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CROP IDENTIFICATION USING SPOT AND TM DATA

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14. Abstract/Notes *The general objective of this experiment is to assess the spatial resolution and spectral characteristics of SPOT HRV data for crop discrimination in Southern Brazil, taking into special consideration the off-nadir viewing capability of SPOT. A test site having a variety of cover types during the winter growing season was chosen. At least thirty fields for each crop class (two stages of wheat, coffee, sugarcane, and pasture) were checked on the ground and information on variety, planting date, phenological stage, plant height, row spacing and orientation, percent soil cover, crop condition, topographic and soil characteristics was obtained whenever feasible. Three cloud free scenes of SPOT were selected during the acquisition period from June 15 to August 15. The general quality of the data was analysed both digitally and visually. Comparisons between the different viewing conditions and spatial resolutions as well as a comparison with LANDSAT TM data for the discrimination of crops were performed. The near infrared band presented the greatest information content in all satellite products analysed. However, using a single band for crop discrimination, the chlorophyll absorption band (band 2 of SPOT and band 3 of TM) performed better than the near infrared band in this experiment.*

15. Remarks *Presented at the SPOT 1 First in - Flight results,Toulouse, France, 17-19 December 1986.*

RESUMO

O objetivo geral deste experimento é avaliar as características espacial e espectral de dados HRV do SPOT para discriminação de culturas no Sul do Brasil, levando em consideração a capacidade de visada lateral do SPOT. Uma área teste contendo vários tipos de cobertura durante a estação de crescimento de inverno foi selecionada. No mínimo 30 campos de cada classe de cultura foi escolhido que incluia dois estágios tecnológicos de trigo, café, cana-de-açúcar e pastagem. Estes campos foram verificados no solo e informações sobre variedades, data de plantio, estágio fenológico, altura da planta, espaçamento e orientações de plantio, percentagem de cobertura do solo, condição de cultura, características tipográficas e do solo foram obtidas sempre que possível. Três cenas do SPOT livre de nuvens foram selecionadas durante o período de aquisição (15 de junho a 15 de agosto). A qualidade geral dos dados foi analisada por processos digital e visual. Comparações entre diferentes condições de visada e resoluções espaciais bem como uma comparação com dados TM/LANDSAT para discriminação de culturas foram feitas. A imagem correspondente à banda do infravermelho próximo apresentou o maior conteúdo de informações de todos os produtos de satélite analisados. No entanto, utilizando uma única imagem na discriminação de culturas, as bandas de absorção pela clorofila (banda 2 no SPOT e do TM) mostraram, neste experimento, melhor desempenho do que a banda do infravermelho próximo.

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1. INTRODUCTION

In the past decade research works at the Institute for Space Research (INPE) have demonstrated that LANDSAT data can be used to obtain satisfactory crop classification results for soybeans, wheat, and sugarcane which have extensive planting fields (Batista et al., 1978, Chen et al., 1984; Batista et al., 1985; Moreira et al., 1986). However, for crops such as corn, beans, or coffee, even the 30m resolution of the LANDSAT-TM data is not suitable due to their small field sizes in Brazil. In addition to the restriction of spatial resolution, the 16-day repetitiveness cycle of TM data is too long for crop survey in Brazil due to the problem of cloud cover. If cloud free data are not acquirable on a certain period, then there will be at least a 32-day gap between data sets with the LANDSAT-5 system, which is definitively undesirable for accurate crop survey.

On February 22nd of this year, the French satellite SPOT was launched carrying aboard a sensor system with two characteristics of special interest for tropical agriculture studies: the improved spatial resolution (i.e. 20m for the multispectral and 10m for the panchromatic mode) and the off-nadir viewing capability (Brachet, 1985; Chevrel et al., 1981).

The off-nadir viewing capability may increase the repetitiveness of data acquisition in certain areas. It is the first time that nonvertical-viewing-angle satellite data are available for application.

In order to explore better the potential of SPOT data for crop survey purpose, SPOT digital and analog data were both requested during the period from June 15 to August 15, for a test site in Paraná State. In this paper, preliminary results of SPOT data analyses and their comparison to LANDSAT-TM data of the same area are presented.

2. OBJECTIVES

1) to investigate the spectral response of different crop types sensed at different viewing angle conditions from orbital platforms;
2) to evaluate the angular effects of SPOT on crop discrimination taking into account the topographic characteristics of the crop fields;
3) to evaluate the contribution of the SPOT panchromatic high resolution sensor system for crop identification.

