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ANALYSIS OF THE QUALITY OF IMAGE DATA ACQUIRED BY THE LANDSAT-4 THEMATIC MAPPER AND MULTISPECTRAL SCANNERS

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1.0 TECHNICAL REPORT

1.1 Background

The primary goal of our research is to characterize the performance of Landsat-4's Multispectral Scanner (MSS) and Thematic Mapper (TM) in terms of spectral and spatial resolution, radiometric sensitivity, and geometric fidelity. A major objective is that of determining how these characteristics affect the utility of the data for natural resources applications. Our overall approach for characterizing the quality of Landsat-4 MSS and TM data entails: (1) analyzing Landsat-4 TM spectral and spatial performance in terms of spectral variability of natural targets and the TM-ground instantaneous field-of-view (IFOV) variability in level and mountainous terrain; and (2) determining the suitability of TM and MSS image products for characterizing renewable resource features.

For the early phases of our research, as reported upon in this progress report, our objectives are to: (1) develop a basic understanding of the TM data in terms of spectral and spatial characteristics, CCT and film formats and products, and special problems in data handling; (2) determine the extent to which major agricultural resources and conditions can be detected and identified on TM image products and field-specific spectral statistical summaries; and (3) evaluate the quality of TM image products in comparison to simultaneously-acquired MSS image products.

During this phase of our research, our focus is on evaluating the quality of TM and MSS data for the interpretation of California's most important resource--agriculture. In California, there is a diversity of crop types and practices, field sizes and shapes, and soil and landform conditions, which provides numerous opportunities for evaluating the quality of Landsat-4 data for meeting the inventory objectives of agricultural statisticians and resource managers.

1.2 Approach

The approach for accomplishing our objectives is as follows:

(1) Acquire the first available Landsat-4 scene of an active test site in California's Central Valley. An active agricultural test site is one in which ongoing projects are collecting detailed field data. These data consist of ground and aerial photographs and descriptions of specific field conditions and cropping practices.

(2) Acquire, process, and catalog small format, low altitude, color oblique aerial photography of selected areas within the scene to document major agronomic conditions including cropping practices, ground cover, and field conditions at the time of the Landsat-4 overpass. Acquisition of this photography should occur coincident with the overpass.

(3) Compile the available ground data for the area imaged to reconstruct, as accurately as possible, the environmental conditions prevalent at the time of the overpass. The sources of ground data for our research include: a) Land Use Survey Maps of the California Department of Water Resources (DWR), published at a scale of 1:24,000 and including individual

field boundaries which are outlined and labeled (Ref. 1); b) the U.S. Department of Agriculture's statistical summaries for crops and climate (Ref. 2), and c) field crew notes and data, as compiled by personnel of our Remote Sensing Research Program (RSRP) at the University of California.

(4) Produce TM and MSS black-and-white and color composite image products for interpretation.

(5) Locate the field data and aerial photographic coverage on the TM and MSS imagery.

(6) Relate the environmental conditions to the TM and MSS spectral data in both analog (film) and digital (numeric) formats.

(7) Determine the interpretability of major agricultural crops using these Landsat-4 spectral data based on established techniques (Ref. 3,4). Interpretability requires that the image products allow both the detection and the correct identification of features of interest. Detection requires, at a minimum, the simple recognition or awareness that a feature is present. To identify the feature requires a synthesis of spectral, spatial, textural and temporal characteristics (Ref. 5).

Our objectives call for interpreting diverse agricultural features using image products. Such products have both advantages and limitations in that photo-like imagery provides the best format for evaluating spatial and textural characteristics, but has limited usefulness for analyzing detailed spectral and temporal characteristics (Ref. 5). When an image is created, whether in black-and-white or in color, from digital data, the data must be compressed into a limited number of gray (or color) levels thus obscuring subtle spectral differences of a feature of interest. In addition, color variation due to photographic processing may obscure data critical for feature identification. Inasmuch as these conditions suggest that some of the analyses of Landsat data can best be made using the original numeric data rather than images produced from these data (Ref. 6) such an analysis is being included in our investigations.

