REMOTE SENSING & GIS BASED LAND COVER, SOIL & LAND CAPABILITY INFORMATION FOR RESOURCES MANAGEMENT IN SEMI-ARID REGION OF PARAIBA, BRAZIL

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ABSTRACT

The present study was conducted from remotely sensed data and GIS technology for resources management of Sume area in Semi-Arid region of Paraiba State. A variety of supervised classification methods has been applied for resources management and land development in the study area. Under this study the SPOT data of the year of 2003 were processed with ERDAS 7.5 & ERDAS imagine Software in the Laboratory of Remote Sensing and GIS, operating on a high performance micro-computer. The digital interpretation was applied to one million pixels in order to extract land use/land cover, major soil associations and land capability classification information. In the digital image classification, based on the field observations, using the interactive capabilities of ERDAS, total 50 observations in the area, were selected for land use/ land cover classes at the Level II. The digital interpretation was modified and corrected in accordance with the conditions of the area. By re-coding the land use/land cover classes, three maps, such as, land use/land cover, major soil associations and land capability classification maps were prepared. These maps were weighted for their relative importance of the land development and management. The results of our were found very beneficial for land development, natural resources management, land evaluation, soil conservation and land reforms programs of the Federal Government of Brazil and for the development of semi-arid region of northeastern Brazil.

INTRODUCTION

The agriculture development of a region totally depends upon the natural resources management with specific limitations. The soil and land management in semi-arid regions is totally different from the humid regions. Nowadays, there is a tremendous pressure on the availability of soil , land and land resources due to increasing population and growing consumption of land for constructing houses and buildings in major cities. In such a situation, we must make an optimum planning and management of our land in order to increase the production on land. An effective development requires a detailed understanding of our natural resources. The remote sensing and GIS are the major tools for solving complex natural resources planning problems.

The main purpose of our research is to apply image processing and pattern recognition techniques to SPOT multi-spectral image data to derive various earth resources information for the land development and management. The data for our project were gathered from various Federal and State Agencies and Institutions of Northeastern States of Brazil. The principal remote sensing image processing system, ERDAS, was used for Image Processing. The classification scheme being modeled after the United States Geological Survey System for use with remote sensing data (**Anderson et al., 1976**), modified to account for local conditions within the study areas. The soil classification (**USDA, 1975**) and Land Capability Classification (**USDA, 1966** & **Brazil, 1983**) were used under this study. The comparison of digital interpretation with reference information indicated that the digital interpretation, closely resembled field observations. The combination of supervised classification of SPOT data and map accuracy assessment demonstrated satisfactory results for the development of the area.

BACKGROUND DISCUSSIONS

Remote sensing and GIS are the fundamental tools for the inventory and analysis of natural resources for regional, rural and local planning, management and development at both the small as well as the large scales in undeveloped and developing parts of the world. Various types of remote sensing data, such as, **SAR**, **MSS**,

TM, **ETM**, **MOMS**, **AVHRR** and **SPOT** etc. lave been used for earth resources management and development of semi-arid regions by various governmental agencies, institutions, and universities of the world. For example: A digital classification was performed of the **Ardeche** region of Southern France using Landsat - TM as part of a region-wide resources inventory being conducted by the French government (**Hill** & **Megier, 1986**). In the KUL, Belgium, the research was conducted on Soil and Land use distribution over a part of northern plains (Indo-Gangetic Plains) of India, based on the optical interpretation of Landsat-2 multispectral satellite imagery (**Teotia et al, 1980)**.

The integrated use of GIS and Image Processing Technologies provided specific examples involving water, soil and vegetation resources management applications (**Ripple, 1987)**. A group of the Scientists from the UCONN have worked on a GIS system for land use planning and management of semi-arid regions of northeastern Brazil, using digital image processing on Landsat-TM and SPOT data **(Kennard et al, 1988**). A digital image analysis of Landsat -TM data in eastern Connecticut was conducted for regional land use and land cover classification (**LaBash et al, 1989)**. The knowledge-based image analysis for classifying Landsat Thematic Mapper region-based spectral data coupled with ancillary digital information, is not only feasible but also preferable to the per-pixel, spectral data only, statistical methods more traditionally employed in deriving land use and land cover information for natural resources management.This approach produces results both more accurate and more visually comprehensive than the traditional method of maximum likelihood classification (**Civco, 1987)**.

The scope and content of remote sensing education and training in the United States and in Brazil, has limited documentation. There have been a few studies to determine the status and content of courses being offered at academic institutions (**Civco et al, 1992; Teotia, H.S., 1992).** The Landsat - TM for remote sensing and GIS application for rural land use analysis, have served as a valuable approach to the rural resources manager (**Neillis et al, (1990**). The supervised classification was made for the soil and land use studies for a part of semi-arid regions of Brazil. They used this methodology for some parts of the states of Paraiba, Ceara, and Piaui (**Ulbricht et al, 1992)**. An integrated study of remote sensing and GIS technologies was carried out for Land Development and Irrigation Potential in the State of Ceara in NE Brazil. It found that the Suitability Map is very beneficial for agricultural development and irrigation potential projects in the region (**Teotia et al, 1992)**. A very comprehensive study at the UFPB, Brazil was done for land use planning in semi-arid regions of NE Brazil, using SPOT HRV data (**Teotia et al, 1996)** .