3. TEST SITE

Figure 1 shows the location of the test site which corresponds to a SPOT scene of 60 x 60 km. This is a very intensive and diverse agricultural producing area in southern Brazil. The main crop categories found in the test site during the winter growing season are wheat, coffee, sugarcane, and pasture, whereas during the summer the major crops are soybeans and corn. Other crops found in the test site are citrus, ground-nuts, edible beans, cotton and rice. There is a well-established soil conservation system, which consists of contour lines designed for the water basins as a whole, independently of the farm boundaries.

Fig. 1 - Location of the test site.

4. SATELLITE DATA USED

Table 1 presents the characteristics of the satellite data used. For this preliminary analysis only digital data in CCT's have been used.

TABLE 1

CHARACTERISTICS OF THE SATELLITE DATA USED

CHARACTERISTICS \ PRODUCTS	1	2	3	4
SATELLITE	SPOT 1	SPOT 1	SPOT 1	LANDSAT
SENSOR	HRV 1	HRV 1	HRV 1	TM
OPERATION MODE	XS	XS	PAN	-
REFERENCE SYSTEM	K = 705, J=397	K=705, J=397	K=705, J=397	ORB=223, PT=76 QUAD = D
ACQUISITION DATE	10 JUL 86	15 JUL 86	10 JUL 86	02 AUG 86
SCENE CENTER	23^o 30' 23" S 52^o 06' 25" W	23^o 30' 17" S 52^o 06' 06" W	23^o 30' 24" S 52^o 05' 50" W	23^o 08' 22" S 52^o 40' 11" W *
SOLAR AZIMUTH	31.5^o	31.1^o	31.5^o	48.3^o
SUN ELEVATION	37.2^o	38.1^o	37.2^o	32.37^o
INCIDENCE ANGLE	L 5.3^o	L 12.8^o	L 5.3^o	0^o
SCENE ORIENTATION	9.2^o	8.7^o	9.3^o	12.3^o
Nº OF LINES	3393	3336	6799	3088 (QUAD)
Nº OF PIXELS/LINE	3635	2995	7263	3500 (QUAD)
PIXEL SIZE	20m	20m	10m	30m
SIZE OF SCENE ON MAP (UTM)	HEIGHT = 67.8km WIDTH = 72.7km	HEIGHT = 59.9km WIDTH = 66.7km	HEIGHT = 68.0km WIDTH = 72,6km	-
PROCESSING LEVEL**	2 (6 GCP's)	1B	2 (11 GCP's)	1A (EQUIVALENT)

* TM image superimposes the SPOT scenes completely.

** Radiometric calibration parameters have been kept the same for the SPOT acquisition dates.

5. FIELD DATA

The analysis of the satellite data was supported by two field works which were carried out in order to obtain general information on the test site as well as to characterize the selected candidate fields for each crop category.

The first field trip, which lasted from June 30th to July 4th, 1986, was done prior to the satellite data acquisitions. Its objetives were both to select candidate fields and to collect basic information on the test site necessary to expedite the second field work.

Although the second field work was planned to occur as close as possible to the SPOT data acquisition, in fact it occurred long after that, from August 26th to September 5th, 1986. This period was still considered timely because it coincided with the harvesting period of wheat and coffee. Thus, it was possible to meet many farmers who furnished valuable information on variety, planting date, yield, cultivation practices, and crop condition on the selected fields.

A total of 181 fields were selected from the two field works for the five crop categories of interest. These fields consisted of the following: 39 of WHEAT I (tillering stage), 41 of WHEAT II (flowering to soft dough stage), 37 of pasture (planted grassland), 31 of sugarcane and 33 of coffee. The wheat stages mentioned refer to the first field trip.

Only 15 fields for each crop category were selected for the preliminary analysis presented in this paper. The selection was based on field size, sharpness of boundaries, spatial distribution (representativeness), spectral variance, and field information content of the candidate fields.

A panoramic 35mm picture was taken from each field. Moreover, vertical photos were also taken from the two classes of wheat and most of the pasture fields to allow for percent soil cover estimation.

Samples of the soil surface were taken from most of the wheat and coffee fields. These crop categories usually presented lower than 100 percent soil cover. A total of 75 soil samples were collected.

