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ABSTRACT

Two research projects were carried out to test the capability of LANDSAT data for pastureland and reforestation studies. The results obtained are 1) the degradation of pastureland after deforestation can be identified automatically using four indicators: the percentages of exposed soil, soil types, types of "juquira" and *Gramineae* species; 2) pine and eucalyptus can be identified manually and automatically. The classification accuracy of Image-100 is 94.31% for pine and ranges from 67.23% to 92.30% for eucalyptus.

1. INTRODUCTION

This paper presents two examples of the methodology developed in the Institute for Space Research (INPE) for the application of LANDSAT data in the survey of forest resources.

Two researches with different methodologies are presented separately: 1) the viability of using LANDSAT data to evaluate the degradation of pastureland after deforestation in the Amazon region (Pará State); 2) the utilization of LANDSAT data to evaluate reforested area in the State of Mato Grosso.

These two research projects were carried out with the cooperation of the National Superintendence for Amazonia Development (SUDAM) and Brazilian Institute for Forest Development (IBDF), and the methods developed are already in the final stage.

2. RESULTS AND METHODS

2.1 PASTURELAND PROJECT

To study the pasture degradation of the pastureland projects, the area of Paragominas (Pará State) was selected as the study area. This area was formerly covered by tropical rain forest and has been deforested since 1960 for the implementation of pastureland projects.

In the study area, the predominant *Gramineae* species is *Panicum* spp., which adapts better to fertile soil (Souto and Lucas, 1973). The pastureland *Panicum* spp. can produce green forage all the year round, under good management. However, the low soil fertility of the study area cannot sustain the *Panicum* spp. during dry season. Thus, eventually, the *Panicum* spp. can be substituted by other species.

"Juquira" (regrowth of native vegetation) or is extinguished, and left as exposed soil.

After deforestation, the soil fertility diminishes progressively. This causes a gradual invasion of unfavorable vegetations for cattle raising and a lowering of the *Gramineae* species in the area (Arnovich et al., 1973).

To evaluate the degradation of pastureland after deforestation, the relative percentage of invading vegetation, exposed soil and *Gramineae* species were used. The other alternative for evaluation was to verify the percentage of grass type which require less soil fertility and substitute *Panicum* spp. in the region (e. *Brachiaria* spp. and *Hiparrhenia* spp.) (Santos et al., 1979).

LANDSAT imagery (1:500,000 and 1:250,000) and CCT's of July, 1977 were used together with information of field trips for dry and rainy seasons. The field data collected were: time lapse after deforestation, management practice of pastureland, *Gramineae* species and their stages of degradation.

For automatic classification of pastureland, the algorithm - MAXVER, which is implemented by INPE, was used in IMAGE-100. This algorithm uses the "maximum likelihood criterion" to classify point by point LANDSAT MSS data (Velasco et al. 1978). The advantage of using this algorithm is that at each interactive stage a classification matrix showing the percentage of correct classification of sampled classes is presented. Based on these results, we can decide whether new class samples are necessary for satisfactory classification.

Four indicators of the degree of pasture degradation were established: 1) the percentage of exposed soil; 2) type and the percentage of "Juquira"; 3) the percentage of lateritic soil; and 4) *Gramineae* species and their percentage. Among the different situations of the eight pastureland projects, thirteen pasture classes were derived using different combinations of indicators (Santos et al., 1979). They were:

- a) tropical rain forest;
- b) arboreal "juquira": regrowth of tropical rain forest;
- c) herbaceous "juquira": regrowth of herbaceous vegetation on soil of low fertility and with greater duration after deforestation;
- d) partially exposed soil: this class is characterized by higher percentage of exposed soil with sparse *graminea* and "juquira";
- e) exposed soil;
- f) lateritic soil: this class is characterized by small proportion of "juquira" and the absence of *Panicum* spp., which is caused by the problem of high iron oxide content in the soil;
- g) pasture of *Panicum* spp.;
- h) pasture of *Panicum* and *Brachiaria* species: this class occurs in degraded pasture of *Panicum* spp. where the substitution of *Brachiaria* spp. is predominant;
- i) mixed pastures of *Panicum* and *Hiparrhenia* species with higher percentage of *Panicum* spp.
- j) pasture of *Panicum* spp. and "juquira": this class exists in humid areas where both species grow with similar vigor and no spatial distinction can be observed;
- k) pasture of *Panicum* spp. with less than 20% exposed soil;
- l) mixed pastures of *Pueraria* and *Panicum* species with higher percentage of *Pueraria* spp., and
- m) alluvion.

