A TIMELY AND ACCURATE POTATO ACREAGE ESTIMATE FROM LANDSAT: RESULTS OF A DEMONSTRATION[1]

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This paper describes the procedures used and results of a joint Canada Centre for Remote Sensing (CCRS) and Statistics Canada project to provide a timely potato acreage estimate for New Brunswick, a major potato producing province in Canada. The project has demonstrated that satellite imagery combined with more traditional potato area estimation procedures can lower respondent burden, produce timely crop distribution maps and produce reliable estimates for subregions.

1. INTRODUCTION

Earlier satellite remote sensing work in St. John Valley, New Brunswick by the Canada Centre for Remote Sensing (CCRS) and the New Brunswick Department of Agriculture has proved that both an accurate and low cost estimate of potato crop area could be made using satellite data (Mosher et al. 1978; Ryerson et al. 1979; Ryerson et al. 1980). Interest in this and other CCRS work on rapeseed-canola (Brown et al. 1980) resulted in Statistics Canada initiating a real-time demonstration using data from Landsat satellite in the 1980 crop year. Statistics Canada, the Federal agency responsible for crop data collection, wanted to compare traditional and satellite-derived estimates of crop area in the same region. Potatoes were selected as the subject crop, and the St. John Valley was the region.

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The particular benefits of satellite remote semsing which are of interest to Statistics Canada are improving accuracy of estimates obtained from their regular surveys, possibly at more local levels, lowering of respondent burden by reducing the number and/or size of questionnaires, and the possibility of providing maps of small areas containing speciality crops to better plan sampling methods.

Following a summary of the main results in the next section, the balance of this paper outlines the remote sensing methodology used in this project, and describes the existing Statistics Canada data collection system, the project region, the ground data sample and data collection, the analysis of remotely sensed data and the verification and analysis of results.

2. MAIN RESULTS

Data collected by satellite were used to produce estimates of the potato area in the St. John Valley region of New Brunswick. These estimates, expanded to the provincial level, were within two percentage points of the Statistics Canada published estimate of 52,000 acres. The published estimate was based on the results of three independent surveys in the province.

The analysis of satellite data was done in real-time (almost instantaneously) at CCRS, as much of the work could be initiated prior to data acquisition. The Agriculture Enumerative Survey (A.E.S.) area sample provided the ground data needed to calibrate the system, and was used to obtain ratio and regression estimates which corrected for biases in the satellite classification of potato fields. Although the demonstration was not carried out in a production environment, the final estimates could have been produced less than two weeks after the satellite pass over the test region.

Problems in the satellite classification were caused by the presence of clouds (satellite nonresponse), and by the confusion of potatoes with "similar appearing" features on the analysis system. The first problem caused loss of data, and required some imputation. The second problem was partly resolved by adjustments to the classification, and by the use of ratio and regression estimators.

A comparison of interviewer - collected ground data with data collected through aerial photographs of sample fields showed that some fields were missed by the A.E.S. interviewers, as these were not required for A.E.S. purposes. This resulted in the aerial photography data being used instead of A.E.S. data for the 1980 satellite estimates. The 1981 A.E.S. enumeration procedure were changed to accommodate both A.E.S. and remote sensing requirements.

As a result of the success of this demonstration, the experiment was repeated in 1981. In addition, a similar experiment was undertaken that year to estimate the canola acreage in the Peace River District of Alberta and British Columbia.

3. REMOTE SENSING USING THE LANDSAT SATELLITE

Remote sensing is the sensing or measuring of the characteristics of an object from a distance, usually from an aircraft or satellite. When satellite data are used, complete coverage of large areas can be provided quickly at a relatively low cost. Possible areas of application include agriculture, forestry, land utilisation, ice formations and general map making.

The United States National Aeronautics and Space Administration Landsat satellites provided the satellite coverage for this, and an earlier experiment in New Brunswick. Each Landsat satellite orbits the earth 14 times a day in a sun-synchronous orbit (permitting coverage of the earth to be done at the same local sun time). Light reflected from the ground is recorded on four narrow bands of the spectrum using a Multispectral Scanner (MSS). The data are transmitted in Canada to one of two receiving stations in Prince Albert, Saskatchewan and in Shoe Cove, Newfoundland. A point on earth is covered once every 18 days by a Landsat satellite (every nine days if two satellites are used).

