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ACQUISITION OF SPECTRAL SIGNATURES OF CROP FEATURES IN THE TRENQUE-LAUQUEN AREA

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ABSTRACT

Training fields have been selected from over a number of each kind of crop, in such a way that a sufficient number of elements to produce reliable statistics will be obtained. The most effective qualitative analysis is made by plotting the spectral signatures of all the crop features. Besides we compare spatially and temporally, all the training fields of each class just to set up homogeneity of each field and the differences among them due to development stage and environmental factors.

A spectral signature plot means the graph of the statistical mean data value versus spectral channel. The mean values are obtained from analysing the training fields of each crop. Identifications of cover types in all fields are recorded on site maps. Detailed agronomic observations, on ground, are made on several fields of each kind of crop.

I INTRODUCTION

Multispectral measurements acquired from satellite data incease knowledge and understanding of the spectral properties of crops and soils in relation to their physical, biological and agronomic characteristics.

The spectral response of the crop repre-sents the integrated effects of all cultur-al, soil and meteorological factors affect-ing crop growth and development.

Multispectral data can take advantages from spectral signature characteristics. Analysis can be successful in delineating several land vegetative classes and can aid in differentiating areas of contrasting densities .Most of the computerized image processing methods are based exclusively on spectral signatures recorded by the mul-tispectral systems.

II GEOGRAPHICAL SITUATION

Argentina, country in which agriculture is extremely important, is suited for using earth resources satellite data in crop production prediction.

Since wheat and corn are the major agro-nomic crops in our country, this study is concentrated on the application of LANDSAT data to wheat and corn development sta-ges and the differences among these kind of crops and other ones such as barley,oat, pastures, etc.

It must be taken into account that crop calendars of the two cereals extend over 12 months of the year. Corn is planted during the September-through-November period and harvested during the March-through-beginning-of-May-period.

The principal type of wheat grown in Ar-gentina is winter wheat. It is planted during the May-through-July period and harves-ted during the November-through-December period. The area we have studied, named Trenque-Lauquen, is situated west from the Province of Buenos Aires and its surface comprehends 550,000 hectares.

III LANDSAT DATA PROCESSING

A. GENERAL CHARACTERISTICS

Crops are best identified from computer processed digital data that represent quantitative measures of radiance (percentage or intensity of reflected light). In general, all leafy vegetation by itself has a similar reflectance spectrum, regard-less of plant or crop species.

In order to properly interpret any type

of remote sensing sensor data, we must consider the spectral reflectance characteristics of both the vegetation and the soil, as well as the percentage of the soil surface being covered by the vegetation.

The determination of the relative amount of vegetative ground cover, in a particular area depends upon the soil background in relation to the wavelength band with which we are working. Spectral reflectance measurements are made to study the effect of soil background, crop density and stage of development on the spectral response of corn and wheat canopies.

To get a complete idea of the importance that spectral signatures, for each class, have all over the year, we must add that the length of the green growth period vary from year to year, depending upon the climate pattern. Production also varies from site to site, depending upon elevation, slope, climate regime and various physical, chemical and biological characteristics of the soil.

B. SPECTRAL CHARACTERISTICS OF THE CROP

Four LANDSAT, cloud-free tapes passed over Trenque-Lauquen area are considered, which include La Candelaria, La María Teresa and la Nueva Bélgica test sites, at the beginning of October, middle of december, end of January, and February periods. These data are acquired to analyze the spectral differences in each of the four spectral satellite bands (4,green; 5, red; 6, near-infrared; 7, near-infrared) of each crop: barley, wheat, oat, pastures and corn. The objectives to be analyzed are:

1) To determine if LANDSAT spectral data provide a reliable means for differentiating wheat from barley, oat, pastures and planting land.

2) To determine relationships among different sown stages wheat.

3) To analyze differences among grown corn stages from the time it is sown till its maturity.

No corrections have been made for atmospheric variables, however, each day of acquired data has been a relatively clear day without any apparent clouds. The average and standard deviation have been computed for the three areas for each date and for each MSS band.

