A STUDY OF THE CAMPOS SUGAR-CANE MICROREGION

Cart. Eng./Geog. Eliane ALVES DA SILVA
IBGE - Instituto Brasileiro de Geografia e Estatística - Degeo - Departamento de Estu dos Geográficos

ABSTRACT

These results are part of a Master of Science Dissertation named "Remote Sensing Applications: a Study of the Microrregiào Açucareira de Campos", in the State of Rio de Janeiro, located in the Southeastern Region of Brazil. Said study was developed by Remote Sensing, being tested the Digital Analysis of LANDSAT images relevant to the studied area where sugar-cane crops are irrigated.

Initially, it was performed a visual analysis of images that was transmitted to the Brazilian ground station by the LANDSAT MSS satellite, during the period 1973-1982. Such procedure is part of the methodology that leads to the further Digital Analysis, through the Image-100 Multispectral Analyser of the "Instituto de Pesquisas Espaciais - INPE", located in São José dos Campos - São Paulo.

The research comprised: field work, consultation of sugar-cane production data statistics, analysis and interpretation of maps, charts, aerial photographs and satellite images, giving a chance to select two areas distinguished by the fact that they offer significant spatial expression as far as the sugar-cane cultivation is concerned, even though of distinct geomorphological aspects. We are talking about the Lowland and the Tableland, where two areas of 225 sq. km each one were selected and automatically analysed.

The LANDSAT Data Digital Analysis, has produced a high percentage of positive results (over 90,4 %) on average, either in the Lowland or in the Tableland, through the classification of eight categories, as follows: coming, ripe and cut down sugar-cane, pasture, forest, swamp, bodies of water and constructed areas.

The inclusion of the category "body of water" changed significantly the classification performance of the area in the Lowland where its presence is remarkable (a number of irrigation channels and very flat terrains). The use of specific programs to filter the influence of the water is therefore recommended for irrigated areas. In the Tableland area such phenomenon did not occur.

We should also emphasize the detection of serious injuries to the environmental conditions with reflexes over the local community as the innumerable lagoons, channels and rivers have been submitted to pollution attacks caused by the "Vinhoto" (sub-product of the alcohol destilleries) and the natural silting up produced by the Paraíba do Sul river in the deltaic mouth that needs to be dragged in order to avoid flooding that damage so much the sugar-cane crops and where the area studied is located. These aspects have been seen in field work as well as in photointerpretation and visual analysis of images. On the other hand, this problem is even more serious when it is artificially caused as a consequence of man-made fills aiming to enlarge the area to be planted, as happens, for instance, at the Feia Lagoon. The Digital Analysis has evidenced this ecological occurrence by the difference of color tones between the rivers and the lagoons.

It is recommendable to study the sugar-cane using this technique as it offers an excellent spectral response, thanks to its biological characteristics, being suggested that it be studied in its different stages of cultivation, in the 1:50,000 scale.

The Digital Analysis was further extended to the entire Microregion offering good results for forest and bodies of water (over 90 %) only. The results for sugar-cane level were low (under 65 %). The fact of enlarging the study area resulted in encompassing many types of landforms.

The reported technique is proper for the study of sugar-cane, particularly in flat terrains where the percentage of positive results is considerably high in Lowland as well as in Tableland.

Introduction

This chapter contains the results of the analysis made through photointerpretation, visual analysis and image digital analysis.

Results of the analysis and the interpretation of the aerial photographs

The adoption of the aerial photographs, in the scale of 1:15,000, have proportioned (presented) the knowledge of the large area, named "Zona Açucareira de Campos" - Campos Sugar-Cane Region. Some aspects like the sugar-cane refineries and their sugar-cane plantations, with different growing states, which are crossed by the irrigation channels, were clearly observed in the vertical photos. The aerial photographs have showed also clearly the homogenous features of the area, providing evidence of the sugar-cane plantations, confirming the idea of the sugar-cane domination; It means to say that sugar-cane is the "law", in the Campos Circuit, where the agricultural and industrial activities counteract mutually with landscape, economy and politics. The specialized character of sugar-cane plantation and its production (refined sugar and alcohol) gives the special panel if compared with other sugar-cane regions in Brazil (São Paulo - Southeast, Zona da mata Nordestina - Northeast). The city of Campos is in the middle of the sugar-cane crops.

The different aspects of the landscape were observed, adding information to the survey that have included field-work, image analysis, maps and plans, qualifying the geographic investigation for the purpose of digital analysis.

The "Fluminense" sugar-cane study area have shown the transformation occured in this region. It should be mentioned the city of Campos development, the

expansion of the sugar-cane area, the rivers silting up, and mainly what occured in the lagoons and the pollution that can be observed comparing the photos with the maps and plans (PLANALSUCAR/IAA) (1), FIBGE (2), as well as the MSS/LANDSAT satellite images, with the results of field and statistical (3) data. The photos added some information or explanation about questions in critical areas noted in the images. Besides that, the photointerpretation and the plans in large scales are showed as parameters to evaluate the Digital Analysis.

The possibility of working with aerial photos and images taken at the same date, contributed to extract information free of errors, because there were, for example, places recently filled up with earth that became pasture land or sugar-cane crop areas.

Following are the photointerpretation results:

The photointerpretation survey permitted the observation of areas close to the city of Campos, formely dedicated to the sugar-cane plantation, that are nowadays divided in two parcels or lots (4), or occupied with new residential blocks where modern houses can be seen. This fact is an indication of the urban area development and the king of present spatial occupation.

This analysis showed the features that could be interpreted as prepared soils for planting sugar-cane, in fields located near the sugar-cane refinery, but in reality there were areas where embankments have been done, for selling the land. The field work along the BR-356 road (5) could detect the existence of modern summer houses.

The photointerpretation and image survey shows the direction of the Campos city growth; that is larger in the East-West direction on the side at the Paraíba do Sul river, where the sugar-cane crops have been eradicated.

The sugar-cane crops have lost areas close to the urban area and have gained other position in the swamp and lagoons. It is suggested to observe the maps 1, 2 and 3 in the scales 1:15,000 and 1:500,000, which present the situation of land use in the Microregion "Açuareira de Campos" (Campos Sugarland) in the years 1973 and 1982.

The photointerpretation reaffirmed the character of highest degree of spatial homogeneity, shown by the sugar-cane plantation in the "Fluminense" landscape. Manioc, orange, pineapple and rice were cultivated at lands situated on the periphery (mainly at the East side of the sugar-cane culvitaded areas), generally where there were poor soil conditions. These crops were planted in small scale production. When these crops appear in the interior of the sugar-cane plantations, we can see that they are orchards in the yards, as well as associated crops with sugar-cane, like corn, but they are not expressive in the cultivated land.

It is obvious that there is spatial competition between the sugar-cane planted areas and the manioc crops (as the specific case of São João da Barra County), the pasture lands, the swamps and the lagoons, during the last years. The Alcohol Project "Projeto Pró-Álcool" had the responsibility to increase the alcohol production in this region, by constructing modern distilleries, close to sugar refineries, reason why the sugar-cane plantation has enlarged. Such expansion has been possible because the Government is practising irrigation and drainage. The consequence of it is the recuperation of soils, where they applied fertilizers also, when it was needed.

The examination of maps (1973 and 1982) showed, for example, the enlarged area with sugar-cane and the lagoons silting up, the Feia Lagoon being the most serious case.

The stereoscopic observation of the photos of Feia Lagoon has shown, in the northwest portion, the former limit (considering the FIBGE Chart - 1968); the result of this study appears in the map (fig. 3), in 1:15,000 scale, which has been compiled from image data too. This old lagoon border is clear in the aerial photos; we can see gray tonalities medium and clear, which correspond to the soil full of curves that indicates deposition in the place filled up with earth ("aterrados") that has become pasture land. The old little island, located inside the Feia Lagoon, is also observed in the Landsat/MSS satellite image dated 1973, but did not exist anymore in the image of 1975, when this part was finally filled up. The Ururai river, here named Jesus river (in the upper birth), has a channel enlarged into the Feia Lagoon.

