VEGETABLE CROP INVENTORY WITH LANDSAT TM DATA

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BIOGRAPHICAL SKETCHES

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ABSTRACT

Landsat thematic mapper (TM) data are being evaluated for inventorying or monitoring the planted areas of vegetables in New York State. TM scenes for western New York were acquired in July and August 1984, and were analyzed digitally with spectral characterizations, enhancements, and supervised classifications being compared to field-measured reflectances and cropping records. Preliminary testing has shown single-date classification accuracies of at least 85% for three vegetables grown on organic soils (muckland), and over 70% for 3 of 4 vegetables grown on mineral soils (upland).

INTRODUCTION

Vegetable crops are important to the economy of New York State; in 1984, sales exceeded $94,000,000 and the crops occupied more than 56,000 acres. The census of vegetable crops by the New York Crop Reporting Service is based on field observations and survey questionnaires. This study was undertaken to determine the extent to which satellite data, specifically Landsat thematic mapper (TM) data, could be used to aid the census.

LITERATURE REVIEW

Previous studies with Landsat multispectral scanner and TM data have been reviewed by Philipson et al. (1984). Although only several studies could be found which considered vegetables, these demonstrated the potential for using TM data for vegetable crop identification, and in particular, the advantages of TM over MSS data. These findings were reinforced by Staenz et al. (1980), who used field reflectance data of crops, including beans and potatoes, to evaluate the dimensionality of TM bands. They showed that bands 3, 4, and 5 could be used to provide most of the data found in all 7 bands. Similarly,

DeGloria (1984) obtained highest accuracies in crop classification (including vegetables) using bands 3, 4 and 5, with either single or multi-date TM data.

MATERIALS AND METHODS

Computer-compatible tapes of two TM scenes of central New York (17 July and 18 August 1984, path 16/row 30) were selected from the limited number of available TM scenes, based on dates of the scenes and locations of major vegetable producing areas. In New York, several vegetables are grown primarily on organic soils (muckland), others are grown primarily on mineral soils (upland), and some are grown in both organic and mineral soils. The 1984 plot maps for muckland vegetables were obtained from the New York Crop Reporting Service, and crop calendars were prepared for both muckland and upland vegetables. In addition, existing panchromatic, 1:40,000 scale, aerial photographs flown in May 1974, and 35 mm color aerial photographs flown in June 1984, were obtained from the U.S. Department of Agriculture.

To aid the analysis of the TM scenes, field observations and spectroradiometric measurements of vegetables were made to determine best dates and bands for crop separation. Muckland onions and lettuce, upland cabbage, snap beans and sweet corn, and both muckland and upland potatoes were sampled.

Two, four-band radiometers (Exotech model 100AXM-T) and a data logger (Omnidata Polycorder) were used to collect spectroradiometric measurements in the first four TM spectral bands (bands 1 through 4 respectively, 0.45-.52, 0.52-.60, 0.63-.69, 0.76-.90 micrometers) following the procedure described by Duggin and Philipson (1982). Due to the limited scope of the field program, only one field was sampled for each crop, with three 1m x 1m sites, selected to represent each field. Sampling was done on ten dates from June through September, 1984.

Reflectances for all crops were computed for each measurement of each site, on each date of data collection. To scale the field measurements to TM pixels, the integrated reflectance of plant and soil within a single 30-m TM pixel was modeled from the field reflectance measurements. The aim was to approximate the reflectance of one entire cycle of crop row and soil since the 30-m pixel would image multiples of this cycle (Fig. 1). The reflectance of the cycle of plant row and soil was calculated from the field-measured reflectances and from areas determined from photographic slides of the plant row and soil, as follows:

$$Rc = [(RrAr - RsAs')/Ap'](Ap/Ac) + Rs(As/Ac)$$

$$= \text{plant reflectance} + \text{soil reflectance}$$

where
Rc = reflectance of a single cycle of plant row and soil
Rs = reflectance of the sunlit soil between the plant rows
Rr = reflectance of area measured by radiometer when held

over the plant row (includes contributions of plant and soil)

Ap = area of one plant row
As = area of the soil within the cycle
Ac = area of a single cycle, where Ac = Ap+As
Ap', As' = respectively, area of plant (sunlit and shaded) and area of soil (sunlit) within the field-of-view of radiometer held over plant row
Ar = area within field-of-view of radiometer, where Ar = Ap'+As'.

Modeled "cycle" reflectances were plotted versus days after planting to examine crop reflectance over time, to compare reflectances of different crops, and to allow for adjusting planting date for relating the reflectances to other fields or to future growing seasons.

An error analysis of the data collection procedure was done to ensure that the variation of reflectances among the three sites in each field was due to natural field variation rather than error in the measurement procedure.