The CCRS Image Analysis (CIAS) analyses the data, received on standard products such as Computer Compatible Tapes (CCT's) covering areas of 25,600 square kilometers. The smallest units for which image data are defined are called picture elements, or pixels. Each pixel carries its own spectral signature, a measurement of its reflectance on the four spectral bands. The spectral signature will depend on the features present in the pixel (roads, crops, etc.), each of which carries its own signature. Crop signature is a function of plant structure, type of soil background visible, crop maturity, height, and leaf density, among other factors.

To obtain estimates of crop areas, it is necessary to identify each pixel belonging to a crop of interest. Large known fields of the crop of interest are located to train the system to identify the crop's signature. All pixels are then classified as belonging to the crop or not, based on their spectral signatures.

Areas for specific regions are obtained by counting the number of pixels inside the regions that are classified as belonging to the crop. Additional training may be done to cover pixels "missed" in the initial classification, or to further separate confusion crops, that is, crops whose spectral signature closely resembles that of the crop of interest.

Accurate ground data are needed, first, to locate large training fields for the crop of interest and second, to correct for any biases in the satellite classification. These data can be obtained by trained ground enumerators, or by using airborne imagery, which is interpreted by image analysts.

4. CURRENT STATISTICAL DATA COLLECTION SYSTEM

Historically, Statistics Canada has used data obtained from annual mail non-probability surveys as the primary input into its crop estimation system. While these surveys are relatively inexpensive and can be completed quickly, they are limited by varying response rates and possible non-representativeness of respondents. Probability enumerative surveys were introduced in the mid-1970's to overcome some of these problems. These involve enumeration of a random sample of farmers by personal interviews. In 1980, Statistics Canada's estimates of potato area in New Brunswick were based on the results of three surveys: the Mail Survey, the Objective Potato Yield Survey (O.P.Y.S.), and the Agriculture Enumerative Survey (A.E.S.).

The Mail Survey questionnaires are mailed out in early June to all farmers listed on a Farm Register maintained by the Agriculture Statistics Division. Replies are compiled on a county basis and county estimates are derived by linking annual changes in reported potato acreages to census potato acreages for the county. The county estimates are aggregated to give provincial estimates by late June.

The O.P.Y.S. is a specialized mail and enumerative survey designed to estimate potato area and yields in the potato growing region of New Brunswick. The Survey is conducted in mid-July on a random sample of potato farmers selected from the Farm Register and potato area estimates are generated by mid-August.

The A.E.S. is a multi-purpose enumerative survey designed to estimate crop, livestock and farm expemse data at provincial levels. The A.E.S. is a multiple frame survey consisting of a random list sample of farmers selected from the Farm Register and a random area sample of segments. Enumerators visit the sampled farms in late June and early July. Acreage estimates from the survey are available in early August. Each year about 20% of the segments are changed.

During the growing season, two potato crop area estimates are published. The first, in late June, is based on the mail survey results. The second estimate, in early September, is based on a review of the estimates from all three surveys and discussion with provincial authorities. The date of the second estimate was the target date for generation of a satellite-derived estimate.

5. PROJECT REGION

The area for which an estimate was required is located in the upper St. John Valley in New Brunswick. It starts in the south at Woodstock in Carleton County and follows the St. John River for 200 kilometers northwest through Victoria County to Claire in Madawaska County.

The region is heavily wooded, of varied, rolling terrain. There are some problems related to stoniness and drainage. Within the area are 70,000 hectares of improved cropland, of which about 20,000 are usually potatoes. Other major crops are grains, hay and processing vegetables such as peas, broccoli and brussels sprouts. Parcel sizes range from 0.1 hectare seed plots to 40 hectare fields.

