VEGETABLE AND FRUIT TREE INVENTORY WITH LANDSAT TM DATA: PRELIMINARY RESULTS

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BIOGRAPHICAL SKETCHES

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ABSTRACT

Landsat thematic mapper (TM) data are being evaluated for determining or monitoring the planted areas of different vegetables and fruit trees in New York State. TM scenes of western New York were acquired in August and September 1982, and the acquisition of new scenes was requested for the summer 1984. The 1982 scenes were analyzed digitally, with spectral characterizations, enhancements and classifications being referenced to cropping records. In anticipation of the 1984 TM scenes, field observations and four-band spectroradiometric measurements of major vegetables were made throughout the 1984 growing season. TM data show promise for distinguishing fruit trees and, especially, vegetables. The work is proceeding with the 1984 TM data.

INTRODUCTION

Fruit and vegetable production is important to the economy of New York State. These crops occupy over one million acres of land, producing combined market sales of over $300 million.

The census of fruit and vegetable crops in New York is conducted by the Crop Reporting Service through periodic field observations and survey questionnaires. This study was undertaken to determine the extent to which satellite data, specifically data acquired by the Landsat thematic mapper (TM), might provide useful information for fruit and vegetable census in New York State.

PREVIOUS STUDIES

Many studies have demonstrated the value of aircraft and satellite remote sensing for crop identification and inventory (Colwell, 1983). The regular frequency of satellite data acquisition makes these data particularly attractive for crop inventory and monitoring.

Most studies of crop inventory with satellite data have used data acquired by the Landsat multispectral scanner (MSS) (Colwell, 1983), and most of these have focused on large area grain crops (e.g., Bauer et al., 1978; NASA, 1979; Mergerson, 1981; Odenweller and Johnson, 1982).

Vegetables have been the focus of Landsat MSS studies by Ryerson et al. (1979, 1981) and by Zhu et al. (1983); and other Landsat MSS investigators have included vegetables among other crops of interest (e.g., Morse and Card, 1983). Although spectral separability of the vegetables studied could be achieved with the four MSS bands, effective crop inventory would be hindered by the small, irregularly shaped fields, and the lack of continuous crop canopy.

Regarding fruit crops, a small number of Landsat MSS studies have examined citrus orchards (e.g., Gausman, et al., 1977; Morse and Card, 1983). Unfortunately, differences in leaf spectral reflectance and management practices limit the information that can be transferred to the inventory of apples and other temperate zone fruit trees.

Although Landsat TM data have been available since 1982, and although these satellite data offer higher spatial resolution, more spectral bands, and increased spectral sensitivity compared to Landsat MSS (Colwell, 1983), no study could be found which used TM data for inventorying vegetables or fruit orchards. The actual and potential advantages of TM data over MSS data for crop studies, including those of corn and soybeans, have been described by several investigators. These efforts have been based on theoretical analyses or studies with simulated TM data (e.g., Markham and Townshend, 1981; Sigman et al., 1981; Williams et al., 1984); field reflectance studies (e.g., Gardner et al., 1982; Daughtry et al., 1984; Crist and Cicone, 1984); and studies of coincident TM and MSS data (e.g., Crist, 1984).

In summary, relatively few directly pertinent studies have been done using Landsat MSS or TM data for inventorying vegetable crops or those fruit trees grown in New York State. The major focus of an evaluation of TM data for vegetable crop inventory in New York would be the small field sizes, while for inventorying New York fruit trees, emphasis would be placed on basic target characterization.

MATERIALS AND METHODS

Computer-compatible tapes of two TM scenes of western New York (28 August and 13 September 1982, path 17/row 30) were selected from the limited number of available TM scenes, based on the dates of the scenes and the locations of vegetable and fruit cultivation in New York. The 1982 field cropping records for muckland vegetables and several fruit orchards were supplied by the New York Crop Reporting Service; and panchromatic, 1:40,000 scale, aerial photographs, flown in May 1982, were also obtained.

A preliminary analysis of the 1982 TM data was performed during the fall of 1983 and spring of 1984 on the interactive digital image analysis system of Cornell's School of Civil and Environmental Engineering (International Imaging Systems model 70, linked to VAX 11/750 minicomputer). The analysis of vegetables focused on potatoes, onions and corn cultivated in organic soils (muckland), while the analysis of fruit trees focused on apple, tart and sweet cherry, peach and pear orchards having nearly equal size trees and uniform management. Although emphasis was placed on simply characterizing the spectral properties of the identified fruit and vegetable crops in the TM bands, the TM data were analyzed through ratioing, principal components transformation, and several vegetative indices.