The serious problems caused by the "aterrados", in the Microregion has extinguished the swamp and their typical vegetation, for example. They modified the configuration of the lagoons (Feia, Campelo, Jacaré). Their water-mirrors were reduced. The filling work in the area of the Dissertation has permitted perceiving the real environmental problems, which implicate the sugar- cane development (and its correlated activities : sugar and alcohol production). The "vinhoto" also causes pollution in the waters, killing fishes, at once.

There are no good environmental conditions in that area and the SAI (Sugar-cane and Alcohol Institute), has produced some alternatives for the destination of all sugar and alcohol residuals.

Results of landsat/MSS satellite images visual analysis

The sequential image study, during nine years, from 1973 to 1982, shows the following results :

— It was possible to study the sugar-cane crops in its different stages of cultivation, ripe sugar-cane, coming sugar-cane and cut down sugar-cane, and outline the large sugar-cane area in the images.

— The city of Campos development, that has been verified by comparing old maps and aerial photos, could be accompanied by images. The urban expansion is happening mainly in the East - West direction, at the Paraíba do Sul right margin. The city of Campos presents two gray lines in the East : the first one coming along the RJ - 216 road (6), where small villages, far from Campos are joining the urban area that is coming over

(1) PLANALSUCAR/IAA - Sugar-cane program/Alcohol and Sugar-cane Institute.
(2) FIBGE - Brazilian Institute of Geography and Statistics.
(3) These data are produced by Sondotécnica.
(4) Lots, Brazilian word "loteamento".
(5) BR - Federal road in Brazil.
(6) RJ - Rio de Janeiro State road.

CAMPOS
SUGAR-CANE MICROREGION
LAND USE

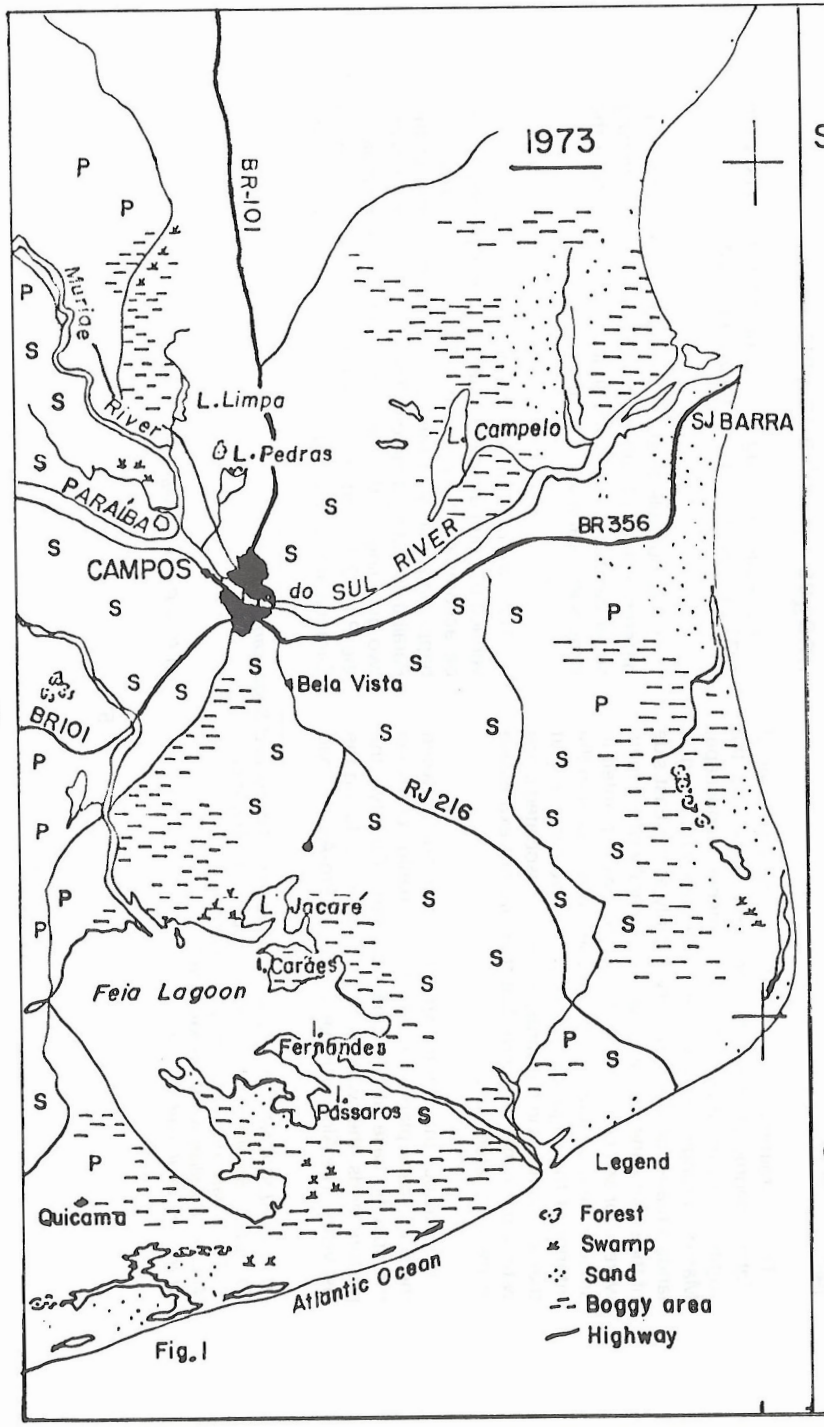


Fig. 1

Conformal Conic Projection-Scale 1:500.000.
Cart Bas. IBGE/DNER/MSS LANDSAT/IAA.
Cart Eng. Eliane Alves da Silva.