6. 1980 GROUND SAMPLE AND DATA COLLECTION

The area sample for the A.E.S. in New Brunswick was considered a suitable vehicle for obtaining ground data for interpreting remote sensing data. This sample is selected in two stages. At the first stage, census Enumeration Areas (EA's), which had farm headquarters in them in the 1976 census (called Census Agricultural EA's), were stratified based on their potato acreages, cattle, and pig numbers (1976 census data). Within each stratum, two replicated simple random samples of EA's were selected. Each sampled EA was segmented into identifiable area units of about 5 to 8 square kilometers using maps, and a simple random sample of one in 10 segments was selected per EA. A.E.S. enumerators working in the study region were supplied with old enlarged aerial photos (scale 1" - 832') for each sampled segment. The photos were obtained from provincial sources. Most of them had been taken in 1976. While contacting the farmers operating land inside the segment, they were required to show the photograph to the farmer and identify on it all potato and corn[3] fields and note their areas as reported by the farmer. Written instructions on procedures to be followed were included in the interviewers' manual and interviewers and supervisors were trained on procedures to be followed.

7. ANALYSIS OF REMOTELY SENSED DATA

7.1 Previous Work

Work in the same region using 1975 data has been reported elsewhere (Mosher et al. 1978), and a detailed description of the approach is available (Ryerson et al. 1980). In the 1975 work, a test area which contained about twenty percent of the province's potato crop was selected for detailed analysis from the potato growing region. This was supported by ground data collection for the entire test area.

The 125 square kilometer test area and two sub-areas were located on the colour video display screen of the CCRS Image Analysis System (CIAS) (Goodenough, 1979). A very simple supervised training scheme was used to gather the statistics of pixels in three contiguous potato fields in the form of four one-dimensional histograms. A four-dimensional parallelepiped in feature space was generated as defined by the limits of each of the histograms to serve as a decision boundary. All points within the parallelepiped were classified as potatoes, and those outside the region as "other".

One of the major problems was the proper classification of boundary pixels. These present special problems, as they fall on the border of two different

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3 Corn fields were also required to be identified since earlier remote sensing work indicated that corn was a confusion crop for potatoes (Ryerson et al. 1980).

fields. Their reflectance is a function of the amount of each field within the pixel and the reflectance of each cover material in the two fields. To attempt to compute the percentage of each cover type present in such pixels is generally very complicated. However, it was found that by modifying the original decision boundary through adding a second parallelepiped formed by training on a number of boundary pixels which appeared to be in potato fields, reasonable area estimates could be achieved. Selection of the appropriate boundary pixels to be classed as potatoes was on the basis of subjective visual interpretation of the display (data from three of the four spectral bands were merged to form a colour display, with colours simulating those of a colour infrared film).

Less then four hours of CIAS time were required to perform the area estimate for the entire potato belt. Location, display and analysis of the primary and sub-test areas required just over one hour. Selection, display and analysis of the subsequent five subscenes required two and one-half hours, while location of the New Brunswick border and elimination of data from outside the province required another hour.

Compared to total area of potato fields interpreted and measured from low altitude aerial photographs taken at the same time, the 1975 satellite estimates were 95% accurate (i.e., 95% of the estimated true value), in the sub-area containing the training site, 80% accurate in the second sub-area, and 88% accurate over the whole primary test area. On repeated tests using different training fields, the accuracy over the primary test area ranged from 85% to 97%. The province wide accuracy was 84.5%. Some of the error in the provincial estimate resulted from the fact that some potatoes are grown outside the potato belt. Other factors contributing to the error are discussed below.

7.2 PROCEDURES TO IMPROVE ESTIMATES

Although the previous work was successful, potential sources of error were identified for applications requiring accuracies greater than say 85%. The major problems arise in the subjective selection of the potato field boundary pixels, in the handling of small fields, and in the resolution of difficulties with the crops confused with potatoes.

