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ABSTRACT

The purpose of this research is to evaluate the potential of digital data of LANDSAT-TM satellite different spectral bands for detecting areas covered by several genus of aquatic macrophytes in the Tucuruí Reservoir. Remote sensing is an adequate technique for studies developed in the Amazonian region, where the Tucuruí Reservoir is very large, its aquatic plants communities occupy extensive areas and are of difficult access. Thus, the management of this environment becomes possible, as for instance, monitoring hosts of endemic diseases, which live between the roots of aquatic vegetation. For this research, it was used an image of July 16th, 1989, and simultaneous observations were done in a field work to verify the occurrence and localization of floating aquatic plants in the Tucuruí Reservoir. Histograms acquired from spectral attributes in bands 2, 3, 4, 5 and 7 were analysed, as well as a vegetation index was done in areas of the reservoir which were occupied by different aquatic macrophytes. Spectral attributes in bands 2 and 7 were selected as those ones that offered better separability between areas occupied by genus Salvinia sp, Scirpus sp, Pistia sp and by several genus of aquatic plants. A supervised classification of the area was done. The spectral attribute in band 5 was added to the supervised classification in order to reduce the confusion between the targets nondense terrestrial vegetation and floating vegetation. Band 5 attribute separes better flooded from nonflooded areas, contributing additionally to distinguish areas with Scirpus sp from areas with Salvinia sp. The results of

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the supervised classification are presented on a map on the scale of 1:250.000.

1.0 INTRODUCTION

Artificial reservoirs interfer and change the environment causing impact on natural ecosystems. Human activities that occur around these reservoirs and the remaining terrestrial vegetation from flooded areas are responsible for the accelerated eutrophization processes in water. The eutrophization process brings as a consequence of the aquatic systems the increase of nitrates and phosphates availability, which benefits the growth of aquatic macrophytes.

The Tucuruí Reservoir, situated at the Tocantins river, Pará State, has 170km in length and an area of 2,430km^2 at its normal maximum height (72.0m). Remote sensing is an adequate technique for the studies realized in this region due to the vast extension of the study area, to the extensive aquatic vegetation coverage, as well as because it is an area of difficult access. Abdon and Meyer (1990) developed a methodology for detecting and mapping areas occupied by aquatic macrophytes in the Tucuruí Reservoir using data from the Landsat-5 satellite. The authors observed that in 1989 the areas occupied by aquatic macrophytes in the Tucuruí Reservoir corresponded nearly to 28.0% of the total inundated area.

Aquatic macrophytes reach their maximum development under special conditions, according to Esteves (1988), Mitchell (1969), and Holm et al. (1969), such as in shallow areas, which are protected of the winds, with small declivity, high residential time and high concentration of nutrients.

The identification of areas occupied by different species of aquatic macrophytes is of great importance for the management of aquatic environments. Through the growth control of this vegetation it is also possible to manage disease vectors associated with these plants. The uncontrolled development of some of these plants can considerably increase the number of transmitting individuals, so affecting a larger part of the human population living near these areas.

This work, which was realized with data from the Landsat-5 satellite about the Tucuruí Reservoir, distinguishes the areas covered by aquatic macrophyte genus - Salvinia sp, Scirpus sp and Pistia sp which, in July 1989, were predominant in the reservoir.

2.0 CHARACTERIZATION OF THE MOST COMMON AQUATIC MACROPHYTE GENUS AT THE TUCURUÍ RESERVOIR

Salvinia sp - It is an aquatic fern belonging to the Salviniaceae family. Its floating "leaves" are green, getting dark brown when, during certain period of time, air temperature reaches 40.0°C (Junk and Howard-Williams, 1984). The leave's upper surface is covered by a series of hairs which confers it impermeability and higher sun radiation reflection (Vickery, 1984). It is native from tropical regions of Central and South America, that, under favourable conditions, have an extremely fast vegetative growth (Aston, 1973). It is found as shelter and transport for mollusks, intermediate hosts of Schistosoma mansoni, vector of schistosomiasis and serve as host of mosquitoes'larvae of Mansonia sp, main vector of filariasis (Pancho and Soerjani, 1978).