1. Wheat

LANDSAT spectral radiance data for the three above mentioned test areas, are extracted from the LANDSAT computer compatible tape acquired in October 1981.

These three test sites are chosen for comparison because they appear within the same LANDSAT frame.

The three regions are exhibited on a color display and the several training areas for each crop type: wheat, barley, pastures, oat, sown lands are recognized by shape and by elementary spectral properties as corresponding to preselected ground truth sites. Once the crops are differentiated on the computer data by using this training sets, the spectral signatures, i.e., the mean vector and scatter matrix, of these known specific crop types are determined.

When data from all four channels of the MSS are used, there are usually enough differences in reflectance from one crop to the next, so as to distinguish them. Several training areas for each crop class are selected from the cloud free chosen test sites and extracted crop signatures. Histograms of these same training areas, in each working scene, are built and thus crop spectral data are acquired. The most widely accepted and used technique for implementing decision processing is the maximum likelihood procedure under the multivariate normal hypothesis.

In this analysis, advantage is taken of the fact that different crops will have different reflectivities in different spectral ranges. The process of selecting different kind of vegetation may be briefly described as follows; consider a plot of the spectral reflectance of different crops as a function of wavelength. Typically, each crop will have a different spectral response such that a set of samples of the spectrum at different wavelength will uniquely describe each class.

Consider our example in order to differentiate kinds of crops; wheat, barley,oat, pastures, sown lands. The three areas previously mentioned are included: La Candelaria, La María Teresa and la Nueva Bélgica, and several training areas of each class. A considerable amount of work has been done with ratios of the visible and infrared wavelength bands.

It can be observed that obtaining a ratio of the infrared to visible reflectance, the influence of the soil background is considerably reduced since the ratio value is related primarily to the amount and density of the vegetative present cover. That is why for simplicity, the case of these samples at $\Delta\lambda$ 1= band 5 (.6-.7 μm) and

$\Delta\lambda_2$= band 7 (.8-1.1 μm), has been considered.

The responses to these wavelengths are used as Cartesian coordinates of a decision plane. It is observed that all the samples of a given crop tend to cluster near the same area of the plane and that each crop sample group is located at a different area. The measurements from each of these classes are used to determine the place in the decision space to be assigned to that group. Figure 1. Some barley samples appear mixed with wheat and other with oat, so a definite area for this type of crop is not possible to be defined.

It is observed that the wheat sown in the middle of July is the only one mixed with barley. The wheat sown in JUne, beginning of July, end of July and August, is quite distiguishable from barley. The rest of barley areas mix with oat areas.

2. Results

Winter wheat can be differentiated from barley if it is sown in May, June, end of July and beginning of August. As it is shown in Figure 1, winter wheat may be distinguished from oat crop, because: wheat radiance is higher than oat radiance in band 7, and, on the other hand, in band 5. In band 5, pasture radiance is higher than wheat radiance. But each of the crops,i.e. wheat, barley, oat, pastures, have a higher reflectance in band 7 than any kind of ploughed or sown land.

Also, if certain crops are not separable at one time of the year, they are normally separable at another time, due to the differences in planting, maturing and harvesting dates.

The degrees of maturity for a given crop also influences the reflectance at any stage of growth. This maturity can be assessed as if it were the history of any crop and is traced in terms of its changing reflectances. The case of several wheat training areas that are included in the three above mentioned test areas and have been sown at different periods of time, since beginning of May, is analyzed.

In random changes the reflectance increases with respect to what was sown during the first stage and as seeding time advances reflectance decreases. This is only visible in bands 6 and 7, i.e. IR bands. FIgure 2.

In these work scenes, it is assumed that the type of soils, moisture content and climate patterns represent no differences among the three test sites and the corresponding wheat training areas.

3. Corn

Temporal profiles of the spectral signature of corn are developed from computer compatible tapes of several LANDSAT scenes. This temporal spectral profile shows a close correspondence between corn and development stages.

The effects of different soil types are evident, early in the season, when the plots containing lighter colored soils have higher reflectances. These differences diminish as the ground cover increases until the soil in the field of view of the radiometer is predominately shaded.