The automatic classification results that 54,995 ha. was deforested in 8 pastureland projects. The class "tropical rain forest" could be easily distinguished from the other classes with an error of classification less than 1%.

The spectral characteristics of the class "arboreal juquira" was overlapped

with that of the *Panicum* spp. pastureland of the humid areas. This can be explained by the fact that in humid areas, the *Panicum* spp. maintain green without the problems of water stress, thus gave a similar spectral response as arboreal "juquira". Other pasture classes were also confused with "arboreal juquira" but with less percentage of classification error.

The class "exposed soil" and "pasture of *Panicum* spp. with exposed soil" were also easily confused due to the same element - exposed soil in these two classes.

The classification results indicate that among the eight pastureland projects, *Panicum* spp. are commonly used as forage for cattle raising. Only one project used the mixtures of *Panicum/Pueraria* or *Panicum/Brachiaria* and another used *Panicum/Hiparrhenia*.

The association of *Pueraria* spp. with *Gramineae* spp. not only provides a higher resistance under dry conditions but also prevents the degradation of *Panicum* pastureland. For degraded *Panicum* pastureland, the *Panicum* spp. are substituted gradually by *Hiparrhenia* and *Brachiaria* spp.

The class of "herbaceous juquira" occurred in projects of more than five years. This is caused by the slash and burn process which lowers soil fertility and substitutes the arboreal species by herbaceous plants.

The class "partially exposed soil" occurred more frequently in projects of more than five years or those recently implanted which the artificial pastures are not totally germinated.

Lateritic soil is unfavorable for the germination of *Gramineae* species. The class "lateritic soil" was easily discriminated owing to the high iron content in the soil, which has a higher absorption in the near infrared region (Rowan, 1972), thus gives a darker tone of MSS channel 7.

According to the pasture quality, the eleven pasture classes (i.e., except tropical rain forest and alluvion) were combined in four groups:

- 1) "juquira" group - including both arboreal and herbaceous "juquira";
- 2) the group of exposed soil - including the classes of exposed soil and lateritic soil;
- 3) the group of pastures - including the classes of pastures *Panicum*, *Panicum/Brachiaria*, *Panicum/Hiparrhenia*, *Panicum/Pueraria*, *Panicum/Juquira*; and
- 4) the group of degraded pastures - including partially exposed soil and the pasture of the *Panicum*/partially exposed soil

The study results show that 45.57% of the deforested area (54,955 ha.) was implanted with pastureland. Also, 24.48% of the deforested area was classified as "juquira" group. This group is less suitable for pastureland project because a long slash and burn process has to be carried out until pasture can be planted. In fact, some unsuccessful pastureland projects were observed in field trips and the areas had been abandoned.

The group of degraded pastures represents 15.26% of the deforested area. To increase the carrying capacity of this group, better techniques and management should be applied.

The group of exposed soil represents 14.69% of the deforested area. For recuperation of these areas, a more sophisticated technique should be used. For the recuperation of lateritic soil class, the seeding of *Brachiaria* spp. is necessary.

The results indicated that using the four indicators: the percentages of exposed soil, the type of "juquira", lateritic soil and the *Gramineae* species, the degradation of pastureland can be evaluated automatically by IMAGE-100 using LANDSAT data.

2.2 REFORESTATION PROJECT

The purpose of this research project was to develop an efficient reforestation survey, using LANDSAT data. The State of Mato Grosso do Sul has the coordinates of 17°20'S - 23°00'S and 51°00'W - 58°10'W, was selected the study area and the reforestation is concentrated between the cities Grande and Três Lagoas.

LANDSAT imagery (1:1,000,000 and 1:250,000) taken from July to August with path/row numbers of 239/74, 239/75, 240/74, 240/75, 241/73, 241/74, and 241/76 were used for manual interpretation. CCT's of the same study were also used for automatic interpretation by IMAGE-100 system. Ground truth was provided by reforestation projects and cartographic maps of 1:100,000.