The research was conducted in the Laboratory of Remote Sensing and GIS at the CCA/UFPB, Paraiba, Brazil in order to know the multi - temporal effects in regional planning over a part of semi-arid regions of Paraíba state and found that the digital interpretation of SPOT data of 20m resolution imagery is more reliable for determining detailed assessment of land use/land cover classes and surface hydrology (**Teotia, H.S. , 1998).** ERDAS Imagine Software é one of the most valuable tool (**Junior Silva, 2000**) for manipulation and interpretation of geo - referenced satellite data for the development and management program of NE Brazil. Studies have been made in the state of Paraiba for the preparation of a Model for Land Information System for agriculture as well as land resources development for the region (**Teotia et al, 2001**) . Landsat-TM data are very important and economic for Soil, Land Use, and Forest Classification in semi-arid regions of northeastern Brazil (**Ferreira et al, 2001).**

The technologies of remote sensing and GIS are economic and adequate for the classification of soils, land survey and for land use classification of semi-arid regions of Paraiba state of Brazil **(Veloso Junior, 2003).** GIS is a very important technology with Image Processing for the study of semi-arid and arid regions of the world (**Gonçalves, 2004)**. The coarse textured soils demonstrate high reflectance properties because of mineralogical constitution and low grade of organic matters, iron oxides and low percentage of water (**Delmolin et al, 2005).** Some recently studies have been made with remotely sensed data at the UFPB, Brazil and found that the ERDAS Imagine Software and SPOT data is a good combination for land use and land cover mapping and for the development of Agreste region of Paraiba of northeastern Brazil (**Ribeiro G. do N. 2006**) .

OBJECTIVES

The Land Use/Land Cover is one of the affecting factors for the region´s economy and the development and management. The interference of men through deforestation for the development of agricultural activities make a serious problem, and therefore is very difficult to conserve the soil and managing the water. Also, are the prime causes for land limitations, such as, draught, topography, desertification, degradation and erosion etc. Remote Sensing plays an important role to study the control and check these agricultural limitations. The main objective of our present research using remote sensing and GIS technologies is to apply image processing and pattern recognition techniques to SPOT multi-spectral image data to derive various types of earth resources information for the planning, management and development of semi-arid region (Sume area) of northeastern Brazil. Further all the information were combined together and three types of maps such as, Land Use/Land Cover , Major Soil Associations, and Land Capability Classification were prepared separately for the study area. Other information about the natural resources, ecological, cultural resources and the environmental resources may be studied under this investigation.

STUDY AREA (Figures 1, 2 & 3 ; Photos 1 and 2)

The semi-arid region of Paraiba is characterized by periodical, and often lengthy, drought causing economic and social disasters. The region is practically undeveloped in comparison to other parts of the states and the country as well. It is the area of low rainfall and high temperatures coupled with topographic, soil and water problems which makes it difficult for agriculture, industrial and economic development.

Our research area has various physiological, geological, geomorphological and cultural features, such as, slightly undulating to undulating and strongly undulating topography, cultivated and uncultivated fields, rocky and stony areas, shallow to moderately deep and deep soils, poor and moderately drained lands, parallel and dandritic drainage pattern. The principal limitations for the study area are lack of water, surface rockiness and stoniness, and susceptibility of the erosion. The study area belongs to the micro region of the Cariris Velhos, which covers approximately an area of 800 square kilometers.

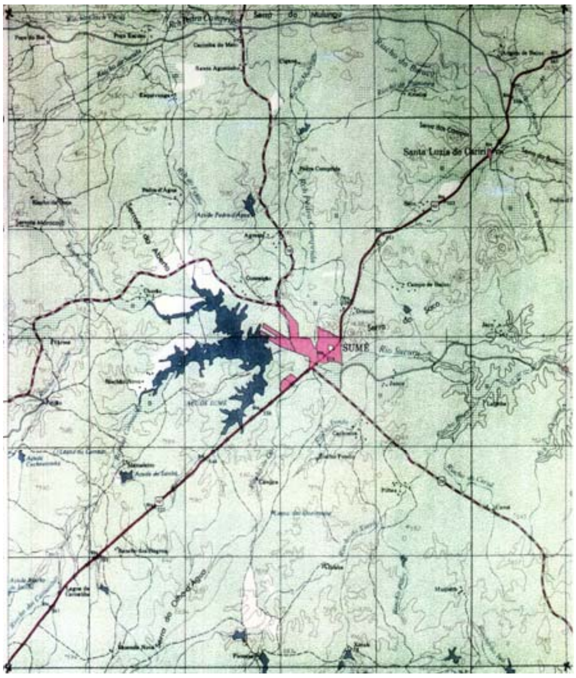


Figure 1. Topographic Map of Study Area.

