SPECTRAL RELATIONSHIPS BETWEEN LANDSAT DETECTED WINTER WHEAT FIELDS AND OTHER IMAGE-100 CLASSIFIED FEATURES - PASSO FUNDO, RS

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ABSTRACT

This paper reports the results of a maximum likelihood classification (MAXVER) and feature space display of a wheat producing pilot area in Rio Grande do Sul. The need for LANDSAT and airborne systems to gather agricultural information is discussed. Brazil's dependency on wheat importation, the occurrence of severe crop infestation and the unreliability of agricultural statistics point to the need for accurate and timely remotely sensed data for economic planning and crop protection. Climatic and geographic conditions of the test area are provided, including wheat growth conditions and blight susceptibility during the August, 1976 LANDSAT acquisition (path 206, row 22). The results of MAXVER classification and spectral ellipsoid display show that in spite of considerable homogeneity between two classes of wheat and pastureland, Wheat Class II is highly reflective in the visible bands pointing to possible premature planting dates (frost) late planting (blight) or leaf rust ("yellowing")."Unimproved" pasture (overgrazing, bare soil) shares a similar high reflectance with Wheat Class I while "improved" pasture (tilled like wheat) will be confused with Wheat Class I in the IR bands until reduction of standing crop by grazing provides for field differentiation. Coefficients of correlation and a computer map with wheat field distribution support the conclusion that topography, soil moisture and climate extremes must be further studied to make definitive correlations with "between class" spectral differences detected by LANDSAT.

1. INTRODUCTION

Several papers presented at a recent syposium on: The Use of Remote Sensing by Satellites For Agricultural Development in Latin America, (1,2) stress the importance of information gathering systems for application in agricultural resource inventories, crop forecasting and economic planning.

This paper discusses some of the economic problems associated with wheat production and the first use of LANDSAT data to improve existing information on wheat crop loss. The wheat project supported by CNPq/INPE (National Council for Scientific and Technological Development/Institute for Space Research), will test LANDSAT and airborne systems and methodologies to 1) measure wheat crop areas, 2) detect and estimate wheat infestation and, 3) integrate test results into wheat yield prediction models. This preliminary phase of the project, to extract spectral signatures of wheat for automatic classification and comparison with other spectral classes, is reported.

2. WHEAT AND THE ECONOMY

Brasilian economic growth is largely dependent on agricultural exports to finance a wide range of development projects, a daily petroleum consumption of nearly one million barrels and a growing deficit in the balance of payments. The push to modernize the agricultural sector will require more mechanization and knowledge of crop conditions to 1) increase domestic and export-crop production, and 2) reduce import-crop (ie.wheat) dependency.

Wheat (*Triticum aestivum* L) was selected as a prime target crop owing to the serious problems afflicting production which accounts for less than one-half of national consumption. Based on statistics provided by the Bank of Brazil, national wheat consumption climbed from 2,655,000 metric tons in 1967 to 5,064,000 metric tons in 1976 (3). Annual comsumption estimations for the 1980's range between 10 and 25% contingent upon government subsidy policy.

3. CROP AREA AND CROP LOSS

No reliable estimates exist on the actual number of hectares planted (and harvested) and on annual crop losses due to blight and unfavorable weather conditions. Various State, Regional and Cooperative agencies responsible for pre-harvest and final estimates differ in their methods for obtaining data. Crop figures often diverge by as much as 400,000 hectares in a single region (4). Area estimations based on seed distribution and "sight guess" do not take into consideration crop failures during the growing season and crop response to climatic changes and varying topography.

It is recognized that accurate information on annual wheat crop losses is vital for economic planning, research on resistant strains and crop protection (5). Past experiments to estimate wheat areas, notably the LACIE Project (6), and to detect crop disease, realized in the "corn blight experiment" (7), demonstrated the viability of using automatically classified LANDSAT and IR remotely sensed data as a timely and cost-saving technique .