For each candidate field, the slope was visually estimated and the aspect, defined as the magnetic angle of the superficial water flow direction, was measured using a field compass. Additionally, the crop type, development stage, variety, plant height, crown diameter, row spacing and direction, percent soil cover, yield or expected yield, soil moisture, field homogeneity, and general condition of the field were registered whenever feasible.

To support the identification of the candidate fields, TM prints acquired on June 15th, 1986 were used. Also, meteorological data and historical crop production at municipal level were obtained from local governmental agencies.

Both field works were assisted by the Secretariat of Agriculture of the Paranã State, where the test site is located.

6. DATA ANALYSIS

For the digital analysis of the satellite data the image processing system, IMAGE-100 (GE, 1975) available at the Institute for Space Research (INPE), was used. This system has several software packages (Dutra et al., 1981) and a 5x512x512 pixels (8 bits configuration) image memory associated with a color image display. The hardware is based on a PDP-11/45 minicomputer.

All 15 selected fields from each crop category were visually identified in the display system for all four satellite products analysed. The working scale on the display system varied according to the spatial resolution of the data analysed, keeping constant the number of pixels (512x512) analyzed. Therefore, an approximate working scale of 1:17,000 for the SPOT panchromatic mode (10m resolution), 1:33,000 scale for the SPOT multispectral mode (20m resolution), and 1:50.000 scale for the TM product (30m resolution) resulted in the image processing display system.

After locating each field on the image display system, the spectral response (digital count) of a representative sample of each field was obtained. In order to locate the samples of pixels in all four different products, a photograph of the image display was taken showing the selected samples in the first satellite data analysed. This photograph was used afterwards to locate the samples in the other products. The mean and the variance of the spectral response values for each spectral band were computed for each one of the selected fields.

The histograms of all spectral bands were constructed based on a systematic sample of the entire test site scenes.

Topographic characteristics of some selected fields were estimated from available 1:50,000 topo maps in addition to the field estimates.

Statistical tests were applied in order to ascertain whether differences in spectral responses were significant.

7. RESULTS AND DISCUSSION

Before examining the spectral response of the crop categories in the satellite data analysed, the general quality of the entire scene was investigated.

Figure 2 presents the histograms of the spectral bands analysed based on a sample of pixels from the entire test site scene. Table 2 shows the histograms parameters.

As it can be seen in Figure 2 all histograms are very similar for the multispectral data, especially for the two SPOT data. The TM data presented more variation on the frequencies of the count levels in bands 3 and 4 than the corresponding SPOT bands 2 and 3.

The histogram of the SPOT pan mode was quite similar to the SPOT band 2 (XS mode). From the comparison of the two SPOT data acquisitions it can be verified that the differences in the count level frequencies are not significant despite the five days interval between acquisitions and a 7.5^{o} difference in incidence angle (Table 1).

The infrared band (band 3 for SPOT and 4 for the TM) is the most informative band followed by the chlorophyll absorption band (band 2 for SPOT and band 3 for the TM).

A visual inspection of the SPOT images indicated that there is an almost vertical systematic noise, parallel to the image border, especially noticeable in band 2 of the XS mode and also in the panchromatic band. This noise occurs when the same HRV is operating simultaneously in the P and XS mode (Begni et al., 1986; Batista et al., 1986).

Figure 3 shows the 95% confidence interval for the mean spectral response of all 15 fields from each crop category studied in the different bands of the satellite data used.

As it can be seen from the histograms (Figure 2) and fron the variances (Table 2), the near infrared is the most informative spectral band. However, it does not allow the discrimination of the different crop categories for this experiment. The two visible bands of both SPOT and TM performed very similarly

(Figure 3). Individually, band 2 of SPOT and the corresponding band 3 of the TM were the best for the discrimination of the crop categories studied.

Spectrally, pasture was the most conspicuous of the crop categories analysed. However, it was never separated from sugarcane in single-band analysis. Pasture was always separated from coffee in the chlorophyll absorption band (band 2 of SPOT and 3 of the TM).

Figures 4 and 5 present the two-dimensional scattering plots of SPOT and TM band combinations. It can be noticed that the near infrared band and the chlorophyll absorption band are not correlated as it is the case of the two visible bands (band 1 and 2 for SPOT and 2 and 3 for the TM) on both SPOT and TM data when all crop categories are considered.

The visual analysis of these graphics (Figures 4 and 5) indicates that one cannot expect much improvement in crop discrimanation through the two-dimensional analysis when compared to that obtained by the single band analysis.