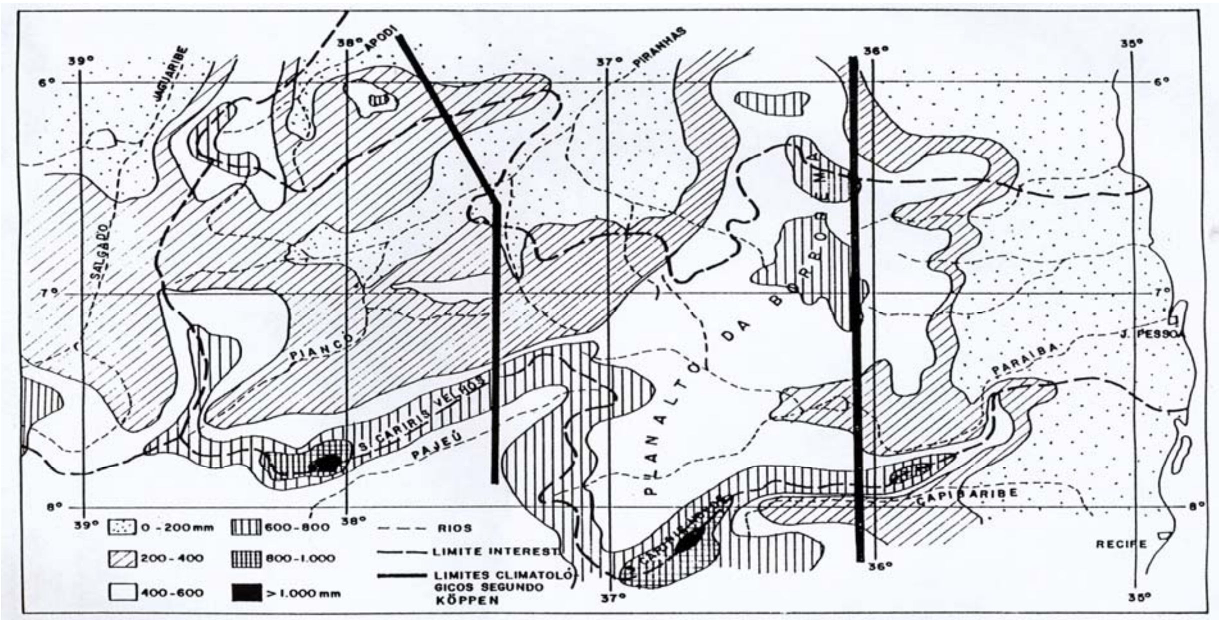
Figure 2. Study area in NE, Brazil.

Geologically, the area is a part of a physiographic zone of the Paraiba **"Borborema Central"** where two types of geologic units are encountered: 1) Pre-Cambrian (CD): Gnessis and Migmatites, 2) Granites. The **Planalto da Borborema Central**, situated in the southern part of the state of Paraiba, where an average altitude is superior to 600m. Various types of physiological forms, such as alluvial plains, cultivated fields, hills, inselbergs, rock ridges and plain areas are encountered in the area of our research. The soils of the region originate from different types of rocks and the main soil groups are: Non Calcic Brown soils, Yellowish Red Podzolic Soils, Alluvial soils, Regosols, Inceptisols Saline-Alkali Soils, and Rock Outcrops.

According to Koeppen the area falls in the BSw 'h' ; BSs 'h'; 3aTh; 4aTh and 2b of the climate. The area is very dry where precipitation is between 510-600 mm per annum. The average minimum and maximum temperature is 22º C and 37º C respectively. Crop production in the area is almost dependent with water of ponds and lakes which is collected during the raining season.

Vegetationally, the area is covered by various types of forestes and shrubs. Mostly Caatinga is the dominant forest of the area which is divided into Hipoxerofila and Hiperxerofila. The principal activities of the area are: agriculture and animal husbandry. The main crops grown in the area areTomato, Cotton, Sisal, Beans, Maize, Sweet Potatos, and Mandioca. Major animals are Sheeps, Goats and Cows.

Photo 1: Sume Region of the Paraiba **Photo 2:** Sume Region of the Paraiba



Fonte – SUDENE **Figure 3.** Physiographic and Climatic Regions of the Study area.

GEOGRAPHIC AND EARTH RESOURCES INFORMATION

Data about various components required for this research have been gathered from Federal, State and Municipalities Agencies and International Organizations as follows:

