REMOTE SENSING APPLIED TO FORESTRY: INPE'S EXPERIENCE

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ABSTRACT

The objective of this paper is to present INPE's
experience in the evaluation of vegetation using Remote
Sensing data. Significant results were obtained in the
following areas: 1) Natural Vegetation - characterization
of the different vegetation classes such as "cerrado",
"cerradão", "campo cerrado", forest, etc.;   2) Forest
Plantation - mapping of *Pinus spp* and *Eucalyptus spp* in
relation to the age and plant homogeneity (stand); 3)
Deforestation - monitoring of deforestation in the Amazon
Region. The paper also analyses and discusses the outlook
of a forest volume inventory multistage sampling technique
using Probability Proportional to Size (PPS).

INTRODUCTION

For a country of the size of Brazil (8.5 million km²), where 80% of the area has a low population density and for which there is little detailed information about natural resources, satellite remote sensing is particularly suitable for conducting rapid and relatively inexpensive surveys. INPE (Institute for Space Research) has developed a general methodology for the use of LANDSAT in a range of discipline including the survey of forest resources and mapping vegetation cover. This includes the examination of black and white LANDSAT images at scales ranging from 1 million to 1:250,000, with supporting interpretation of existing aerial photography,field survey and the application of other relevant information. The results were obtained in the areas of natural vegetation, forest plantations and deforestation.

NATURAL VEGETATION

For mapping the natural vegetation cover over an area of some 620,000 km², including Minas Gerais and Espírito Santo States (Nosseir et al., 1975), visual interpretation of black and white images of LANDSAT from spectral bands, at 1:1 million scale, were used. This was also the mapping scale. Five test areas were established, covering a range of terrain,ecological conditions and vegetation types. Ground survey was conducted on two of these and other available information used included aerial photography and vegetation and geomorphology maps. Applying climatic and other ecological stratification, thirteen classes of forest were mapped on phenological, edaphic and floristic criteria. These included broadleaved evergreen forest; semideciduous, mixed deciduous and deciduous forest;

.114.

swamp and gallery forest; forest dominated by palms; and mountain forest with and without Araucaria. Three classes of cerrado (open woodland with short trees and sharbs) were also mapped.

Another work dealt with the mapping of Cerrado vegetation in Central Brazil, occupying an area of approximately 1,500,000 km² (Santos et al., 1980). The landscape Cerrado is predominant over flat and gently ondulated terrain, which is suitable for agricultural mechanization, silviculture and grazing land uses. The study area is located on the "Planalto Central" in the Federal District (DF) - Brasília. This area was selected because of its geo-economic importance in the Cerrado region and principally owing to its localization in the core of the vegetation dominions. Based on visual interpretation, the following classes were defined: "cerrado", "cerradão", "campo cerrado" and "campo sujo de cerrado".

An investigation concerning vegetation mapping was carried out in the Mato Grosso area in relation to deforestation for the development of pastures (Santos and Novo, 1977). Visual interpretation of 1:1 million images of bands 5 and 7 were used to map vegetation cover, band 7 proving to be particularly useful for distinguishing edaphic types with different water regimes (riparian, periodically inundated). Data from existing maps and reports on the area were used, as well as from aerial and ground reconnaissance surveys. Dry season imagery proved to be useful for distinguishing between evergreen and deciduous vegetation. Dense, open and gallery forest were mapped, as well as "cerrado", grassland and floodplain vegetation over an area of some 70,000 km² at a scale of 1:1,250,000.

FOREST PLANTATIONS

Forest plantation studies using remote sensing techniques in Brazil began in 1976 in the Ribeirão Preto Agricultural Administration Division of São Paulo State (Hernandez Filho and Shimabukuro, 1978). A study area had approximately 35,000 km².

Eight training areas were selected to represent the various existent age and species groups. Based on visual and computer-aided analysis four reforestation classes were derived: Pinus elliottii (PE), Pinus taeda (PT), Eucalyptus from eight months to two years old (E1) and over two years (E2). The accuracy in visual interpretation was 87.79% for Pinus and 94.80% for Eucalyptus.

