THE STUDY
ON SUSTAINABLE GROUNDWATER DEVELOPMENT
FOR BOGOTA PLAIN
IN THE REPUBLIC OF COLOMBIA

FINAL REPORT
SUPPORTING REPORT

PART 10

LAND USE ANALYSIS WITH SATELLITE IMAGE

Final Report
(Supporting Report)

Part 10 Land Use Analysis With Satellite Imager

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PART - 10 LAND USE ANALYSIS WITH SATELLITE IMAGER

CHAPTER - 1 Collection of Satellite Image Information

1.1 Introduction

The JICA Study carried out the image data processing of LANDSAT ETM 7 data to monitor land cover and to survey the hydro-geological study for a preliminary investigation. The objectives to uses satellite data are as follows:

To acquire the latest satellite image data that covers with the study area with the complementary information needed to carry out the image interpretation.

To generate a thematic map of land cover classified to shows the areas where covered with forests, vegetations, cultivations, settlements, greenhouse, water body and others by LANDSAT 7 satellite image data.

The image classification was performed over the JICA Study area which ranged from Muña reservoir (South) to Villapinzón (North) and from East Mountains to Facatativa (West). JICA study area covers with all CAR and DAMA jurisdiction. Methodology, results and the statistics obtained after the interpretation, classification and edition process of the land use map are presented in the following chapter.

1.2 Geographic Frame

The definitive study area corresponds to Bogotá plain, where is located in the eastern mountain chain on Cundinamarca State within the coordinates 4^{o}15’ at 5^{o}20’ latitude north and 73^{o} 30’ at 74^{o} 30’ West to Greenwich longitude. The study area presents an altitude gradient that ranges from 2500 meters alt to 3600 meter alt above sea level. The basin is divided to 26 municipalities and a part of the Capital District administratively. Geomorphology around Bogotá river basin is conformed by cretaceous mountainous chains and an extensive fluvial- lacustrine deposit of quaternary origin, located at 2600 meter alt above sea level that gives origin to the plateau so called the Bogotá Plain (CAR 1985).

1.3 Data Acquisition of Satellite Image

To purchase satellite imagery, available imagery data in the EOS Data Center were reviewed not only for LANDSAT 7 but also for LANDSAT 3 and 5. The latest satellite image data was searched to monitor the land cover around the Study area.

LANDSAT-7 satellite was launch on April 15 of 1999 and provided with the enhanced Thematic Mapper Plus (ETM+) sensors which were added a panchromatic band and two gain ranges to improved spatial resolution in the thermal band, also the ETM Mapper includes two solar calibrators. In the following Table1.1 which is taken from EOS data center information, the bands for LANDSAT 7 sensor is presented with a comparison with the bands for older LANDSAT TM.

A series of quick looks imagery was reviewed and classified according to the date and the percentage of cloud that cover the image. Most of the recent imagery was covered with high percentage of cloud. Since 1986 there were some LANDSAT 5 images around all Bogotá plain that had cloud percentage less than 2%, however these images were not chosen because the study needed the latest one.

By reviewing quick look image of latest LANDSAT 7, it was concluded that it was necessary to get two scenes in order to cover all the study area. Because LANDSAT 7 data covered with two granules in the upper of north east part of Bogotá plain and in the lower of another part around the Study area. Row-Path of satellite image in the study area was as follows: 8-57 and 8-56;

The first image covered with most of the study area where ranged to nearly the Tominé reservoir. The second image covered with the northern part of the study area where ranged from Suesca to Villapinzón. Satellite data in the second image less than 10% was used for the classification.

Two quick Looks were selected: satellite data of 8-57 on November 16 in 1999 and of 8-56 on February 4 in 2000 as shown in Table-1.2. These images present a relatively high cloud cover percentage with a mean of 22%, however in the study area the cloud cover percentage is reduced to 1%.