4. STUDY AREA AND IMAGE-100 ANALYSIS

Wheat is grown in six states with considerable variations in soils, climate and planting schedules: Rio Grande do Sul, Santa Catarina, Paranã, São Paulo, Minas Gerais and South Mato Grosso (formerly the southern region of Mato Grosso State). Figure 1.0 shows the distribution of wheat cultivation in Brazil. The greatest concentrations are in Rio Grande do Sul with 1,800,000 hectares planted (1976 estimation), followed by Paranã with 1,500,000 hectares. An estimated 3,500,000 hectares were planted in the six states in 1976.

Complete LANDSAT coverage of Brazil's wheat growing regions is provided on 32 scenes totaling over 1 million Km^2. A LANDSAT cloud free scene, path 206 row 22, was selected over the Passo Fundo agricultural area (August 22, 1976). This scene was acquired when wheat growth is characterized by complete or nearly complete effective cover and nearly maximum Kcp - a calculation of evapotranspiration (8). Wheat is in the elongation stage (flag leaf extension and enlargement of boot) and susceptible to mildew and early outbreaks of leaf rust, *Septoria* and *Gibberela*. Climatic normals for the month of August including rainfall - 138.0 mm, ambient temperature - 14^0 C, and relative humidity - 76.0% are considered optimal for extension and emergence of the spike. However, temperatures above 20^0 C favor infestation and temperatures below 8^0 C or rainfall below 40 mm greatly reduce final production (9).

The pilot area selected for maximum likelihood classification is located 684 meters above sea level on the "Planalto Médio" a stepped plains region in northern Rio Grande do Sul (S lat. 28^0 15' and W. long. 52^0 24'). The region, formerly forested in *Araucária* and Brazilian hardwoods, is characterized by undulating topography and red-latosol soils on a basaltic base.

The town of Passo Fundo was centered on the IMAGE-100 screen and a 26.0 Km by 26.0 Km test area was amplified to a scale of 1:100,000 for analysis. The centering of an urban area served as a useful coordinate reference to load other single-date scenes or superimpose two scenes with different orbital dates. The maximum likelihood algorithm (MAXVER) was set at $\pm$ 5 mean standard deviations and 50 training samples (4,608 pixels) were cursored before classification. A preview of class separability between *jth* field of class *i* was provided on a graphic display program-"matrix of classification". This program allows for the elimination or addition of sample pixels and the division of general classes into subclasses before final clustering and graphics display.

5. RESULTS OF IMAGE-100 FEATURE SPACE DISPLAY

The maximum likelihood classification of the test area resulted in six spectrally definable classes: 1- Urban Class I (commercial), 2- Urban Class II (peripheral), 3- Wheat Class I (dominant IR), 4- Wheat Class II (dominant visible), 5- Pastureland (improved/unimproved) and 6- Other (unknown). Following classification, a program was executed to transform the matrix of covariances into 2- dimensional ellipsoids in feature space. The program reads the archive created by MAXVER and projects onto the graphics terminal (TEKTRONIX 4012) ellipsoids corresponding to each class in each combination of two spectral bands(10).

Figure 2 shows the feature space representation of Urban Class I, Wheat Class I and Wheat Class II. "CANAL" 1, 2, 3 and 4 are computer Portuguese synonyms for bands 4, 5, 6 and 7. The abscissa and ordinate axes are measures of spectral grey level response (0 to 265 grey levels).

It was anticipated that regional farm towns, being small in population and physical space, would be confused or "lost" with surrounding wheat fields. However, the graphic display shows that reflectance or "brightness" levels of Passo Fundo are sufficient to distinguish a town from wheat fields in all spectral band combinations except the two infrared ("canal" 3 and 4). As expected, the weakest response of wheat is in the two visible band combinations (1 and 2) but strengthens with visible/IR combinations. However, the nearly linear correlation of classes 1,3 and 4 in bands 6 and 7 suggest the unsuitability of this combination for wheat identification adjacent to urban centers. The combination of bands 5 and 7 appears to provide optimun contrast for wheat interpretation.

Figure 3 shows the spectral characteristics of pastureland and the two classes of wheat. The grey-level response of pastureland is slightly higher in the visible bands, although a great deal of homogeneity observed between the three classes suggests interpretation problems to be encountered in the temporal period selected for analysis. The fact that "unimproved" pastureland is heavily grazed and interspersed with bare soil, rocks and ant hills explains the higher reflectance in the visible bands. However, "improved" pasturelands which are tilled and seeded, often with a wheat-oats mixture, are likely to present spectral confusion until winter grazing reduces standing crop and elicits field patterns distinct from that of maturing wheat.