1.3 Results and Discussion

The first available Landsat-4 scene for one of our active test sites was acquired on December 8, 1982. This site is located in San Joaquin County, California. The image data were received by the Prince Albert Station in Canada and forwarded to NASA-Goddard Space Flight Center (GSFC) for subsequent processing. The scene identification number is #84014518082X0, World Reference System (WRS) Path 43, Row 34. The TM data were processed as a "P" tape by the Landsat Assessment System (LAS) at GSFC using the interim SCROUNGE image processing system. The "P" tape product is both radiometrically and geometrically corrected. The computer compatible tape (CCT), at 6250 bpi, was forwarded to the IBM Palo Alto Scientific Center, c/o Mr. Ralph Bernstein, for subsequent processing and analysis by IBM and U.C. Berkeley. The MSS data were purchased at the EROS Data Center as a CCT-AM ("A" tape) which is radiometrically, but not geometrically processed.

Due to winter ground fog in the Central Valley, the first opportunity during which to acquire small format, low altitude color oblique photography after the December 8 Landsat pass occurred on January 20, 1983. On that day, several preselected transects within San Joaquin County were flown and specific fields photographed using dual 35mm cameras. One camera contained natural color film and the other, color infrared film. The aircraft altitude was 500m. The film was processed commercially, and each transect and frame was labeled and annotated on DWR land-use maps at 1:24,000 scale.

Given the vast area covered by each Landsat frame, two 21,000 hectare study areas within the County were selected for detailed analysis due to the diversity of their agronomic and pedologic conditions. The Vernalis Study Area is dominated by alluvial and low terrace soils supporting orchards, field crops, and native pasture. The Caswell Study Area is dominated by basin and alluvial soils supporting mixed pasture, field crops, some orchards and vineyards, and extensive native vegetation in Caswell State Park (Ref. 7).

By thoroughly examining these detailed land use maps along with the oblique aerial photographs and published agronomic and climatic data, we were able to determine environmental conditions prevalent at the time of the overpass. Climatic conditions one week prior to the overpass were varied. A series of Pacific Ocean storms had crossed the State with over one inch of precipitation falling in northern San Joaquin County. No precipitation fell during the week of the overpass, and temperatures were near normal for the study area. Precipitation was heavy during the period between the overpass and the acquisition of the oblique aerial photography. As periodic storms and cool temperatures preceeded both the satellite and aerial photography acquisitions, variations in surface soil moisture between the two dates of data acquisition were minimal. Agronomic conditions were dominated by slow growth of small grains, which were 50% emergent, statewide, at the time of the overpass. Preparation for planting the remaining small grain fields was in progress with much moist, fallow soil present. Field preparation included weed control, pre-irrigation and planting. Harvesting of grain sorghum and corn had recently been done in some fields. This is indicated in both study areas by the presence of grain and corn stubble fields. Some limited alfalfa cutting was in progress, and many overwintered sugar beet fields were evident. Pruning and weed control were the dominant field activities in the deciduous orchards and vineyards. Many spectral variations in the orchards resulted from the high spectral reflectance of the grass canopy understory in orchards of varying age. Pasture growth and conditions were above normal due to favorable climatic conditions prior to the overpass. Both native and irrigated pasture experienced rapid herbaceous growth prior to the overpass. The cool, wet conditions that prevailed after the overpass retarded grass growth; conditions documented on the aerial obliques acquired six weeks after the overpass were very similar to those present at the time of the overpass.