Imagery data corresponding to these date was purchased for data analysis. Chosen Imagery data was Level 1 which was geometrically corrected (L1G) with radio metrical correction(systematic) form EOS data center with NASA. Table-1.3 is represented to show parameters established for the correction.

Table-1.1 Spectral Band Widths of Landsat TM and ETM+

Band width (μ): Full Width - Half Maximum								
Sensor	**Band 1**	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 6**	**Band 7**	**Band 8**
TM	0.45 - 0.52	0.52 - 0.60	0.63 - 0.69	0.76 - 0.90	1.55 - 1.75	10.4 - 12.5	2.08 - 2.35	N/A
ETM+	0.45 - 0.52	0.53 - 0.61	0.63 - 0.69	0.78 - 0.90	1.55 - 1.75	10.4 - 12.5	2.09 - 2.35	.52 - .90

Table-1.2 Data acquisition of satellite image data

Path - Row	Date of data acquisition	Scene-ID
8 - 56	February 4,2000	2000724634
8 - 57	November 16 1999	2000431753

Table-1.3 Georeference parameter of data correction for LANDSAT7 ETM.

- Output map projection: UTM	- Zone number: 18
- Image orientation: NUP	- Re-sampling kernel: CC
- Pixel grid-cell size: For BAND(8): 15 m, For BAND(1,5,6): 30 m, For BAND(6l, 6h): 60 m	

The correction algorithms used by EOS data center, model the spacecraft and sensor using data generated by onboard computers during imaging. Sensor, focal plane, and detector alignment information provided by the Image Assessment System (IAS) in the Calibration Parameter File (CPF) is also used to improve the overall geometric fidelity.

In this way the product that had been purchased is free from sensor distortions such as jitter, and view angle effect. Also it is corrected by satellite distortions produced by altitude deviations from nominal and other distortions produced by the rotation and the curvature of the earth. According to the information from EOS data center, the residual error in the systematic L1G product is less than 250 meters (1 sigma) in flat areas at sea level.

CHAPTER - 2 Method of Analysis

2.1 Software and Method of Image Data Analysis

The software ERDAS was used for imagery data processing including multi spectral analysis. On the image, a supervised classification was carried out, which included the ground truth for field sampling confirming procedure to determine the accuracy of the image classification. During the ground truth, a good number of entities are mapped by using a GPS and after this information is confronted with the image classification, the corresponding corrections were done. Also the software IRWIS was used for the data analysis.

2.2 Image Data Processing

(1) Image Correction and Georeferentiation

As mentioned before, the images corrected by pre-processing of 1G type were processed with georeference from a slave map that cover all the study area using a total of 32 control points which are easily identifiable and verifiable. In the georeference process a mean error of the matching residual was obtained closely to zero, which determined a pixel size of 29. 8 meter. When to compare with the pixel size of LANDSAT imagery (30 m), it shows that the georeferentiation adjustment is achieved. The images had georeference data according to IGAG maps about map sheet of 208, 209, 227, 228, 246 and 247 at scale 1:100.000.

(2) Band Composition

As part of the first phase, a series of bands compositions on LANDSAT ETM 7 in False Color were produced. In Figures-2.1, 2.2 and 2.3 are presented about some combinations, which allow to some highlighted image characteristics. Figure-2.1 presents composition of RGB: 453 that allow to clearly stand out water bodies of the images such as: San Rafael, Tominé, Neusa and Sisga reservoir, likewise it is clear as same as the contour of Bogotá river channel which crosses the Bogotá plain. This band combination appealed also highlighted smaller reservoirs as La Regadera and Chisacá reservoir and Los Tunjos lagoon.

Figure-2.2 presents band composition of RGB: 457 in which the geomorphologic structures and the land use are stood out. Within the patterns presented in this composition stood out bare soils areas, region with traditional crops and grasses cropping. In this combination vegetation appears brilliant red color, the urban areas appears like patches of dark blue color and bare soils appears as tonalities of clear blue and gray color.

It is important to the highlighted contrast that is obtained the geologic contours through this band combination, where is easy to draw fractures and/or faults where dominates the regional geology of the study area without doubts.

