APPLICATION OF SPOT TO GIS/LIS IN LAND CAPABILITY EVALUATION FOR REGIONAL PLANNING OF JAICO SEMI-ARID REGION OF PIAUI, BRAZIL

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ABSTRACT

Remote Sensing provides one or a few of the many data required in GIS/LIS for evaluation of various types of land capabilities, such as land capability for urban land use, agricultural use, and for forestry use.In northeastern Brazil, satellite data such as SPOT HRV and Landsat-TM have been utilized to provide land use information for the semi-arid areas of the region. The present investigation was conducted over an area of approximately 700 Km2 in northeastern Brazil at JAICO and its environs located in the sul of the Piaui state. A Raster based Computer Mapping System-ERDAS (Earth Resources Data Analysis System) for a hybridized unsupervised-supervised classification (Maximum Likelihood) approach was used in order to extract of 17 land use/land cover classes at the Level II of Anderson Classification (USGS, 1976). These classes were recoded in order to detect the 11 soil association classes in accordance with the Brazilian and USDA Systems (Brazil, 1983 and USDA, 1975, 1983), which were then recoded into 9 land capability units using the Brazilian and American Systems (USDA, 1966, 1983 and Brazili, 1971, 1983). Finally, three maps were derived for the objectives of regional planning under this investigation:1) Land use/Land cover map, 2) Soil Associations map, and 3) Land Capability Units map. This system is used to store information of various properties of land development for regional planning in NE Brazil. Comparison of digital interpretation with reference information indicated that digital interpretation, closely resembled field observation and the overall classification accuracy was observed 84.7%.

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BACKGROUND DISCUSSION

Information on land use and land cover using SPOT satellite is very essential for various natural resources regional planning projects utilizing land information systems. A more synoptic vantage point, such as provided by remote sening, is required for effective earth resources monitoring. (Trotter, 1991).

Remote sensing is the art and science of detecting, identifying, classifying, delineating, and analyzing earth surface features and phenomena with imagery acquired from terrestrial, aircraft, and satellite sensors using both visual and computer-assisted interpretation techniques (Civco and Kiefer, 1990). Remote sensing and GIS/LIS technologies (visual and digital interpretation) for the inventory and analysis of natural resources for regional and local planning at both small and large scales are used in most of the countries of the world. Various types of remote sensing data through its visual/optical and digital analysis have been used for natural resources management and development of tropical humid, semi-arid and other regions of the world. Visual interpretation and classification involves the consideration of a variety of information types such as tone or color, (spectral properties), shape, size, shadow, pattern, texture, and association (spatial properties) across a temporal profile (Avery and Berlin 1992; Tinney, 1982). Pettinger (1982) performed a comprehensive digital classification of vegetation and land cover in Idaho producing several maps of different levels of detail for natural resources management purposes. LaBash et al (1989) conducted a digital image analysis of Landsat-TM data in eastern Connecticut for regional land use and land cover classification.

Civco (1989) concluded that knowledge-based image analysis for classifying Landsat Thematic Mapper region-based spectral data, coupled with ancillary digital spatial information, is not only feasible but also perferable to the per-pixel, spectral data only, statistical methods more traditionally employed in deriving land use and land cover information for natural resources management. Zhou (1989) develdoped a Relational Image-based GIS (RIGIS) for interfacing geographic information system and remotely sensed data for land resources studies in the arid zone of Australia. Lyle and Stutz (1989) described systematic methods using GIS and remote sensing for rural land planning which formed the bases for land use planning for the areas of southern California. Kennard et al (1988) 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.

Ripple (1987) provided specific examples involving water, soil and vegetation resources management based on the integrated use of GIS and image processing technologies. Teotia et al (1991) have used SPOT HRV data for land use/land cover and soil/land classification in the Piaui state of northeastern Brazil. Hui et al (1992) used the remote sensing techniques combining with ecological and geological information and digital analysis system to produce a series of systematic, convincing and synthetic maps for a part of China. Civco et al (1991) concluded that land use and land cover information can be derived in better way, when a combination of unsupervised land cover class definition , using a multiblock clustering approach, and supervised training area selection, using pixel seeding and region growing, was employed.

