação dos perfis descritos no Levantamento Exploratório - Reconhecimento de solos do estado da Paraíba. *Revista de Biologia e Ciências da Terra*, 6 (1).

Carvalho, V. C. de; Freitas, M. W. D. de. (2005). Mapeamento das paisagens em nível de geossistema de três áreas representativas do bioma Caatinga. 12.º Simpósio Brasileiro de Sensoriamento Remoto, Goiânia, 2005, INPE, p.2087-2099.

Chagas, M. das; G. Santos das; Galvíncio, J. D.; Pimentel, R. M. de M. (2008). Avaliação da dinâmica espectral da vegetação de caatinga em Arcoverde, Pernambuco. *Revista de Geografia*, 25 (2).

Costa Filho, J. F. da; Francisco, P. R. M.; Andrade, M. V. de; Silva L. da; Dantas, R. L. (2007). Estimativa do índice de vegetação da diferença normalizada (NDVI) na microrregião de Sousa-PB utilizando imagens do CBERS-2. 15.º Congresso Brasileiro de Agrometeorologia, Aracajú - SE, 2007.

Elvidge, C. D.; Lyon, R. J. P. (1985). Influence of rock-soil spectral variation on the assessment of green biomass. *Remote Sensing of Environment,* 17, p.265-279.

Francisco, P. R. M. (2010). Classificação e mapeamento das terras para mecanização do Estado da Paraíba utilizando sistemas de informações geográficas. 122f. Dissertação (Mestrado em Manejo de Solo e Água) Centro de Ciências Agrárias. Universidade Federal da Paraíba, Areia, 2010.

Folhes, M. T. (2007). Modelagem da evapotranspiração para a gestão hídrica de perímetros irrigados com base em sensores remotos. Tese (Doutorado em Sensoriamento Remoto). Instituto Nacional de Pesquisas Espaciais – INPE, São José dos Campos. 175p.

Guimarães, A. P. (2009). Dinâmica da resposta espectral da vegetação de caatinga na bacia hidrográfica do açude Soledade, utilizando técnicas de sensoriamento remoto. Dissertação (Mestrado) UFPB, Areia-PB.

Holben, B. N.; Tucker, C. J.; Fan, C. J. (1980). Spectral assessment of soybean leaf area and leaf biomass. *Photogrammetric Engineering and Remote Sensing*, 46, p.651-656.

IBGE. (2009). Instituto Brasileiro de Geografia e Estatística. CDROM.

Ideão, S. M. A. (2009). Imagens multiespectrais e aplicações em recursos hídricos: temperatura da superfície e balanços de radiação e energia. 156f. Dissertação (Mestrado). Universidade Federal de Campina Grande-UFCG.

Lourenço, R. W.; Landim, P. M. B. (2004). Estudo da variabilidade do índice de vegetação por diferença normalizada/NDVI utilizando krigagem indicativa. *Holos Environment*, 4, p.38-55.

Madeira Netto, J. S. (2001). Comportamento espectral dos solos. In: Meneses, J. R.; Madeira Netto, J. S., org. Sensoriamento remoto: reflectância dos alvos naturais. Brasília, DF. UnB/Planaltina: Embrapa Cerrados, p.127-154. 262p.

Mantovani, W., Rossi, L. Romaniuc Neto, S. (1989). Estudo fitossociológico de áreas de mata ciliar em Mogi-Guaçu, SP, Brasil. Simpósio Sobre Mata Ciliar. Campinas: Fundação Cargil, São Paulo, 1989. p.235-267.

Martins, R. A.; Santos, E. V. Dos; Ferreira, I. M. (2009). Atualização do mapa de remanescente florestal do município de Morrinhos–GO: utilizando imagem Landsat-TM. 11.º EREGEO - Simpósio Regional de Geografia, UFG, Jataí-GO, 2009.

Markham, B. L.; Barker, J. L. (1987). Thematic mapper band pass solar exoatmospherical irradiances, Int. *Journal of Remote Sensing*, 8 (3) p. 517-523.

PARAÍBA. (2006). Secretaria de Estado da Ciência e Tecnologia e do Meio Ambiente. Agência Executiva de Gestão de Águas do Estado da Paraíba, AESA. PERH-PB: Plano Estadual de Recursos Hídricos: Resumo Executivo & Atlas. Brasília, DF. 112p.

Ramalho Filho, A.; Beek, K. J. (1995). Sistema de avaliação da aptidão agrícola das terras. 3.ed. Rio de Janeiro: EMBRAPA-CNPS, 65p.

Sousa, R. F. de; Barbosa, M. P.; Sousa Júnior, S. P. de.; Terceiro Neto, C. P. C.; Morais Neto, J. M. (2007). Estudo da degradação de terras do município de Boa Vista-Paraíba. *Revista Engenharia Ambiental*, 4 (2), p.5-13.

Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8, p.127-150.