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MANIPULATION OF LANDSAT SPECTRAL CHARACTERISTICS TO CLASSIFY VEGETATION AND SOIL WETNESS IN THE RAINFOREST OF BOLIVIA

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ABSTRACT

This study attempts to classify tropical region soils and vegetation by moisture content from multispectral imagery. Identified wet areas were used to determine the percentage of wetness in the study area, by evaluating the spectral response of tropical rainforest vegetation and soils. Supervised classification, unsupervised classification, and manipulation of spectral band techniques were used to determine percentages of wetness in the study area.

Using these methodologies, vegetation and soil units associated with wet conditions were classified. Soil types were categorized into the following: (1) areas that are moist, (2) forested areas that are moist or wet depending upon the season, and (3) forested/swamp/land subject to inundation, areas that are wet a good portion of the year. Vegetation was classified into the following: (1) marsh, (2) tropical swamp forest, and (3) tropical moist forest.

Results demonstrate that digital spectral data from Landsat imagery can be used to locate and evaluate varying degrees of wetness in soils and different vegetation types associated with wet conditions.

1. INTRODUCTION

The study was an attempt by the Terrain Analysis Center (TAC) to classify tropical region soils and vegetation by moisture content from multispectral imagery. This paper examines the different methodologies employed in the study and the ability to use each in an effective manner. TAC attempted to compare and contrast three different analytical techniques. The techniques used in this study were:

A. Supervised Classification- Where known pixels were used to determine the content of other pixels within the study area.

B. Iterative Self-Organizing Data Analysis Technique (ISODATA)[1] Unsupervised Classification- This technique uses TAC's SUN/ERDAS/ARCINFO system to examine the pixels and to lump them into a prespecified number of categories.

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[1]Richardson, B.F. 1983, Remote Sensing of the Environment

C. <u>Manipulation of Spectral Bands</u>- Different spectral band combinations were used to determine category criteria.

Questions and concerns addressed in this paper include:

A. How does each spectral manipulation procedure address the effectiveness of differentiating wetness within the study area?

B. How effectively does each classifying procedure identify varying levels of moisture?

C. Does one methodology better determine wetness regimes than any of the other techniques?

D. Which technique works best in a production environment given a variety of different parameters (timeline, scale of product, size of study area, etc.)?

This study originated from discussions with representatives from USAID/Bolivia, Corps of Engineers/Mobile District, and the Terrain Analysis Center. During these meetings TAC proposed a prototype baseline study, in an attempt to help the Bolivian Government and USAID/Bolivia assist in the management of Bolivia's natural resources. Components of the study include Soils, Vegetation, Lines of Communications, and a Surface Drainage Network.

To provide the ground detail as well as broad area coverage, TAC conducted the study at a scale of 1:100,000. The basemap for the project was taken from a landsat image, rectified and scaled to 1:100,000. The basemap was produced using spectral band combinations 7,4,2 and 7,3,2. These band combinations were used to simplify the analysis and provide the user with a standard format for future studies. TAC had in-house, landsat coverage of the Beni region in northern Bolivia (See Figure 1.0.1).

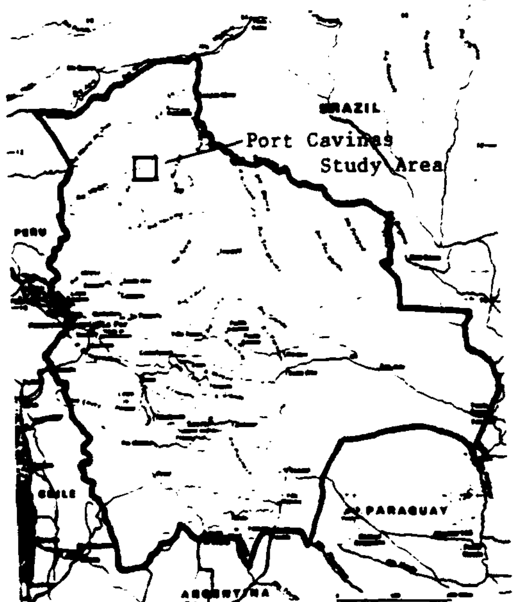

Figure 1.0.1 Port Cavinas, Bolivia

Within the landsat scene, the Port Cavinas area was selected for the study based on the following criteria:

A. a diverse mixture of savannahs and tropical forests;
B. large expanses of wetlands; and
C. major rivers (Rio Beni and the Rio Madidi) running through the study area.

The Port Cavinas area is a flat low-lying area, where savannahs are used for cattle grazing and ranching. The rivers, Beni and Madidi are navagable and are used to ship logs to the mills that are located along the rivers. The transportation network within the area is sparse, comprised mainly of fair-weather loose surface roads and tracks that connect villages and farming enclaves. Many of the ranchers have their own dirt airstrips to facilitate movement of cattle and supplies.