Image products and numeric data were extracted from both the TM and MSS data. TM image products were generated using the IBM 7350 Image Processing System at the IBM Palo Alto Scientific Center (Ref. 8). Various single band

and multi-band images were displayed on the 7350's color monitor; 35mm slides were used to image the data displayed on the screen. Initial analysis of the TM data was accomplished using these 35mm slide products. MSS image products were generated using the Remote Sensing Image Analysis Computer System at the Space Sciences Laboratory on the U.C. Berkeley campus. Digital displays were copied onto 35mm and Polaroid (Type 809) color film using a Matrix Color Graphics Camera. Through the use of black-and-white and color image products, direct comparisons of tone and textural signatures were made between the oblique photography and the ground data in order to determine the TM and MSS spectral characteristics of major agricultural fields in the area, and to locate specific fields for extracting numeric data from both the TM and MSS CCT's. Using these numeric data, we estimated the within-the-field and within-region spectral variability, by band, for both the Landsat-4 sensors. These numeric data for the Caswell Study Area are summarized in Figure 1 where spectral data for each of the TM spectral bands are plotted. The thermal band (TM6) displays the lowest variability and range of values for this area. This is expected given the 120-meter IFOV and limited radiant temperature variability of the area sampled. In the reflective bands, the spectral variability increases with wavelength. Field-specific spectral data for the Caswell study area are tabulated in Table 1, and plotted in Figure 2. The fields and crops selected are those which dominate the study area in terms of spectral, spatial, and textural characteristics.

Systematic analyses of both image products and numeric data for these study areas have yielded the following early results:

(1) The overall quality of the TM data are excellent. Spectral variations in fallow fields are primarily the result of soil moisture and surface roughness variability due to various stages of field preparation for planting small grains.

(2) There is extensive coherent noise in the MSS data for all bands. The noise affects data quality in Bands 1 and 2 to a greater extent than in two near-infrared bands. We anticipate this noise will cause significant classification errors for mapping small fields and speciality crops in California when using MSS data. This noise is also apparent in TM Band 1 for both Study Areas. The period of this MSS and TM noise has not been determined by these investigators.

(3) Spectrally, the addition of the first short-wave infrared band (Band 5) has significantly enhanced our ability to discriminate different crop types as shown in Figure 2. In the visible and near infrared bands, there is no significant difference between the sugar beet and alfalfa spectra. In the middle infrared band, however, we see significantly different spectral values resulting from the increased absorption of the radiation by the higher content of leaf water of the sugar beet plant. Several other spectral crossovers (tone shifts) between the visible and near-infrared regions are also displayed. These crossovers provide enhanced capabilities for discriminating and identifying major crop groups and land cover conditions that are commonly confused spectrally in the visible and near-infrared regions on single-date imagery. These obvious crossovers occur between orchard and bare soil; between mixed pasture, sugar beets, and alfalfa; and between grain stubble,

mixed pasture, alfalfa, and sugar beets. The accuracy of crop group or crop type classification using single-date or multi-date Landsat-4 data will increase if TM Band 5 is used in conjunction with TM Band 4 and/or Band 3 as simple ratios, linear combinations, or other commonly used transformations.

Photographic images of the thermal data acquired by the TM sensor for both Study Areas were analyzed in a similar fashion. The dark tones on the imagery are those land surfaces which have low radiant temperatures at the time of the overpass (0908 hours, PST), and represent primarily fields of grain stubble and bare soil which have low thermal inertia. The light tones are those surfaces which have high radiant temperatures at the time of the overpass, and represent fields of deciduous orchards, field crops and mixed pasture which have a relatively higher thermal inertia than the bare soil fields. Improvements in the processing of the TM thermal data is still needed to reduce the radiometric striping resulting from the bi-directional scanning.

(4) Spatially, the twofold decrease (28.5 m vs. 57 m) in interpixel distance, and fourfold decrease in area per pixel of TM data allow for improved spectral characterization of individual features due to a reduction in measurement errors. This reduction results from the ability to extract a higher number and proportion of "pure" pixels that are minimally contaminated by "boundary" pixels. Mapping at more detailed levels of classification will also be enhanced by using the spatially improved TM products.