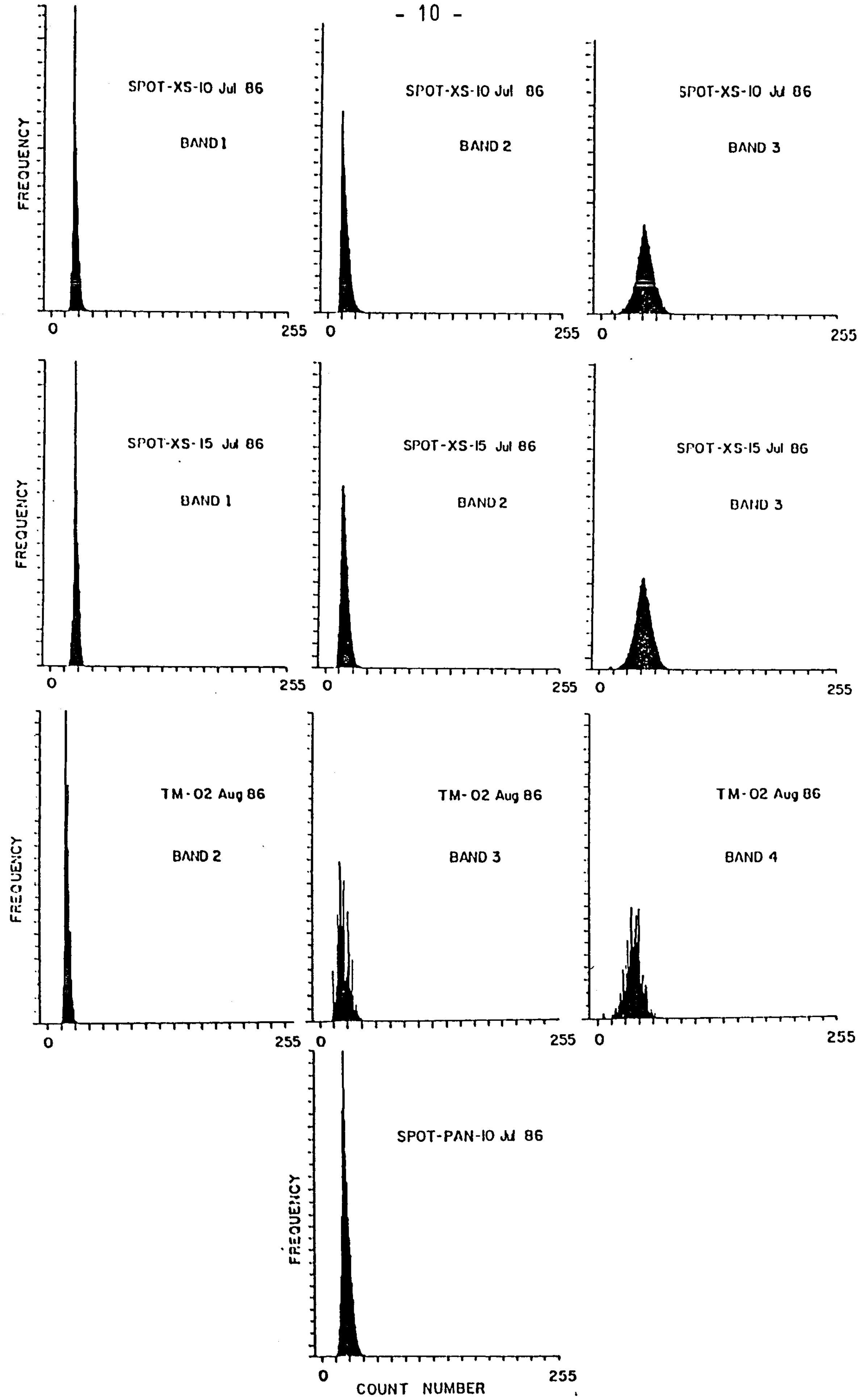

Fig. 2 - Histograms of the satellite data used.