The study provided USAID/Bolivia with a true understanding of TAC's capabilities to provide a baseline study that was beneficial to the user. It also allowed TAC to better understand the level of effort needed to undertake such a project.

2. DATA MANIPULATION

The landsat thematic mapper(TM) scene (2 August 1987) was input into TAC's SUN Sparcstation Four workstations, which run ERDAS/ARCINFO programs for image manipulation and analysis. A portion of the image was cut out of the scene to define the study area. This subset was rectified using a Cubic Convolution algorithm[2]. The imagewas manipulated by the analyst and the computer system to produce values which were analyzed.

2.1 SUPERVISED CLASSIFICATION

Supervised classification requires the analyst to identify known features[3]. Using this methodology pixels were chosen that represented distinct classes. Supervised classifications were performed on the image by using the ERDAS SEED program[4]. This program uses spatial and spectral parameters to search for like pixels throughout the image. The pixels are then put into a signature file, which is a set of statistical data that defines a sample. The ERDAS ELLIPSE[5] program was used to acquire scatterplots of the signatures. Analysis of the ellipse graphics determines which signatures and which bands provide the most

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[2]ERDAS 7.5 Field Guide

[3]Richardson, B.F. 1983, Remote Sensing of the Environment

[4]ERDAS 7.5 Field Guide

[5]ERDAS 7.5 Field Guide

accurate classification results. The ERDAS program MAXCLAS[6] was used to determine the total number of pixels in each signature and the percentage of each signature within the image.

Using these methodologies, two supervised classification schemes were performed on the image. The first classification was broken down into ten signature classes:

1. River (Upper Beni)
2. River (Lower Beni)
3. Lakes and oxbows
4. Oxbows
5. River (Madidi)
6. Forest 1 (darker tone)
7. Forest 2 (lighter tone)
8. Cleared (wet)
9. Savannah 1 (darker tone)
10. Savannah 2 (brighter tone)

Scatterplots for bands 3,4, and 2 indicated good separation and these bands were the most promising for accurate results(See Figure 2.1.1).

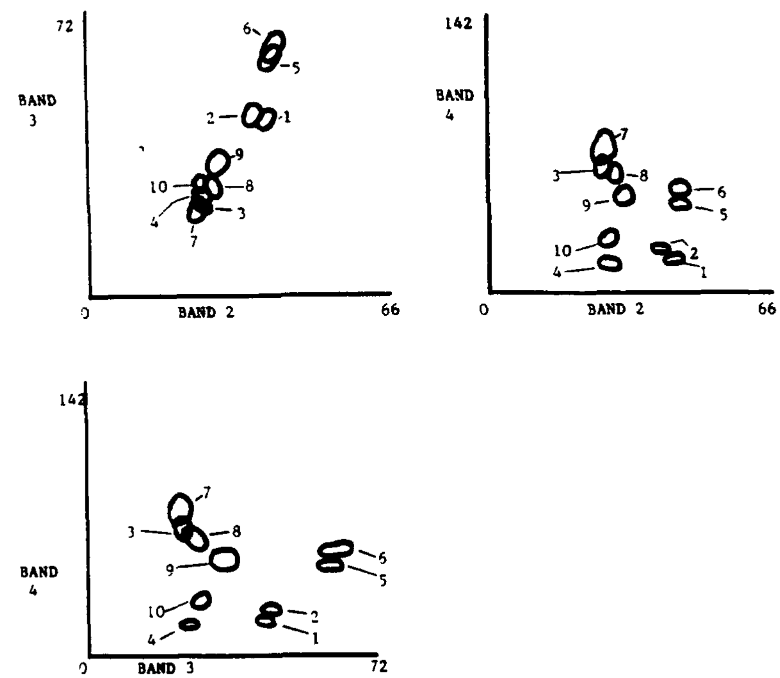

Figure 2.1.1 Scatterplots for bands 3,4, and 2.

The number of pixels in a signature and the percentage of that signature within the image was calculated using the MAXCLAS routine. This routine attempts to assign the ambiguous pixels to a signature, defined by the set of training pixels.

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[6]ERDAS 7.5 Field Guide

Class	Number of Points	Percent(%)
0(Unknown)	715716	14.035
1	20578	0.404
2	15097	0.296
3	15421	0.302
4	2086	0.041
5	14116	0.277
6	945515	18.541
7	819286	16.060
8	213235	4.181
9	1720171	33.731
10	618405	12.126

This supervised classification yielded a considerable number of unknown pixels (14 percent); most of these were located within the forests and savannahs.