Figure-2.3 presents a zooming image with band combination RGB: 453 for Bogotá city area. There are a few vegetation areas inside the city. Likewise the contour of Bogotá River, the city area is clearly identified. Using recent satellite images, it was observed that Bogotá river channel was deviated in order to build the second landing strip for International Airport El Dorado, however this deviation did not appear on IGAC cartography.

CHAPTER - 3 Land Cover Map and Land use Analysis

3.1 Not Supervised Classification

For LANDSAT TM satellite images, King-Benayas and Pope (1995) proposed to use TM4 band to determine vegetation density, TM3 band for leave covering, because this band presented an inverse relationship with the chlorophyll content. Likewise, these authors presented TM5 band and TM7 band as bands with information about dead biomass, and with a very clear and specific signal for the bare soils.

For the exposed previously, from all bands compositions carried out, the corresponding to False Color composition of RGB: 453 was chosen for the classification process for land cover since this presented a strong contrast between different land uses and coverings. On this band combination the samplings to separate the coverings of the study area were carried out. The classification of Mahalanobis and Maximum Likelihood methods were used in this process and it was determined that the best result of the classification carried out with Maximum Likelihood classification method, since it appears more compact.

16 coverings types of land cover as shown in Table-3.1 were separated for the classification and on the results of the same one cluster with minimum 1000 pixels were selected and each class was chosen in such a way that it was compound at least for five clusters. For each cluster of two-dimensional graphs by band were revised to verify that they were compact and they didn't cross with other coverings. There were some separation problems between greenhouse coverings, clouds and populated centers as well as between moor vegetation and the straw vegetation. However, these inconveniences during the non-supervised classification were overcome using field control points.

Table-3.1 Legend of land cover by the supervised classification

Bn:	Native Forest	Bp:	Cultured Forest
K:	Pits or mining exploitation areas	Cp:	Populated Centers
Ca:	Water bodies	Ct:	Transitory crops
Iv:	Greenhouses	Mr:	Scrub and bush vegetation
Mpc:	grass and crop matrix	Pj:	straw
PP:	Pasture and straw vegetation over erode soils	Pm:	cropped Grass
Sd:	Bare soil	Va:	Aquatic vegetation
Vp:	moor Vegetation.	Unclassified class	

On the other hand, during the classification process, the information from other LANDSAT TM and SPOT (1995) imagery was used to replace and/or to supplement the information in the pixels that were covered by clouds.

3.2 Field Verification

Based on the printout at 1:100.000 scale of band composition of RGB: 457, four ground truth were carried out to verify the coverings initial separation by using the classification of ERDAS data.

During the field verification the information was gathered for the initially outlined coverings by using a GPS with a precision of 9 meter. Considered with the minimum precision required to cartography at 1:100.000 scale is 50 m and GPS´s precision with 9 meter, it was guaranteed that the precision during the field verifications was within the standard precise for cartography works.

During the verification about 56 points in the fields were taken account into four different routes to be distributed as follow:

Route Not. 1 This route part from Fusagasuga to Girardot and returns to Bogotá through the road La Mesa Mosquera bordering la Cuchilla Peñas Blancas.

Route Not. 2 This route is through the road Via al llano, passing by Gacheta until Guayabetal in the creek Perdices.

Route Not. 3 Begin in the highway Carretera cental del norte goint until the crossing to Sesquile and from there part toward the Suesca lagoon to get out for Ubate, Zipaquirá, Tabio and Tenjo.

Route Not. 4 Begin in Siberia arriving to Villeta and Guaduas.
As it can be appreciated, these field trips were programmed in such a route that the control points not only to cover Bogotá plain but also to close regions to the classification area where allowed to have a regional control on the main geomorphologic type of structures.

3.3 Description of Final Classes

NATIVE FOREST: This corresponds to the native vegetation that has been little intervened. It is located in areas of difficult accessibility or in the protected area. The following picture presents vegetation of this class.