Corn radiance versus development stage have been plotted for four training areas that correpond to La Candelaria test site and training areas of La Nueva Bélgica test site; corn is analyzed from the sown stage till the maturity corn state. It must be noticed that each training area corresponds to a different sown day. Figure 3.

It is important to clear up that the first tape is from October 3, when the crop is recently sown; December 15, when the corn is pre-flourishing, January when the corn is flourishing and February when it is matured.

4. Results

Once the annual plants have germinated the IR (bands 6 and 7) increases its reflected radiance in response to increasing cover and density of vegetation. The visible bands 4 (green), and 5 (red) decrease their reflected radiance due to absorption by the plants in these wavelengths and remain fairly constant through the slow growth period.

Reflected radiance in the infrared wavelengths increases rapidly while the visible wavelengths increase very slowly when growth begins to accelerate. In La María Teresa test field five training areas are observed having the same type of crop: corn. But each of these training areas have different corn variety.

These five ares are compared in band 6 and band 7 (IR), in two different dates, December when the corn is pre-flourishing and January when it is flourishing. The point that these soils have been ploughed, including different kind of rests of pastures, is taken into account. Figure 4.

Many factors may affect the results: variety of soil composition, influence of the pasture rests ploughed with the soil (they have been sown during the first days of OCtober), and the degree of uncertainty with which the mean values are computed.

For example, in a very dark colored soil, in the visible portion of the spectrum, the soil and the vegetation tend to blend together and an accurate measurement of percent ground cover is not possible to be obtained, though it can be distinguished in the near infrared portion of the spectrum.

In the case of light colored soils the near-infrared is not effective because soil and vegetation have approximately the same level of response, where as in the visible part of the spectrum the soil has a much lighter tone than the low reflecting vegetation, and therefore the vegetation from the soil in the visible wavelengths can be clearly differentiated.

Observing Figure 4, there are oscillating radiance values with corn varieties in December tape as well as in January tape, although, in general, the radiance values in band 7 are higher than in band 6, besides they are higher in January than in December. This experience is observed as the corn develops till it arrives at the flourishing stage; when corn dries, the radiance values decrease again.

IV. GENERAL CONCLUSIONS

From all what has been stated, we arrive to the conclusion that to set up a spectral signature for a crop is very difficult.

Previous research has indicated that the reflectance of crop canopies is related to the amount of photosynthetically active vegetation present in the canopy.

But, besides all the factors mentioned above which are related to agriculture, meteorology and soil types, there is another important factor that is essential while talking about spectral signatures.

The multispectral satellite scanner records the scene in a number of discrete bands. One generally preferred way of doing this, while maintaining data registration between bands, is to let the entrance slit of a spectrometer serve as the scanner field stop. Thus, it turns to be a dominant factor in determining both the spectral and spatial resolution of the system. That is to say, separated detectors in a detector array of the spectrometer record the same resolution element of the scene, but in different wavelength regions. As a result, the output signal from multiple detectors can be combined to determine the spectral distribution of the radiation from each resolution element of the scene.

The video signals from each of the channels are recorded in parallel on magnetic tapes, permitting data playback in the laboratory and visual observation on a video monitor, with extraction of the spectra of selected objectsand backgrounds. The output of a radiation detector is an observable physical change, response or signal indicative of the character of the incident flux on the sensor.

The ideal radiometer for incoherent radiation would be one that produces a signal in proportion to the radiant flux arriving at the sensor from a well defined direction within a known solid angle and which contains components only in some spectral band between two wavelenghts λ_1 and λ_2.

The proportionality constant R relates signal out of the radiometer S to incident flux $\phi(\lambda_1 \text{ to } \lambda_2)$.

$$S = R\,\phi(\lambda_1 \text{ to } \lambda_2)$$

Actually, radiometers are not equally responsive to radiant flux at all wavelengths within their operating range. The spectral responsivity of a real radiometer generally has a maximum (or peak value) for flux at one wavelength with reduced values for flux at other wavelengths.