Scirpus sp - It is a perenial aquatic herb that belongs to the Ciperaceae family. Each plant is composed of aerial erected leaves, that are dark green, while young, and yellow from the top to the bottom, when older. It reaches about 1.0m height (Correll and Correll, 1975). It has a pronounced vegetative growth, favouring its occurrence on extensive water surfaces.

Pistia sp - It is an aquatic floating herb from the Araceae family. The leaves are green, 3.0cm to 15.0cm long and nearly 8.0cm wide; they are spongeous and covered by hairs. It has a little propagation through seeds, but its vegetative growth is significative (Silva, 1981). It is used as host for several species of mosquitoes'larvae vectors of encephalomyelitis and filariasis (Holm et al., 1969).

3.0 MATERIAL

A Landsat-5 satellite image, 224 orbit, 63 point, obtained in bands 2,3,4,5 and 7, from TM sensor, corresponding to spectral intervals of 0.52μm to 0.60μm, 0.63μm to 0.69μm, 0.76μm to 0.90μm, 1.55μm to 1.75μm and 2.01μm to 2.35μm is used. This image was taken on the July 16th, 1989, coinciding with the dry season in the study area.

4.0 METHODOLOGY AND RESULTS

4.1 RECONNAISSANCE OF THE STUDY AREA

A field work was carried out in the Tucuruí Reservoir in July 1989 to verify the occurrence of aquatic vegetation. The visited areas were occupied mostly by Salvinia sp, Scirpus sp and Pistia sp.

Salvinia sp was found building homogeneous mats at the bottom of sheltered regions in the Tucuruí Reservoir. At the time of field work, vegetation was densely grouped and leaves were mostly brown.

Scirpus sp was observed colonizing mats of Salvinia sp, forming vast heterogenous groupings varying in density and predominance of plants. According to Junk and Howard-Williams (1984) and Mitchell (1968), Salvinia sp works as a substratum for nonfloating aquatic species. Salvinia sp and Scirpus sp are the two genus with larger occurrence in the Tucuruí Reservoir.

Pistia sp was observed composing homogeneous vegetation mats, as well as being associated with Salvinia sp. During the field work, these plants showed vigorous leaves of a strong bright green with herbivory signs.

Besides the aquatic macrophytes genus previously mentioned it was noticed some other genus with smaller occurrence like Eichhornia sp, Utricularia sp and Ludwigia sp taking part in floating mats. However, the occurrence of these genus is not significant for their detection by the Landsat-5 satellite. It was observed the presence, in smaller number, of Typha sp and plants from Gramineae family along shallow reservoirs margins. These regions could not be evaluated through satellite images, because their vegetation was being confused with surrounding terrestrial vegetation.

4.2 AREAS LOCALIZATION ON THE IMAGE

During the field work realized in the Tucuruí Reservoir, areas with different characteristics, caused by the presence of aquatic macrophyte vegetation, were observed. These areas were localized on the Landsat-5 satellite image, obtained on July 16th, 1989, and can be seen in figure 1.

4.3 HISTOGRAMS ACQUISITION

Histograms were obtained from images of bands 2,3,4,5 and 7 of areas observed in the field work, as well as in other areas covered by aquatic macrophytes in the Tucuruí Reservoir, where there were no access condition. These areas can also be seen in figure 1.

Histograms at the spectral attribute "Vegetation Index of the Normalized Difference", elaborated according to Gallo and Daughtry (1987), were also obtained. This "Vegetation Index" image was used by Abdon and Meyer (1990) for the identification of aquatic macrophytes in the Tucuruí Reservoir.

Histograms provided the lowest, highest and peak values for grey levels at the representative mode of each area occupied by the different genus of aquatic macrophytes, as is exemplyfied in table 1.