With regard to confusion crops, ideally one should know the spectral reflectances of potatoes and all of its confusion crops throughout the growing season. With such information, it is possible to specify the phenological window during which potatoes can be reliably separated from other crops. Unfortunately, such a data set does not exist, although knowledge of the region's crops and the cultural practices does provide some general guidelines. In this case, based on the field experience of the authors, it was hypothesized that the optimum date for separation of potatoes from other crops in this region would be from mid-July to mid-August. To test this hypothesis and provide an indication of the degree of separability of potatoes from other crops, an analysis was performed of a Landsat MSS Computer Compatible Tape (CCT) acquired over the St. John Valley on August 8, 1975. Figure 1 shows the Landsat band radiance values for potatoes, corn, peas, hay, broccoli, pasture, buckwheat, bare soil and grains. It can be seen from this that potatoes are easily separable from the other crops except for the peas, which are usually harvested by mid to late August. It would therefore appear that the analysis of data collected late in the growing season is likely to lead to the separation and identification of potatoes.

The problem of small fields and boundary pixels can be handled by an approach which uses available ground information over a limited area to produce a more accurate crop area estimate over an extended area. Given the size of the potato growing region here, the area of potatoes within each of ten to fifteen segments is required. Each segment is of the order of five to eight square kilometers in size. The whole area is still classified as well as possible, but the subjective boundary pixel class is not produced. The classification result for each segment is then used, along with the available ground information (the aerial photograph data in 1980, A.E.S. data for future years) to obtain a regression relationship which is applied to the entire area estimate to produce a revised estimate (Hanuschak et al. 1979). A ratio estimate, based on the total area estimates obtained from satellite and aerial photograph data, is also produced.

7.3 GENERATION OF THE 1980 ESTIMATE USING LANDSAT

The generation of a satellite-based potato area estimate can be described as a three part process: ordering of old and new data, pre-location of A.E.S. segment boundaries, and image analysis.

The Landsat data ordered where Digital Image Correction (DICS) Computer Compatible Tapes (CCT's) using the Sin × / × interpolation for geometric correction (Guertin et al. 1979) and Cal 3 radiometric correction (Ahern and Murphy, 1978). Each CCT covers four 1:50,000 National Topographic System (NTS) map sheets with a resampled square pixel of 50M. Four CCT's are required to cover the region. Existing data were ordered for delivery in May of 1980, while new data were ordered for the appropriate satellite passes from mid-July to mid-August. The ordering process proceeded smoothly for existing data, but was complicated for the real-time data by the failure of Landsat-III. A Landsat-II pass on August 17 was used to create DICS CCT's which were delivered to the analysis facility on August 22, well ahead of schecule.

The pre-location of A.E.S. segments was done in the spring of 1980 using the polygon cursor option on the CCRS Image Analysis System (Goodenough, 1977). A.E.S. segment boundaries were provided by Statistics Canada on 1:50,000 map sheets and on photocopies of the airphoto enlargements given to the A.E.S. enumerators. Although some segments had boundaries which were easy to locate (streams, forested edges, lakes, etc.), others based on political or census boundaries proved very complex. Segments whose boundaries were a combination of major roads and/or major rivers could be located, bounded and stored after less than five minutes work on the enlarged colour display of 128 x 128 50M pixels on a 512 x 512 monitor. The most complex took up to an hour - with an average of 20-25 minutes. Once located, the segment was stored by specific DICS pixel coordinates so that it could be overlaid on new data as it arrived to locate both training data and inputs for the estimator. Because of the location of some segments on the boundary between two DICS CCT's and other similar problems, a number of segment boundaries were not located in the preparatory phase. Software is now being written to shorten the time required for the entire project, especially the pre-location phase. Use of original photographs in place of photocopies planned for the 1981 project's new segments (15 rotated in for 1981), should also shorten the time required.

Once the 1980 ground data were delivered to the analysis center, potential training sites (based on field size) were selected. Several fields were selected from one segment in the north of the region (near St. André) while several others were selected from a segment in the south (near Hartland).

Upon receipt of the 1980 satellite data, it became a relatively simple task to recall the segment boundaries, overlay them, locate training fields and begin classification using methods described in 7.1. In addition to the selected training areas, another group of large fields was selected as were areas of known potato fields which appeared brighter red on the monitor than those in the training set. As classification results were available, crop areas were recorded for each 512 x 512 pixel subscene and for each of seventeen A.E.S. segments.