The effective spectral bandwidth (λ_1 - λ_2) of a real radiometer is found by the relation:

$$R \text{ peak } (\lambda_1-\lambda_2) = \int_{\lambda_2}^{\lambda_1} R(\lambda)\, d(\lambda)$$

As long as λ_2 approaches λ_1, R peak has more accurate value over this wavelenght range. Consequently, there are multispectral scanners that range to the 12 channels air-borne scanner system and are mounted on an airplane. Although they reach 12μm, i.e. thermal channels, the visible and near infrared bands, the range band is shorter than in the satellite, so the sum radiation measured on a scanner band is more accurate than the satellite scanner band. Figure 5.

This is the reason why when talking about spectral signatures of crops, the radiant measurements have been recorded with a multispectral scanner mounted on an airplane or a radiometer with, at least, 8 bands.

As a final conclusion an important example is included which has been frequently observed in this research and it relates histogram and its respective mean value for each band. This is a corn training area; a histogram of this sample, band 7 is shown.

There are many peak values; the highest is between 126 and 127 radiance value and the respective mean value is 122.34, so it can be said that the mean value is shifted to the left. Figure 6.

This example for corn ilustrates multimodal and widely dispersed distribution, very common to find in our agricultural fields. This is a new corroboration of all that has been said before.

V. ACKNOLEDGEMENT

I want to acknowledge Eng.Agr. Claudia Gargantini and Eng.Agr. Cristina Serafini who have given the Trenque Lauquen ground samples which are a part of the UNDP Project.

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AUTHOR BIOGRAPHICAL DATA

Mirta A. Raed was born in Buenos Aires,Argentina. She received the degree of Licentiate in Physics from the National University of Buenos Aires, in 1975. For two years, she worked in the Remote Sensing Group of the Ministerio de Agricultura y Ganadería (Ministry of Agriculture and Livestock) of Argentina. She attended the International Symposium on Remote Sensing and subsequent Seminar, held in La Paz, Bolivia between November 28 and December 8, 1977. This Symposium was sponsored by the United Nations and the Organization of American States. At present, she is a staff member of the Comisión Nacional de Investigaciones Espaciales of Argentina.

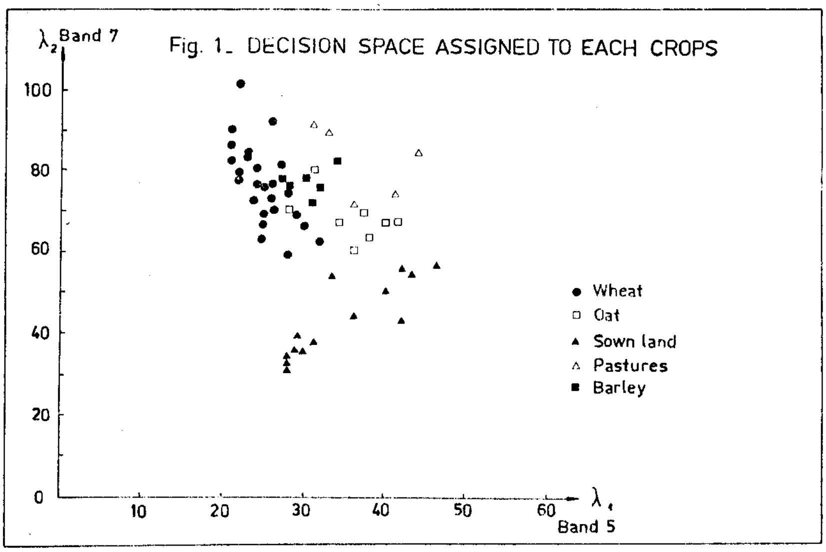
Fig. 1_ DECISION SPACE ASSIGNED TO EACH CROPS
λ2 Band 7
100
80
60
40
20
0
10
20
30
40
50
60
λ1
Band 5
Wheat
Oat
Sown land
Pastures
Barley