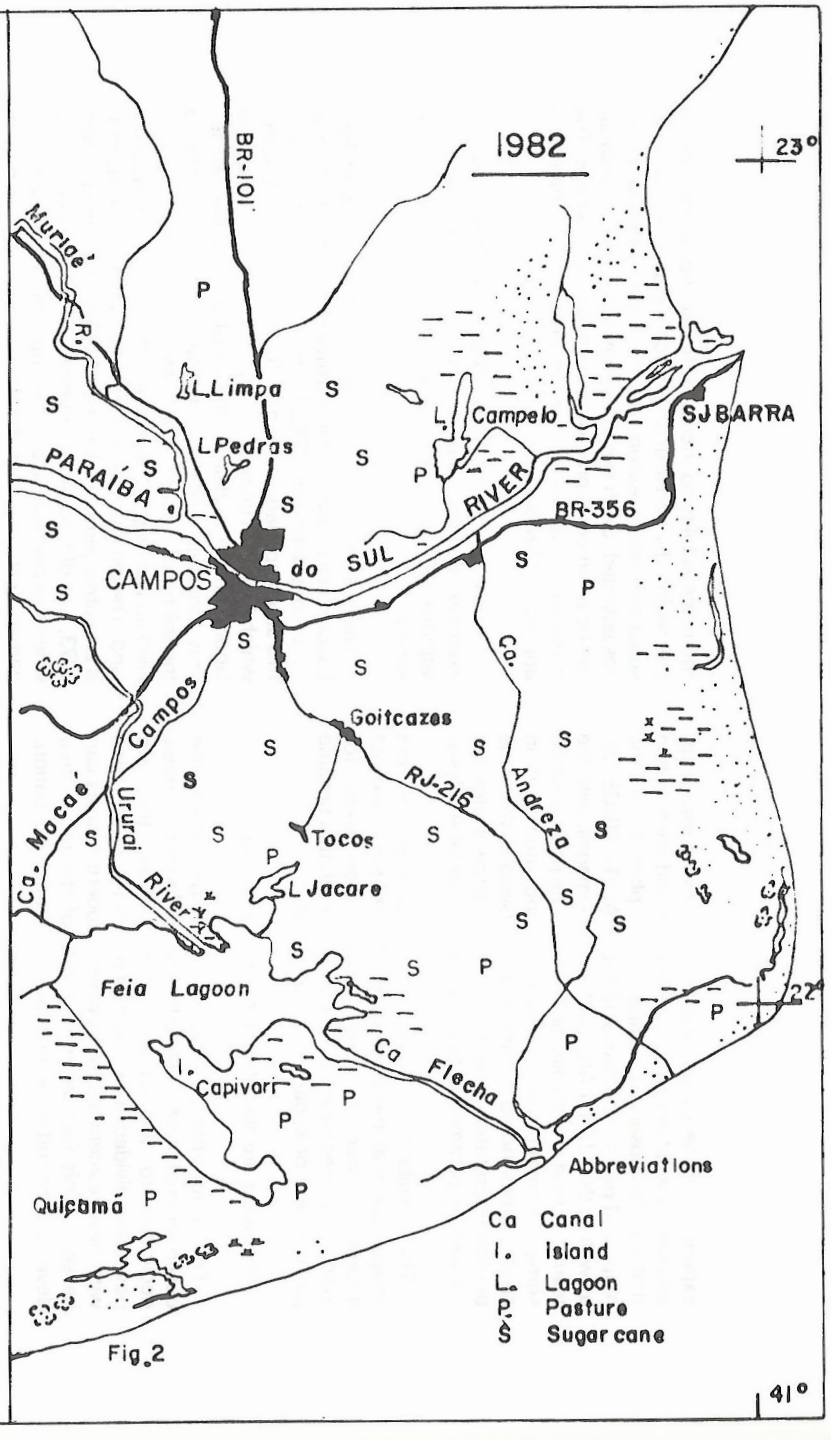


Fig. 2

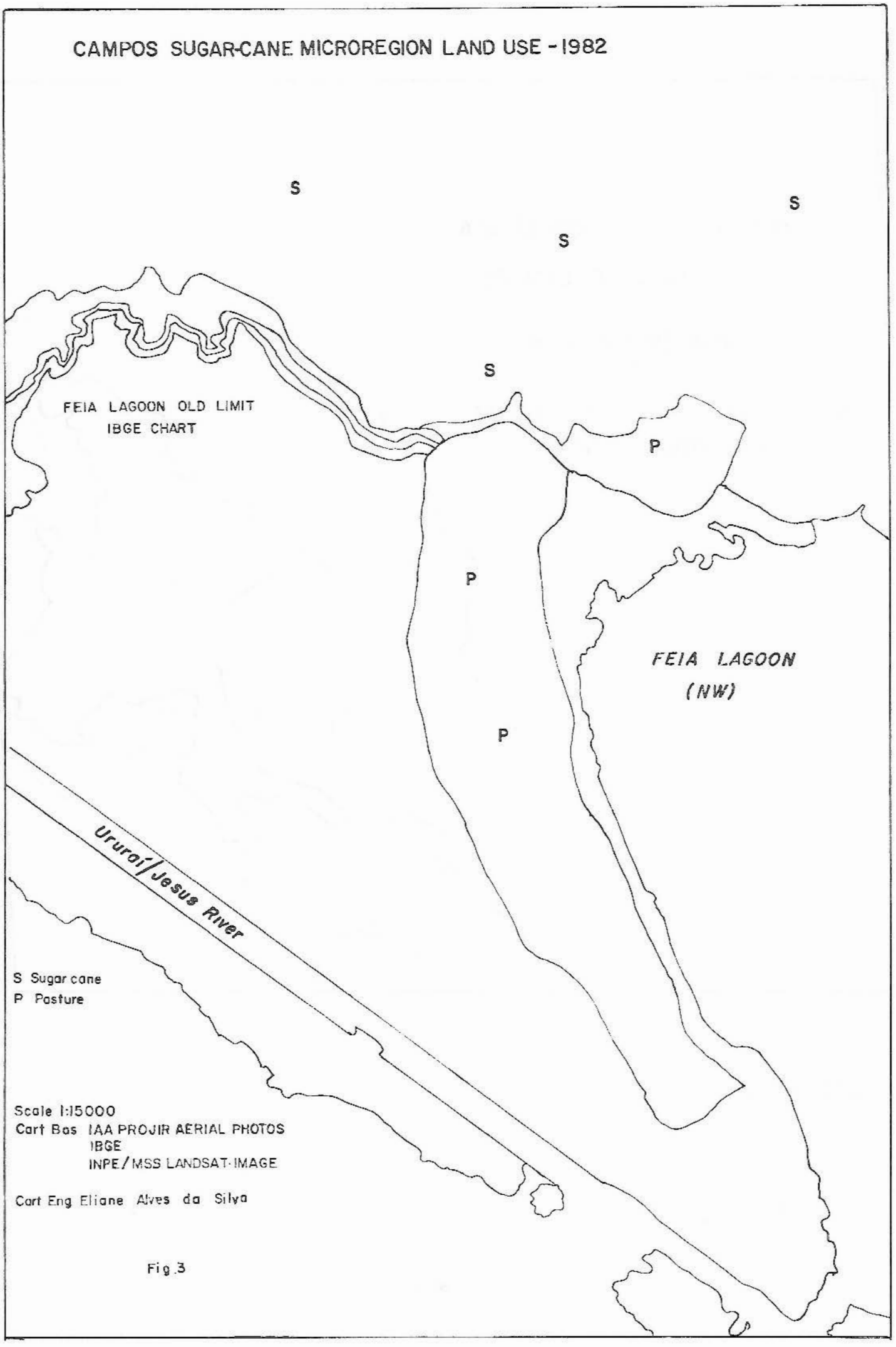
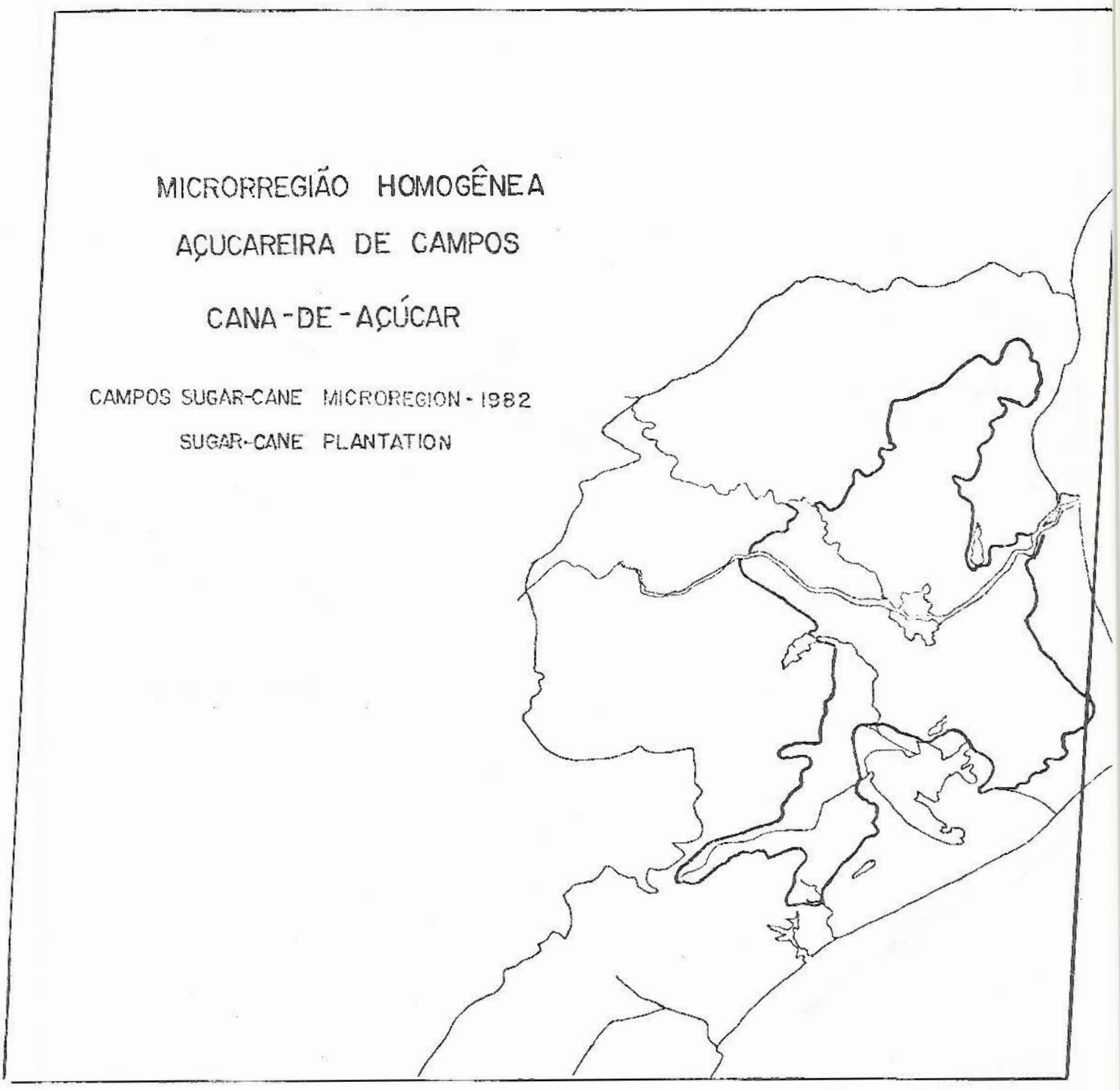