CULTURED OR PLANTED FOREST: This corresponds to areas of cultured forest composed by exotic species such as: gum, cypress and especially the patula pine.

PITS: It corresponds to areas of mining exploitation where materials for construction are extracted.

POPULATED CENTERS: It corresponds to the urban areas or human establishments and roads. Likewise small areas without vegetation that are beside the main roads are included in this class.

WATER BODIES: It corresponds to lagoons, reservoir, flood areas and rivers.

TRANSITORY CROPS: It corresponds to areas with potato, wheat, barley, beans and other cold weather cropping.

GREENHOUSE: It corresponds to areas with green house for flowers cropping.

BUSH: It corresponds to areas with small trees and scrubs on hillsides.

PASTURE AND SCRUB: It corresponds to areas where there are rotation of cropping and where there are lands for shepherding of bovine livestock; likewise, it includes very small areas with scrub, careless and/or planted forests.

STRAW: It corresponds to straws that grow up over eroded rocks, skeleton soils or soils very poor in nutrients.

STRAW AND PASTURES OVER EROSE SOILS: It mainly corresponds to grasses and straws over eroded soils due to mainly to solifluction of terraces. It is characterized about thin vegetation.

MANAGED PASTURE: It corresponds to land covered by well conserved by Kikuyo grass which is dedicated to the shepherding of bovine livestock for the production of milk .

BARE SOILS: It corresponds to the non vegetation areas where is not classified as populated centers. They are characterized because it presents regularly erosive processes such as gully erosion.

AQUATIC VEGETATION:It corresponds to macrophyte. This unit is presented in eutrophic reservoirs, wetlands and swamps.

MOOR VEGETATION: It corresponds to the coverings located above 3000 meter alt sea level with vegetation such as fraylejon, straw, and chusque, which are characterized that they are big water producers.

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3.4 Classification Results

Figure3.1 presents the results of the supervised classification carried out on the LANDSAT 7 imagery. As can be appreciated from this figure, land cover is mainly: pasture and crops matrix, scrub and bush, straw and urban areas which obviously has its maximum representation in Bogotá city.

From the land cover map it can be appreciated that the areas covered for native forests are minimal and where it had been replaced mostly by planted forests and by bush and scrub vegetation. Likewise it is appreciated that, there still exists specific areas with moor vegetation which it is indispensable for the production and protection of superficial waters sources toward all efforts for natural resources protection.

On the other hand, it pointed out that the aquatic vegetation of macrophyte class was basically represented by Muña Reservoir in spite of a water body. It is completely eutrophicated and its lens was covered by Buchón vegetation type. Although other water bodies (especially some lagoons) that were eutrophicated exist in Bogotá plain, they don't represent a cluster of big size and therefore they are mixed with other classes.
It was important that result of the classification was the discrimination of the greenhouses in spite of the spectral signature similar to bare soil and hidden area by clouds shades, was identified and differentiated with the help of field control points. This class was important since it could represent a reflection of the extensive use in these areas of groundwater for irrigation supply porpoise. The following is a summary of the histogram in each areas of land cover class shown in Table-3.2.

Table-3.2 Area of Each Discriminated Cover Class

CLASS	Pixels count	AREA (m2)
Native forest	187581	168822900
Cultured forest or forest plantations	19172	17254800
Scrub and bush	715626	644063400
High grass	461930	415737000
Grass	152212	136990800
Temporal crops	43852	39466800
Gras and crops matrix	613161	551844900
Grass, crops and scrub matrix	1251723	1126550700
Acuatic vegetation	7195	6475500
Moor vegetation	336842	303157800
Naked soil	272821	245538900
Pasture and high grass over naked soil	208915	188023500
Urban areas or populous center	333448	300103200
Greenhouse	79408	71467200
Water bodies	43995	39595500
Mining and opent pits.	387	348300