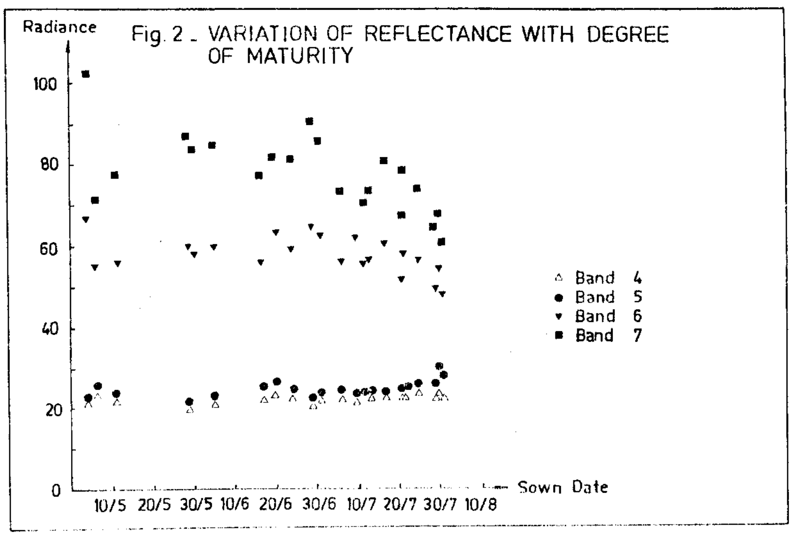
Fig. 2 _ VARIATION OF REFLECTANCE WITH DEGREE OF MATURITY
Radiance
100
80
60
40
20
0
Sown Date
10/5 20/5 30/5 10/6 20/6 30/6 10/7 20/7 30/7 10/8
Band 4
Band 5
Band 6
Band 7

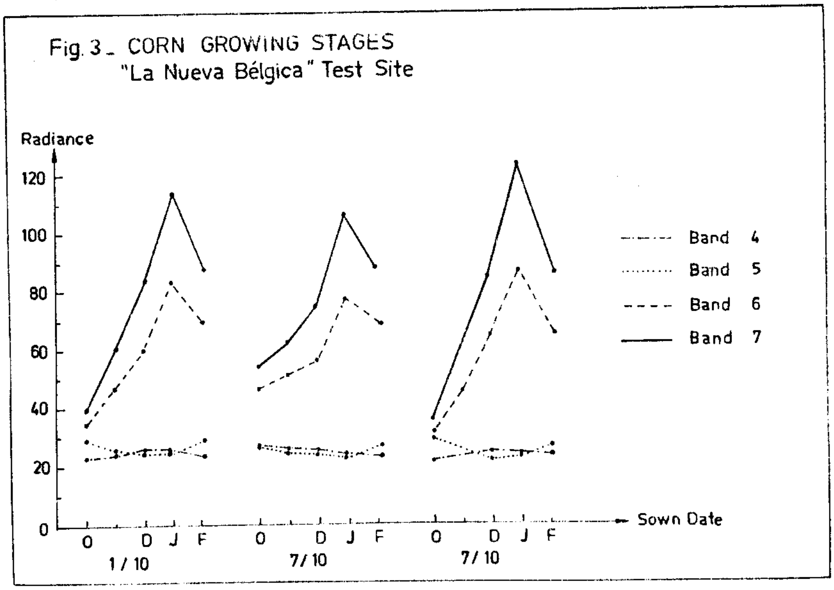
Fig. 3 _ CORN GROWING STAGES
"La Nueva Bélgica" Test Site
Radiance
120
100
80
60
40
20
0
O D J F O D J F O D J F
1/10
7/10
7/10
Sown Date
Band 4
Band 5
Band 6
Band 7