The TM data were analyzed on an International Imaging System (IIS) model 70 interactive digital image analysis system linked to a VAX 11/750 minicomputer. The TM data were first analyzed visually with TM bands 3, 5, and 4 displayed in blue, green, and red on the IIS display. Crops were identified with the aid of plot maps and aerial photographs. Means and standard deviations of TM digital counts (0 to 255) in all seven bands were obtained for the interior pixels of the identified fields to characterize the crops and determine separability. If the variation in digital counts between crops did not overlap (based on one standard deviation), the crops were considered separable.

The relationship between average "cycle" reflectance and TM measurements was assessed as a separate step. The sampled vegetable fields were examined in the first four TM bands; correspondence between ground and satellite measurements was based on the means and standard deviations of the TM digital counts.

With an understanding of the spectral properties and spectral separability of crops in single bands, classifications were done using a supervised maximum likelihood classifier. Different band combinations were used for classification: bands 1-4, bands 1-7, and other band combinations, including a ratio of bands 4/3, a normalized vegetation index of (4-3)/(4+3), and [(4-3)/(4+3)]+5.

When training, fields best representing the variability in reflectance (e.g., the variety of growing stages) of each crop were used whenever possible. Field data identifying upland crops, however, were limited. In some cases only 1 or 2 fields were available for training and testing, and often these fields did not represent the typical growing stage of area crops. On the mucklands, plot maps and field data identifying crops were available, but, in some cases, representative fields for training and testing

were also limited: only one field of lettuce was grown in the area, and clouds masked potato fields on the July TM scene.

RESULTS AND DISCUSSION

The relationship between the average field reflectances made on 17 July 1984 and same-day TM measurements of the same fields is shown in Figure 2. Correspondence between the two data sets was good: when one crop was spectrally discriminable from the others in the field reflectance data, it was usually discriminable in the TM data. Similarly, although field data were not concurrent with the 18 August TM scene, interpolation of field reflectances between sampling dates produced average cycle reflectances which corresponded well to the TM digital counts.

The utility of the field data for characterizing crops and predicting crop separability with TM was limited by having only four of the seven TM bands and by having only one field of each crop. Although the field data showed crop separation would be best with the 17 July image, better results were obtained with the 18 August image. However, once the data were adjusted to account for a representative planting date, they did provide useful information regarding best dates and best bands for crop separation on the TM data.

The results of classifying upland and muckland vegetables with all bands of TM data are shown in Tables 1 and 2. In spite of the limited data for training and testing of some crops, these classifications indicate the potential accuracies.

With the 17 July 1984 TM data (Table 1), best results were obtained classifying with all TM bands. For muckland crops, accuracies were greater than 70%. For several upland fields, however, accuracies were low; the growth stage was too early to identify most crops by their spectral characteristics. In general, errors of omission were frequent because most crops were young, percent cover was low, and the variety of growth stages (causing variability in reflectance) was especially apparent early in the season.

Classifications improved using the 18 August scene with all TM bands (Table 2). Preliminary testing has shown classification accuracies of at least 85% for three vegetables grown in mucklands, and over 70% for 3 of 4 vegetables grown in uplands. At this date, the crops were mature and more easily identified. Only snap beans was classified poorly. Training data were limited, and did not contain the variation in reflectance found in most fields in the region.

Although other bands and band combinations were used for classification--TM bands 1-7 plus either a ratio of bands 4/3, a normalized vegetation index of bands (4-3)/(4+3), or bands [(4-3)/(4+3)] + 5--results changed little. In addition, multi-date classification (combining

July and August) has not yet been attempted.

At this writing, more data on upland crops are being collected from past cropping records. With more fields available for training and testing more reliable estimates of classification accuracy will be obtained. We expect that classifications will improve.

CONCLUSION

Based on one season's analysis, TM data appear to be useful for inventorying vegetable crops in New York and likely other states. Preliminary testing of a single-date, supervised maximum likelihood classifiction has shown accuracies of at least 85% for muckland vegetables and over 70% for most upland vegetables. Best results have been obtained using all TM bands for classifying scenes acquired midway to late in the growing season. With knowledge of the regional planting dates and crop calendars, the field reflectance data have provided useful information regarding best dates, best bands and crop separability with the TM data.

Further work will be done to improve the accuracy and testing of classifications.

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TABLE 1

Confusion matrix for the classified 17 July 1984 scene.