Table 1. Lowest (I), Heighs (III) and Peak Value (II) Acquired From Histograms From Areas Occupied by Different Aquatic Macrophytes

SAMPLE NUMBER	GREY LEVEL VALUE	BAND 2	BAND 3	BAND 4	BAND 5	BAND 7	VEG INDEX
2	I	17	15	22	23	2	157
	III	17.6	17.6	27.1	28.3	6.7	171.9
	II	20	21	34	37	7	184
10	I	21	23	43	38	7	173
	III	23.1	25.5	45.7	40.2	11.4	183.5
	II	25	30	50	51	15	192
11	I	23	24	70	62	12	209
	III	23.2	24.5	74.1	66.9	16.9	212.6
	II	27	27	87	95	19	221
18	I	29	27	67	33	7	187
	III	39.8	36.2	82.9	41.8	9.1	196.6
	II	46	43	95	51	13	207

4.4 SPECTRAL BEHAVIOUR ANALYSIS OF SELECTED AREAS

The spectral behaviour analysis of sampled areas of the reservoir was based on graphics elaborated using grey level values versus spectral intervals corresponding to Landsat-5 satellite bands. One example can be examined in figure 2, done only with peak values of modes acquired for four areas differently occupied by aquatic macrophytes.

It can be noticed that some groupings composed mostly by Salvinia sp (area 2) reflect a little more radiation at wavelenght intervals of 0.76μm to 1.75μm. While Salvinia sp mats are being occupied by Scirpus sp (area 10), the reflected radiation at intervals of 0.76μm to 1.75μm increases significantly, reaching its maximum when the aquatic macrophyte grouping is nearly totally composed of Scirpus sp (area 11). The spectral behaviour curve of Pistia sp shows a peak of reflected radiation at intervals of 0.76μm and 0.90μm, decreasing markedly towards higher wavelength (area 18).

4.5 SUPERVISED CLASSIFICATION OF THE STUDY AREA

The selection of spectral intervals for better separability of aquatic macrophyte genus was done through a comparative analysis between occupied areas.

Spectral attributes in bands 2,5 and 7 for classifying the study area through the MAXVER program - maximum likelihood - (Mather, 1987) were used. Seven themes were differentiated as follows:

a) area occupied mostly by Salvinia sp;

b) area occupied mostly by Scirpus sp;

c) areas with by Salvinia sp and Scirpus sp mixed;

d) areas occupied mostly by Pistia sp;

e) Amazon forest;

f) water;

g) altered forest.

On table 2, data related to the classification matrix and obtained through the process described above can be observed.

Table 2. Classification Matrix

Themes	N	1	2	3	4	5	6	7
1 Salvinia sp	2.8	94.4	0.0	0.0	0.0	2.8	0.0	0.0
2 Scirpus sp	1.2	0.0	94.0	0.6	0.0	0.0	0.0	4.2
3 Mixture	0.0	0.0	0.0	98.1	0.0	1.9	0.0	0.0
4 Pistia sp	3.3	0.0	0.7	0.0	96.0	0.0	0.0	0.0
5 Forest	1.2	6.5	0.4	2.2	0.0	89.3	0.0	0.5
6 Water	2.8	0.0	0.0	0.0	0.0	0.0	97.2	0.0
7 Altered vegetation	2.4	0.0	5.8	0.0	0.0	1.1	0.0	90.8

Mean performance = 94.54

Mean abstention = 1.34

Mean confusion = 4.12

N = percentage of samples not included in a theme

The thematic map acquired through the classification algorithm can be seen in figure 3.

5.0 CONCLUSIONS

The set of bands 2 and 7 from Landsat-5 was selected as the most adequate for separing areas occupied by Salvinia sp, Scirpus sp, Pistia sp and the mixture of Salvinia sp and Scirpus sp. At spectral intervals 0.52μm to 0.60μm, the areas with Salvinia sp and Pistia sp were well-distinguished, but areas with Scirpus sp and a mixture of Scirpus sp and Salvinia sp were similar to this spectral interval. Areas of Salvinia sp and Scirpus sp were well-distinguished at the spectral interval 2.08μm to 2.35μm, but areas with Pistia sp and with the mixture of Salvinia sp and Scirpus sp showed no differentiation.

Certain similarity between the spectral response presented by the terrestrial less dense vegetation and aquatic macrophytes were observed. To the confusion between these targets, band 5 (spectral interval from 1.55μm to 1.75μm) was added to the selected bands set, which offers better separability between flooded and nonflooded environments, besides contributing to the differentiation between areas covered by Salvinia sp and Scirpus sp.