CAMPOS SUGAR-CANE MICROREGION LAND USE - 1982
S
S
S
S
FEIA LAGOON OLD LIMIT
IBGE CHART
P
P
P
FEIA LAGOON
(NW)
Ururaí/Jesus River
S Sugar cane
P Pasture
Scale 1:15000
Cart Bas IAA PROJIR AERIAL PHOTOS
IBGE
INPE/MSS LANDSAT-IMAGE
Cart Eng Eliane Alves da Silva

Fig.3



MSS/LANDSAT IMAGE
SCALE 1:1000.000

CART. ENG. ELIANE A da SILVA

Figure 4

the sugar-cane cultivation areas. A discontinuous area that could be seen between the urban area of Campos and Bela Vista (a small village), 1973, did not exist in 1982, nine years later.

— The rivers and lagoons filled up are a very serious problem, the largest occurs in the Feia Lagoon, see the maps presented. Some aspects, have already been mentioned above, however in view of the various images analysed, it is necessary to consider the filling up phenomena, firstly in the North and secondly in the East.

— The Jacaré Lagoon was so reduced, and the swamp around it is today becoming pasture lands, which appear in medium gray in the MSS band 5. The North position of the Feia Lagoon is a natural extension of the clay lowland, with fertile soils for the sugar-cane plantation. After the drainage work it became pasture land followed by sugar-cane crops. Where the soils are recently filled up they show a clear gray tonality, present on the images.

— This analysis also showed the great filling up in the East (Feia Lagoon), following the general tendency in the Microregion. The filling up process is growing fast. In 1976 (MSS images), the Islands : "dos Fernandes", "da Lama", "da Samambaia", "do Capivari" and "dos Pássaros", that appear in The Land Use Map (1973), and in the images (1973/1975), nowadays are filled up. They practise cattle breeding. Such activity is going down in the Lowland and growing in this area. The land filled up at the Jacaré Lagoon coming from the Flecha Channel (the only Feia Lagoon water escape to the Atlantic Ocean), with swamps, were replaced by the sugar-cane plantation.

— The west side of the Feia Lagoon, where the soils are poor, the filling up process is very small, it can be considered as normal. On the other side of the Paraíba do Sul river (left margin), the drainage work, runs into the Muriaé river and Campelo lagoon (also filled up) ; it gave the possibility for the sugar-cane and pastureland expansion, following the same tendency as in the Lowland. In the very beginning men filled the lagoon with earth, after building a drainage structure ; then the boggy area was changed into pasture land and years later in to cultivated areas. The Pedras and Limpa lagoons are keeping its original features, even though the swamp is taking place in the North portion of them. Some of the lagoons reach are covered by it.

— The images visual analysis gave support to the Digital Analysis and has proportioned the selection of those dated 01/08/1982 (the most recent images). Many phenomena, that occur in the Campos Sugar-Cane Microregion could be examined. It proves the special quality of the images revealed by its time capacity for spatial survey. The research could detect the area evolution and the spatial transformations.

Landsat/MSS images digital analysis results

First of all, it should be observed that fig.5 shows the selected area of the image, that was analysed digitally.

Eight classes were selected for the present interpretation : ripe sugar-cane, coming sucar-cane, cut down sugar-cane, pasture, forest, constructed area, swamp and body of water. In the digital analysis was included, in the swamp category, the areas subject to floods, without vegetation. These classes are the maximum limit that the Image-100 System can perform in one turn. The researcher could have used more categories, but she prefered these because they have more significance for the studied area. The MAXVER Classification can classify up to sixteen categories per iteration.

Results of the interpretation for each area digitally analysed are presented bellow :

— Lowland Region (Southweast of Campos City)

Categories	Number of selected points
1 - Ripe sugar-cane	73
2 - Coming Sugar-cane	144
3 - Cut Down sugar-cane	108
4 - Pasture	144
5 - Forest	116
6 - Constructed area	108
7 - Swamp	108
8 - Body of water	56

The points were selected considering the occurrence of each category. The coming sugar-cane, for example, presented smaller extension than the other categories of sugar-cane crops ; that is why it was necessary to introduce more points in the I-100. The bodies of water (rivers, lagoons, lakes) were so clear and neat in the video.

The Campos area morphological characteristics, with fluviomarine origin where are many irrigation channels, rivers, swamps and lagoons, suggested the researcher to produce two matrices of classification. One with the eight classes and the other without the body of water, in order to test the performance of the MAXVER Classification program, in irrigated areas. This digitally analysed area appears in Figure 6.

In accordance with the first classification matrix, we have :

TABLE 1

THRESHOLD = 5,0	N	1	2	3	4	5	6	7
1 - Ripe sugar-cane	0,0	77,8	0,0	22,2	0,0	0,0	0,0	0,0
2 - Coming sugar-cane	2,3	0,0	97,7	0,0	0,0	0,0	0,0	0,0
3 - Cut down sugar-cane	0,0	0,0	0,0	100,0	0,0	0,0	0,0	0,0
4 - Pasture	0,0	2,8	0,0	0,0	91,7	4,6	0,0	0,9
5 - Forest	0,0	0,0	0,0	5,2	3,4	89,7	0,0	1,7
6 - Constructed area	0,0	0,0	5,6	0,0	0,0	0,0	94,4	0,0
7 - Swamp	0,0	0,0	0,0	0,0	0,0	13,0	0,0	87,0

Average of Performance - AP = 93,3 %
Average of Abstention - AA = 0,6 %
Average of Confusion - AC = 6,1 %

It may be observed that, among all the categories, was the cut down sugar-cane the one that offered the best performance, with approximately 100 %. It means that all cut down sugar - cane selected points were correctly sampled. The other kinds of sugar-cane were also well classified, reason why the average of confusion was so small.