The spectral extraction and graphic comparison of Wheat Class I and Wheat Class II (Fig.4) raised the question of what characteristics or possible environmental factors are responsible for the higher reflectance of Wheat Class I in the combination of the two infrared bands and Wheat Class II in the visible bands. At this writing, data from color IR photography were not available, although field data and published information revealed that variations in planting dates and pest outbreaks produced "observed" differences in adjacent wheat fields during the 1976 season. The reflectance data for Wheat Class II may indicate wheat fields prematurely planted (susceptible to frost), fields planted late (less than complete ground cover) or a "yellowing" of leaf foliage, a common condition after the outset of leaf-rust infestation. It is anticipated that LANDSAT sensed and IMAGE-100 classified variations in the wheat fields interpreted, will be definitively correlated with data to be collected from a color IR underflight and field mission scheduled for early September, 1979.

6. COEFFICIENTS OF VARIATION AND CLASSIFICATION MAP

Spectral differences between reflectance bands for each identified class were further demonstrated by calculating the coefficients of variation; defined as the ratio of the standard deviation to mean reflectance: c.v. = $(S^2/ \bar{X}) \times 100$.

From table 1 the mean c.v.'s shows that Wheat Class I (7.54%) is less varied than any other spectral class, followed by pastureland (9.76%) and Wheat Class II (10.88%). Of these three classes, the greatest variation observed in either visible band is in the means of Wheat Class II suggesting again phenomena related to higher plant or soil reflectance.

A computer printout of a sample of the classified test area (Fig. 5) shows the distribution of Wheat Class II amongst irregular field patterns on undulating topography. The predominance of Wheat Class II in low lying, poorly drained areas at the base of or between hills might suggest a relationship between soil humidity and temperature, which often encourage blight conditions, plant rot or frost damage. Also, wheat planted on extreme, unterraced slopes is often washed downslope leaving bare eroded soils, which can be detected on LANDSAT imagery if a large area has been left exposed.

Approximately four operator hours, or US$ 800.000 in system costs were expended for CCT processing , MAXVER classification, graphics display and copying and Dicomed photographic transfer of the IMAGE-100 classified scene (not included in this report).

7. SUMMARY

A project to test the use of LANDSAT and airborne remote sensors to estimate wheat crop areas and annual losses, due to infestation had as its first consideration the spectral relationships between wheat fields and other IMAGE-100 analyzed classes.

The maximum likelehood (MAXVER) classification of six spectral classes and analysis of 2- dimensional ellipsoids in feature space demonstrated the following: a) unexpectedly, small towns, including Passo Fundo, could be distinguished from wheat fields in all spectral band cominations except 6 and 7; b) although pastureland reveals a great deal of homogeneity with wheat in the IR bands, the

higher reflectance of pastureland in the visible range suggests that "unimproved" pasture (heavy grazing, bare soil) may prove distinguishable after wheat has started to mature, c) "improved" pastureland (tilled and wheat-oat seeded) will be highly confused with wheat until grazing reduces standing crop to elicit differences in field patterns, d) Wheat Class II with high reflectance in the visible bands suggests a possible association with prematurely planted fields (susceptible to frost), late planted fields (incomplete ground cover) or a leaf rust condition ("yellowing" of foliage).

The analysis of coefficients of variation of spectral means between bands showed Wheat Class II to be less uniform in the visible bands compared with pastureland and Wheat Class I. The distribution of Wheat Class II on a computer map predominates in low lying, poorly drained areas and on steep, unterraced slopes. The former condition could encourage frost damage, blight and plant rot, while unterraced slopes are subject to severe erosion, which could be detected in the visible bands of LANDSAT if large in areal extent.

Further research will be required to confirm whether spectral variation between wheat fields as detected by LANDSAT is a characteristic of variations in wheat physiognomy and/or soil, topographic and climatic extremes or a consequence of resolution capabilities, machine data processing limitations or user judgement error.