(5) The 8-bit signal quantization level of the TM provides an image that is rich in detail, optimizing the textural characteristic--a major attribute used in feature identification. The improved tone contrast and increased sharpness of feature boundaries on the TM image products, in comparison to the MSS products, is readily apparent from a careful viewing of the image products.

(6) No geometric comparisons were made between the MSS and TM data because the MSS data had not been geometrically corrected. Qualitative comparisons between the TM data and USGS 7½' topographic quadrangles, however, appear to indicate that the geometric quality of TM data is sufficient for updating land use maps and field boundaries at this scale (1:24,000).

1.4 Summary

Even at this early stage of our research we find the quality and utility of the TM data to be excellent for meeting most of the inventory objectives of the agricultural resource specialist. The TM data will be extremely valuable for crop type and area proportion estimation, updating agricultural land use survey maps at 1:24,000-scale and smaller, field boundary definition, and determining the size and location of individual farmsteads.

Ongoing research activities are focused on making spectral and spatial analyses of both MSS and TM analytical film products. Based on the improved spectral, spatial and radiometric quality of the TM data, we see a renewed emphasis and interest in direct visual interpretation of these image products, both for updating and improving land stratification in support of resource inventory and for enhancing the image analyst's contribution to computer-assisted analysis procedures.

1.5 Acknowledgments

We wish to acknowledge our GSFC Science Representative, Mr. Darrel Williams, for his support in expediting the distribution of the TM data to both IBM and U.C. Berkeley. In addition, we wish to express our gratitude to Messrs. Ralph Berstein and Jeff Lotspiech for the cooperative and timely effort at the IBM Scientific Center in producing the TM image products for the Early Results Symposium. Special acknowledgment is extended to Mr. Kevin Dummer and Ms. Louisa Beck for the acquisition, processing and compilation of the high quality color aerial oblique photography and ground data. This research project is supported by NASA Contract #NAS5-27377, Goddard Space Flight Center.

1.6 References

1. California Department of Water Resources. 1982. Land use survey maps, Vernalis and Ripon quadrangles. Sacramento.

2. U.S. Department of Agriculture. 1982. California crop-weather. Vol. 2, Nos. 21, 22, 28. Statistical Reporting Service, USDA, Sacramento, December 1982, January 1983.

3. Colwell, R. N. 1978. Interpretability of vegetation resources on various image types acquired from earth-orbiting spacecraft. J. Appl. Photogr. Eng. 4(3):107-117.