There were four problems encountered during the classification; one involving imputation of crop under scattered cloud and cloud shadow and the other three related to confusions. The method of imputation of potatoes under cloud was quite straightforward. It was assumed that the percent area of crop under the clouds was similar to the area of crop in an adjacent "like-appearing" region. A simple formula was used to determine potato area under cloud, PC:

$$PC = \frac{P_M}{T_A - C_A} \times C_A$$

where: P_M = potato area measured in the cloud free region; C_A = area in cloud and shadow in the region and T_A = total area in the region. These areas were incorporated into the total satellite estimate, no A.E.S. segments under cloud were included in the ratio or regression analyses. The problems with confusions were, for the most part, solved through careful modification of the classification parameters. In one case, an unknown form of widely scattered natural regrowth in forest cut-overs was confused. In another case, hay fields with regularly spaced piles of stone were similar to potatoes. Only a few fields of clover in one segment and some of the fairways of a golf course in another remained as confusions after modifying the classification.

The areas calculated for the region are presented and discussed in more detail below.

8. RESULTS AND ANALYSIS OF THE 1980 NEW BRUNSWICK POTATO PROJECT

8.1 INTRODUCTION

The analysis of data from the 1980 New Brunswick potato project was done at the regional, segment, and field levels. Two types of estimates were obtained for the total potato area of the test region in the St. John Valley using satellite data and ground verified measures from high altitude aerial photograph data (the aerial photography data were obtained and analysed by CCRS). The estimates and their variances were then compared to other estimates from Statistics Canada surveys in New Brunswick. Segment potato acreages reported by the A.E.S. and by satellite were then compared to the aerial photograph acreages (which are considered here to be closest to the actual values) to determine the strength of their relationship at the segment level. This analysis was complemented by examining the variation in A.E.S. reporting of field acreages for each interviewer's assigned area.

8.2 ESTIMATION OF POTATO AREAS USING SATELLITE DATA

A ratio and a regression estimate of the total potato area in the test region in New Brunswick were obtained using satellite data and the aerial photograph segment data. Estimates, along with their variances, were calculated using the A.E.S. sample design. The A.E.S. in New Brunswick is a multiple-frame stratified replicated two-stage sample of segments, designed to give accurate estimates of various items at the provincial level (see sections 4 and 6). Since the A.E.S. strata did not coincide with the test region boundaries, the technique of post-stratification was used for estimation, treating the EA's as a with-replacement-sample. Segments with missing satellite data were not included in the sample, nor was one outlier (see Figure 3). These estimates were based on 40 segments. Finally, since A.E.S. enumerators did not always collect data on all farms inside the segment (see 8.3), aerial photograph segment acreages were used for estimation.

Let the label x represent the reported satellite potato data and y represent aerial photograph data. The ratio and regression estimates of Y, the total potato area in the test region were calculated as:

$$\hat{Y}_{Ratio} = \hat{R}\, X = \frac{\hat{Y}}{\hat{X}}\, X, \text{ and}$$

$$\hat{Y}_{Reg.} = \hat{Y} + \hat{B}\,(X-\hat{X}),$$

where $\hat{Y} = \sum_{h=1}^{L} \frac{N_h}{n_h} \sum_{i=1}^{n_h} \frac{M_{hi}}{m_{hi}} \sum_{j=1}^{m_{hi}} y_{hij}$ is the design estimate of Y;

$\hat{X}$ is the design estimate of X, the total uncorrected satellite potato area in the test region. $\hat{X}$ is obtained by substituting x_{hij} for y_{hij} in the formula for $\hat{Y}$;

y_{hij} and x_{hij} are the observed values for the jth selected segment in the ith selected first-stage unit (EA) from stratum h;

N_h and n_h are the total and sampled number of EA's in stratum h, h=1, ..., L;

M_{hi} and m_{hi} are the total and sampled number of second-stage units (segments) in the ith selected EA of stratum h;

$\hat{R}$ is an estimate of Y/X; and,
$\hat{B} = \text{cov}\ (\hat{Y},\hat{X})/\ \text{var}\ (\hat{X})$ is the linear regression coefficient.