PROCEDURE

LOCATION AND EXTENT:

The study area is semi-arid and situated at a distance of about 372 km from the city of Teresina, capital of the state of Piaui and 44 km from Picos city of the region. It has various types physiographical relief and geomorphological forms such as alluvial plains, low land, cultivated fields, rock ridges, rocky and eroded and waste lands. Rocks are mainly of sand stone. Generally, the topography of the area varies from nearly levelled to slightly undulating and undulating. Soils are shallow to moderately deep, and coarse to medium textured. The major soils are: alluvial soils, rocky (lithic subgroups of various orders), Inceptisols, Entisols, and Alfisols. Crop production in the area is dependent principally on natural rains. The mean annual precipitation is 664.1 mm and mean annual temperature is 26.71 degree Centigrades and therefore area falls under the "Bsh" class of the classification system of Koppen. The major forest of the area is divided into Caatinga hipoxerofila and Caatinga hiperxerofila.

COMPONENTS REQUIRED FOR EVALUATION:

Data about the various components required for the research were gathered from sources as follows:

1. Land use and Vegetation - Information about the land use and vegetation were collected from the aerial photographs of the area, Satellite data (SPOT) and IBAMA, the Institute for Ecological and Environmental studies of the state.

2. Soils - Informations about the soils were received through the aerial photographs, soil survey maps, soil survey technical reports existed in the Federal University of Piaui and EMBRAPA and field survey.

3. Slope and Elevation- Inforamtion regarding the Slope and Elevation were procured through the topographical maps received from the SUDENE, field survey using the ABNEY LEVEL. To classify the slope and elevation, mainly the Brazilian and USDA systems were used.

4. Climate - The information about the precipitation, temperature and humidity were received from the Federal University of Piaui and the EMBRAPA.

5. Aerial Photographs and Satellite data - Aerial photographs were taken from soil department of the Federal University of Piaui and the SPOT HRV satellite images were donated by the DLR (Aerospace Research Institute) of Germany to conclude this work.

6. Municipality and State Boundaries - These information were gathered from the administrative units of the State of Piaui, Mayor's office of the city and the topographical maps (scale of 1:100,000 and 1:25,000) received from the SUDENE.

CRITERIA ADAPTED FOR LAND USE/LAND COVER CLASSIFICATION:

During the conduction of the project, we used the following important criteria suggested by the USGA and others:

1. 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 or activity.

4. 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 Colomb, Kennard, and Civco (1985) and by Civco and Kennard (1983) were also considered.

1. Individual land use and land 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.

ERDAS-PC SYSTEM AND PROGRAMS:

The present project was conducted using the ERDAS-PC System and its programs used for unsupervised and supervised classifications and Accuracy assessment. The ERDAS-PC System is a stand-alone image processing system developed for use on the IBM PC family of computers with the DOS operating system. It is a powerful tool for generating, managing, displaying, and processing geographic and image data.

The ERDAS-PC System performs image analysis of:

*remotely-sensed data, such as Landsat or SPOT satellite data;
*video-digitized image data, such as aerial photographs;
*and grided polygon data, such as digitized soil maps or topographic maps.

The ERDAS-PC software package also provides further geographic analysis functions, including:
*an integrated geographic information system (GIS), which allows the user to overlay or combine many different types of data for one analysis;
*Polygon capture software that allows the user to capture data directly from maps of any scale when used with a tablet digitizer;
*amapping package that produces true hard copy map output on an optional color inkjet printer;
*and data base management utilities.

Features and Benefits:

The ERDAS-PC System provides the following features and benefits to users:
*users can use the system effectively without a detailed knowledge of computers of programming.
*image processing functions are easily accessibile from a series of menus.
*an on-line Help facility describes the purpose of each menu and program.

Hardware configurations: (Minimum Requirements).

The ERDAS-PC System has the following Hardware configurations:

*CPU: PC (386 or 486) with Super VGA Monitor.

*IMAGE DISPLAY DEVICE: Image Processor (512 or 1024).

*RGB Monitor: Mitsubishi RGB Monitor (14 or 20 inches).

*DISK STORAGE CAPACITY: IOMEGA Bernouli Box.

*TAPE DRIVE: Cipher Tape Drives.

*TABLET DIGITIZER: Calcomp Digitizer.

*COLOR PRINTER. Tektronix Inkjet Printer or Thermal Printer.