In anticipation of 1984 TM scenes, field observations of fruit trees were made during the spring and summer of 1984, along with field observations and spectroradiometric measurements of vegetables on organic and mineral soils (i.e., upland cabbage, snap beans and sweet corn, muckland lettuce and onions, and both muckland and upland potatoes). The spectroradiometric measurements were made in the first four TM spectral bands, with two four-band radiometers (Exotech model 100 AXM-T) and a data logger (Omnidata Polycorder), following the procedure described by Duggin and Philipson (1982). Three sites, approximately 1x1 meter, were sampled in each field on ten dates between June and September 1984. Measurements were made directly over the rows, midway between two rows, and over the bare soil. Due to the limited scope of the field measurement program, only one field was sampled for each crop. For future analysis, crop yields were obtained at the test sites when the fields were harvested.

RESULTS AND DISCUSSION

Fruit Trees

The spectral and cultural characteristics of the orchards are being examined. The most significant cultural practice with apples is the planting of different varieties by row for effective pollination. A single variety rarely occupies a strip in the orchard more than 50 meters wide. This practice effectively precludes the use of TM data for obtaining varietal separations of apple trees.

Another farming practice which affects identification is the wide range in ground cover adopted by the orchardists. The background predominates in the spectral measurement of young trees, and the variability of the background makes it unlikely that TM data can be used to reliably classify immature orchards by their spectral characteristics alone. Although the background is also a factor in the spectral measurement of mature orchards, preliminary results with the 1982 TM data indicate that, to some degree, all types of mature fruit trees considered in the study are separable (Table 1). The maximum confusion has been encountered in separating applies, pears and forest.

The TM band 7 differences between forest and fruit trees

(Table 1) appear related to moisture differences, caused by differences in tree spacing and possibly pruning, or simply the drainage properties of the respective sites.

Band ratios and vegetative indices are being examined along with convolution routines, which should enhance spatial (textural) differences that might aid in separating forests from fruit trees as well as separating the different fruit trees. Although the spatial resolution of TM data is not sufficient to recognize orchard rows, orchards appear more homogeous than forest stands.

Vegetable Crops

The 1982 TM data were studied using different band combinations. In spite of the small field sizes, the crops (onions, potatoes, corn), drainage ditches and windbreaks could normally be identified with the aid of the field plot maps. The TM spectral values for the three crops differed most in bands 4 and 5 of the August scene (Table 1). A ratio of TM bands 4 and 3, and a normalized vegetative index incorporating these two bands, allowed improved separation of all crops.

The 1984 field reflectance data are being analyzed to determine the spectral separability and spectral characteristics of the seven vegetable crops considered. Crop reflectances in the first four TM bands appear to be sufficiently different that all crops would be separable with satellite data on at least one date of field data collection (e.g., Table 2). In addition, to provide a means for studying crop phenology, predicting crop separability, and relating the field data to the 1982 and later TM satellite scenes, average crop reflectances are being plotted against days after planting (Fig. 1).

CONCLUSION

Analysis of TM data acquired in 1982 shows promise for distinguishing fruit trees and, especially, vegetables. Field reflectance measurements of vegetables support this conclusion.

The acquisition of new TM scenes was requested for three dates during the 1984 growing season. Their analysis and comparison with field observations and measurements will proceed during 1984-85.

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REFERENCES

Bauer, M.E., M.M. Hixson, B.J. Davis and J.B. Etheridge. 1978. Area estimation of crops by digital analysis of Landsat data. Photogram. Eng. & Remote Sensing 44:8: 1033-1043.

Colwell, R.N., ed. 1983. Manual of remote sensing. 2nd ed., 2 vols. Amer. Soc. Photogrammetry, Falls Church, Va. 2440 pp.

Crist, E.P. 1984. Comparison of coincident Landsat-4 MSS and TM data over an agricultural region. p. 508-517. In: Proc. 50th Ann. Mtg. Amer. Soc. Photogrammetry. ASP, Falls Church, Va.

Crist, E.P. and R.C. Cicone. 1984. Application of the Tasseled Cap concept to simulated thematic mapper data. Photogram. Eng. & Remote Sensing 50:3:343-352.