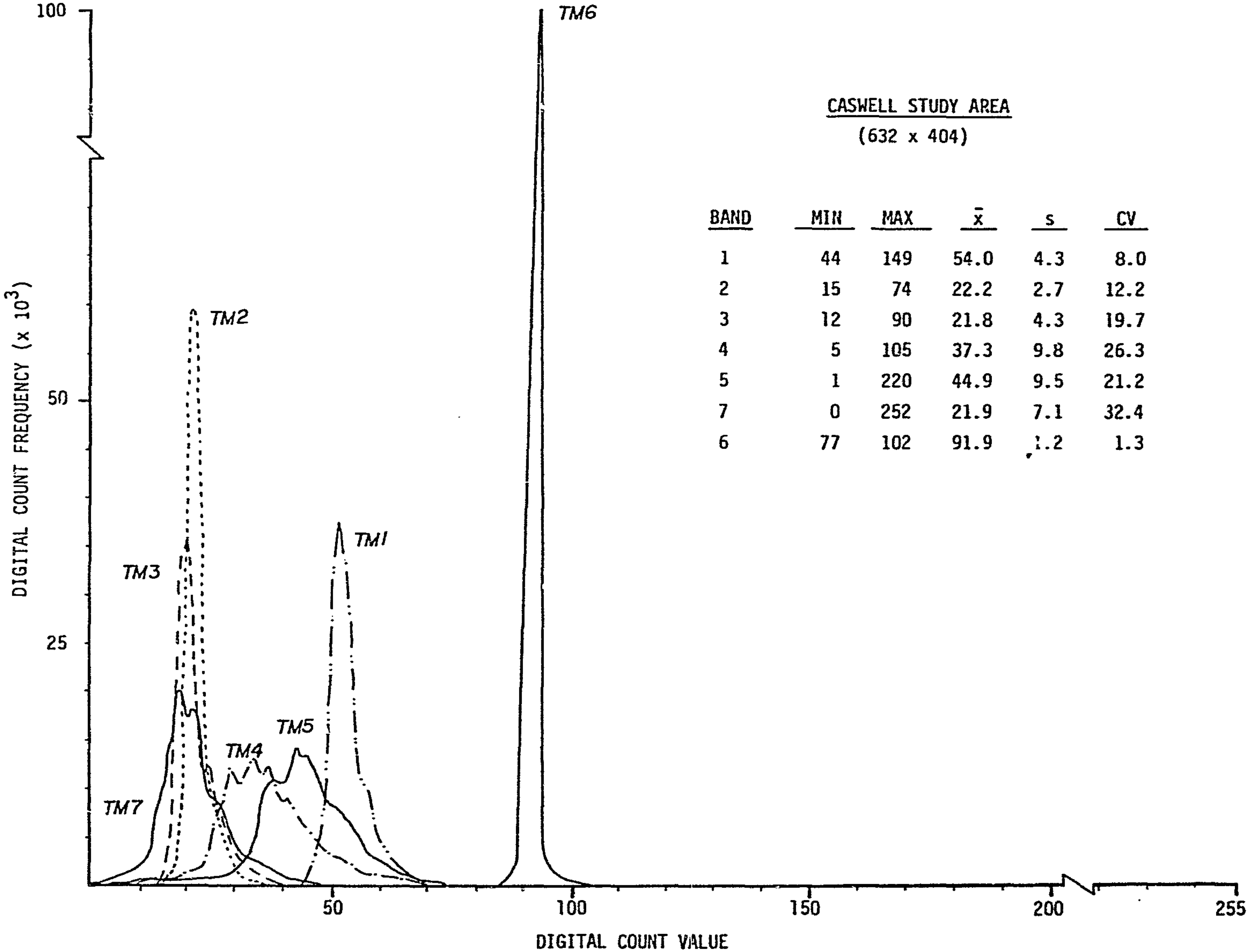
4. Benson, A. S. and K. J. Dummer. 1983. Analysis of photo interpretation test results for seven aerospace image types of the San Juan National Forest, Colorado. Proc. 49th ASP Annual Meeting Washington, D.C. pp. 121-130.

5. Hay, C. M. 1982. Remote sensing measurement techniques for use in crop inventories. pp. 420-433. In C. Johannsen and J. Sanders (eds.) Remote Sensing for Resource Management. Soil Conservation Soceity of America, Ankeny, Iowa.

6. Odenweller, J. B. and K. I. Johnson. 1982. Crop identification using Landsat temporal-spectral profiles. Proc. Symp. Machine Processing Remotely Sensed Data, Purdue University, West Lafayette, IN. pp. 469-475.

7. Weir, W. W. 1952. Soils of San Joaquin County, California. Agric. Exp. Station, College of Agric., University of California, Berkeley. 137p.

8. Niblack, W. 1982. IBM 7350 Image Processing System: A tool for earth resources data processing. Proc. Symp. Machine Processing Remotely Sensed Data, Purdue Univ., West Lafayette, IN. pp. 533-537.



CASWELL STUDY AREA
(632 x 404)

BAND	MIN	MAX	$\bar{x}$	s	CV
1	44	149	54.0	4.3	8.0
2	15	74	22.2	2.7	12.2
3	12	90	21.8	4.3	19.7
4	5	105	37.3	9.8	26.3
5	1	220	44.9	9.5	21.2
7	0	252	21.9	7.1	32.4
6	77	102	91.9	1.2	1.3

Figure 1. Spectral data plot for each of the TM spectral bands using the Caswell Study Area.