TABLE 2

HISTOGRAM PARAMETERS OF THE SATELLITE DATA USED

PRODUCTS / HISTOGRAM		SPOT 10 JUL 86			SPOT 15 JUL 86			TM 02 AUG 86			SPOT 10 JUL 86
		BANDS			BANDS			BANDS			BANDS
		1	2	3	1	2	3	2	3	4	PAN
SAMPLING	LINE	16	16	16	10	10	10	4	4	4	16
	PIXEL	16	16	16	10	10	10	4	4	4	16
MAX. FREQ.		4,919	3,173	1,412	14,662	8,705	4,339	39,982	20,670	14,291	12,365
LOWER COUNT Nº*		18	10	10	18	11	10	14	11	4	14
HIGHER COUNT Nº*		43	42	85	53	60	88	46	67	93	69
MEAN		26.3	19.2	48.2	27.3	20.6	47.6	22.1	25.0	39.4	26.7
VARIANCE		9.7	21.9	96.4	9.8	22.2	92.9	8.8	40.0	88.9	25.1

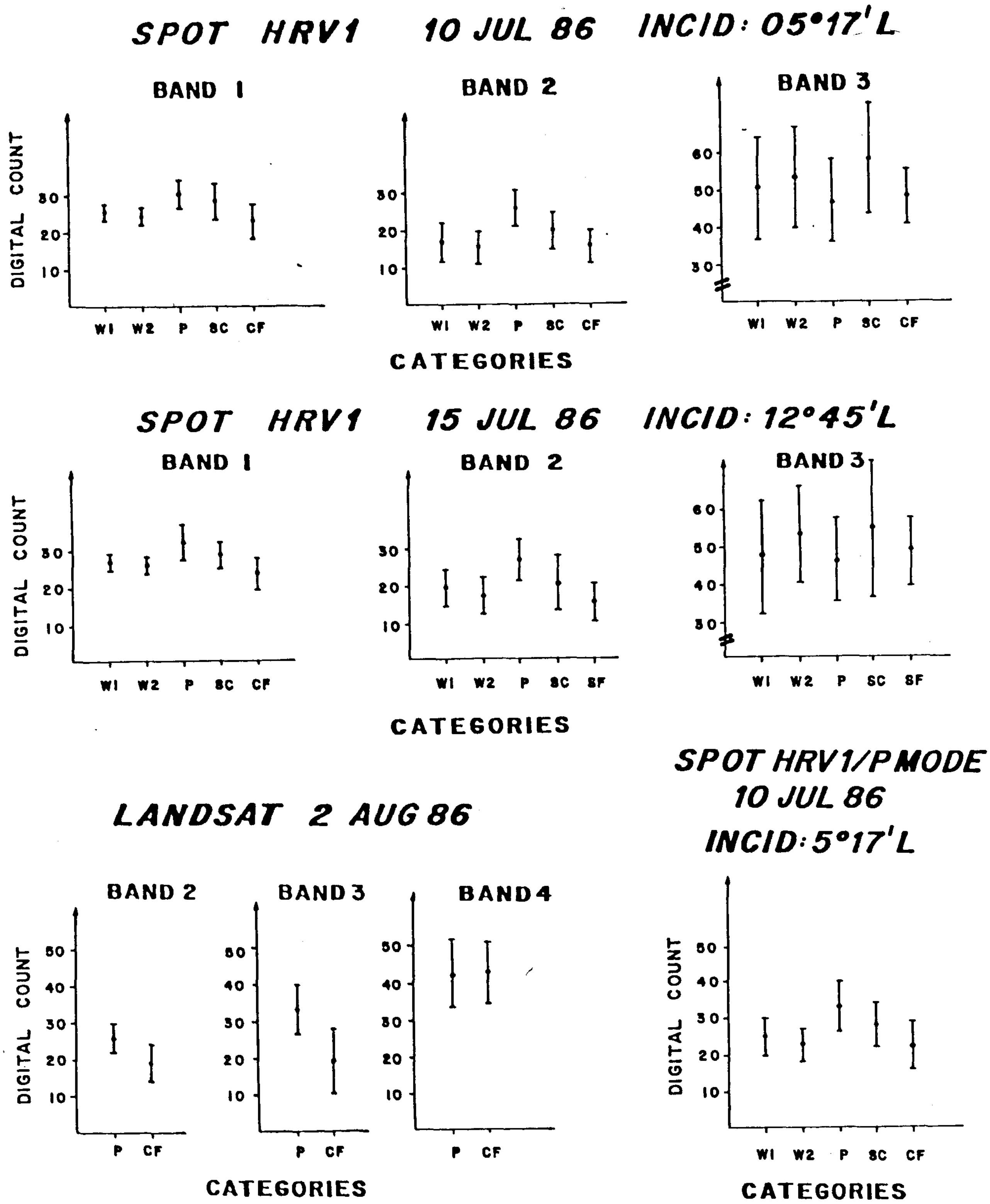

Fig. 3 - Confidence interval (95%) for the mean of each crop category (W1 = wheat (tillering stage), W2 = wheat (flowering to soft dough stage), P = pasture, SC = sugarcane, CF = coffee) for the SPOT and LANDSAT products studied.