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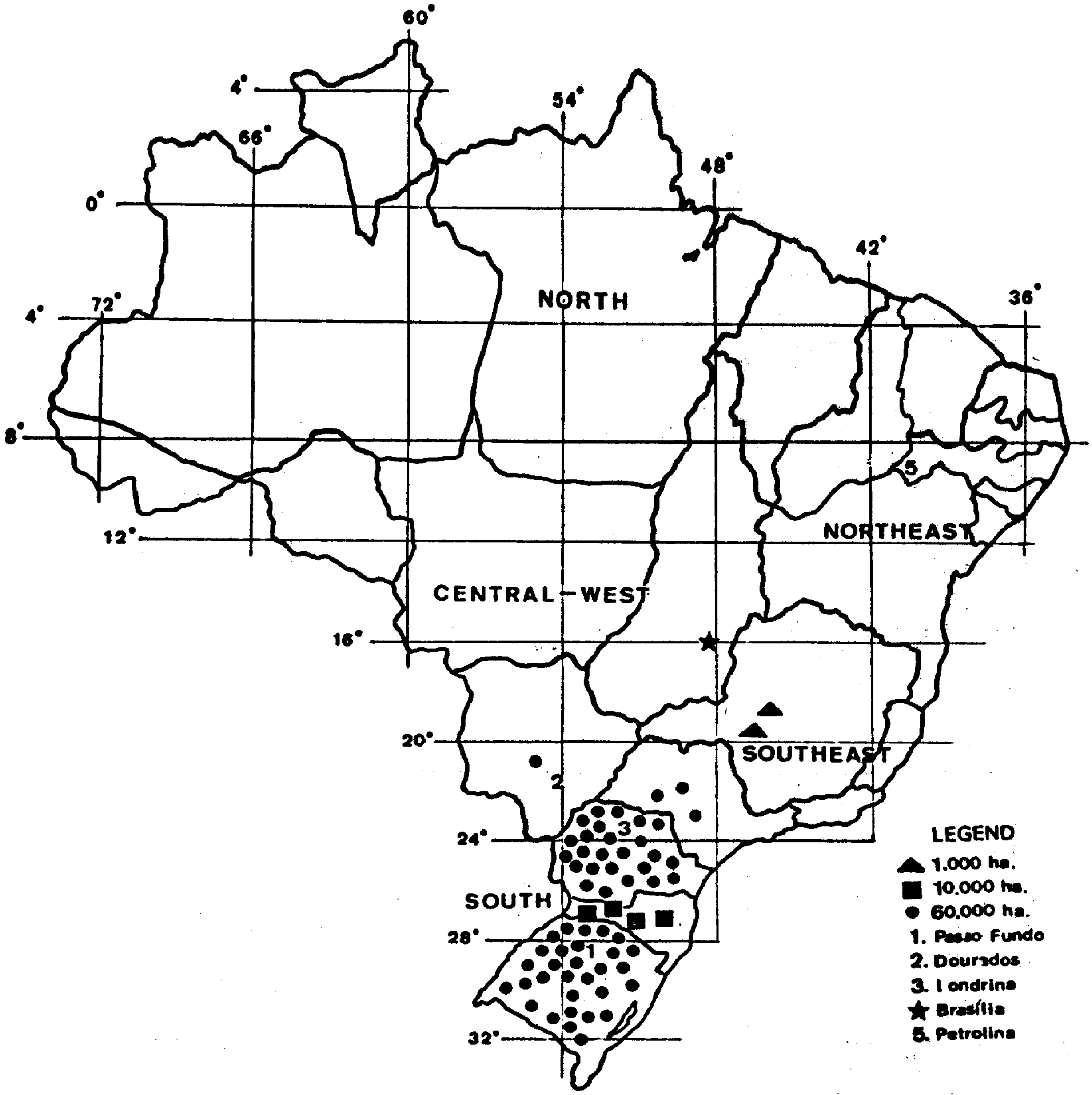

Fig. 1 - Map showing the distribution of wheat producing regions in Brazil.