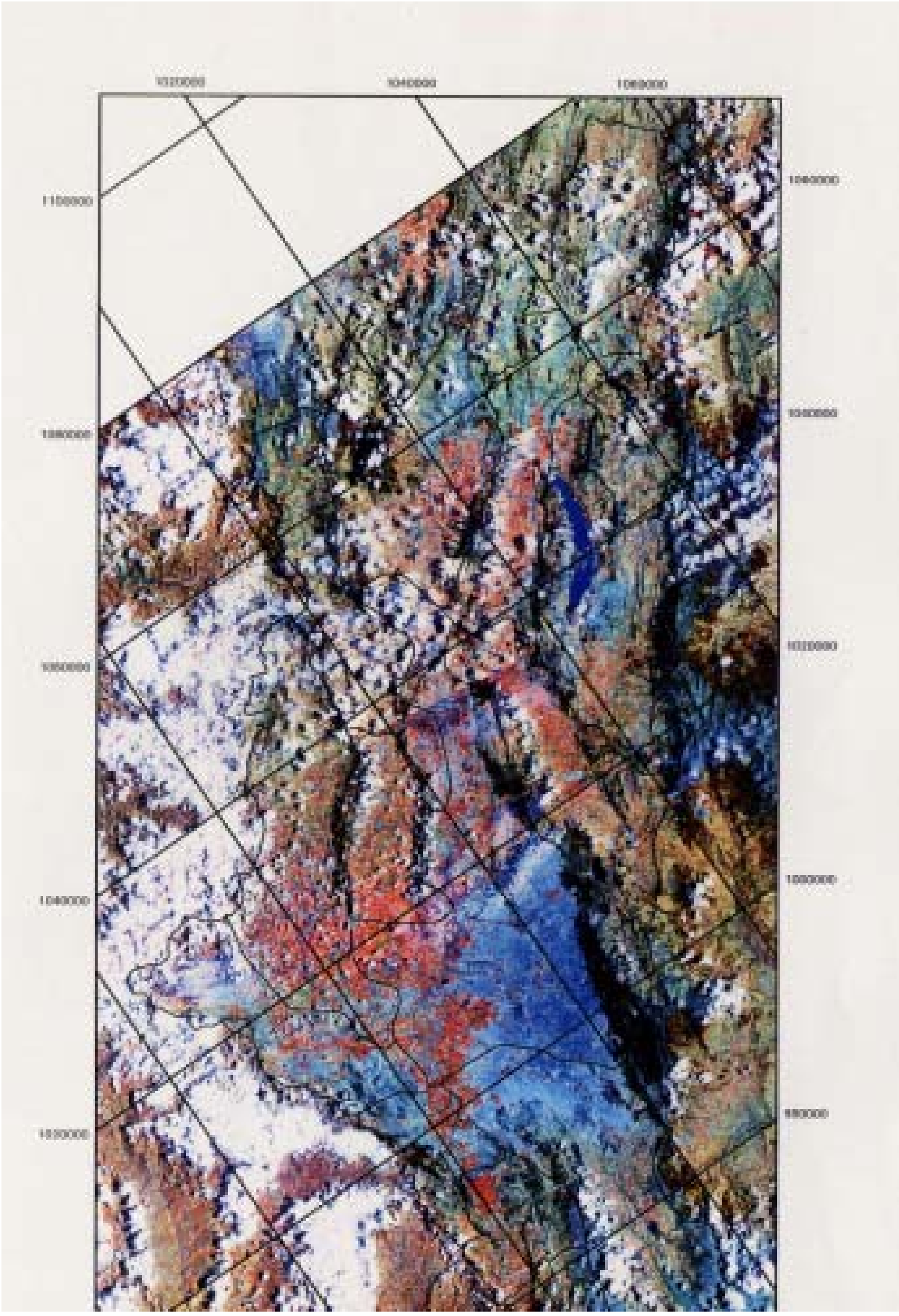

Figure-3.1 Band composition of RGB: 453