Hernandez Filho et al. (1978), reporting on a similar study over some 770,000 ha in the northeast of São Paulo State, found that more or less homogeneous plantation areas of more than 20 ha could be identified on 1:250,000 black and white images of band 5, partly by virtue of their linear boundaries, while separation of pine and eucalyptus was clearest on band 7. Multiseason imagery was stated to be helpful in locating plantation areas, presumably by reducing confusion with other vegetation when the latter was leafless.

Another investigation was carried out in the Mato Grosso do Sul State (Hernandez Filho et al., 1980). This study area is located between the cities of Campo Grande and Três Lagoas and corresponds to an extension of about 300,000 km². Information about farms with reforestation was obtained from IBGE (Brazilian Institute for Geography and Statistics) maps.

Six preliminary classes were defined according to their species and age groups (Table 1).

TABLE 1

PINUS AND EUCALYPTUS CLASSIFICATION: PRELIMINARY CLASSES

(MATO GROSSO DO SUL STATE)

CLASSES	AGE	CONDITION
Assigned Reforested Area	Eucalyptus < 4 months Pinus < 2 years	-
E1	8 months<Eucalyptus<1 year and 2 months	-
E2	1 year and 2 months<Eucalyptus<3 years	homogeneous
E3	1 year and 2 months<Eucalyptus<3 years	heterogeneous
E4	Eucalyptus > 3 years	-
Pinus	> 2 years	-

Due to the low leaf-area index, Pinus plantation with an age less than two years and Eucalyptus with less than four months were mapped as bare soil. After this initial classification three classes of reforestation were defined (Table 2).

TABLE 2

PINUS AND EUCALYPTUS CLASSIFICATION: FINAL CLASSES

(MATO GROSSO DO SUL STATE)

CLASSES	AGE
Assigned Reforested Area	Eucalyptus < 4 months Pinus < 2 years
Eucalyptus	Eucalyptus > 4 months
Pinus	Pinus > 2 years

DEFORESTATION

In 1978, a great controversy was created about the amount
of deforested area in the Amazon region (5 million km²). Then,
in order to clarify the situation, an agreement was established
between IBDF (Brazilian Institute for Forest Development) and
INPE, in order to verify to what extent (percentage) the Legal
Amazon was deforested. The area is cover by 234 scene centre
points, and the interpretation was carried out for the periods
from 1973 to 1975 and 1976 to 1978 (Tardin et al., 1980). The
results for each period were mapped by photographically
enlarging existing 1:1 million maps to 1:500,000 and using the
latter as a planimetric base for orienting the delimited areas
on the compilation film for each of the 26 map sheets produced.
The areas from the first period were drawn in outline and those
from the second period were shaded to obtain a graphic
representation of the progress or incidence of deforestation
over time. Areas of deforestation for the two periods were then
measured with a dot grid, which could also enable average rates
of the loss of the forest area to be calculated.

The results showed that during the period 1976/1978 the whole Legal Amazon deforestation reached a total of 7,717,175 hectares. As the Legal Amazon Region has 497,552,700 hectares, then the total deforested area corresponds to 1.55%.

MULTISTAGE FOREST INVENTORY

A study about forest inventory was carried out in 1982 (Lee et al., 1983). The objective of this study was to develop and evaluate a multistage sampling technique, with Probability Proportional to Size (PPS), for forest volume inventory using remote sensing data. The study area (12 x 12 km²) was located in the Southeastern Brazil. LANDSAT-4 digital data of September 11, 1982 of the study area were used in the first stage for automatic classification of reforested areas. Four classes of pine and eucalyptus with different tree volumes were classified utilizing a maximum likelihood classification algorithm. Color infrared aerial photographs (1:10,000) obtained in July, 1982 were utilized in the second stage of sampling. In the third stage (ground level) the timber volume of each class was determined. The total timber volume of each class was expanded by a statistical procedure taking into account all the three stages of sampling. This procedure resulted in an accurate timber volume estimate with a smaller number of aerial photographs and reduced time in field work.

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