The study area, Passo Fundo(1) is located in northern Rio Grande do Sul. The northern most limit of wheat cultivation is south latitude 18^{o} with experimentation underway in Petrolina (S. lat. 9^{o} 0'). Complete LANDSAT covarage can be provided with 32 orbital scenes.

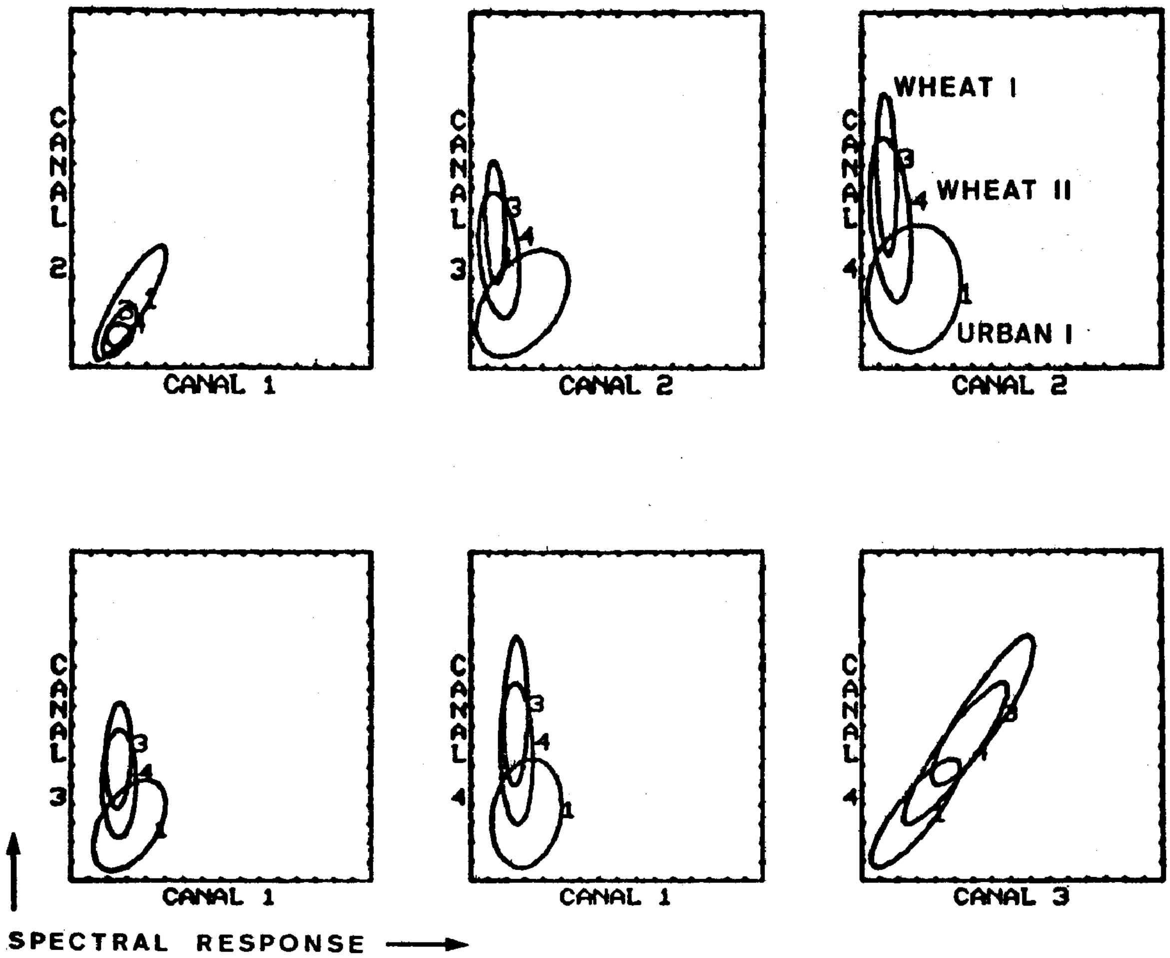

Fig. 2 - Image-100 feature space display.

The feature space display of three spectral classes in each combination of four spectral bands ("canal" 1, 2, 3, 4 = band 4, 5, 6, 7) shows ellipsoids designated as 1 - "Urban Class I", 3 -"Wheat Class I" and 4 - "Wheat Class II".