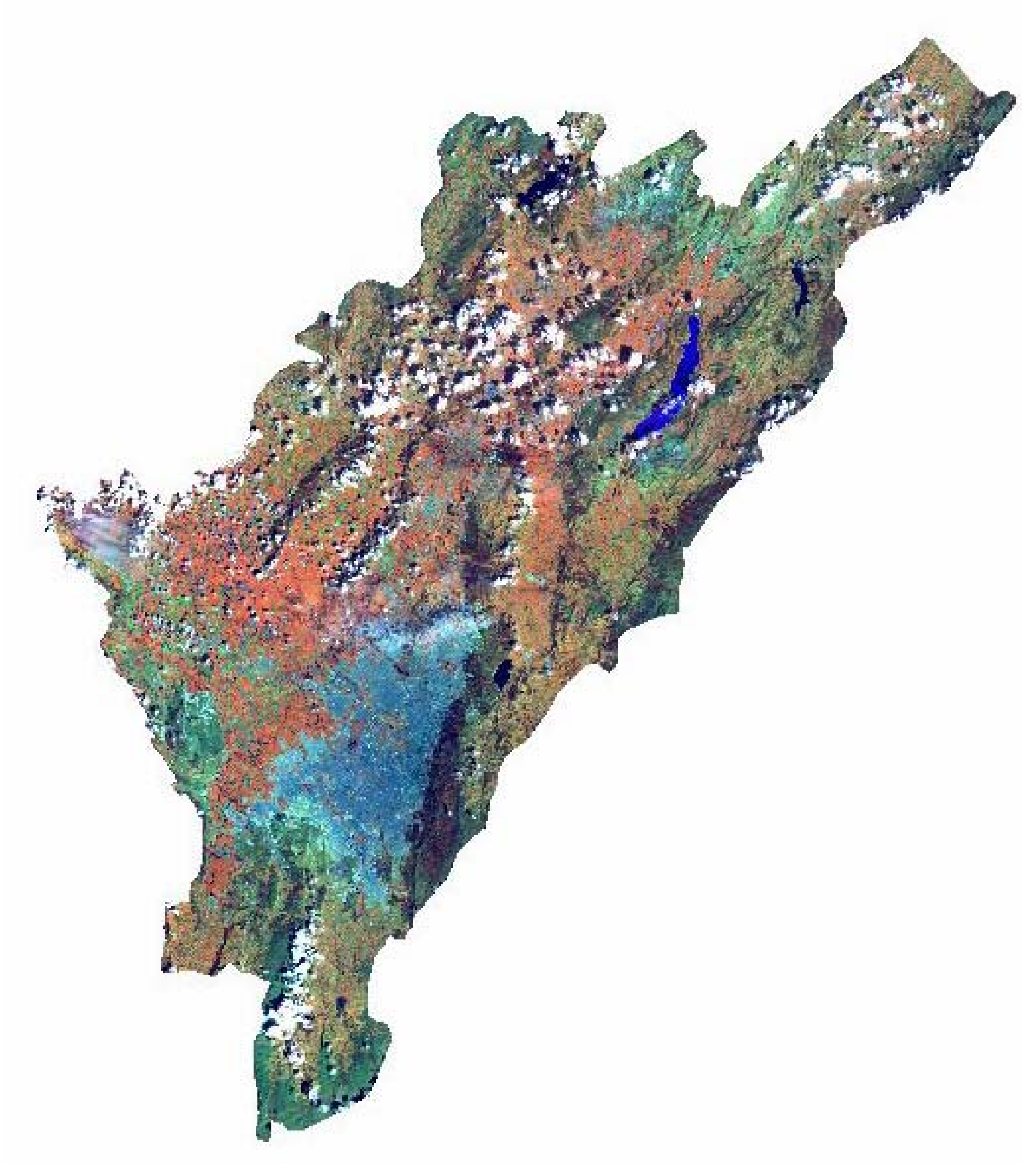

Figure-3.2 Band composition of RGB: 457