About 97,7 % of coming sugar-cane were correctly classified ; only 2,3 % were not classified as shown in column N.

The worst performance in this matrix was obtained for the ripe sugar-cane plantation, which presents spectral reflectance response similar to pasture. It happened also with digital analysis of sugar-cane crops in the State of Sao Paulo (Mendon ça 1980), using the maximum likelihood too.

Much disseminated swamp areas in this region are responsible for the confusion with forested areas because there are a large number of swamps with vegetation near the pasture areas.

The forest category is the variable of least expression in the surface Region, due to the primary coverage of deforestation during the last century ; positive results were obtained at the rate of 89,7 %.

The constructed areas also offered good results (94,4 %) but led to a little confusion with coming sugar-cane (about 5,6 %). This result has a special significance as the sugar-cane crops are shown as a green coverage, like a carpet. In spite of being in areas mostly covered with sugar-cane plantation, when the constructed area classification started, at once the urban areas appeared well delineated in this category, the boundary of the Campos City being the best example.

The pastures present some confusion with forest (4,6 %), ripe sugar-cane (2,8 %) and swamp (0,9 %) because it was summertime, that is our dry season, and most of the pasture areas keep water in Lowland.

Now, the researcher presents the results obtained in the Lowland Region, with the Digital Analysis including the body of water category, which brings less performance than observed with the first results (table 1).

It is really interesting to mention in this matrix the low performance in the case of bodies of water category where only 50 % of the selected points was actually classified. The other bodies (21,4 %) were classified as swamp as well as with cut down sugar-cane (19,6 %), and finally with pasture lands (mainly where recent fill-up work has been made).

This aspect shows the great importance, in this research, of considering the irrigation practice and the physical characteristics of the Campos Region. In future surveys it is recommendable to make use of the SINGLE-CELL program (in the MSS-7), to filter the body of water influence during the MAXVER Classification.

It could be observed at the end of this iteractive operation, which presents few changes in general, but gave evidence of particular problems into the sugar-cane region, cultivated on Tableland (only) without irrigation, studied by the MAXVER Classification too.

TABLE 2

THRESHOLD	N	1	2	3	4	5	6	7	8
Ripe sugar-cane	0,0	83,3	0,0	0,0	16,7	0,0	0,0	0,0	0,0
Coming sugar-cane	0,0	0,0	97,2	0,0	0,0	0,0	2,1	0,0	0,7
Cut down sugar-cane	0,0	0,0	0,0	83,3	1,9	0,0	0,0	0,0	14,8
Pasture	0,0	4,2	0,0	1,4	89,6	0,0	0,0	0,7	4,2
Forest	0,0	0,0	0,0	0,0	8,6	79,3	0,0	1,7	10,3
Constructed area	0,0	0,0	3,7	0,0	0,0	0,0	93,5	0,0	2,8
Swamp	0,0	0,0	0,0	0,0	13,0	13,0	0,0	82,4	4,6
Body of water	0,0	0,0	0,0	19,6	8,9	0,0	21,4	21,4	50,0

Average of Performance - AP = 85,2 %
Average of Abstention - AA = 0,0 %
Average of Confusion - AC = 14,8 %

The inclusion of the body of water category occurred after the research to study the region and climatic characteristics and the irrigation process, a matter of great concern for the sugar-cane crops.

Taking all categories of sugar-cane into consideration, where the MAXVER presented a performance of approximately 92 % it fell down to 83,3 %. Confusion was made with body of water (14,8 %) and pasture (1,9 %).

Most of the bodies of water are caused by the large number of irrigation channels and boggy areas caused by the rainfalls.

The ripe sugar-cane had a better performance than in the other matrix ; on the other hand, the coming sugar-cane kept its very good results. The first category of sugar-cane was victim of a little confusion with the second, because, when the harvest time comes, some areas have stubble fields.

The constructed areas as well as the pastures have maintained their percentage, both with some confusion with sugar - cane plantation.

The swamps are always well classified, although they present some confusion with forest and body of water. This fact is explained by occurrence near the rivers, lagoons and irrigation channels.

Tabele region located Northwest of campos city

The same procedure was adopted in the Northwest (Figures 7 and 8), as much as the Southwest, in regard to the selection of points, with the expansion of the body water class, because the researcher wanted to know what would be its influence on the Digital Analysis, in comparison with the formely observed (see table 3).

Categories	Number of selections points
1 - Ripe sugar-cane	144
2 - Coming sugar-cane	72
3 - Cut down sugar-cane	72
4 - Pasture	108
5 - Forest	144
6 - Constructed area	136
7 - Swamp	72
8 - Body of water	252

TABLE 3

THRESHOLD	N	1	2	3	4	5	6	7	8
1 - Ripe sugar-cane	0,0	89,6	0,0	5,6	0,0	0,0	0,0	4,9	0,0
2 - Coming sugar-cane	0,0	0,0	93,1	0,0	0,0	0,0	6,9	0,0	0,0
3 - Cut down sugar-cane	0,0	16,7	0,0	83,3	0,0	0,0	0,0	0,0	0,0
4 - Pasture	0,0	0,0	0,0	0,0	89,8	0,0	0,9	0,0	9,3
5 - Forest	0,0	1,4	0,0	0,0	0,0	90,3	0,0	4,9	3,5
6 - Constructed area	5,9	0,0	0,0	0,0	0,0	0,0	94,1	0,0	0,0
7 - Swamp	0,0	9,7	0,0	0,0	0,0	1,4	0,0	89,9	0,0
8 - Body of water	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	100,0

Average of Performance - AP = 92,7 %
Average of Abstention - AA = 0,8 %
Average of Confusion - AM = 6,5 %

The coming sugar-cane presented better performance than the other kind of sugar-cane, made some confusion with constructed areas. Still speaking of sugar-cane,

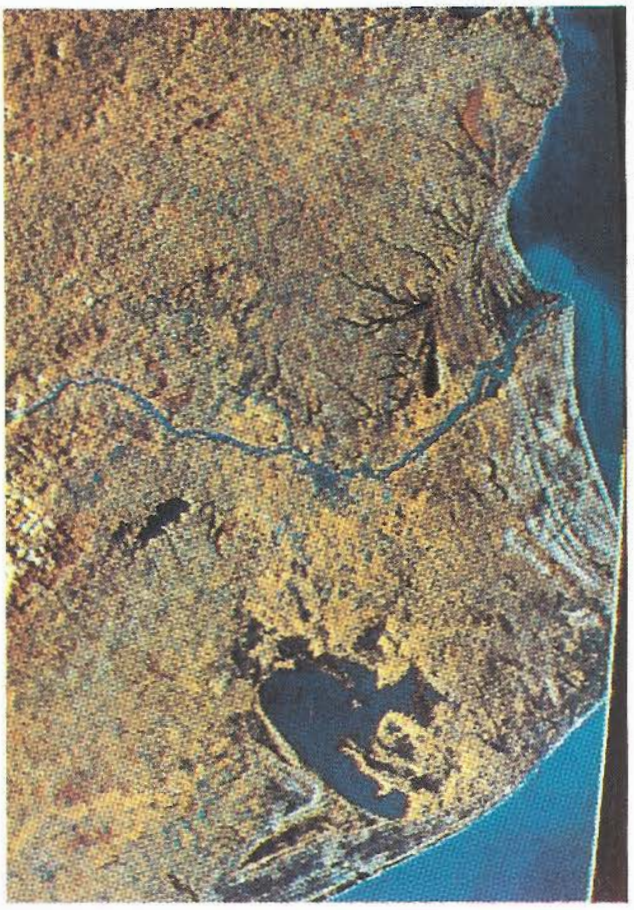
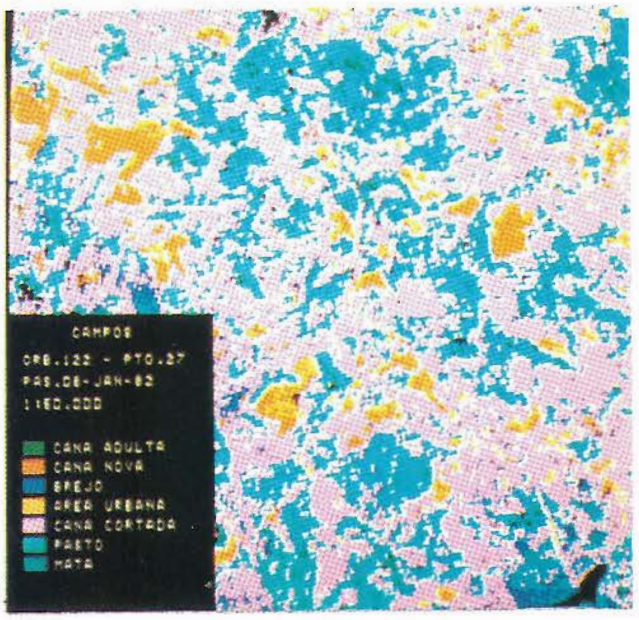