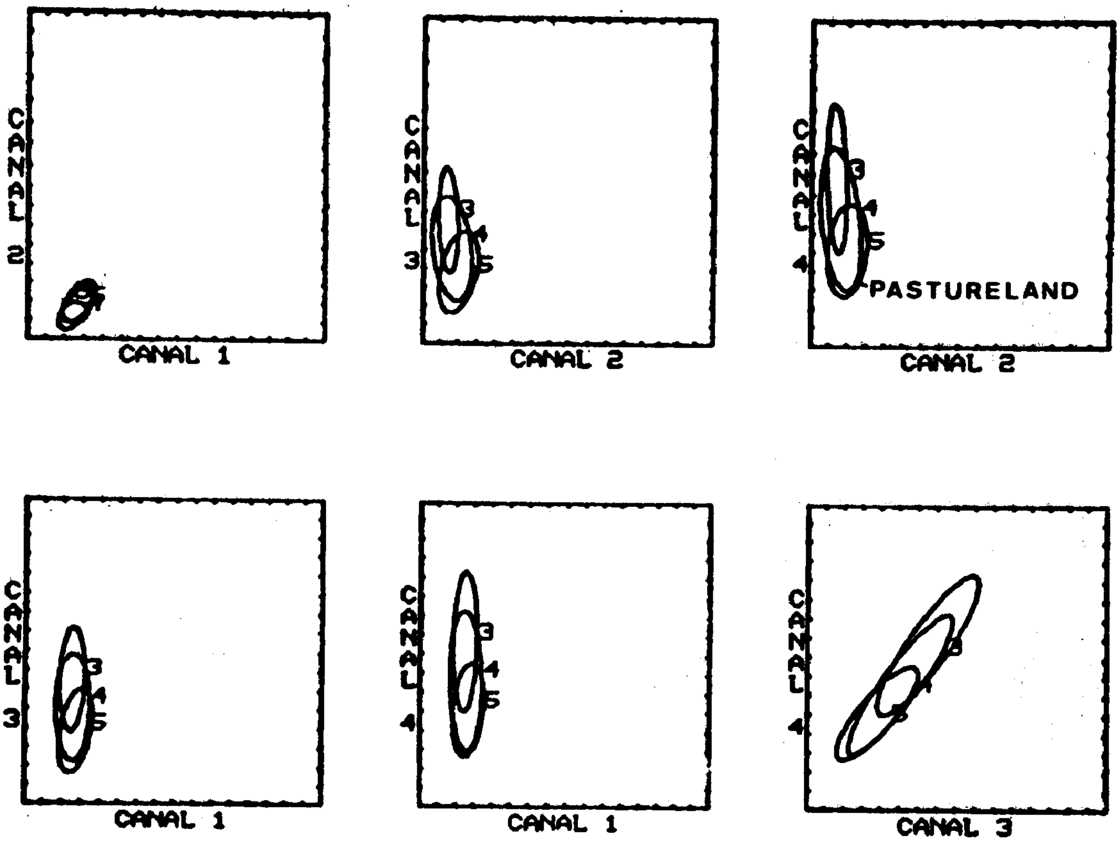

Fig. 3 - Image-100 feature space display

Diagram showing the following classes in 2-dimensioanl feature space: Wheat Class I, Wheat Class II and Pastureland. Note low IR response and slightly higher visible response of Pastureland.