Software Configurations:

ERDAS software is available in a variety of optional modules that can be used independently or combined to meet the user's application requirements. The major modules are given below:

*CORE MODULE
*IP (Image Processing) MODULE

*GIS (Geographical Information System) MODULE
*TAPES MODULE
*HDCOPY (Hard Copy) MODULE
*PDIG (Polygon Digitizing) MODULE
*VDIG (Video Digitizing) MODULE
*TOPO (Topographic) MODULE
*3-D MODULE
*TOOL KIT MODULE
*SSS (Software Subscription Service) MODULE

Programs:

Under this project various types of programs have been used for the Unsupervised Classification, Supervised Classification and Accuracy Assessment. Series of these programs used for Unsupervised and Supervised Classifications and Accuracy Assessment are described below:

Unsupervised Classification:

Series: READ-CLUSTR-DISPLAY-COLORMOD-CLASNAM-RECODE-COLORMOD-CLASNAM-ANNOTATION-CLASOVR-BSTATS-LISTIT.

Supervised Classification:

Series: READ-SEED-SIGDIST-SIGMAN-ELLIPSE-CLASNAM-MAXCLAS-DISPLAY-COLORMOD-CLASNAM-ANNOTATION-CLASOVR-RECODE-INDEX-COLORMOD-CLASNAM-ANNOTATION-SCAN-BSTATS-LISTIT.

Accuracy Assessment:

Series: READ-DISPOL-DIGSCRN-GRDPOL-CLASOVR-CLASNAM-SUMMARY.

DIGITAL INTERPRETATION:

A 1000 by 1000 pixel subscene of level 1B multispectral data from a SPOT-1 HRV scene centered around JAICO in the state of Piaui, Brazil, was subset from 9-track magnetic tape for subsequent analysis. A hybridized unsupervised-supervised classification approach was used for the analysis of land use/land cover and other earth resources information. The field studies conducted provided the ground truth reference data necessary for land use and land cover classification of SPOT multispectral data. More than 50 unique sites were visited in the study area, and observations for land cover, land form, vegetation, soil and slope were made. The observations were used to guide a supervised classification of the SPOT image. Finally, 17 categories were classified at the Level II of Anderson et al (1976), which was modified in accordance with the local conditions of the region. (Table-1).

The accuracy was assessed by cross-tabulating the maximum likelihood classification results with their respective ground truth digital maps. The intersecting of maps revealed the category amount of agreement and disagreement. The soil associations and land capability maps were produced by a recoding and correlating the final 17 land use and land cover classes of Level II. Elevel soil associations and nine land capability units were identified and mapped. (Table-2 and Table-3).

Table-1: JAICO LAND USE/LAND COVER

No.	MAPPING UNITS	DESCRIPTION
1.	W0	Deep clean water
2.	W1	Moderately deep water
3.	W2	Shallow silted water
4.	W3	Moist areas
5.	SFA	Swampy flooded area
6.	UO	Urban area with barren rocky land
7.	EFA	Eroded flooded area
8.	PDC	Poor drained cultivated and eroded
9.	PDC1	Poor drained cultivated
10.	AMC	Alluvial mixed cultivated
11.	CRB	Cultivated river bed
12.	CRB1	Cultivated river bed with dense shrubs/vegetation
13.	SCD	Saline cultivated depressions
14.	WERM	Weathered eroded rocky and moist land with sparse vegetation
15.	DCF	Dense caatinga forest
16.	MDCF	Moderately dense caatinga forest on undulating topography
17.	SPC	Sparse caatinga forest on undulating and eroded topography and with poor cultivation

Accuracy Assessment: 84.7%

Table-2: JAICO SOIL ASSOCIATIONS

No.	MAPPING UNITS	SOIL ASSOCIATIONS
1.	Water	
2.	E-L-R	Entisols-L. Subgroups-Rock-outcrops
3.	E-I	Entisols-Inceptisols
4.	E-I-L	Entisols-Inceptisols-L.Subgroups
5.	I-E	Inceptisols-Entisols
6.	I-E-A	Inceptisols-Entisols-Alfisols
7.	I-E-L	Inceptisols-Entisols-L.Subgroups
8.	I-A	Inceptisols-Alfisols
9.	L-R-E	L.Subgroups-Rock-outcrops-Entisols
10.	L-A	L.Subgroups-Alfisols
11.	L-R-A	L.Subgroups-Rock-outcrops-Alfisols