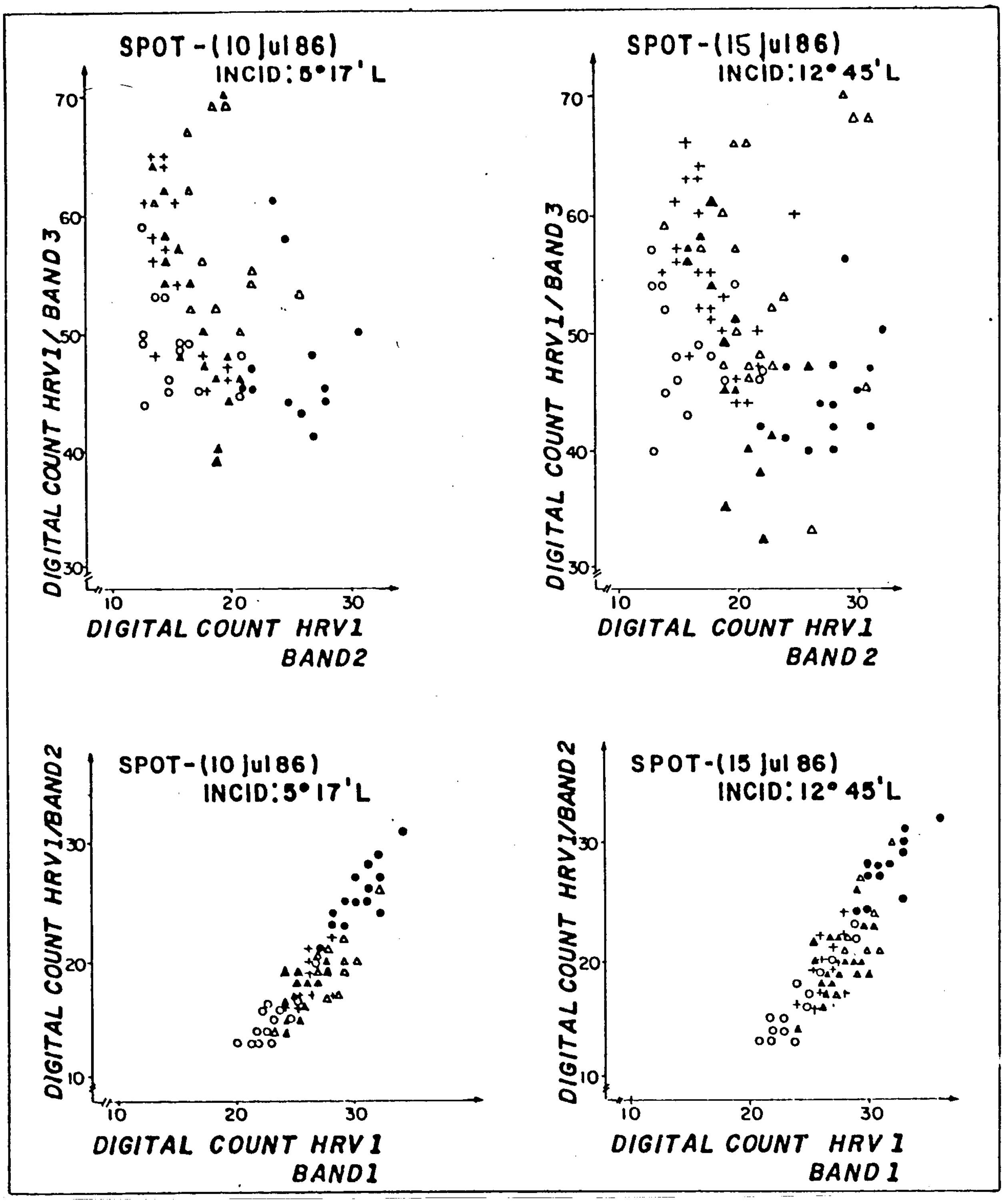

Fig. 4 - Scattering plots of SPOT band combinations for each crop category (Δ wheat1, + wheat 2, • pasture, Δ sugarcane, o coffee).