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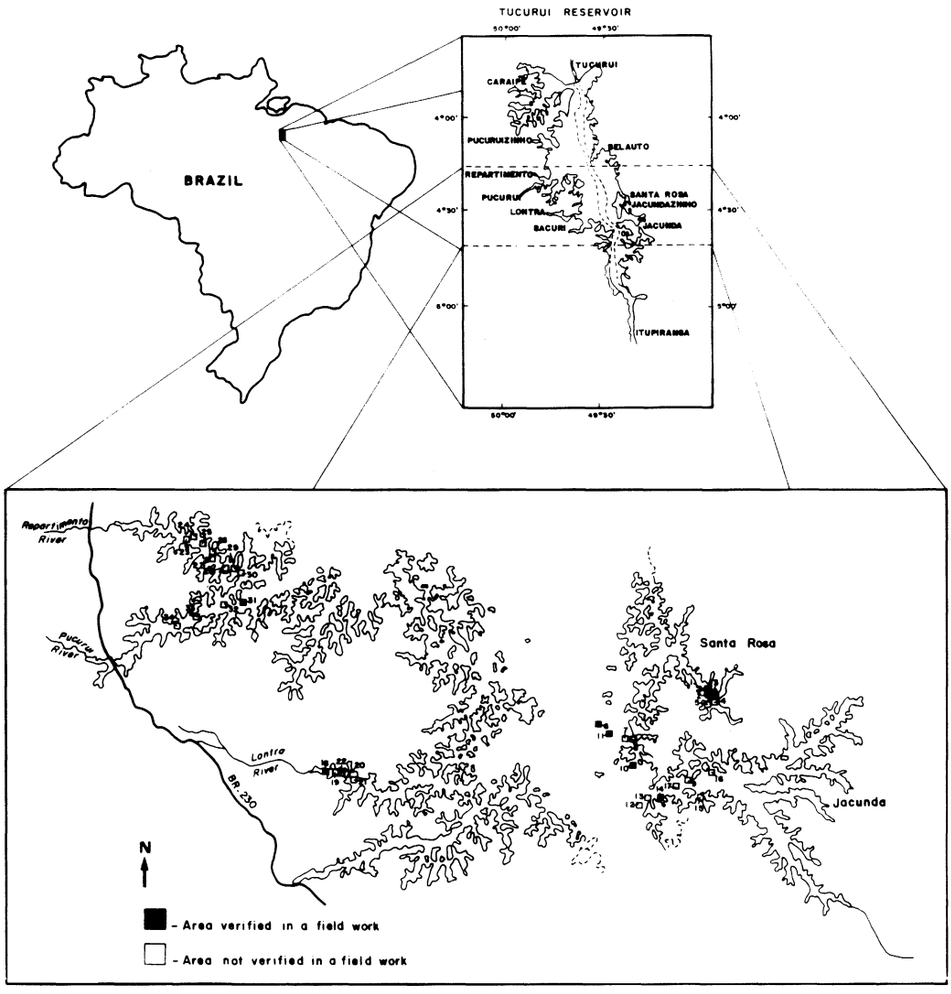