TEST AREA	UCN	UCAB	UBN	UPOT	MPOT	MLET	MON	UN	number pixels
				CLASS*					
UCN	1+	0	0	0	0	0	0	99	90
UCAB	0	11	0	0	0	0	0	89	102
UBN	0	0	9	0	0	0	0	91	35
UPOT**	0	0	0	86	0	0	0	14	28
MOT**	0	0	0	0	79	0	0	21	43
MLET**	0	0	0	0	0	85	0	15	41
MON	0	0	0	0	0	0	72	28	113

* UCN-upland corn, UCAB-upland cabbage, UBN-upland snap bean, UPOT-upland potato, MPOT-muckland potato, MLET-muckland lettuce, MON-muckland onion, UN-unclassified.
** Field used for both training and testing.
\+ Numbers represent percent correct classification.

TABLE 2

Confusion matrix for the classified 18 August 1984 scene.

TEST AREA	UCN	UCAB	UBN	UPOT	MPOT	MLET	MON	UN	number pixels
				CLASS*					
UCN	89+	0	0	5	0	0	0	6	151
UCAB	0	71	0	0	0	0	0	29	84
UBN	0	0	9	0	0	0	0	91	57
UPOT**	0	0	0	76	8	0	0	16	25
MPOT**	0	0	0	0	85	0	0	15	27
MLET**	0	0	0	0	0	94	0	6	31
MON	0	0	0	0	0	0	96	4	111

(see footnotes to Table 1)

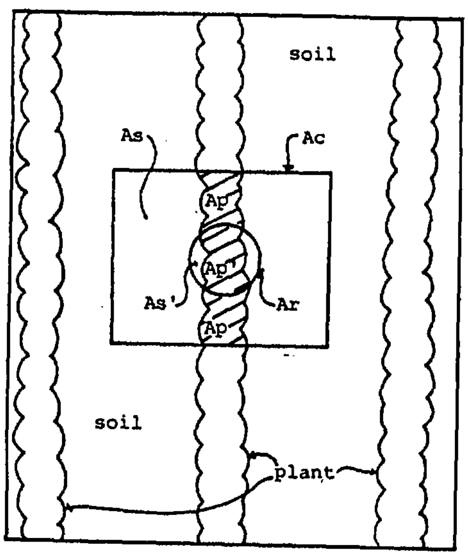

FIGURE 1: AREA RELATIONSHIPS FOR DETERMINING CYCLE REFLECTANCE OF ROW CROPS

Ac=area of one cycle, Ar=area of radiometer field-of-view over row, As=area of soil within the cycle, Ap=area of plants within row, Ap' and As'=respectively, area of plant (sunlit and shaded) and area of soil (sunlit) within the field-of-view of radiometer held over plant row.

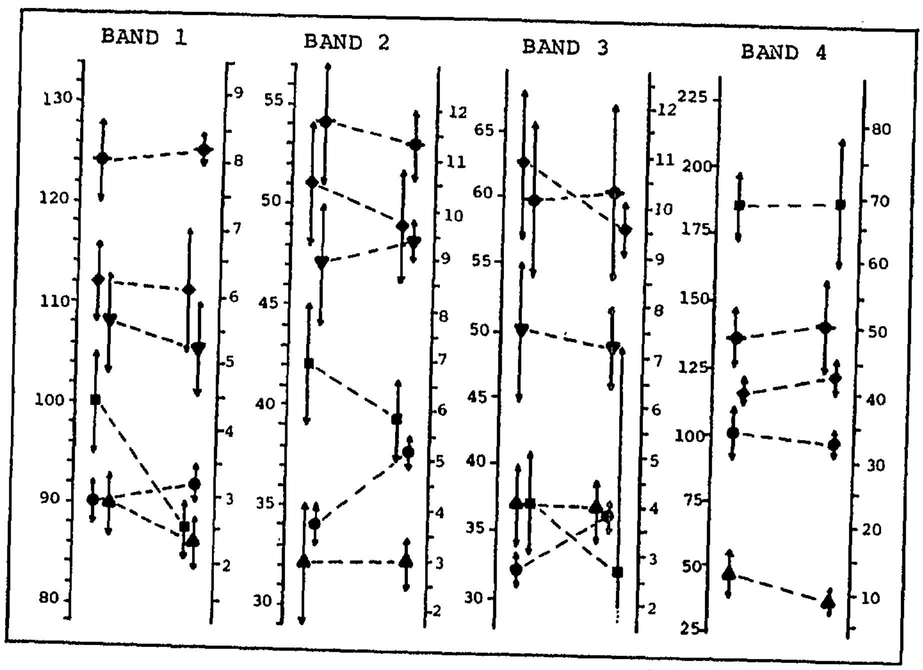

FIGURE 2: AVERAGE AND STANDARD DEVIATION OF FIELD REFLECTANCES (on right) AND THEMATIC MAPPER DIGITAL COUNTS (on left) OF VEGETABLE CROPS 17 JULY 1985

(average denoted by symbol: cabbage ♣, upland potato ♦, upland snap bean ▼, muckland potato ■, muckland lettuce ▲, onion ●).