Table 1. Major Components and its Sources

Names of Components	Sources
1. Land use Maps 2. States and Federal Universities and Governments	
3. Soil Maps and Reports	States and Federal Universities and Governments
4. Slope and Elevation	SUDENE, State and Federal Government
5. Drought and Flood Data	IBGE Agency of Federal Government
6. Climatic Data	EMBRAPA, Federal University (UFPB, UFCG)
7. Geology/ Geomorphology Data	SUDENE & University Departments
8. Hydrological Data	University Centers & Water Resources Depts.
9. Soil Conservation Data	Universities and Soil State Departments
10. Irrigation and Drainage	Water Resources Depts of the UFPB & UFCG
11. Vegetation and Forest Data	IBAMA & INCRA Agencies of Federal Govt.
12. Topographic Maps	SUDENE and University Dept. of the UFPB
13. Socio-Economic Data	IBGE and Bank of Brazil
14. State & Municipality Boundaries	SUDENE & Municipalities
15. Landsat Data	INPE, Brazil and DLR, Germany
16. SPOT Data	INPE, Brazil and DLR, Germany
17. Aerial Photographs	TERRAFOTO Agency and State Departments
18. Technical Reports	Federal Universities of the UFPB & UFCG
19. Articles	Google, Congresses and Conferences
20. Hardwares	DSER/CCA/UFPB, Areia-PB
21. WERDAS Softwre	ERDAS LTD. Corporation, Atlanta, USA
22. SPRING Software	INPE, Brazil
23. Field & Cartographic Material	DSER/CCA/UFPB

PROGRAMS OF ERDAS SOFTWARE USED UNDER THIS INVESTIGATION

For development and management of the semi-arid parts of the Paraiba state, we derived the digital land use and land cover information using image processing and GIS procedures and the latest Image Analysis Systems (ERDAS and ERDAS Imagine). Different types of programs of ERDAS for digital analysis and for the accuracy assessment were used. For our interest the following programs have been used for unsupervised, supervised and Accuracy Assessment.

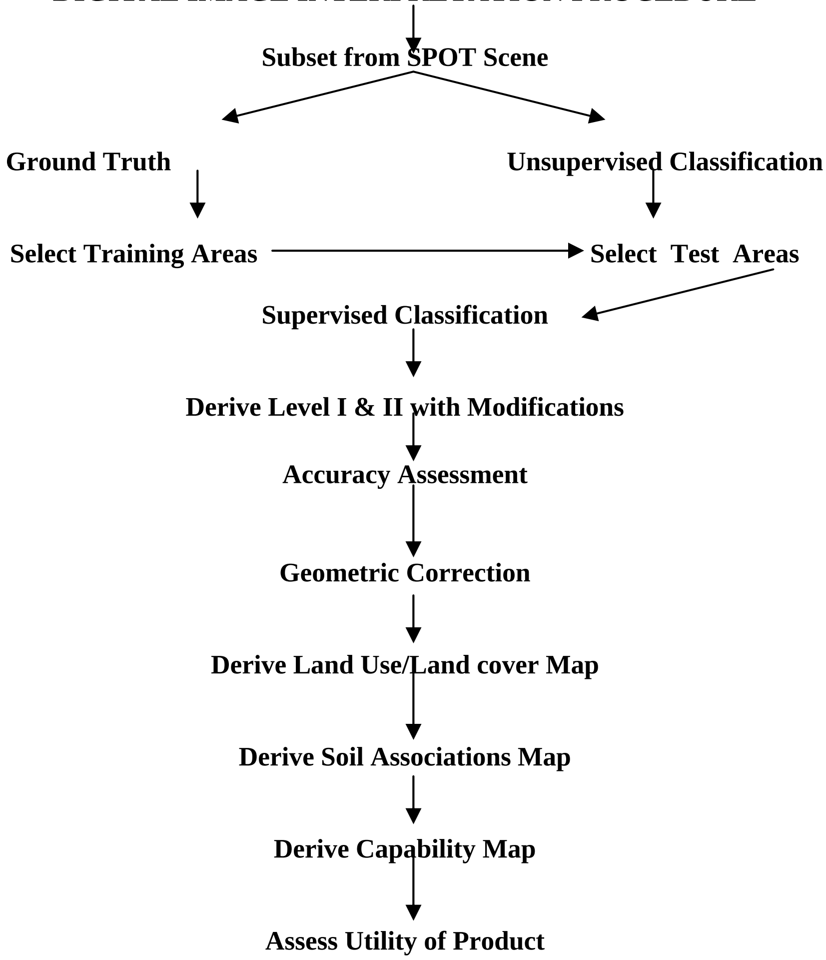
Series of programs used for Unsupervised Classification:
READ-CLUSTR-DISPLAY-COLORMOD-CLASNAM-RECODE-COLORMOD-CLASNAM-ANNOTAT-CLASOVR- BSTATS-LISTIT.

Seies of programs used for Supervised Classification
READ-EEDS-SIGDIST-SIGMAN-ELLIPSE-CLASNAM-MAXCLAS-DISPLAY-COLORMOD-CLASNAM-ANNOTAT-CLASOVR-RECODE-INDEX-RECODE-INDEX-COLORMOD-CLASNAM-ANNOTAT-SCAN-BSTATS-LISTIT.

Series of programs used for Accuracy Assessment
READ-DISPOL-DIGSCRN-GRDPOL—CLASOVR-CLASNAM- SUMMARY.