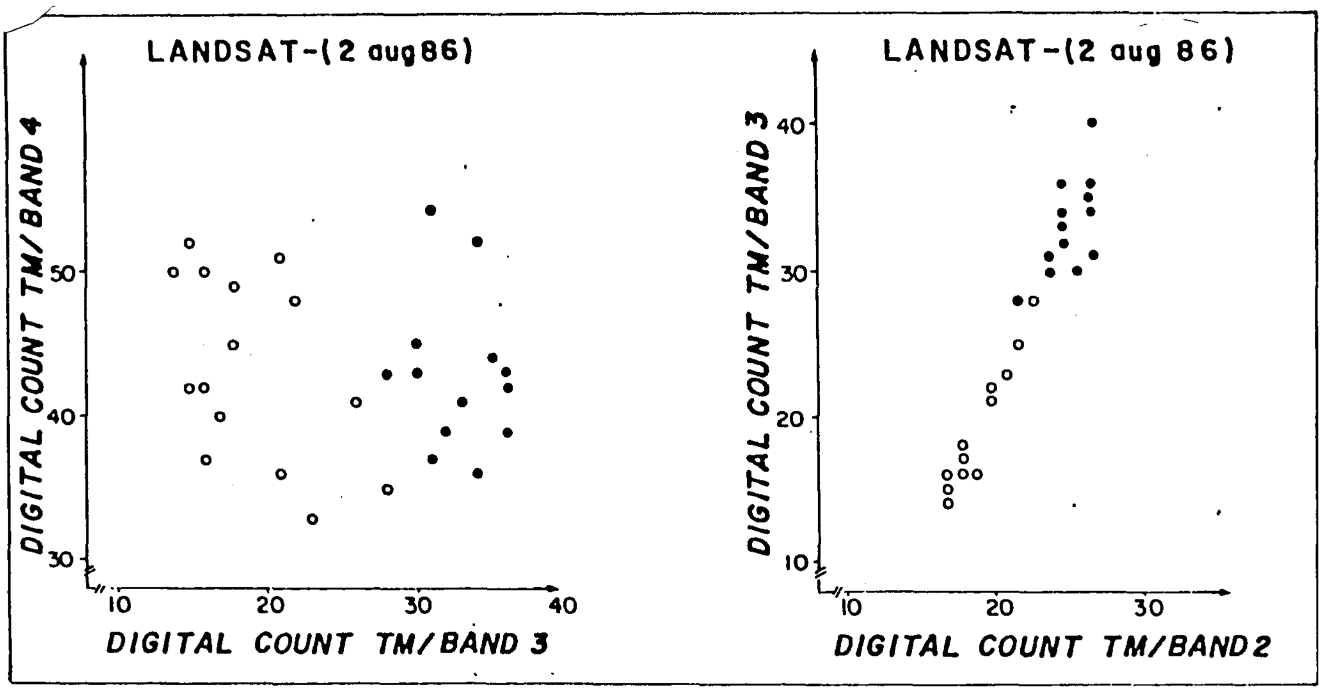

Fig. 5 - Scattering plots of TM band combinations (3vs4 and 2vs3) for coffee (0) and pasture (0).

The effect of the topographic characteristics, i.e. slope and aspect of the selected fields, was investigated both visually and quantitatively. Even though the test site has a great topographic variability with predominantly rolling slopes (0 to 5^{0}), the visual analysis indicated that the topographic effect on the spectral response of the crop categories studied was not signifcant.

A sample of the selected fields was chosen to carry out the quantitative analysis of the effect of both the slope and the aspect on the spectral response. These chosen fields had the following characteristics: 1) a single azimuth; 2) an aspect oriented either to 98.7 + 30 or to 278.7 + 30; 3) a slope ranging from 1 to 5. The spectral response of these fields was examined in the SPOT XS mode CCT acquired on July 15, 1986 with 12.8 incidente angle. Coffee was the major crop selected because it presented about 60% soil cover which permitted the associated soil effect to be studied.

Results indicated that the effect of the topographic variation on the crop response was not significant. However, a more detailed study oriented towards a better investigation of this effect should be performed, considering the within field topographic variation.