The variance estimates of $\hat{Y}_{Ratio}$ and $\hat{Y}_{Reg.}$ are given by:

$$v(\hat{Y}_{Ratio}) = v(\hat{Y}) - 2\hat{R}\ \text{cov}\ (\hat{Y},\hat{X}) + \hat{R}^2\ v(\hat{X}),\ \text{and}$$

$$v(\hat{Y}_{Reg.}) = v(\hat{Y}) - 2\hat{B}\ \text{cov}\ (\hat{Y},\hat{X}) + \hat{B}^2\ v(\hat{X}),$$

where $$v(\hat{Y}) = \sum_{h=1}^{L} \frac{N_h^{\ 2}}{n_h(n_h-1)} \sum_{i=1}^{n_h} \left[\frac{M_{hi}}{m_{hi}} \sum_{j=1}^{m_{hi}} y_{hij} - \frac{1}{n_h} \sum_{i=1}^{n_h} \frac{M_{hi}}{m_{hi}} \sum_{j=1}^{m_{hi}} y_{hij} \right]^2$$

and $v(\hat{X})$ is calculated by substituting x_{hij} for y_{hij} in $v(\hat{Y})$.

It can be seen that $\hat{B} = \text{cov}\ (\hat{Y},\hat{X})/v(\hat{X})$ is the value of B which minimizes $v(\hat{Y}_{Reg.})$.

Table 1 shows the ratio and regression estimates, along with other Statistics Canada estimates of the potato area in New Brunswick. The ratio and regression estimates, pro-rated to the provincial level, are both very close to the Statistics Canada published figure of 52,000 acres. There is very little difference between the two estimates, and they both have the same coefficient of variation. In order to give an idea of the gain in efficiency obtained by the ratio estimate, the variance of the ratio estimate was as low as one-fifth of that of $\hat{Y}$, design estimate of Y based on the post-stratified design (area sample only). It may be noted that the C.V.'s of the ratio and regression estimates are of the same order as that of the A.E.S. multiple-frame estimate, although the latter is based on a larger sample size.

8.3 COMPARISON OF DATA AT THE SEGMENT AND FIELD LEVEL

Figures 2 and 3 show plots of segment potato acreages, as reported by the A.E.S. enumerators and by satellite, against aerial photograph acreages. Not all sample segments were used in the analysis. Satellite data were missing for 16 segments due to cloud cover and image location. Eight A.E.S. segments, containing survey non-respondents and very large farms whose field data were not to be collected by the enumerators, were not used. The two outliers in the plots are not used in the calculations here and in Section 8.2.

The plots show a strong linear relationship between A.E.S. and aerial photograph data, as well as between satellite and aerial photograph data, at the segment level, with correlations[4] of .991 and .968 respectively[5]. There is a tendency for both the A.E.S. enumerators and the satellite classification to underestimate the acreages. This is less marked for the A.E.S. Causes of discrepancies of satellite acreages were explained in Section 7. Some segments with little or no potatoes were over-estimated because of confusion crops. (The satellite outlier had confused a large hay field with rocks for a potato field - this error could have been removed by modifying the classification). One major cause of A.E.S. underestimation was that the interviewers did not enumerate some farms in the segment because of the multiple-frame procedures (these include farms which appeared on the list frame as well as farms that had land in more than one sample segment). Specific instructions have been written up in the 1981 A.E.S. field procedures to ensure that all farms in the segment are enumerated for their potato acreages next year when the test is to be repeated. This is expected to bring the A.E.S. reported acre-

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[4] The correlations were estimated using the sample design weights.

[5] A plot of satellite data against the A.E.S. data looked very similar to Figure 3, with a correlation of .957.

ages closer to the aerial photograph acreages. The strong relationship between the A.E.S. and the aerial photograph data for the sampled segments is encouraging and supports making adjustments to the satellite estimates using the data collected by the A.E.S. enumerators.