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	SUGAR BEETS $\bar{x}$	SUGAR BEETS CV	ALFALFA $\bar{x}$	ALFALFA CV	MIXED PASTURE $\bar{x}$	MIXED PASTURE CV	ORCHARD $\bar{x}$	ORCHARD CV	VINEYARD $\bar{x}$	VINEYARD CV	GRAIN STUBBLE $\bar{x}$	GRAIN STUBBLE CV	BARE SOIL $\bar{x}$	BARE SOIL CV	NATIVE VEGETATION $\bar{x}$	NATIVE VEGETATION CV
TM1	50.4	2.5	50.1	2.3	53.8	2.8	51.4	2.6	52.5	3.1	65.2	2.6	56.4	2.5	50.6	3.2
TM2	20.3	3.9	20.5	3.6	22.5	4.1	20.2	3.8	21.3	3.8	29.9	4.3	23.4	4.0	18.9	3.9
MSS 1	13.8	7.4	14.4	7.5	15.1	7.8	14.1	8.3	14.7	6.8	21.4	7.1	16.1	7.5	13.4	9.2
TM3	16.9	4.0	17.1	3.7	22.4	5.4	19.4	4.4	21.5	5.4	36.3	4.4	24.9	3.8	18.0	6.1
MSS 2	8.8	12.0	9.3	11.5	12.0	8.5	10.4	8.6	11.8	8.3	21.6	6.7	14.2	9.1	9.5	11.4
TM4	60.4	3.9	58.8	3.8	46.2	5.6	30.4	3.5	33.3	5.1	38.6	4.9	28.2	7.1	25.4	11.1
MSS 3	37.2	7.3	38.4	7.0	30.4	1.8	20.1	5.9	22.4	8.9	30.3	5.6	20.8	8.6	15.7	14.7
MSS 4	34.4	7.5	35.4	2.9	28.0	1.8	18.5	5.6	18.9	1.6	22.8	6.8	16.2	8.8	13.4	18.7
TM5	28.0	5.0	44.8	2.8	53.9	4.8	37.5	4.6	46.4	6.7	65.8	4.2	43.8	4.5	33.7	13.2
TM7	9.1	11.1	15.2	9.1	21.5	8.2	17.5	10.6	23.8	7.8	43.7	5.4	25.7	6.4	16.2	18.2
TM6	91.8	0.5	92.7	0.7	93.4	0.6	92.1	0.6	92.7	0.7	91.8	0.6	90.9	1.0	92.0	0.7

Table 1. TM and MSS Spectral Statistics for the Caswell Study Area.