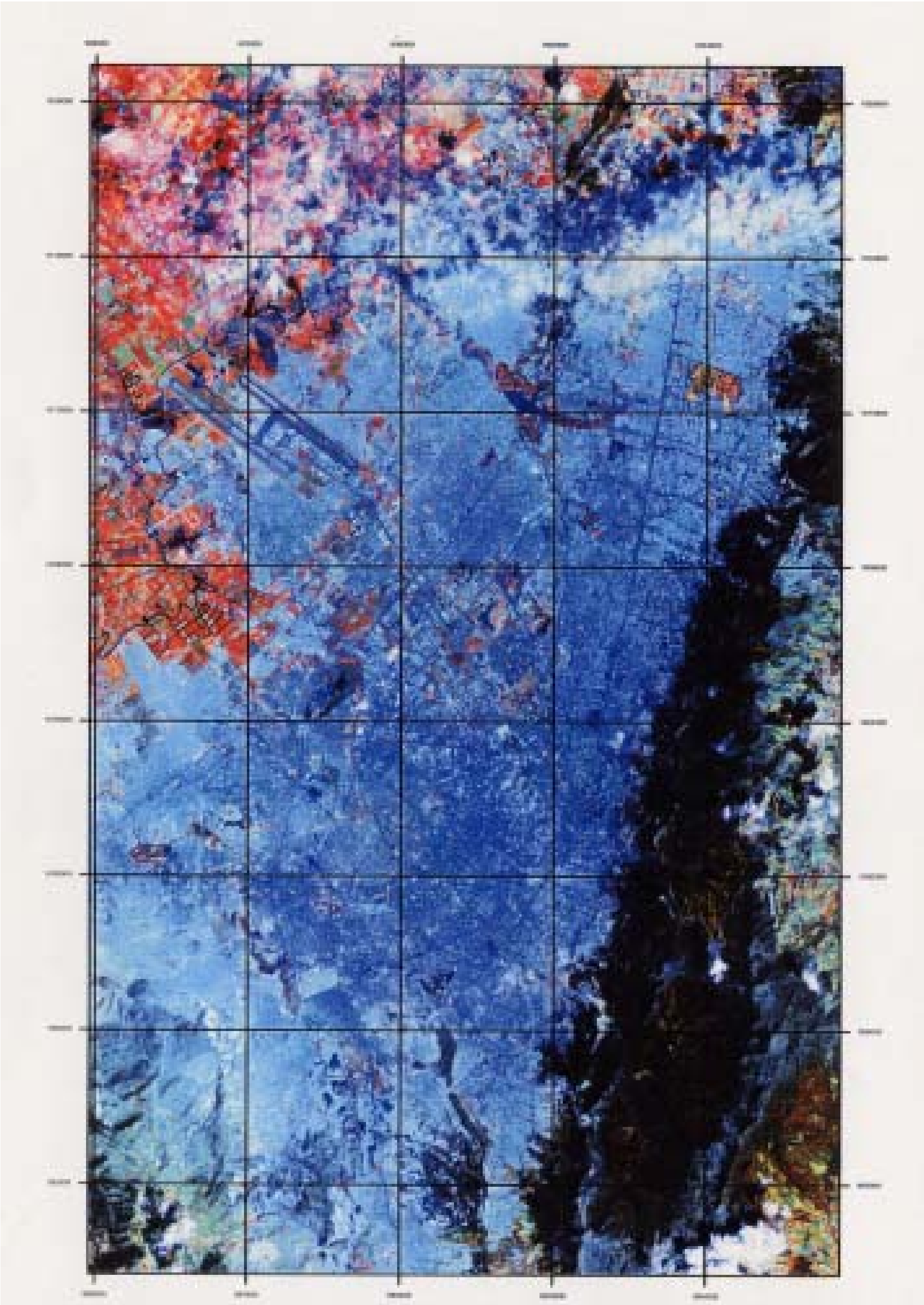

Figure-3.3   Zoom for Bogotá city of band composition of RGB: 453