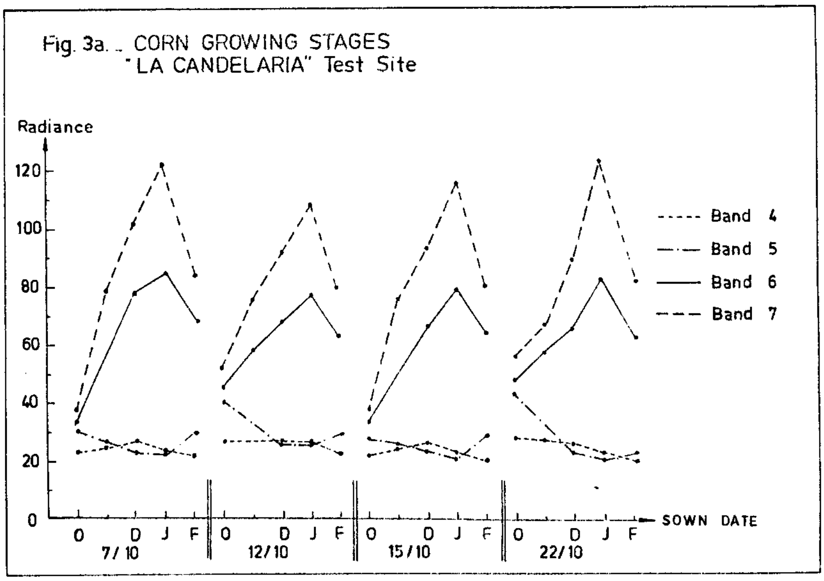
Fig. 3a. _ CORN GROWING STAGES
"LA CANDELARIA" Test Site
Radiance
120
100
80
60
40
20
0
O D J F O D J F O D J F O D J F
7/10
12/10
15/10
22/10
SOWN DATE
Band 4
Band 5
Band 6
Band 7

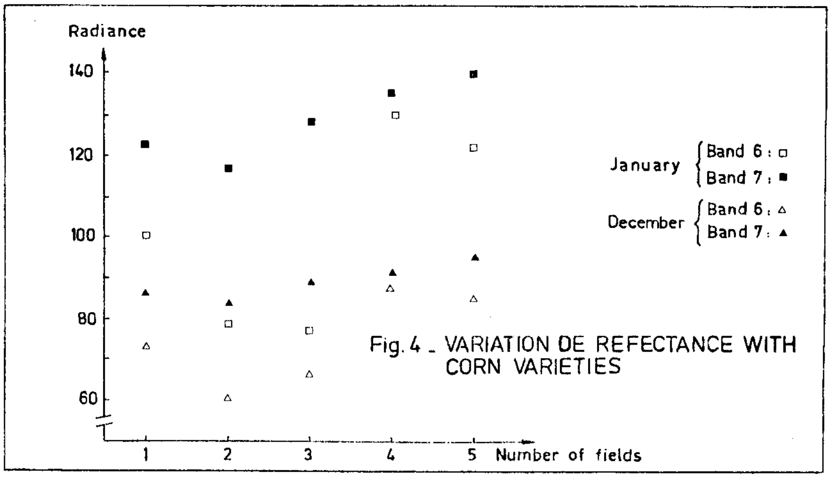

Fig. 4 _ VARIATION OE REFECTANCE WITH CORN VARIETIES

Fig. 5 _ COMPARISION BETWEEN LANDSAT'MSS AND AIRCRAFT MULTISPECTRAL SCANNER BAND WIDTHS

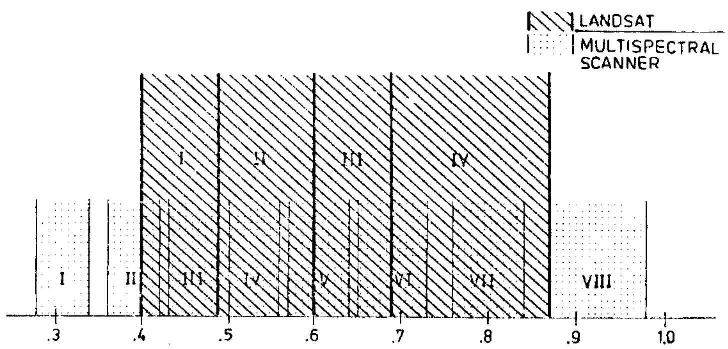

Fig. 6 _ CORN SAMPLE HISTOGRAM _ Band 7