The methodology of this research work is based on the work conducted in the Laboratory of Remote Sensing and GIS at the UCONN, CT, USA (Civco, 1989). Under this investigation, the 1000 by 1000 pixel sub-scene of SPOT multi-spectral data (band 1,2,3) was used for analysis. More than 50 sites were visited in the study area and reference data, such as soil, vegetation, geology, topography, climate and others were used to the supervised classification. Various field trips served as a basis for accuracy assessment of computer assisted, satellite-derived earth resources maps which were produced during the execution of this study. Based on the field observations, 30 training areas were selected, using the interactive capabilities of an image analysis system for the land use/land cover classes of interest. The training areas were correlated with ground truth observations, gathered in the field. Generally, field observations were gathered at the interval of 500 meters to one kilometer. The digital interpretation was checked three times by three field trips. The relevant statistics (mean, mode, medium, standard deviation, variance and co-variance matrices) were generated for the study area and a maximum likelihood classification (**MAXCLAS)** was applied to one-million pixel and finally resulted into 13 categories at the Level II of land use/land cover classification were selected **(Anderson et al, 1976)**. **T**he accuracy assessments of the transformed and non-transformed SPOT image were conducted to compare the test areas of known reference data with the same areas on Level II land use and land cover classification on a pixel-by pixel base produced by supervised classification. All the pre-selected polygons were displayed over the test areas. Then the test-site areas were selected to allow the data file co-ordinates for polygons to be digitized directly from the image. The total 13 Land use and land cover were further recoded on the bases of their values and soil association and land capability classification maps were depicted for the areas with the total number of classes 10 for soil associations and 7 for land capability classification. The over all accuracy was found 85.60%.

DIGITAL IMAGE INTERPRETATION PROCEDURE



CRITERIA FOR LAND USE AND LAND COVER MAPPING

For our study of semi-arid regions of NE Brazil, the land use and land cover classification (Anderson et al., 1976) is modified in accordance with the local climate, local needs and existing conditions. For our project, we used the following important criteria suggested by the USGS.

1. The Interpretation accuracies in the identification of land use and land cover categories from remote sensor data should be 85% or greater.
2. The classification system should be applicable over extensive areas.
3. The categorization should permit vegetation and other types of land cover to be used as indicators of activity.
4. The Multiple uses of land should be recognized where possible.

5.The classification system should be suitable for use with remote sensor data obtained at different times of the year and in different years.

In addition, the following criteria suggested by the Laboratory of Remote Sensing and GIS has also been considered.

1.Individual land use and cover classifications should be customized to facilitate interpretations of digital images with different resolutions.

2.To reduce processing costs and increase accuracy, digital images should be classified and then corrected geometrically.

RESULTS AND DISCUSSIONS (Tables 2, 3 and 4)

A more vigorous quantitative measure of accuracy performed using the test areas indicated that some categories were classified and mapped more reliably than others. The tables 1, 2, and 3 present a summary for the maximum likelihood classification results of the Sume region of the Paraiba state of northeastern Brazil. The overall classification accuracy of 85. 6% is good with respect to the classification categories used for this study. The water, wet land, alluvial land, forest classes shown better results than others. Some classes of barren land, urban land with pasture, rock outcrops, cultivated land with forest and pasture shown lower classification accuracy. The cultivated land with forest and pasture showed the lowest classification agreement. From these results it is concluded that the inability to discriminate among certain classes is due to the spectral similarity between those categories. Other spatially-oriented data are required to augment and enhance the classification process. The classification shows that the percentage accuracy decreases as the level of detailed is increased. The more spectrally heterogenous areas also reduce the accuracy percentage of the classifications. The results of computer classification (Supervised Classification) of SPOT-2 Satelite data received through various programs of ERDAS software into 13 mapping units as follows:.

Table 2. Land Use and Land Cover Classification: (Sume Region of Paraiba State)

Mapping Units	Description	Pixels	%
0		2	0,00%
W1	Deep Clear Water	6057	0,61%
W2	Moderately Deep Water with Sedimentation	3086	0,31%
W3	Shallow Water with Sedimentation	6229	0,62%
U1	Urban Area with Rock Outcrops	25028	2,50%
C1	Coarse Textured Culti. Alluvial Land	74320	7,43%
C2	Mode. Cultivated Alluvial with Eroded Rocky Land	79506	7,95%
C3	Intensive Culti.Alluvial with Regosols & Alfisols	104165	10,42%
F1	Few to Moderate. Caatinga with little cultivation	266338	26,63%
F2	Moderately Caatinga with Cultivation	54227	5,42%
F3	Intensive Caatinga with Rocky Land	38759	3,88%
FR1	Rock Land with Sparse Caatinga Forest	145972	14,60%
FR2	Rocky Land with Moderate Caatinga Forest	151002	15,10%
FR3	Rocky Land with Intensive Caatinga Forest	45309	4,53%
Total:		999998	100,00%

Table 3. Major Soil Associations (Sume reigion of Paraiba State)