Fig 5. This is the LANDSAT/MSS/INPE satellite image. It is a part of the scene 01/08/1982. Here we have the sugar-cane in yellow tonality close to the Paraiba do Sul river and all the way to Feia Lagoon. This area was digitally analysed.



Note : Translation of photo-legend

1 _ Ripe sugar-cane
2 _ Coming sugar-cane
3 _ Swamp
4 _ Constructed area
5 _ Cut down sugar-cane
6 _ Pasture
7 _ Forest

Fig 6 . This is the Southwest Campos area (Lowland) digitally analysed . The black portion (above) shows the Jacaré Lagoon (North).

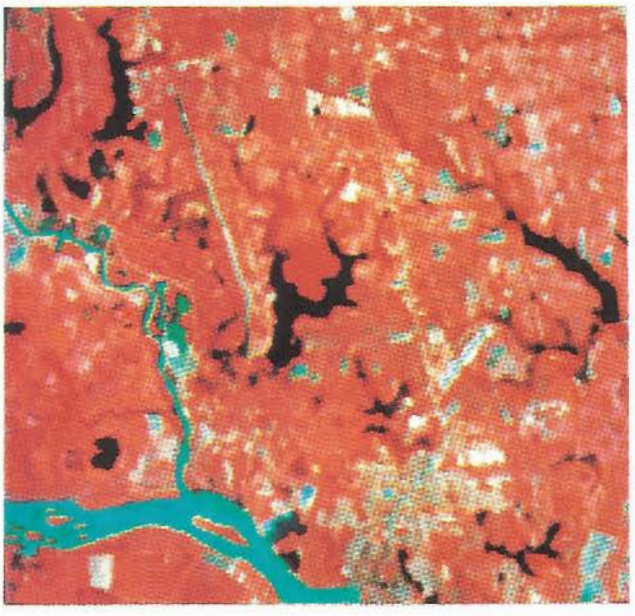


Fig 7 . This is the Tableland Region image

Ripe sugar-cane
Coming sugar-cane
Cut down sugar-cane
Constructed area
Swamp
Pasture
Forest
Body of Water

Fig 8 . The same image digitally analysed.

the cut down crops furnished worse results (83,3 %) than the other classes. They have the same spectral signature of ripe sugar-cane ; the reason for this fact seems to be what happened in the Southwest area.

The constructed areas, the pasture lands and the forests kept the former results ; their respective confusions were considered normal.

The body of water category offered the best performance (100,0 % in Tableland) in opposition to what happened in the Lowland. The inclusion or not of the body of water category did not exercise power over the MAXVER Classification. This surface has different relief soil conditions and its hydrography is not so complex as in the south portion, although this area presents lagoons and swamps.

Campos sugar-cane Microregion

The MAXVER Classification, applied to the Campos Microregion, shows different results, at once. This time, the researcher used the same computer tape used in the Tableland as it contained samples of the Microregion previously classified. The Performance was increased from 61,0 % to 80,4 % by introducing other samples (see Table 4).

TABLE 4

THRESHOLD = 5,0	N	1	2	3	4	5	6	7	8
1 - Ripe sugar-cane	0,0	51,3	11,8	4,3	32,9	0,0	1,3	1,3	1,4
2 - Coming sugar-cane	0,0	10,0	40,0	6,2	11,3	1,2	28,8	2,5	0,0
3 - Cut down sugar-cane	0,0	9,5	11,9	65,5	4,8	0,0	2,4	6,0	0,0
4 - Pasture	0,0	22,7	11,4	1,5	59,8	0,8	8,0	3,0	0,0
5 - Forest	0,6	0,6	0,6	0,6	1,7	90,0	0,0	5,1	0,0
6 - Constructed area	1,7	2,5	19,2	5,8	0,0	0,0	70,0	0,8	0,0
7 - Swamp	0,0	1,4	2,1	2,8	9,0	4,2	0,7	78,5	1,4
8 Bodies of water	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,9	98,1

Average of Performance - AP = 80,4 %
Average of Abstention - AA = 0,2 %
Average of Confusion - AC = 19,4 %

The enlarged classified area, working with images in the scale 1:400.000, covered all that appeared in the video. Obviously all the results were changed, when working in small scale, to the system resolution. The MAXVER Program was not able to classify all sugar-cane categories so well. For example, the sugar- cane study, in regional level, presented lower results. The best one was offered by cut down sugar-cane, 65,5 %.

The coming sugar-cane presented the worst result, 40,0 %. One of the reasons may be the small area planted with coming sugar- cane, compared to the entire region, the existence of other kinds of crops and the similarity of the spectral reflectance. The level of confusion with ripe sugar-cane, coming sugar-cane, pasture, forest and swamp has shown new aspects in this analysis, not observed before.

The constructed area made confusion of about 28,8 % with coming sugar-cane, a very high percent, more than in other classification tables.

Talking about the coming sugar-cane, it should be considered that the expansion of the universe to be studied, encompassed a different geomorphological landscape. This argument is valid for all analysed categories.

The forest category offered the best level (90,0 %) in this part of the Microregion covering larger areas. The first one located in the mountains of Santa Maria Madalena County (RJ) and the second one, named Mata do Carvao, in the Sao Joao da Barra County.

The abstention of the print-outs, charts and aerial photographs showed that the present research does not need the statistical treatment adopted in other studies. Rivers, lagoons, the city of Campos, sugar-cane crops, etc, could be identified because the relief was very flat.

Conclusions

1 - In the case of rural areas, like the Campos Sugar- Cane Microregion, it is very important to make the visual analysis using the MSS/LANDSAT (four channels) to identify the crops stages.

2 - The sugar-cane density and its spatial distribution, where are too many irrigation channels (mainly in the Lowland), are important to be studied by means of the spectral analysis.

3 - The sugar-cane crops, in the Lowland, appeared very well in the images, particularly if compared to the Tableland, because this one shows a dark tonality, indicating different spectral responses, that could be understood by the variations of : pedology, geomorphology, waterness and relief.

4 - When the studied area was enlarged, the MAXVER Classification performance fell down specifically in the case of sugar- cane (coming, ripe and cut down). All categories presented a high level of confusion. It can be explained by the system resolution and the other geomorphological aspects, since considering only Tableland and Lowland.

5 - The forests, the swamps and the bodies of water offered good performances in both classification scales (1:50.000 and 1:400.000) as well as the city of Campos. It proves that some objects seen in the MSS/LANDSAT images do not depend on the scales ; they have good spectral response in any scale.