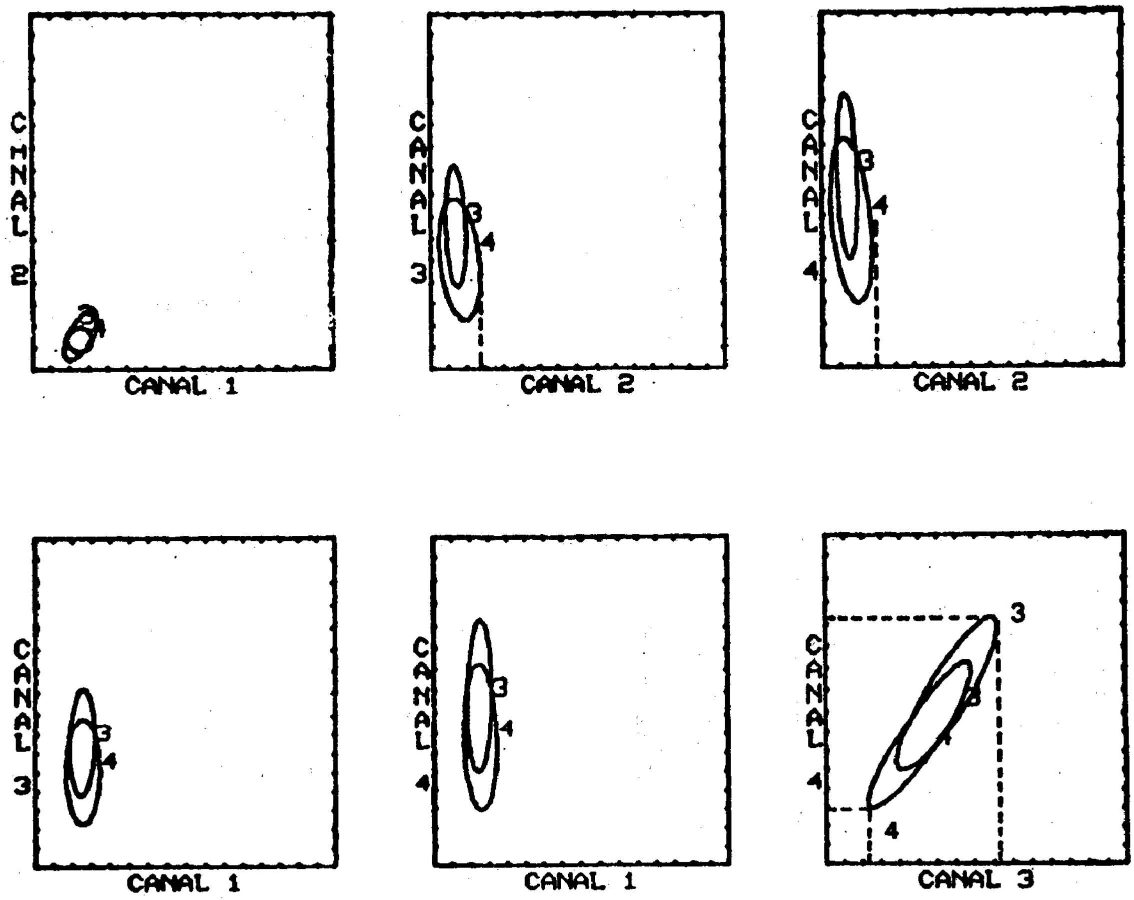

Fig. 4 - Image - 100 feature space display

The ellipsoids showing two spectral classes of wheat with higher reflectance in Wheat Class II (4) in the visible bands and high IR reflectance of Wheat Class I (3). Note dashed lines. Both classes extend over a wide grey level range in the IR bands 6 and 7 conbination.