Figure 1. Aquatic Macrophyte Areas Studied Through Digital Data From Landsat - 5

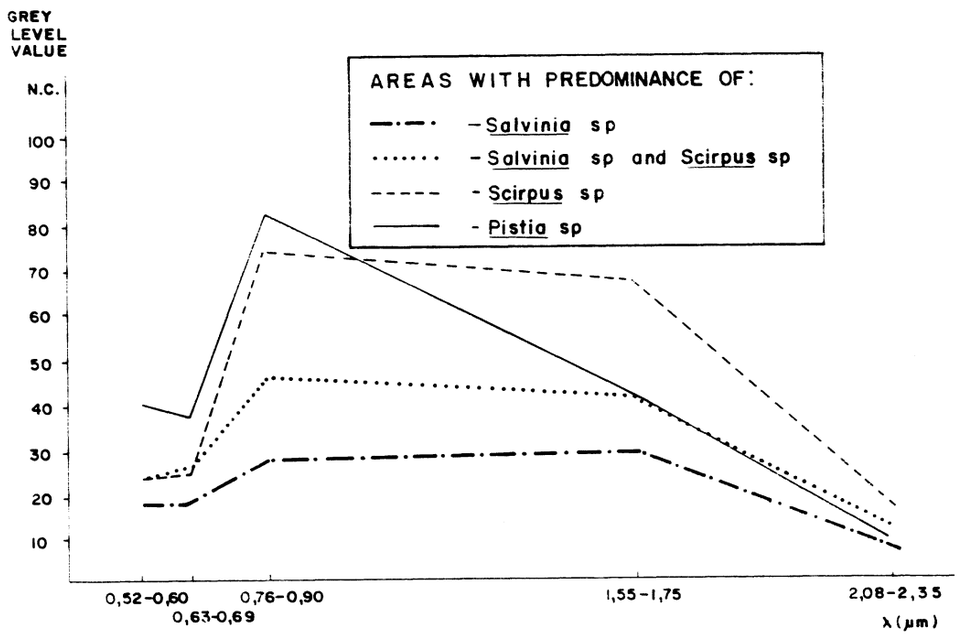

Figure 2. Spectral Behaviour From Some Studied Areas

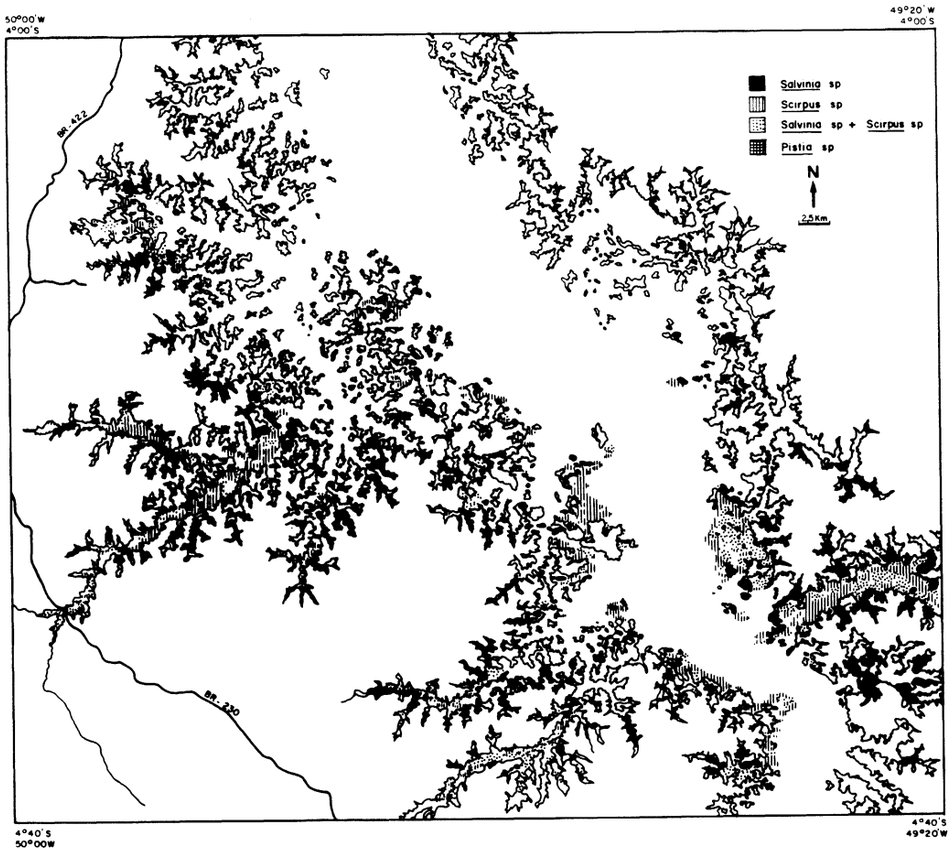

Figure 3. Areas Occupied By Different Aquatic Macrophytes In Tucurui Reservoir