Mapping Units	Description	Pixels	%
0		2	0,00%
Água (Water)		16669	1,67%
Ae-SS-Re	Alluvial-Saline/Alkali-Rocky Soils	121035	12,10%
Ae-SS	Alluvial-Saline/Alkali	65811	6,58%
Ae-REe-NC	Alluvial-Regosols-Alfisols (Vertic)	101741	10,17%
NC-Re-PE	Alfisols(Vertic)-Rocky Soils-Alfisols	292178	29,22%
NC-Re-Ae	Alfisols (Vertic)-Rocky soils-Alluvial	48869	4,89%
NC-Re-V-Ae	Alfisols(Vertic)-Rocky soils-Vertisols-Alluvial	33827	3,38%

Re-AR-NC	Rocky Soils-Rock-Outcrops-Alfisols (Vertic)	152300	15,23%
Re-NC-AR	Rocky Soils-Alfisols(Vertic)-Rock-Outcrops	130554	13,06%
Re-NC-PE-AR	Rocky soils-Alfisols(Vertic)-Alfisols-Rock-Outcrops	37014	3,70%
Total:		000008	100,00%

Table 4. Land Capability Classification (Sume region of Paraiba State)

Mapping Units	Description	Pixels	%
0		2	0,00 %
Água (Water)		15372	1,54%
IIIs	Land with limitations/Problem of Soil	283019	28,30%
IVes	Land with limitations/Problems of Erosion and Soil	54227	5,42%
IVs/VIs	Land with limitations/problems of Soil	305097	30,51%
VIes	Land with limitations/problems of Erosion and Soil	151002	15,10%
VIs/VIIs	Land with limitations/Problems of Soil	45309	4,53%
VIes/VIIes	Land with limitations/problems of Erosion and Soil	145972	14,60%
Total:		999998	100,00%

GENERAL CONCLUSIONS AND RECOMMENDATION

The SPOT imagery is found more reliable for land use and land cover mapping and could be used effectively for the Sume semi-arid regions of northeastern Brazil in order to submit the natural, ecological and environmental resources information for the development and management of the study area.

The orbital images proved to be an extremely useful source of data for the purpose of detailed regional, local and rural planning and management and development of our natural resources.

Digital interpretation of SPOT imagery with 20m resolution proved to be effective to determining detailed assessment of land use and land cover classes, soils, capability classes and surface hydrology for selected areas in the semi-arid regions of NE Brazil.

The supervised classification of SPOT data for land use/land cover mapping and accuracy assessment provided satisfactory results. In terms of operational reliability, the per pixel maximum likelihood classification of SPOT image data offered the most satisfactory results in comparison to other classification systems. To get more information about the land use and land cover classes the multi-temporal images from different seasons are necessary.

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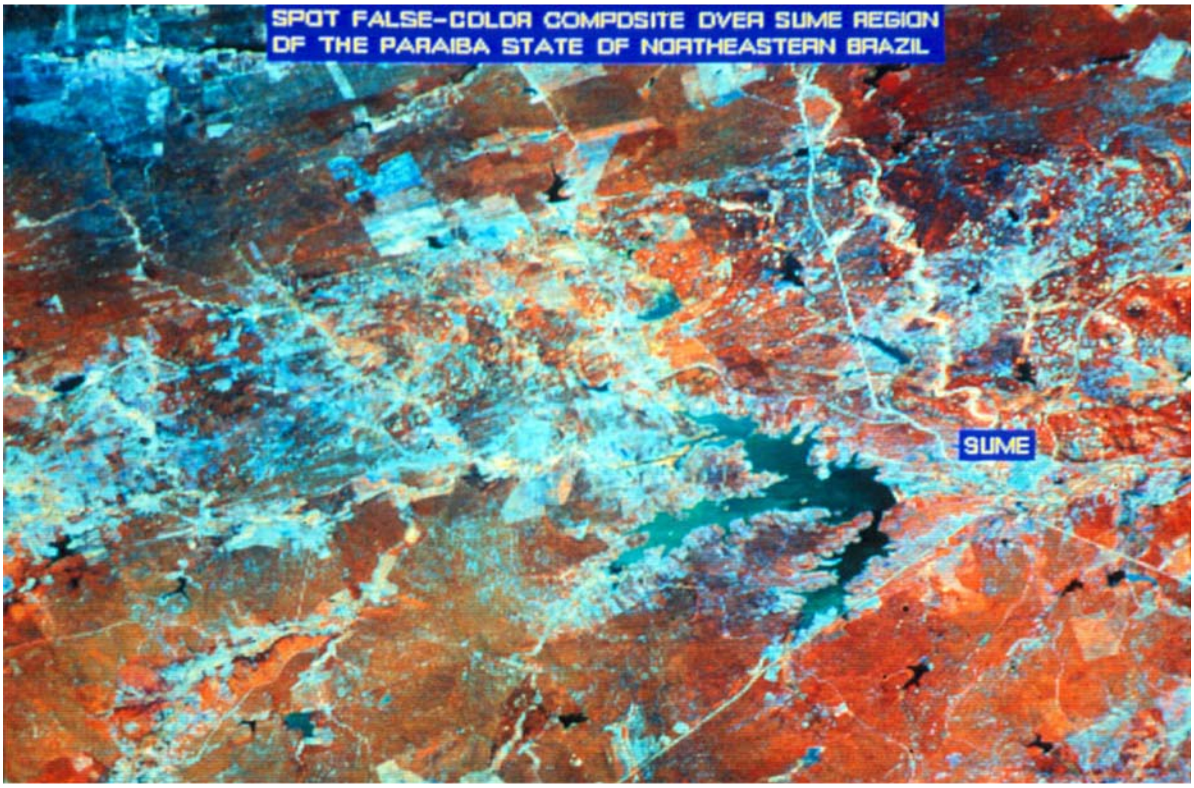