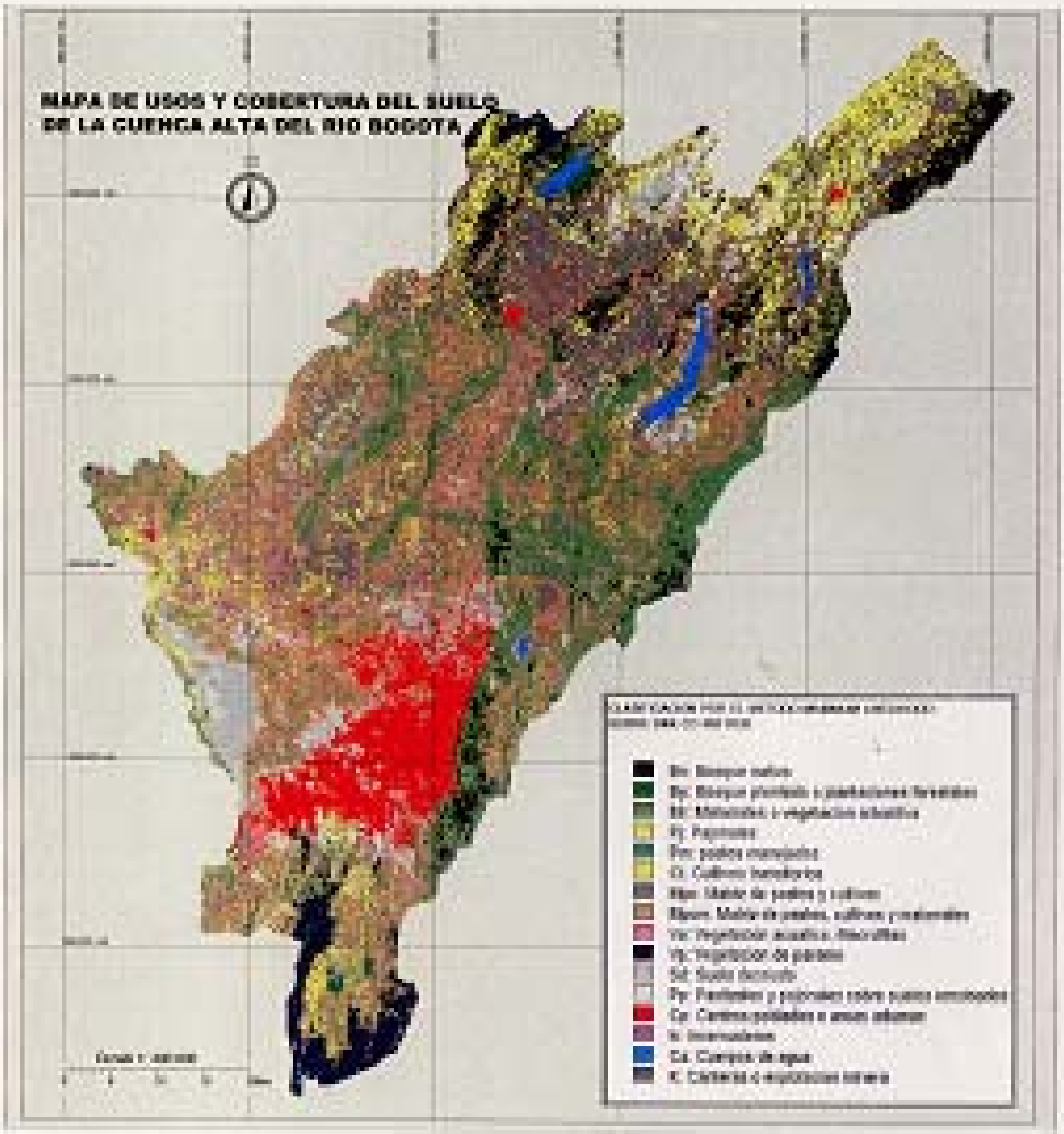

Figure-3.4 Land use image classification