A second supervised classification was performed on the image to compare the results, when different spectral bands were used. Two new signature classes were added, one in the forest and one in the savannah regions. The second classification used the following categories:

1. River (Upper Beni)
2. River (Lower Beni)
3. River (Madidi)
4. Lakes and Oxbows
5. Forest 1 (Dark tones)
6. Forest 2 (medium tones)
7. Forest 3 (light tones)
8. Cleared (wet)
9. Savannah 1 (medium tone)
10. Savannah 2 (light tone)
11. Savannah 3 (dark tone(burn areas))

Statistical analysis of the signature files yielded the following set of statistics for each band.

Band	1	2	3	4	5	6	7
Min.	76	28	32	47	74	136	23
Mean	79.8	30.5	34.6	50.1	78.1	137.6	26.8
SD	1.15	0.76	0.93	1.44	2.01	0.61	1.26
Max.	83	33	37	54	84	137	30

Bands 7,4,and 2 were selected as the most representative, because of their scatterplots(See Figure 2.1.2).

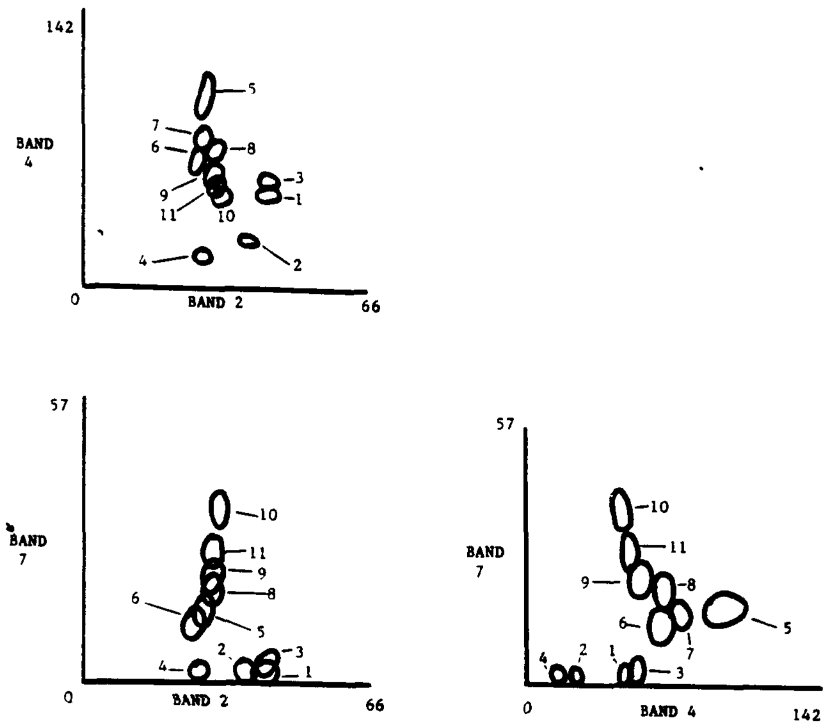

Figure 2.1.2 Scatterplots for Bands 7,4, and 2.

The pixels per signature and percentage of that signature within the image were calculated using the MAXCLAS routine.

Class	Number of Points	Percent(%)
0(Unknown)	715716	14.035
1	24374	0.478
2	15609	0.306
3	9735	0.191
4	17017	0.334
5	36427	0.714
6	1581683	31.016
7	145940	2.862
8	147260	2.888
9	1243240	24.379
10	483580	9.483
11	679061	13.316

2.2 UNSUPERVISED CLASSIFICATION

An unsupervised classification technique uses an iterative clustering process to group pixels into like categories. Iterative Self-Organizing Data Analysis Technique (ISODATA)[7] classifier was used on the image to generate unique signature files. An ISODATA classification iterates clusters of pixels, combining and splitting them until predefined threshold values are met. Fifteen categories were predetermined, and a convergence threshold of 95 was specified. The convergence threshold takes the maximum percent of pixels whose class values are allowed to be unchanged between iterations[8]. The maximum specified number of iterations performed on the image was twenty-four.

2.3 MANIPULATION OF SPECTRAL BANDS

Several different spectral band combinations were used to determine wetness regimes. Attention was given to spectral band wavelengths, favorable band characteristics for enhancing water features, and each spectral bands ability to contrast the wet areas sufficiently for pattern recognition.

3. DATA ANALYSIS

TAC analysts used photo interpretation skills and techniques in conjunction with a thorough literary review to analyze the manipulated and enhanced data. Field work was not possible for this project because of timeframe and cost factors. Instead, TAC's library provided a thorough literature review to compenstate for the lack of field analysis.

3.1 INTERPRETATION OF WETNESS

This study demonstrated that three levels of moisture could be identified. These three levels were categorized into the following:

1. Areas that may be moist
2. Areas that are moist or wet depending upon the season
3. Areas that are wet a good portion of the year

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[7]Richardson, B.F. 1984, Remote Sensing of the Environment

[8]ERDAS 7.5 Field Guide

The supervised classification routines portrayed three levels of moisture. Areas in and around the oxbows and meander scars showed evidence of being wet a good portion of the year. Along the rivers, seasonally moist or wet areas could be located and moist areas were shown by a different color characteristic of the tropical forest areas.

