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ROLE OF REMOTE SENSING IN THE NEW BRUNSWICK FARM LAND INVENTORY PROJECT

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ABSTRACT

Procedures followed in establishing, monitoring and updating a Farm Land Inventory in the Province of New Brunswick, Canada is described. The inventory data was collected by ground survey, recorded graphically on photo-maps and then converted into digital form. Monitoring and updating of the data are performed by digital image analysis techniques using precision processed Landsat MSS images, which are registered on the UTM projection grid. Small-format camera photography is employed as an additional source of information.

INTRODUCTION

Effective management of renewable-resources, such as agricultural land, is impossible without an accurate, up-to-date information system. Such a system should incorporate the inventory data file of the commodity in question, base-line data which pertains to the management of all resources (e.g. topography, boundaries, soil, climatology) and data files on changing conditions affecting the quantity or quality of the particular resource (e.g. soil moisture, insects, disease). A conceptual model of a renewable-resource information system has been outlined by Hamilton [1978].

Requirements and conditions which govern the establishment of a an information system for use at the regional and local level are quite different from those which apply to those covering continents or sub-continents, such as the Large Area Crop Inventory Experiment (LACIE). According to J.B. McLaughlin [1969], two of the important characteristics that such an information system should have are:

(i) "The data should relate to the smallest recognizable and geographically identifiable parcel or tract or unit of land."

(ii) The classification "... should be flexible in that it can be used either in great detail or in summary form and be capable of many different kinds of re-combination without altering the classification itself."

Furthermore, a crucial requirement is that all data must be referenced to a common geographical base. A purely object-oriented information system is of limited value.

Remote sensing can play a major role in the realization of renewable-resource information systems, however, it must be employed to the best advantage and its limitations must be recognized.

Procedures followed in establishing an agricultural information system for the Province of New Brunswick, Canada, are now discussed to serve as an example for the implementation of the concepts presented here.

FARM LAND INVENTORY PROJECT

A prerequisite for establishing an agricultural information system is, of course, the availability of a complete and accurate set of data on the agricultural resources and practices. Accordingly, a comprehensive Farm Land Inventory (FLI) program was undertaken in the Province during the summer of 1979. [Derenyi, 1979].

Three methods were considered as alternatives for data acquisition:

- satellite imagery analysis;
- airborne imagery analysis; and
- ground survey.

At first glance, the use of Landsat MSS imagery appeared to be the most feasible alternative for the following reasons:

- Repetitive coverage is readily available in a nine-day cycle.
- Existing digital image analysis systems can classify agricultural crops with a high degree of reliability. For example, on repeated tests to obtain potatoe area estimates in New Brunswick the accuracy ranged from 85% to 97% [Ryerson et al., 1978].
- Cost is very reasonable. Computer compatible tapes can be purchased for $220 per MSS frame while the commercial charge for classifying up to 16 separate themes is $250 per frame. Four MSS frames pratically cover all of New Brunswick.

There are, however, rather serious shortcomings as well, which greatly reduced the feasibility of employing this method for the said program:

- For each crop to be surveyed, imagery must be acquired through the "biological window" and unfavourable weather conditions do pose a serious problem in this regard. In 1979, for example, from early June to the beginning of September, none of the imagery covering the Province was reasonably cloud free. Needless to say, data collected over a time span of several years is of questionable value. Similar concerns have been expressed by other investigators as well [Lee, 1979].
- The spatial resolution of the Landsat MSS makes the recognition of small farm fields a most difficult task. The nominal pixel dimensions are 57 x 79 metres (about 0.5 hectare area) and the extent of a feature must be considerably larger than that to ensure unambiguous classification of cover types.
- Landsat imagery is an excellent medium to collect aggregated information, such as the total acreage of a certain crop grown on a regional or province-wide basis. It is very difficult, if not impossible however, to separate this data into site and crop specific information for individual farms and farm fields.

In agriculture, the smallest recognizable unit of land is the "farm field". It can be defined as a piece of land under cultivation which has a visually distinguishable boundary to separate it from surrounding parcels of land. The boundary may be a natural or an artificial feature or simply a dividing line formed by the method of cultivation i.e., the direction of planting. In New Brunswick, farm fields range in size from 0.5 hectare to about 20 hectares, the average size being 5 hectares. The fields tend to be irregular in shape, orientation and exposure. Cultivated lands are mostly "pockets" in a great expanse of forest. It is certainly doubtful that data collected by Landsat sensors can be related to such small unit areas and that the cover types of one or two hectare farm fields can be successfully classified.