Table-3: JAICO LAND CAPABILITY UNITS

No.	MAPPING UNITS	DESCRIPTION
1.	Water	
2.	IIIs	Land has limitations of soils
3.	IIIsw	Land has limitations of soil and water
4.	IIIes	Land has limitations of erosion and soil
5.	IVw	Land has limitations of water
6.	IVs	Land has limitations of soil
7.	IVes	Land has limitations of erosion and soil
8.	VIes	Land has limitations of erosion and soil
9.	VIIes	Land has limitations of erosion and soil

ACCURACY ASSESSMENT:

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 preselected polygons were displayed over the monitor. Then the test areas were selected to allow the data file coordinates for polygons to be digitized directly from the image. Three to four test areas (polygons) were selected for each original class. Then GRDPOL, CLASOVR, and CLASNAM programs of ERDAS were used in order to know the equal size of file,, overlapping of the classes and to write the title and class names for all the classes. The resulting test area file was then digitally overlaid on the classified JAICO land use and land cover map and a pixel-by-pixel comparison was performed using the SUMMARY program. Accuracy was assessed by intersecting the maximum likelihood classification results with their respective ground truth digital map, which revealed the per-category agreement and disagreement. The data for the supervised (original) interpretation and verified interpretation were then put in a table showing row-column totals, percent agreement by class, overall mapping accuracy, as well as errors of omisson and commission for each class, established by Short (1982).

The percentage agreement by class was determined by dividing the number of correctly classified pixels for each class by the number of ground truth test pixels plus number of commissions for that class. The overall mapping accuracy was obtained by adding the number of correctly classified pixels in each class and dividing by the total number of ground truth test pixels.

RESULTS AND DISCUSSIONS

Comparison of digital interpretation with reference information indicated the digital interpretation closely resembled field observations. A more rigorous quantitative measure of accuracy performed using the test areas, however, indicated that some categories were classified and mapped more reliable than others. The over all classification accuracy was nearly 85% (84.7%).

The deep clean water, moderately deep water, shallow silted water, swampy flooded areas, eroded flooded areas, poor drained clutivated and eroded, alluvial mixed cultivated, cultivated river bed, cultivated river bed with dense shrubs/vegetation, saline cultivated depressions, and dense caatinga forest classes produced the best results in terms of high percent agreement with ground truth data (78-100%) and relatively low percent commissions (0.01-11.7%). This indicates that the digital data of these classes are spectrally homogeneous and easily have been discriminated from other classes. The other classes such as very shallow water or mostly moist areas, urban areas with barren rocky land, weathered eroded rocky and moist land with sparse vegetation, moderately dense caatinga forest on undulating topography, sparse caatinga forest on undulating and eroded topography and with poor cultivation are more spectrally heterogeneous and explain the lower overall classification accuracy (57.87% to 75.73%) and high commissions percentages of (25.21 to 49.73%).

From these results it is observed that the inability to discriminate among certain classes, such as urban areas and barren rocky land, is due to the spectral similarity between categories. Also, the limited range of the SPOT HRV sensor may not permit adequate spectral discrimination of the classes being mapped. Discrimination may be better using other regions of the electromagnetic spectrum, such as Landsat-TM and Landsat-ETM. The percentage accuracy is decreased as the level of detail is increased. To get better results and more accuracy, it is necessary that we should use the aerial photographs of large scale. The more spectrally heterogeneous areas also reduce the accuracy percentage of the classification.

GENERAL CONCLUSIONS

1. Digital interpretation of SPOT with 20 meters resolution imagery proved to be effective in determined detailed assessment of land use and land cover classes, soil and surface hydrology for JAICO semi-arid region of NE Breazil.

2. The limited spectral range of the SPOT HRV sensor did not appear to permit adequate discrimination of some land use and land cover categories. To obtain more reliable information regarding the land use and land cover classes, SPOT images from several seasons are necessary.

3. Soil associations and capability classification are very relevant for detailed regional planning and management of the region if used by extension services of the state of Piaui.

4. The combination of unsupervised and supervised classifications

of SPOT data and map accuracy assessment proved satisfactory results. The more accurately identified categories may be used as a framework for the addition of residual classes through a more conventional approach, such as aerial photointerpretation.

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