Unsupervised classification showed three distinct color variations for wetness. This classification technique lacked some of the detail provided by the supervised classification, but the results were comparable and favorable to the other classifying methods.

The manipulation of spectral bands produced quick, easy to exploit results that were reasonable for this type of analysis. Tonal variations were used to identify the different moisture regimes.

One item of interest to this study that would require additional analysis beyond the original scope of work, is the junction where the Beni and Madidi rivers converge. Of note at this junction was that distinct color and tonal characteristics exist for the Madidi, the Beni north of the junction, and the Beni south of the junction. Data manipulation shows that each river segment had its own unique color and tonal characteristics.

3.2 SURFACE MATERIALS ANALYSIS

The standard FAO soil classification system was a basis for the surface materials portion of the study[9]. The FAO system was selected due to its familiarity to the users. Three basic soil groups were found within the study area:

1. Mollic Gleysol (Gm)- Soils formed from unconsolidated alluvium materials, having a mollic A horizon or an eutric histic H horizon. This soil type was found along the rivers, oxbows, and meander scars, anywhere a reduced environment existed[10].
2. Orthic Acrisols (Ao)- Soils having an argillic B horizon and lacking plinthite within 125 cm of the surface. These soils were found mainly in the wetter portions of the forested areas.
3. Plinthic Acrisols (Ap)- Quaternary sediments that exhibit a plinthic layer within 125 cm of the surface. These soils were found in the savannahs and were concentrated east of the Beni river.

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[9]UNESCO-PARIS 1971, The Soils of South America

[10]Campbel, K.E. 1985, The Geology of the Rio Beni

The textural classification of soil particles was consistently fine to medium with the dominant particle size being clay to clay loam[11]. The study area was characterized by alluvium material overlying deep clay to clay loam soils. Surface roughness factors were analyzed to address the conditions on the surface, and interprete what was taking place between the contour lines. The dominant surface roughness classifier was the percentage of wetness within the soil.

The 3,4,2 and 7,4,2 supervised classification techniques and the unsupervised classification technique were utilized to examine the differences in moisture content so that gleysols could be differentiated from the Orthic Acrisols. Landcover types helped to make distinctions between Orthic Acrisols(forest) and Plinthic Acrisols(Savannahs).

3.3 VEGETATION ANALYSIS

Landsat band combinations 4,5,7 and 4,7,2 and 4,7,5 (blue, green, red respectively) were processed to create false color image maps for vegetation analysis. Five distinct tonal variations were classified: tropical swamp rainforest, tropical moist rainforest, marsh, forest clearing, and savannah/pasture. The first three classifications occur along the rivers and differ significantly in tonal characteristics.

The tropical swamp rainforest, which is located next to the river channels has a lighter tone than the moist rainforest, which is situated further from the river. The tonal differences were evident in all three band combinations used for the analysis. The tropical swamp rainforest is inundated with moisture most of the year, while the moist rainforest is inundated only a portion of the year.

The marsh category contains areas of oxbow lakes and areas dominated by grasses and floating meadows[12].

A number of tonal variations were lumped into the savannah/pasture classification. These variations were the result of cattle ranching operations. The ranchers burn the grassland areas before the rainy season to stimulate growth for forage[13].

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[11]UNESCO-PARIS 1971, The Soils of South America

[12]Goulding, M. 1989, AMAZON The Flooded Forest.

[13]Kandell, J. 1984, Passage through El Dorado.

4. CONCLUSIONS

This prototype study proved that TAC has the capability to execute an environmental baseline study. Each of the image classifying techniques discussed in this paper were carefully examined. Each classifying technique was determined to be a valid classifier for an environmental baseline study. However, to optimize the supervised classification technique, field work would be necessary. Field work allows the supervised classification scheme to be used as intended instead of picking areas by photo interpretation keys. The fast effective broad area analysis from spectral band manipulation was found to be sound methodology for the 1:100,000 scale. A more detailed but slower analysis could be achieved using the supervised and unsupervised classifying techniques. A larger scale product (1:24,000 or 1:50,000) may have required a more extensive use of these two classsifying routines. All three techniques were used in conjunction with each other, so that optimum results could be achieved. Varying moisture levels could be determined from each of the techniques.

Manipulation of the spectral bands was a good quick look technique for the 1:100,000 scale of this study. The supervised and the unsupervised classification routines were slower, took considerable more system knowledge, time, and interpretation ability, but each of the classifying techniques portrayed the detail necessary.

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1. Rainforest
2. Soil
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4. Soil Wetness
5. Supervised Classification
6. Unsupervised Classification
7. Spectral Band Manipulation
8. Bolivia
9. Beni Region
10. Savannahs