Airborne imagery overcomes most of the limitations of Landsat but it presents new problems. On the positive side:

- the timing of data acquisition can be controlled, although weather conditions still impose some limitations;
- spatial resolution and spectral range of the data can be controlled;
- accurate geographical referencing of the data is possible by photogrammetric and mapping techniques.

On the negative side:

- it is highly unlikely that all the imagery needed can be acquired during one growing season, even over relatively small areas like the agricultural regions of New Brunswick;
- conventional airborne imagery cannot readily be processed on existing digital image analysis systems and thus the evaluation of the imagery becomes a lengthy and tedious task;
- the cost of data acquisition from airborne imagery is quite high.

Airborne data acquisition was used for the forest inventory in New Brunswick. It required three flying seasons to acquire all the photography and two full years were necessary for the analysis.

At first glance, data collection by ground survey seems to be an inefficient, antiquated approach. A closer examination however, reveals a distinct advantage in favour of this method which was the one finally selected for the inventory project. Reasons for making this decision will become apparent from the discussion that now follows.

The FLI was compiled by teams of enumerators who called on each farm, armed with photo-maps and questionnaires. With the assistance of the farmer concerned, they delineated the boundaries of all his/her farm fields on a photo-map and recorded the type of crop grown in each field. A unique identification number was assigned to each farm field. A series of questions were also asked on agricultural practices such as crop rotation, livestock, land tenure, future intentions, awareness of government assistance programs, farm labour situation and a note was made of any comment(s) the farmer(s) had to offer.

Through this personal contact a wealth of information was collected, but which does not appear on any imagery. This approach eliminated the elaborate gathering of reference data and the "field checks", which are always necessary to aid in the analysis and interpretation of imageries and to verify the information extracted. Last, but not least, it removed the element of mistrust on the part of the public which is often associated with the "eye in the sky" approach.

The 1:10 000 scale provincial orthophoto map series provided the geographic reference base for the inventory. The same map base is used for property mapping, which is now being conducted by the Maritime Provinces Land Registration and Information Services (LRIS) for the purpose of setting up a boundary data base.

Photo-maps have the distinct advantage over line-maps in that the boundaries of farm fields are easily recognizable. Line maps, such as tax maps, on the other hand, are very difficult to relate to the land. So much so, that in areas where orthophoto mapping is not yet completed, photo mosaics were prepared. Although this product does not have the geometric quality of a map, the pictorial presentation of the terrain allows the identification and delineation of field boundaries like on the orthophotos. In future, when proper photo-maps become available, this information can easily be transferred.

Hence, the information was based on the smallest recognizable unit of land. It was place-related (geographically referenced) and was recorded in a form compatible with other data bases being developed for the Province.

In addition to the ground survey, colour oblique aerial photographs were taken, with a hand held small-format camera, of all the farm land in the Province. These photos provided a general overview of the agricultural land in the Province and were employed to spot check the inventory.

The FLI was carried out as a Youth Job Corps project, under the technical direction of the New Brunswick Department of Agriculture and Rural Development and in cooperation with the Department of Surveying Engineering, University of New Brunswick. It was funded by the Canadian Employment and Immigration Commission and was sponsored by the Federal Department of Regional Economic Expansion. The total budget for the project was $200 000, and over 80 university and high school students were involved.

Further processing of the inventory data will include digitizing the boundaries and the centroid of farm fields as well as computing the area. This data, along with the crop code and the identification number will then be stored on magnetic tapes. Key information extracted from questionnaires on each farm land will also be encoded for computer storage along with the property identifier number.

FARM LAND MONITORING PROGRAM

The dynamic nature of renewable-resources information renders inventories out-of-date rather quickly. Nowhere is this statement more valid than in agriculture, where crops being grown in particular fields may change from year to year, or even during the same growing season. Growth pattern and yield of crops can change much faster. These conditions imply the need for monitoring, and remote sensing can play a major role here.

From a technology and organizational point of view, monitoring requirements can be divided into two categories:

1. Monitoring changes which take place at a predictable frequency or show an appreciable effect only over a long period of time. A change in the crop(s) planted in a particular field from one year to the next and changes in land use are typical examples. This type of monitoring can be characterized as "strategic application".
2. Monitoring changes which occur within a short period of time and/or at unpredictable frequency. For example, monitoring crop vigour and stress conditions, spread of disease or insect infestation fall into this category. It is quite appropriate to call these activities "tactical applications".