6 - This **land use study,** made by means of photointerpretation, visual analysis and digital analysis of images, made possible characterizing the geographical space of The Campos Region. These comparative study showed the Land Use tendency in Campos.

7 - Therefore, the digital analysis should be put in practice by researchers with good knowledge of the study area. This Analysis furnished very good information of the Campos Region, particularly as it was complemented by maps, charts, aerial photographs and field work, to produce a real reference board for everyone who study the spatial phenomena (Cartographic Engineers, Geographers and other professionals).

Recommendations

It is recommended that other classifications be'used, particularly in order to improve the technique, due to the presence of water, aiming to minimize its influence.

The LANDSAT/MSS Digital Analysis, when applied in mountain regions with many crops, requires great care, due to the similarity of spectral responses.

The percentage of ripe sugar-cane samples confused with pasture, verified in this Dissertation, suggests changes in the MAXVER CLASSIFICATION PROGRAM.

It is recommended, in the future, to use LANDSAT 4 MSS images or Thematic-Mapper images, taking into account their resolution of 30 m.

It is also recommended to make more use of visual and digital analysis of satellite images in Cartography, either on Thematic Mapping or in the updating of Topographic maps, that give support to several researchs performed in the geographic space.

ACKNOWLEGDMENTS

Dr. PLACIDINO MACHADO FAGUNDES - AEROFOTO CRUZEIRO GROUP (ADVISER of this Master Dissertation Thesis).

Dr. PAULO EURICO DE MELLO TAVARES - PROJIR (IRRIGATION PROJECT of the Sugar-Cane and Alcohol Institute - IAA, Manager).

Dr. MARCIO NOGUEIRA BARBOSA - INPE (Brazilian Institute of Spatial Survey, Associated Director).

Dr. PAULO CESAR TRINO - SBC (Brazilian Society of Cartography, Photogrammetry, Geodesy and Remote Sensing, President).

Dr. DIETER MUEHE - GEOGRAPHY MASTER COURSE DEPARTMENT - UFRJ (Co-ordinator).

Dr. CLAUDIO IVANOF LUCAREVSCHI - Member, AD-HOC Commission Thematic Mappying from Satellite Imagery - ICA/BRAZIL.

REFERENCES

AMERICAN SOCIETY OF PHOTOGRAMMETRY. (1960) *Manual of Photointerpretation* Falls Church.

. *Manual of remote sensing.* (1975) Falls Church.

. *Manual of photogrammetry.* (1983) Falls Church.

BADHWAR, G.C. (1980) Crop emergence date determination from spectral data. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 46(3) :369-77, March.

(1984) Automatic corn-soybean classification using LANDSAT MSS DATA I. Near harvest crop proportion estimation. *Remote Sensing of Environment,* New York (14):15-29.

BAKER, John R. & DRUMMOND, Jane E. (1984) Environmental monitoring and map revision using integrated LANDSAT and digital cartographic data. *ITC Journal,* Enschede (1):10-9.

BARBOSA, Marcio N. (1982) The LANDSAT system implemented in Brazil by CNPq/INPE. Results obtained in mapping future perspectives. *Proceedings of the Technology Exchange Week.* Panama. p.504-25.

BAUER, M.E. (1975) The role of remote sensing in determining the distribution and field of crops. *Advances* in Agronomy, N.C. Brady Academy Press, New York, vol. 27, pp.271-304.

, CIPRA, J.E. (1973) Identification of agricultural crops by computer processing of ERTS MSS data. *Proceedings of Third Earth Resources Technology Satellite* - I Symposium, Washington D.C., Sec. A, p. 205-12.

, CIPRA, J.E., ANUTA, P.E. ; ETHERIDGE, J.B. (1979) Identification and area estimation of agricultural crops by computer classification of Landsat MSS data. *Remote Sensing of Environment,* New York, 8(1)77-92.

BERNARDES. Lisia M.C. (1957) Planicie litorânea e zona açucareira do Estado do Rio de Janeiro, Guia de excursao n°5, CONGRESSO INTERNACIONAL DE GEOGRAFIA, 18, Rio de Janeiro. *Anais.* Rio de Janeiro, Conselho Nacional de Geografia.

BRASIL. Ministério do Exército. Diretoria de Serviço Geográfico. (1975). *Manual técnico :* convençoes cartográficas. Brasilia. 2v. T.34.700.

, (1982) *Manual técnico :* normas gerais para operaçoes geodésicas, astronômicas, topográficas, fotogramétricas e cartográficas. Brasilia, T.34.201.

CAPPELLINI, Vitto ; FAENZA, Vicenzo ; FONDELLI, Mario. (1982) Il teleri levantamento e l'informatica per lo sviluppo dell' agricoltura nei Paesi del Terzo Mondo. *Revista di Agricoltura Subtropicale.* Firenze, 76(1-2):5-17, Gennaio-Giugno.

CENTRE NATIONAL D'ETUDES SPATIALES. (1984) Nouvelles de SPOT, Toulouse, 6, dec., 19p.

CESAR, Josette L. (1980) Cartografia, geomorfologia. In: *Curso de Sensoriamento Remoto Aplicaçoes Sistemas Operacionais* Instituto de Estudos da Terra - IET, Rio de Janeiro, 1980.

COLVOCORESSES, Alden P. (1970) ERTS- A satellite imagery, *Photogrammetric Engineering and Remote Sensing,* Falls Church, 36(6):555-60, June.

(1977) Proposed parameters for an operational Landsat. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 43(9):1139-45, Sept.

DOYLE, Frederick J. (1981) Satellite systems for Cartography. *ITC Journal,* Enschede, (2):153-70.

. (1984) The economics of mapping with space data. *ITC Journal,* Enschede, (1):1-9.

ESTEIO ENGENHARIA E AEROLEVANTAMENTO S.A. (1979) *O emprego da Fotogrametria na demarcaçao de lotes rurais,* Curitiba. Fev.

ESTES, J.E. ; JENSEN, J.R. ; SIMONETT, D.S. (1980) Impacts of remote sensing on U.S. Geography. *Remote Sensing of Environment,* New York, (10):43-80.

EYTON, J.R. (1983) A hybrid image classification instructional package. *Photogrammetric Engineering and Remote Sensing.* Falls Church, 49(8):1175-81, Aug.

FAGUNDES, Placidino M. (1957) Development of photogrammetry in Brazil. *Photogrammetric Engineering,* Falls Church, 17.

. (1960) Um dispositivo para orientaçao de vôo fotogramétrico. *III Reuniao de Consultas sobre Cartografia,* Porto Alegre.

. (1975) The RADAM project - RADAR in Amazon, *Bildnessing und Sujtbild.*

. (1976) Final report of the working group on the "Inventary of natural resources in the tropical regions. XIII International Congress of Photogrammetry, Helsinkin, 1976, *Annals* Helsinki. International Society of Photogrammetry. Helsinki.

. (1976) *O emprego da fotogrametria e da fotointerpretaçao nos projetos de irrigaçao.* Rio de Janeiro.

. (1978) Geodesy mapping and cartography in Brazil. In : 1° Simpósio Inter-Americano de Cartografia Automatizada. *Annals.* International Society of Photogrammetry, Washington.

. (1979) Introduçao aos sistemas inerciais. Congres - so brasileiro de Cartografia, 9. Curitiba, *Anais.* Curitiba. Sociedade Brasileira de Cartografia.

. (1980) Education in photogrammetry, geodesy and cartography in South America. XIV International Congress of Photogrammetry and Remote Sensing, 13 Hamburgo. *Annals.* International Society of Photogrammetry.