Another cause of A.E.S. discrepancy with aerial photograph segment data was the mis-reporting of field boundaries and field sizes. A.E.S. field acreages were obtained by interviewing farm operators, and thus, were frequently reported in multiple of five acres. Plots of A.E.S. reported field acreages against aerial photograph acreages by interviewer assignment areas indicate that there may be a difference in field reporting between the assignment areas. This could be caused by the interviewers themselves, but also by other factors such as geographic location and structures of fields within sample segments, or by variation in reporting errors. More variation was observed in the region east of the St. John River, where average field sizes were generally larger. The relationship between the A.E.S. data and aerial photogrpah data was stronger at the segment level than at the field level.

9. SUMMARY AND CONCLUSION

Satellite data were used in 1980 to generate a highly accurate potato area estimate for the three major potato producing counties of New Brunswick. Through the project described here, refinements have been identified for field procedures and analysis methods which should provide even more accurate estimates of crop area with satellite data, reduce respondent burden, and provide detailed spatial information previously available only in Census years.

10. ACKNOWLEDGEMENTS

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TABLE 1

SURVEY ESTIMATES OF THE TOTAL POTATO AREA FOR THE TEST REGION AND FOR THE PROVINCE OF NEW BRUNSWICK[1]

Survey and/or Estimate	Test Region Estimate	New Brunswick Estimate	Coefficient of Variation (%)
	(Acres)	(Acres)	
Satellite			
Uncorrected	42,354	N/A	N/A
Ratio	49,504	51,524	5.5
Regression	49,115	51,119	5.5
Mail Survey	N/A	50,800	N/A
A.E.S. Multiple Frame	N/A	53,854	5.2
O.P.Y.S.	47,203	49,129	4.59
Statistics Canada Published (Sept. 5)	N/A	52,000	N/A

[1] The test region, composed of the counties of Carleton, Madawaska, and Victoria, accounts for about 96.08% of the total potato area of New Brunswick.

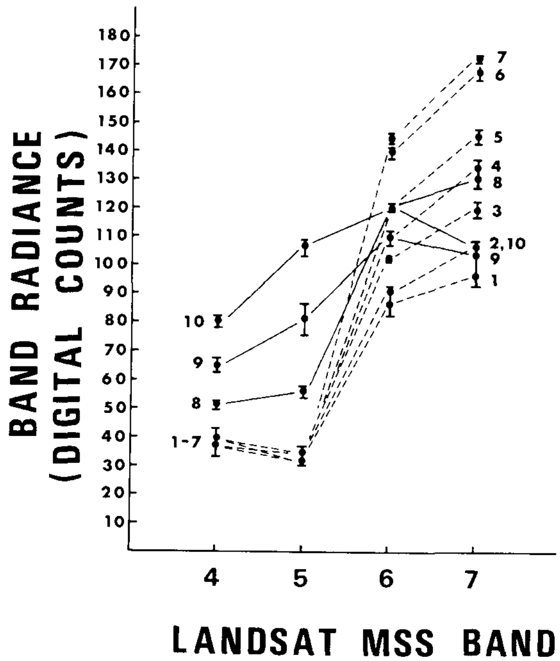


FIGURE 1 Comparison of Satellite Band Radiances for Various Crops.

Landsat MSS band radiance (August 8, 1975) for grains (1), buckwheat (2), pasture (3), hay (4), corn (5), peas (6), potatoes (7), broccoli (8), bare soil (9), weeds (10). The bands are numbered 4 to 7. The relative distances between the digital counts in each column indicate how separable the crops are for the given band.