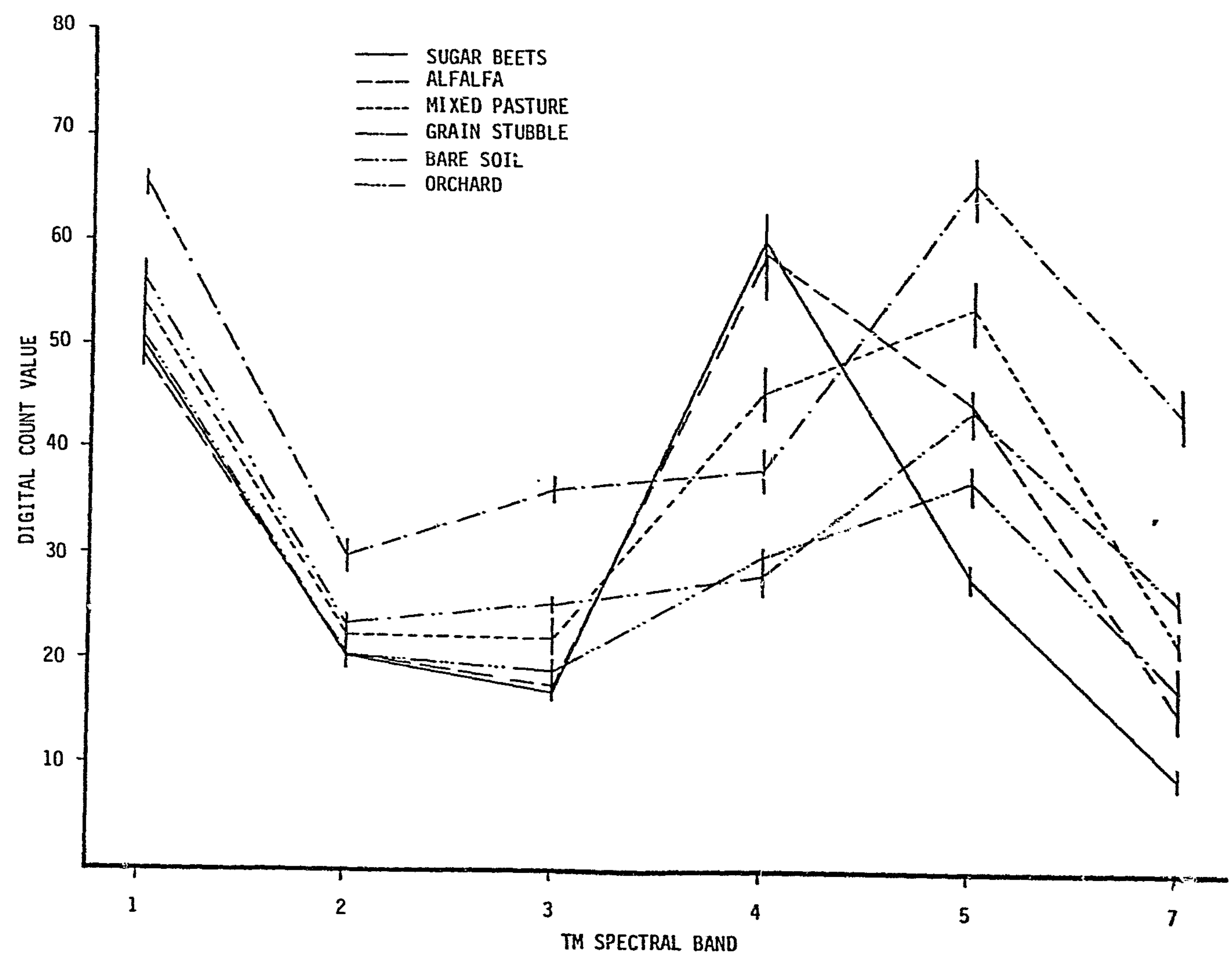

Figure 2. Plot of the spectral values for several crops for each of the reflective TM bands. Data values represent field means ($\pm$ 1 s.d.) using one or more fields per crop. Values are tabulated in Table 1.

2.0 PUBLICATIONS AND PRESENTATIONS

Landsat-4 Early Results Symposium
NASA-Goddard Space Flight Center
Greenbelt, MD
February 22, 1983

"Characterization of Landsat-4 TM and MSS Image Quality of the Interpretation of California's Agricultural Resources"

American Society of Photogrammetry (ASP)
49th Annual Meeting
Washington, D.C.
March 17, 1983

"Characterization of Renewable Resources Using Landsat-4 TM and MSS Imagery"

3.0 FUNDS EXPENDED TO DATE

The funds expended to date under this contract are summarized in NASA Form 533M, "Monthly Contractor Financial Management Report", dated March 1983.

4.0 PROBLEMS ENCOUNTERED TO DATE

Problems encountered to date have been summarized and submitted to the contract Science Representative, Mr. Darrel Williams in PI Status Reports, dated January 11, February 4, and March 1.