IMAGE 1. SUME SPOT FALSE COLOR COMPOSITE

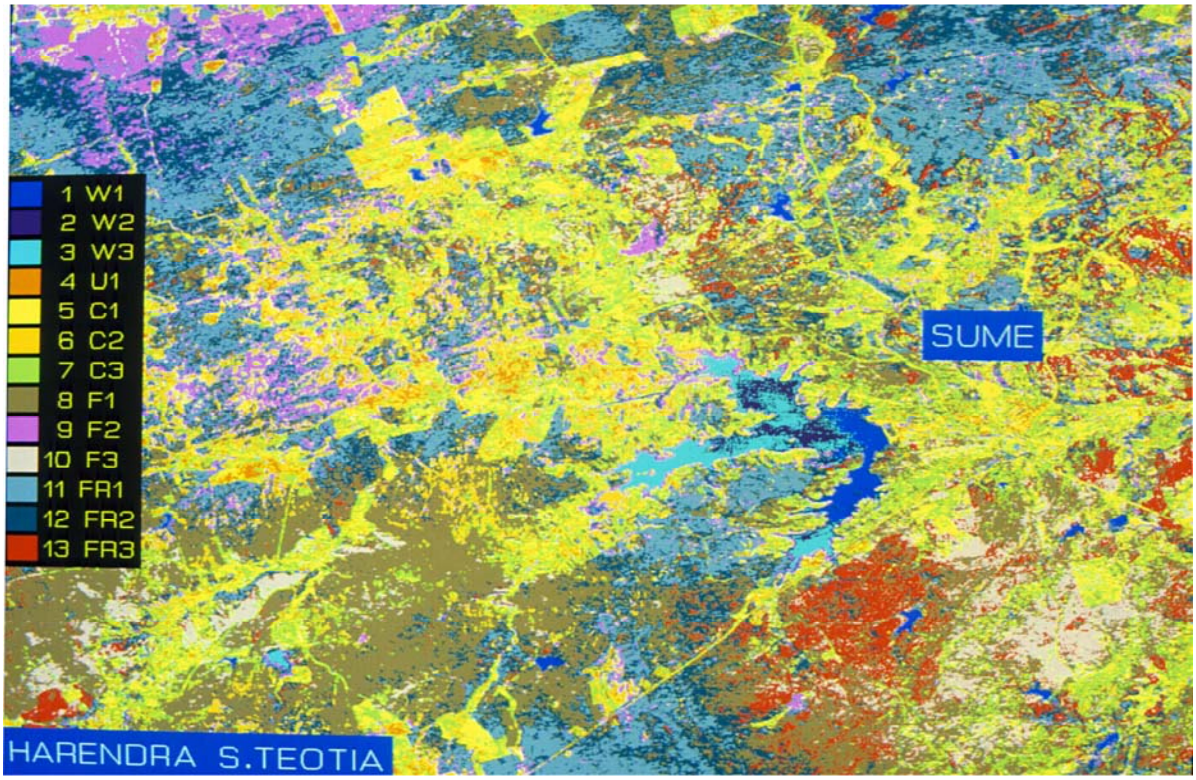

IMAGE 2. SUME LAND USE/LAND COVER MAP (MAXCLAS)