Daughtry, C.S.T., K.P. Gallo, G. Asrar, L.L. Biehl, B.L. Blad, B.R. Gardner, E.T. Kanemasu and J.M. Norman. 1984. Spectral estimates of agronomic characteristics of crops. p. 348-355. In: Proc. 10th Intl. Symp. Machine Processing Remotely Sensed Data. LARS, Purdue Univ., W. Lafayette, Ind.

Duggin, M.J. and W.R. Philipson. 1982. Field measurement of reflectance: Some major considerations. Applied Optics 21:15:2833-2840.

Gardner, B.R., D.R. Thompson, K.E. Henderson and B.L. Blad. 1982. Development of thematic mapper vegetative indices for assessing biomass in corn, soybeans and wheat. Report no. JSC-18264; SR-J2-04337. NASA/JSC, Houston, Tex.

Gausman, H.W., D.E. Escobar, A.J. Richardson, R.L. Bowen and C.L. Wiegand. 1977. Use of Landsat-1 data to distinguish grapefruit from orange trees and estimate their hectarages. Jour. Rio Grande Valley Hort. Soc. 31:139-143.

Markham, B.L. and J.R.G. Townshend. 1981. Land cover classification accuracy as a function of sensor spatial resolution. p. 1075-1090. In: Proc. 15th Intl. Symp. Remote Sensing of Environ. ERIM, Ann Arbor, Mich.

Mergerson, J.W. 1981. Crop area estimation using ground-gathered and sampled Landsat data. ESS Staff Report AGESS810408. Economics & Statistics Service, USDA, Washington, D.C.

Morse, A. and D.H. Card. 1983. Benchmark data on the separability among crops in the southern San Joaquin Valley of California. p. 907-914. In: Proc. 17th Intl. Symp. Remote Sensing of Environ. ERIM, Ann Arbor, Mich.

NASA. 1979. Proc. of the LACIE (Large Area Crop Inventory Experiment) Symposium. Held 1978, Houston. JSC-16015. NASA/JSC, Houston, Tex. 1125 pp.

Odenweller, J.B. and K.I. Johnson. 1982. Crop identification using Landsat temporal-spectral profiles. p. 469-475. In: Proc. 8th Intl. Symp. Machine Processing Remotely Sensed Data. LARS, Purdue Univ., W. Lafayette, Ind.

Ryerson, R.A., R.J. Brown, J.-L. Tambay, L.A. Murphy and B. McLaughlin. 1981. A timely and accurate potato acreage estimate from Landsat: Results of a demonstration. p. 587-597. In: Proc. 15th Intl. Symp. Remote Sensing of Environ. ERIM, Ann Arbor, Mich.

Ryerson, R.A., P. Mosher, V.R. Wallen and N.E. Stewart. 1979. Three tests of agricultural remote sensing for crop inventory in eastern Canada: Results, problems and prospects. Canadian Jour. Remote Sensing 5:1:53-66.

Sigman, R. and M. Craig. 1981. Potential utility of thematic mapper data in estimating crop areas. p. 1057-1064. In: Proc. 15th Intl. Symp. Remote Sensing of Environ. ERIM, Ann Arbor, Mich.

Williams, D.L., J.R. Irons, B.L. Markham, R.F. Nelson, D.L. Toll, R.S. Latty and M.L. Stauffer. 1984. A statistical evaluation of the advantages of Landsat thematic mapper data in comparison to multispectral scanner data. IEEE Tranac. Geosci. & Remote Sensing 22:3:294-302.

Zhu, M.H., S.Y. Yan, W.R. Philipson, C.C. Yen and W.D. Philpot. 1983. Analysis of Landsat for monitoring vegetables in New York mucklands. p. 343-353. In: Proc. 49th Ann. Mtg. Amer. Soc. Photogrammetry. ASP, Falls Church, Va.

TABLE 1: SPECTRAL CHARACTERISTICS OF SELECTED CROPS IMAGED BY THE THEMATIC MAPPER.
(Scene: 28 August 1984, western New York, path 17/row 30)