To support the interpretation of the crop spectral response, several samples of the soil surface were colected especially from fields with lower than 100 percent soil cover. The curve in Figure 6 represents the mean of the percent bidirectional reflectance factor of 11 samples of the soil type denominated "Terra Roxa Estruturada", which is a well-structured clayey Alfisol. This is the major soil type of the test site, which occurs from flat to ondulating slopes (MA, 1981). It can be noticed that this soil presents low reflectance and a broad absorption band centered at 870mm due to the high iron content of these soils (Stoner and Baumgardner, 1980).

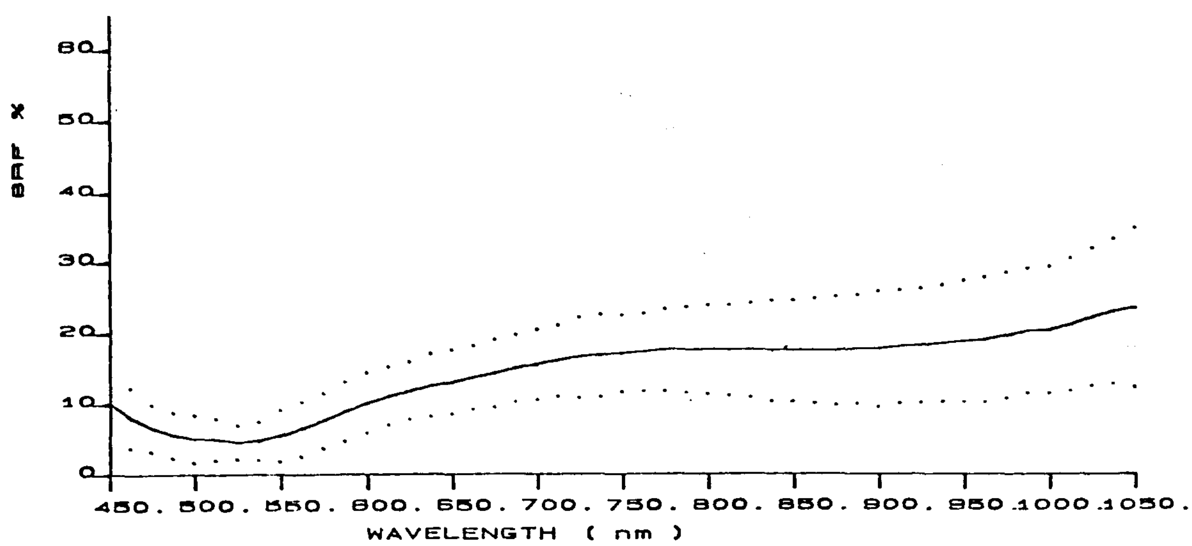

Fig. 6 - Mean and the 95% confidence interval of the percent bidirectional reflectance factor (BRF%) of 11 soil samples of the test site.

Although spectrally the SPOT panchromatic imagery does not add much information to the SPOT XS mode or the TM data (Figures 2 and 3), in fact its high spatial resolution brings a new dimension to crop surveys, especially for establishing "area sampling frames". The possibility of observing homesteads, rural industries, and commodity storage buildings is very helpful for crop surveying, especially in such diverse region as the test site under investigation. Texture information seems to be enhanced in this sensor system as compared to the SPOT XS mode or to the TM imagery. With few exceptions, the contour lines and field boundaries could be clearly outlined with the panchromatic imagery.

8. FINAL REMARKS

Based on the preliminary analysis of this experiment, the following remarks can be made:

1) The analysis of the entire scene showed that the near infrared band (band 3 of SPOT and 4 of the TM) is the most informative band. The two visible bands are highly correlated when all cover types are jointly analysed. Although band 2 (chlorophyll absorption band) had a lower count number mean, it presented a greater variance than band 1.

2) The single band analysis of all satellite products investigated revealed that only pasture was spectrally separable from all but the sugarcane category.

3) The joint effect of differing viewing angles and data acquisition in crop discrimination for the two SPOT XS products analysed was not significant.

4) Despite the topographic characteristics of the area, with slopes varying from flat to 5 percent, the effect of the incidence angle was not significant. A more detailed study should be performed to investigate this effect.

5) Although spectrally the panchromatic image does not add much information to either the SPOT XS mode or to the TM imagery, the improvement in the spatial resolution seems to be very valuable for crop surveying in a diverse region such as the one under investigation in this experiment.

6) Due to the time lag between acquisitions, the comparison between SPOT and TM data was limited.

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