FIGURE 2

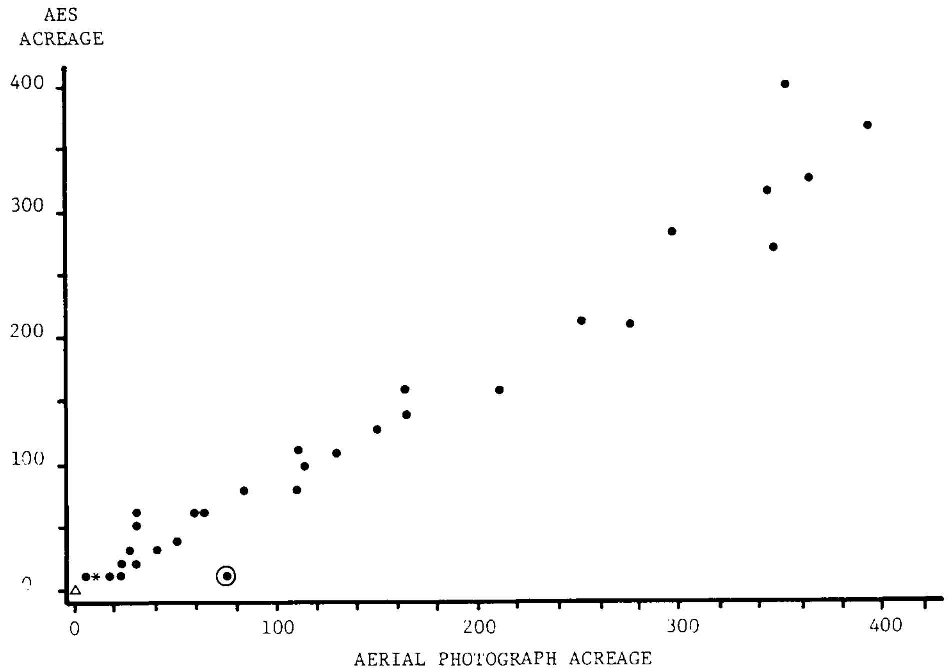
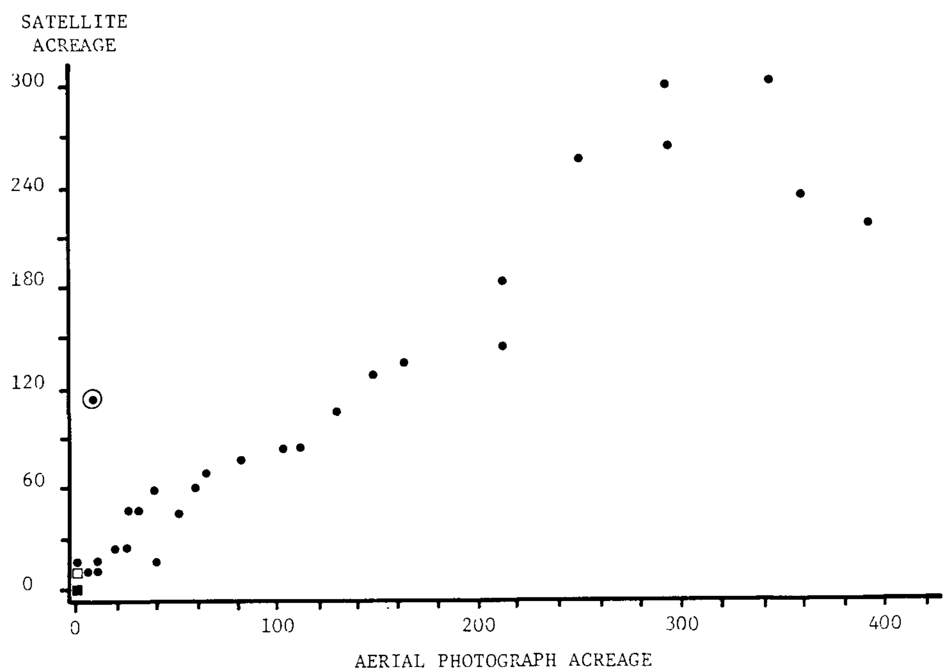


FIGURE 3



FIGURES 2 and 3 - Plots of reported A.E.S. and satellite potato acreages vs. low altitude aerial photograph acreages for sampled segments in New Brunswick. The circled observations represent outliers.
Legend: .=1 obs., □ =2 obs., *=3 obs., ■ =11 obs., and Δ =15 obs.