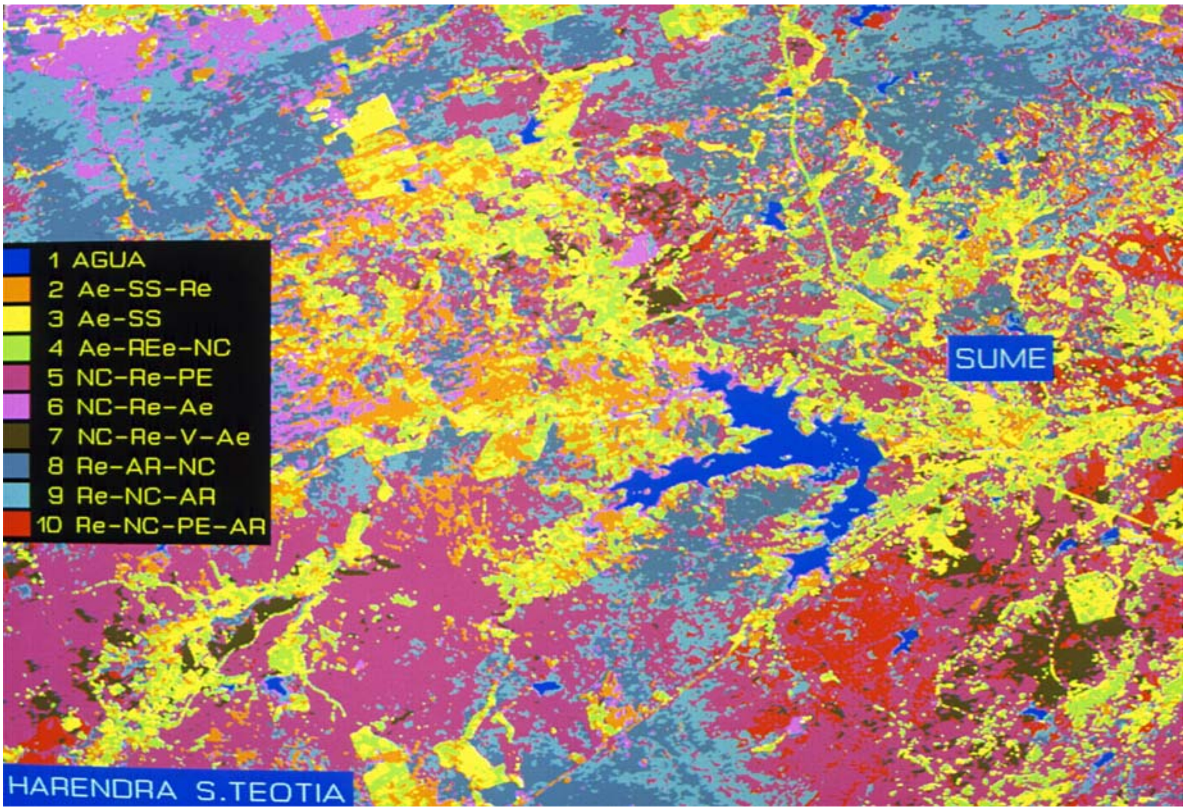

IMAGE 3. SUME SOIL ASSOCIATIONS MAP

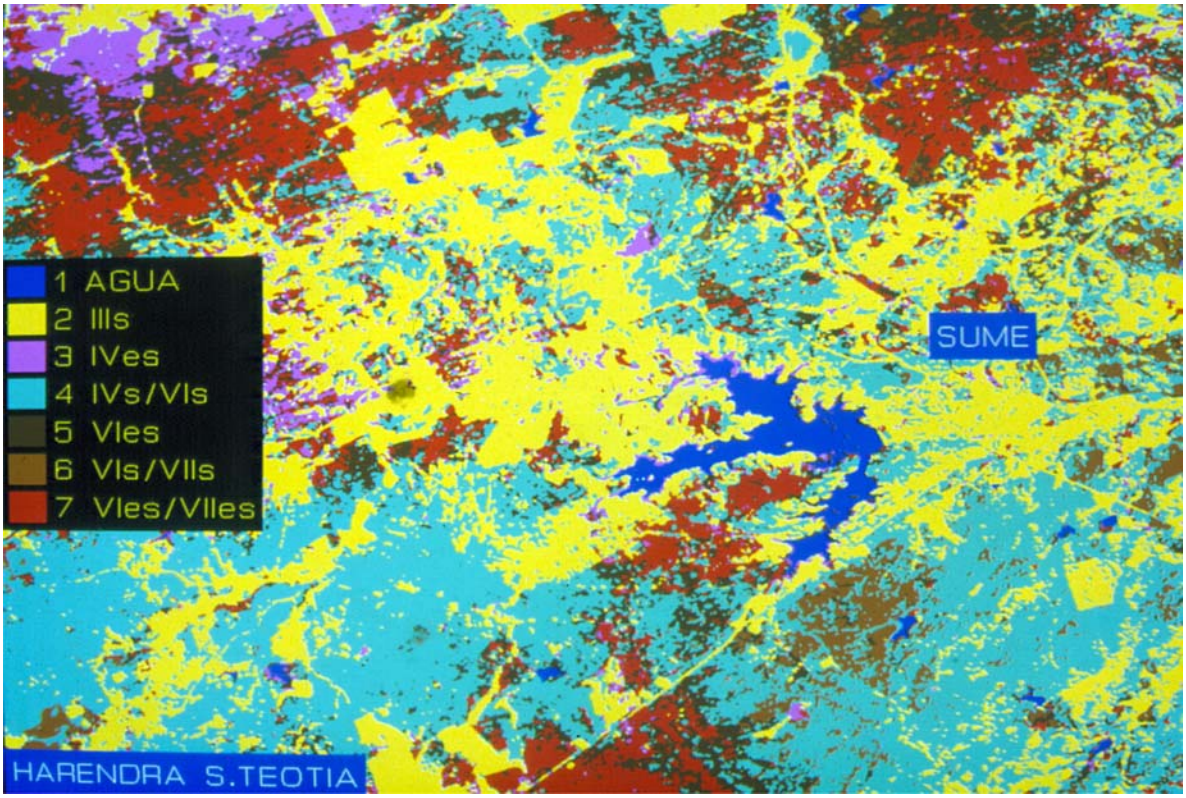

IMAGE 4. SUME LAND CAPABILITY INFORMATION MAP