. (1980) Final report of the working group on the RADAR interpretation technique. XIV International Congress of Photogrammetry and Remote Sensing, 13. Hamburgo. *Annals.* International Society of Photogrammetry, and Remote Sensing.

. (1981) Sensoriamento remoto. *Curso de formaçao profissional em engenharia cartográfica.* UERJ.

. (1984) The meaning of cartography engineering in Brazil. XV International Congress of Photogrammetry and Remote Sensing, 15, Rio de Janeiro. *Annals.* Sociedade Brasileira de Cartografia/International Society of Photogrammetry and Remote Sensing.

FI, F.H. ; MOREIRA, J.C. ; DUTRA, L.V. ; SOUZA, R.C.M. de (1980) Análise automática de imagens multiespectrais. In : *Curso de Treinamento : Introduçao às técnicas de sensoriamento remoto e aplicaçoes* - Instituto de Pesquisas Espaciais INPE, Sao José dos Campos. Ago. Cap. X.INPE-CM.2/MD.

FRIEDMANN, D.E. ; FRIEDEL, J.P. ; MAGNUSSEN, K.L. ; KWOR, R ; RICHARDSON S. (1983). Multiple scene precision rectification of spaceborne imagery with very ground control points. *Photogrammetric Engineering and Remote Sensing,* Falls Church. 49(12):1697-67, Dec.

GEIGER, Pedro P. (1959) A regiao setentrional da Baixada Fluminense. In: *Anuário Estatistico do Estado do Rio de Janeiro.* Instituto Brasileiro de Geografia e Estatistica, Rio de Janeiro, 12. pp.19-72.

HALL, F.J. ; BAUER, M.E. ; MALILA, W.A. (1974) First results from *crop identification tecnology assessment for remote sensing.* LAPS. Pardue University, Lafayette, Indiana. (LARS information note 041874).

HAMMERLI, Sulamita M. (1982) *A racionalizaçao da produçao canavieira na regiao açucareira de Campos e seus reflexos na organizaçao do espaço agrário.* Rio de Janeiro, UFRJ/Departamento de Pós-Graduaçao em Geografia. Dissertaçao de Mestrado.

HENDERSON, Floyd (1979) Land-use analysis of radar imagery. *Photogrammetric Engineering and Remote Sensing.* Falls Church, 45(3):295-307, March.

. (1980) Efects of interpretation techniques on land - use mapping accuracy. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 46(3):359-67, March.

KOFFLER, N.F. ; CAVALLI, A.C. ; CHIARINO, J.N. ; NOGUEIRA, F.F. de P. (1979) Inventário canavieiro com auxilio de fotografias aéreas - A grande regiao de Piracicaba no Ano Safra 1978/79. *Bol. Técnico PLANALSUCAR-IAA,* Piracicaba, Sao Paulo 1(2):3-38. Dez.

IAA/PROJIR. (1982/1984) *Projeto de irrigaçao e drenagem da canade-açúcar no Norte Fluminense,* Relatórios, Rio de Janeiro - SONDOTECNICA.

IBGE. (1977) *Geografia do Brasil - Regiao Sudeste,* SUEGE, DEGEO, Rio de Janeiro.

JENSEN, John R. (1979) Spectral and textural features to classify elusive land cover at the urban fringe. *The Professional Geographer,* Washington, D.C., 31(4):400-9, Nov.

. (1983). Biophysical remote sensing. *Annals of the Association of American Geographers,* Laurence, 73(1):111-32, March.

LAMEGO, A.R. (1940). *O homem e a restinga.* Rio de Janeiro, Conselho Nacional de Geografia.

. *O homen e o brejo,* Rio de Janeiro, Conselho Nacional de Geografia.

. (1956). Geologia das quadriculas de Campos, Sao Tomé, Lagoa Feia e Xexé. In : *Anuário Geográfico do Estado do Rio de Janeiro,* Instituto de Geografia e Estatistica, Rio de Janeiro, 9.

MENDONÇA, F.J. (1980a). *Uso de dados do Landsat para avaliaçao de áreas ocupadas com cana-de-açúcar no Estado de Sao Paulo.* INPE-Sao José dos Campos, INPE. Tese de Mestrado. INPE. COM. 1/TDL.

. (1980). Metodologia de dados orbitais (LANDSAT) na agricultura. In : *Curso de Treinamento : Aplicaçoes de Sensoriamento Remoto, com ênfase em imagens LANDSAT, no levantamento de recursos naturais,* INPE, Sao José dos Campos. Nov. INPE-1949-MD/008.

. LEE, D.C.L. ; SHIMABUKURO, Y.E. ; TARDIN, A.J. ; NOVAES, R.A. ; CHEN, S.C. (1980). *Utilizaçao de dados do LANDSAT para inventário da cana-de-açúcar do Estado de Salo Paulo.* INPE. Sao José dos Campos. INPE.COM.6/NTE.

. LEE, D.C.L. ; SHIMABUKURO, Y.E. ; TARDIN, A.J. : CHEN, S.C. ; LUCHT, L.A.M. ; MOREIRA, M.A. ; LIMA, A.M. ; MAIA, F.C.S. (1981) *Levantamento da área canavieira do Estado de Sao Paulo, utilizando dados do LANDSAT ano safra 1979/80.* INPE. Sao José dos Campos. INPE-COM. 4/RPE. Volumes I e II.

STUDNITZ, Hanns J.C. von. (1981). *Filmes aéreos.* Aerofoto Cruzeiro S.A. Rio de Janeiro.

TAVARES, Paulo E. de M. & FAGUNDES, Edvaldo A. (1982a). *Projeto de irrigaçao e drenagem da cana-de-açúcar na Regiao Norte Fluminense - Estrutura Cartográfica.* Piracicaba. PLANALSUCAR/IAA.

& . (1982b) *Projeto de Irrigaçao e drenagem da cana-de-açucar na Regiao Norte Fluminense.* Manual de utilizaçao de Cartas, Piracicaba PLANALSUCAR/IAA.

THOMAS, J.C. & OERTHER, G.F. (1977). Estimation of crop conditions and surgarcane fields aerial photography. *Proc. American Society of sugarcane,* Tech. 6:93-99.

THOMPSON, David R. ; WEHMANEN, Oscar A. (1979) Using LANDSAT digital data to detect moisture stress. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 45(2):201-7, Feb.

TUCKER, C.J. (1977). Spectral estimation of grass canopy variables. *Remote Sensing of Environment,* New York, (6):11-26.

. (1978a). The question of photogrammetric infrared sensor redundancy for monitoring vegetation. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 44(3):289-95.

. (1978b). *An evaluation of the first four LANDSAT - D Thematic Mapper reflective sensore for monitoring vegetation.* NASA/GSFC TM, 79617, 55p.

(1978c). Comparision of satellite sensor bands for vegetation monitoring. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 44(11):1369-80, Nov.

. (1979). Red an photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment.* New York.

. ELGIN JUNIOR, J.H. ; Mc MURTREY III, J.E. (1979). Temporal spectral measurements of corn and soybean crops. *Photogrammetric Engineering and Remote Sensing,* Falls Church, 45(5):643-53, May.

WALL, Sharon L. ; THOMAS, Randall, W. ; BROWN, Catherine E. ; BAUER, Ethel H. (1984). Landsat Inventory system for agriculture in California, *Remote Sensing of Environment,* New York, (14):267-278.

WILD HEERBRUGG. (1972). *The pratical use of filters and A.V. coasting aerial photography.* Switerzland.

WITENSTEIN, M.M. (1955). Uses and limitations of aerial photography. *Photogrammetric Engineering,* Falls Church, 21(4):566-73, April.

. (1956). A report on application of aerial photography to urban use inventory, analysis and planning. *Photogrammetric Engineering,* Falls Church, 22(4):656-64, April.