An agricultural monitoring program is currently under development in the Department of Surveying Engineering, University of New Brunswick and the conceptual model is now discussed.

It is anticipated that Landsat MSS and small-format camera photography will be the main sources of data. As a "baseline inventory" of agricultural crops is now available, the shortcomings of both data sources, as discussed in the previous section, are substantially reduced.

The geographic location, boundaries and dimension of each field will be available from the data file. A prior knowledge will also exist of the kind of crops which are most likely to be grown in a particular field. Up-dating the inventory will then involve classifying clusters of Landsat MSS pixels, situated well within the boundaries of a farm field, with the aid of "training sets" of two or three crops which will be expected to be grown in this particular field on the date of the satellite overpass. Fields where the classification appears uncertain would be flagged for audit check by either an aerial or a ground inspection.

It is intended to perform the classification on one of the digital image analysis systems available in Canada. The Canada Centre for Remote Sensing Image Analysis System (CIAS) or the Applied Resource Image Exploitation System (ARIES), developed by DIPEX Systems Limited are the most likely choices. Landsat MSS imagery on Computer Compatible Tapes

(CCT), produced on the CCRS Digital Correction System (DICS) will be employed for this operation, to facilitate the merging of MSS data with the crop inventory.

DICS produces precision processed subframes of Landsat MSS imagery, which is registered on National Topographic System (NTS) map sheets [Butlin et al 1978 and Shlien 1979]. Corrections are applied for various geometric distortions such as those caused by variations in the altitude, attitude and velocity of the satellite, detector sampling delay, mirror scan nonlinearity and panoramic effect. Radiometric distortions in the MSS data due to sensor effects such as changes in the detector calibration, atmospheric attenuation and scattering are also corrected. Resampling is necessary to correct for the geometric distortions and ground control points are used to generate a proper transformation model. The corrected image has a pixel size of 50 x 50 metres and is registered to the Universal Transverse Mercator (UTM) map projection grid. Hence, the UTM coordinates of pixel centres are always a multiple of 50 m. Each DICS processed subframe corresponds to one quarter of a 1:250 000 scale NTS map sheet. DICS has been operational since the fall of 1979.

With this approach area computation will not be necessary. The impossible task of attempting to recognize individual farm fields no longer exists, and the all too frequent problem of proper classification of boundary pixels will substantially be reduced. Identification of "training sets" will also be simplified since those can be specified by coordinates. The actual merging of the existing and new information will be performed by fitting the inventory information, which has a polygon format, to the MSS data, which has a grid cell format.

Weather related problems will continue to be a factor in monitoring but to a lesser degree. Prior knowledge will exist, gained through experience and from the inventory questionnaires, where changes will most likely occur from one year to the next, thus making it unnecessary to "look" at the entire Province every year. As a back-up source of data, small-format camera photography from light aircraft is being considered. The photo-maps with the farm fields delineated are invaluable for this operation as a navigational aid and for referencing the photography.

It is doubtful that Landsat MSS will be feasible for the "tactical applications" of monitoring. Nevertheless, it could identify potential trouble spots where closer inspection will be necessary. The actual monitoring of conditions which fall into this category will be performed by small-format camera photography and visual interpretation. It is anticipated that this approach will provide the kind of flexibility and quick response called for in such situations.

CONCLUSIONS

Remote sensing could become a great asses to effective management of agricultural resources provided it is applied to the best of its advantages. In this connection attention is drawn to the following points:

(i) Farm land inventory data should be related to individual farm fields, which are the smallest recognizable unit of land.

(ii) All inventory data should be geographically referenced in a common system which is compatible for other data bases in the information system.

(iii) Photo-maps are the most suitable base for registering crop inventory data, because it renders boundaries of farm fields easily recognizable.

(iv) Site visit is the most feasible method for collecting farm land inventory data for use at the regional and local level. Spaceborne and airborne sensing has its serious limitations.

(v) Spaceborne sensors augmented by small-format camera photography appear to be the most feasible source of data for monitoring changes in crop production and in land use. It is highly desirable to employ precision processed digital image, registered to a map projection grid, for this purpose.

(vi) Small-format camera photography can probably provide the kind of flexibility and quick response necessary in monitoring changes, which occur within a short period of time and/or at an unpredictable frequency.

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