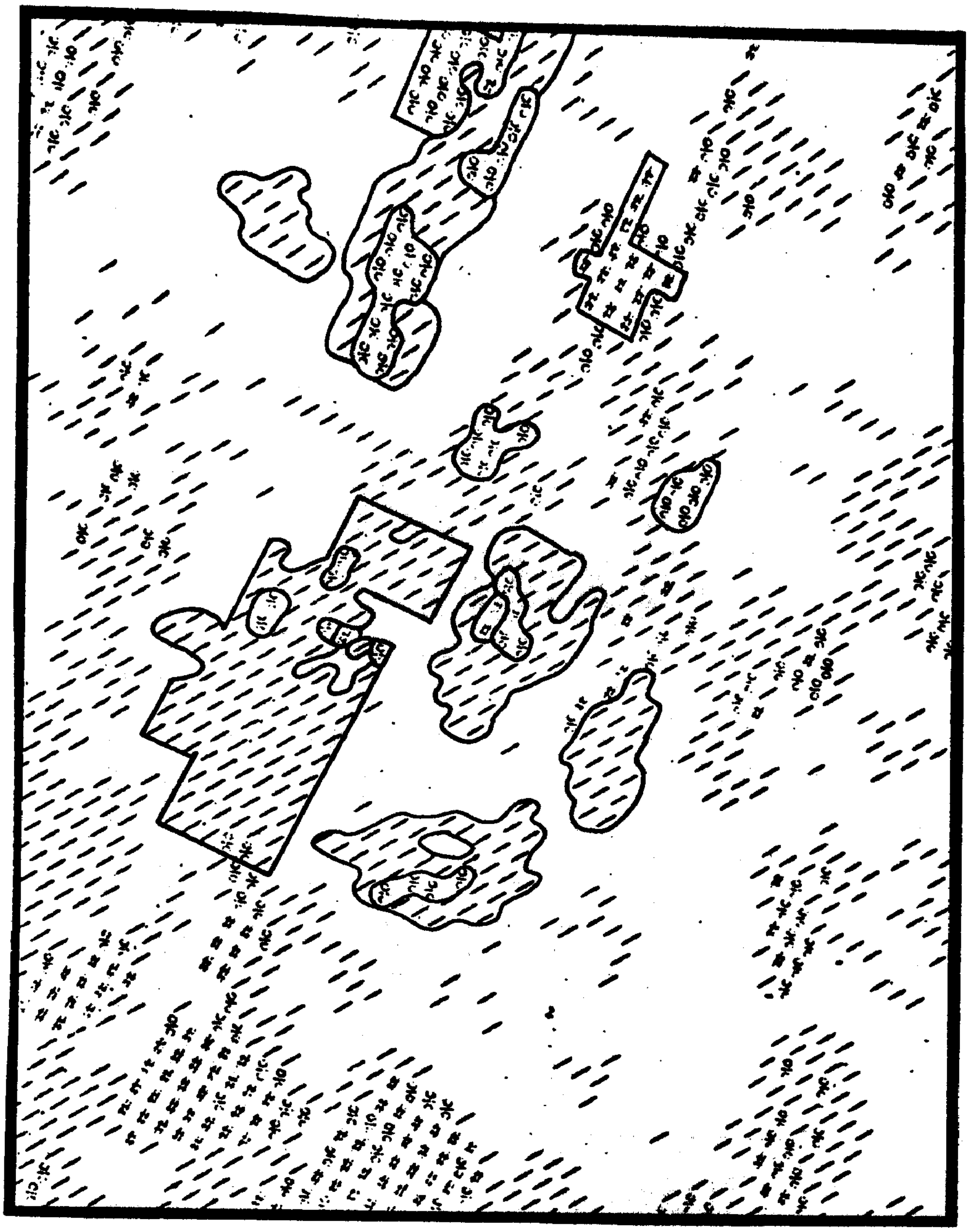

Fig. 5 - LANDSAT CCT classification map

Delimited examples of three classes: Wheat Class I (/), Wheat Class II (%) and Pastureland ( ). Non-Classified areas (#) are also indicated. Note irregular field patterns, a result of undulating topography and small landholdings.

IMAGE-100 CLASSIFICATION AND SPECTRAL COEFFICIENTS

SPECTRAL CLASS	CODE	PERCENT AREA	AREA KM^2	NO. CURSOR POINTS	COEF. VAR. (c.v.%) BANDS 4	5	6	7	MEAN c.v.'s
URBAN I	1	1.11	7.50	536	12.40	17.70	16.52	16.15	15.69
URBAN II	2	.28	1.90	204	15.92	26.10	15.11	12.00	17.28
WHEAT I	3	48.01	325.07	1008	5.33	7.95	8.38	8.51	7.54
WHEAT II	4	11.33	76.70	584	7.06	14.17	11.14	11.16	10.88
PASTURELAND	5	31.32	212.04	1704	6.60	11.20	11.60	9.36	9.76
OTHER		6.45	43.70	572	10.60	33.26	25.30	25.26	23.61
UNCLSSIFIED		1.50	9.09						
		100.00	676.63	4608					

Table showing IMAGE -100 classified spectral classes and occupied areas. Coefficients of variation of spectral means and mean c.v.'s for each class are presented.