CROP	BAND 1[1]		BAND 2		BAND 3		BAND 4		BAND 5		BAND 6		BAND 7	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Apple	63.3[2]	1.6	24.9	1.1	20.5	1.1	91.2	2.8	68.8	3.4	114.2	1.9	23.1	2.5
Cherry														
Tart	62.9	2.4	24.8	1.4	21.0	1.9	86.9	3.0	61.0	5.6	122.4	0.6	20.6	2.8
Sweet	61.4	1.4	25.3	0.9	21.0	1.1	85.9	2.4	58.7	1.6	113.8	1.1	19.4	2.1
Pear	62.2	1.5	24.1	0.9	20.0	1.0	73.0	1.9	59.3	3.2	116.4	0.8	21.1	1.8
Peach	60.9	2.0	22.9	1.0	18.5	1.1	103.8	2.7	60.1	1.4	122.4	1.3	18.6	1.2
Forest	59.9	1.5	23.5	0.9	17.8	0.8	89.6	4.5	55.3	3.0	112.0	3.2	15.3	1.4
Onion	76.4	3.6	37.0	3.0	33.3	3.8	114.8	8.6	48.1	4.7	122.3	1.1	17.3	2.4
Potato	67.7	1.9	32.0	1.5	23.3	1.2	148.6	7.9	77.8	4.0	116.8	1.7	21.0	1.7
Corn	64.1	1.5	28.0	1.8	22.9	1.8	93.2	9.7	60.1	4.2	114.9	2.6	19.2	2.1

1 Bands 1 through 7 are, respectively: 0.45-.52 µm, 0.52-.60 µm, 0.63-.69 µm, 0.76-.90 µm, 1.55-1.75 µm, 10.4-12.5 µm, and 2.08-2.35 µm.
2 Values listed are digital counts based on 0 to 255.

TABLE 2: SAMPLE FIELD REFLECTANCES OF SELECTED VEGETABLES MEASURED IN FIRST FOUR THEMATIC MAPPER BANDPASSES. (measurements taken 8 July 1984)

CROP	BAND 1[1]	BAND 2	BAND 3	BAND 4
Cabbage*[2]	8.1[3]	10.9	11.0	34.1
Snap Bean*	6.7	10.8	9.2	41.9
Corn*	2.6	4.4	3.2	28.0
Onion**	2.6	4.2	3.3	21.5
Lettuce**	4.6	10.9	5.4	79.5
Potato**	2.7	5.8	3.3	58.7
Potato*	8.3	12.6	13.7	41.7

[1] Bands 1, 2, 3 and 4 are defined in note to Table 1.
[2] *Crop grown on mineral soil, **crop grown on organic soil.
[3] Reflectances (%) are the average of measurements made on and between rows.

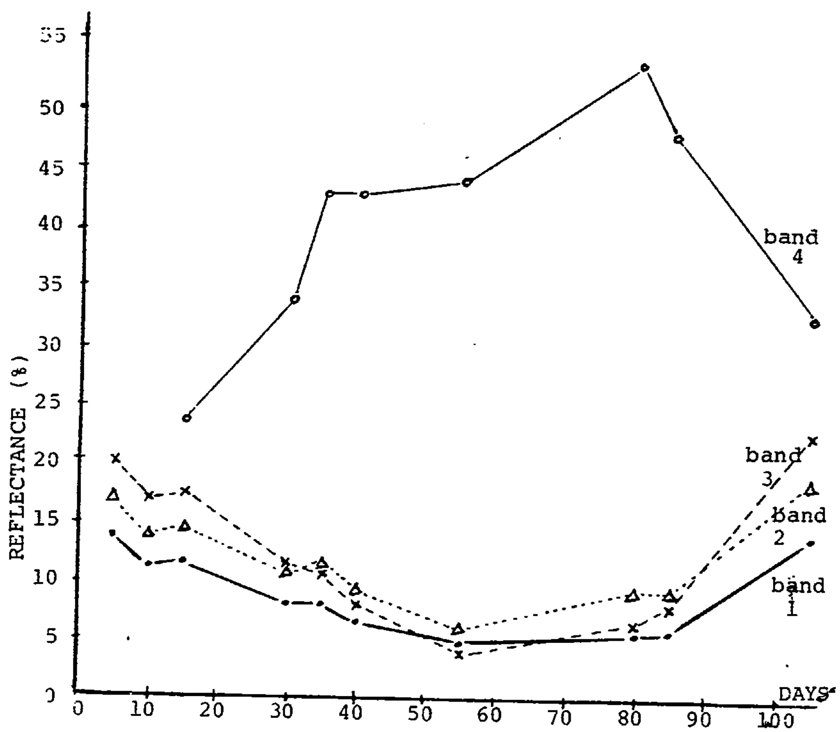

FIGURE 1: AVERAGE FIELD REFLECTANCES OF CABBAGE VERSUS DAYS AFTER PLANTING (8 June 84)