Four study stages were established to study this reforestation project: 1) preliminary manual interpretation, 2) field work, 3) final manual interpretation, and 4) automatic interpretation. Based on cartographic maps 1:100,000, limits of the reforestation farms were delineated and later transferred to the imagery of channels 5 and 7. These reforested farms were classified preliminarily according to their gray levels. Afterwards, a field trip was carried out to verify the interpretation key was established and classification legend defined for final interpretation.

For automatic classification, the area at the vicinity of Ribas do Pardo and Água Clara which has the highest concentration of reforestation was chosen for study. Five training areas were selected: Mutum farm of Itapeva, Transparaná farm of Transparaná, São Guilherme farm of Vale do Rio Grande, Mansa and Passagem Nova farms of Uniflora, and São Guilherme farm of Floresta Estância. Automatic classification was carried out using the scale 1:250,000 for Itapeva and Transparaná training areas; 1:110,000 for Uniflora training areas; and 1:100,000 for the Florestadora Estância and Rio Grande training areas.

The computer program "Tracing" and the limits obtained from manual interpretation were used to delineate the training areas on image monitor. The algorithm "MAXVER", using the information of four channels and with 256 levels, was applied for classification. The area of each identified class was calculated using the program "Theme areas" and the results presented in digital format.

To test the classification accuracy, a point by point alphanumeric print of a test area was used to compare with ground information and the indices were calculated:

$$PA \text{ (percentage of class density in the test area)} = \frac{NA}{NT}$$

$$Pa \text{ (percentage of correct classification)} = \frac{NC}{NA}$$

$$Pb \text{ (percentage of commission error)} = \frac{NE}{NT-NA}$$

where

NA = is the total number of points of class X in a test area;

NT = is the total number points of all classes in a test area;

NC = is the total number of points of class X which have been classified correctly; and

NE = is the total number of the points of non-X classes which have been erroneously classified as class X.

Based on manual interpretation, the following legend was established:

ADR = areas designated for reforestation with tree ages up to 8 months for *Eucalyptus spp.* and 2 years for *Pinus spp.*;

Channel Class	5	7
ADR	mottled white	light gray
EUCALYPTUS (EU)	mottled light grey to dark gray	medium gray
PINUS (PI)	very dark grey	medium gray

Using the interpretation key, the three classes were mapped and their areas calculated (Table II).

Table II. Comparison between Ground Information and Manual Interpretation Data

Class Area (ha.)	ADR	EU	PI	Total	Relative Difference
Ground Information	49,192.17	222,594.07	12,815.36	284,601.60	2.5
Manual Interpretation	48,827.50	229,532.00	13,593.00	291,952.50	

For automatic interpretation, five classes were separable:

- 1) eucalypt (EU1) = dense eucalypt plantation without exposed soil;
- 2) young eucalypt (EU2) = eucalypt plantation with partially exposed soil;
- 3) area in preparation for reforestation (AP);
- 4) deforested area (DA); and
- 5) "cerrado" (CE) = native vegetation.

Table III shows an example of the results of automatic interpretation of the Mutun farm of Itapeva.

Table III. Results of Automatic Interpretation
for Mutum Farm of Itapeva

Classes	Area (ha.)	Percentage
EU1	18,319.40	17.36
EU2	6,613.50	6.27
AP	8,084.60	7.67
DA	26,826.60	25.43
CE	44,604.00	42.27
NOT CLASSIFIED	1,091.80	1.03
TOTAL	105,539.90	100.00

The classification accuracy for this area is showed in Table IV.

Table IV. Classification Accuracy

Class	PA (%)	Pa (%)	Pb (%)
EU1	25.10	76.21	1.20
EU2	5.59	77.41	3.36

The percentages of correct classification for both classes, EU1 and EU2 are similar, however the class EU2 has a higher percentage of commission error. This was caused by the similarity of spectral characteristics of classes AP and DA to that of the young eucalypt.

3. CONCLUSIONS

The results of these two research projects conclude that LANDSAT data can be used to verify the pasture quality after deforestation and to classify pine and eucalyptus plantations.

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