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SATELLITE REMOTE SENSING FOR DOMESTIC CROP REPORTING IN THE UNITED STATES AND CANADA: A LOOK TO THE FUTURE

LA TÉLÉDÉTECTION SPATIALE, OUTIL NATIONAL D'INFORMATION SUR LES CULTURES AU CANADA ET AUX ÉTATS-UNIS: PERSPECTIVES D'AVENIR

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ABSTRACT

The benefits of foreign crop monitoring through remote sensing have been well documented and well researched through programs such as LACIE and AGRISTARS. Although there are fewer benefits to be realized in domestic crop monitoring, they are still significant, while the technical problems of implementation are somewhat reduced compared to foreign monitoring. As a result of the efforts of various agencies in solving the technical problems there have been successes in domestic crop reporting with remote sensing in the United States since 1978, with successes in Canada being more recent.

As a first step towards looking to the future this paper addresses, in tabular form, the commonalities and differences in the approaches taken to remote sensing for domestic crop reporting the United States and Canada. From this table, other sources, and the authors' experience, the focus is then shifted to what the future of operational domestic crop reporting with satellite data is likely to require and what this implies in terms of Research and Development. The kinds of problems addressed include among others, central vs distributed analysis, satellite requirements, data volumes and delivery times, integration with other information systems, and yield prediction.

RESUMÉ

Les avantages du contrôle des cultures étrangères par télédétection sont largement relevés dans la documentation publiée et font l'objet d'amples recherches par le biais de programmes tels le LACIE et l'AGRISTARS. Bien que peu nombreux, les avantages à retirer d'un contrôle des cultures nationales sont encoure importants, et les problèmes techniques de mise en oeuvre sont réduits comparativement à ceux du contrôle étranger. Les efforts déployés par diverses agences pour résoudre ces problèmes ont connu un certain succès aux Etats-Unis depuis 1978, les succès du Canada étart plus récents.

En guise de première étape de l'exploration de l'avenir, la présente communication expose, sous la forme de tableaux, les similitudes et les différences des méthodes de contrôle des cultures par télédétection employées au Canada et aux États-Unis. En puisant dans ces tableaux, dans d'autres sources et dans leur propre expérience, les auteurs placent ensuite l'accent sur les impératifs vraisemblables du contrôle opérationnel des cultures par satellite et traduisent ces impératifs en termes de conséquences en matière de recherche et de développement. Les types de problèmes dont il est question sont notamment: centralisation et décentralisation de l'analyse, caractéristiques nécessaires des satellites, volumes des données et délais de livraison, unification à d'autres systèmes d'information et prévision des rendements.

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1. INTRODUCTION

This paper provides a look at the future of satellite based domestic crop monitoring in the United States and Canada from the perspective of what developments have occurred in the past, what the technical problems are likely to be in the future, and what options will likely be considered within the next decade or so.

2. THE PAST

The benefits of crop monitoring through satellite remote sensing have been estimated to be millions of dollars for both the United States (Osterhoudt, 1978) and Canada (Clough, 1974). Although these studies have identified most of the potential benefits in the area of foreign crop monitoring, some significant benefits for domestic crop reporting have also been identified. These and similar benefit studies have led to the support for the necessary R and D in both countries to develop satellite-based foreign and domestic crop reporting methods.

From these efforts, a number of successes have resulted in the area of domestic crop reporting. The first success in the United States came in 1978 (Hanuschak et al, 1980) when results using satellite data were incorporated into official crop estimates for corn and soybeans in Iowa. The success in Canada came later (Ryerson et al, 1981), when satellite data were used to generate an acreage estimate for potatoes in New Brunswick before the official estimate was released.

Table 1 compares the two approaches which resulted in these successes. The evolution of the methods has been different, partly as a result of the crops and regions studied, size of organization, data products available, and hardware used. Table 1 is therefore organized by major topics of comparison: crops and regions, data used, corollary data, field data, users, approach, and state of use. It should be noted that the statistical approach of a regression estimator used in Canada was patterned after that used in the United States. The full approaches are outlined in the various papers listed at the end of the paper.

Given the variety of approaches adopted, a wide range of past experience is available from which to identify problem areas which are peculiar to certain approaches and those which are common to both.

3. TECHNICAL ISSUES

3.1 Introduction

The major technical issues in using satellite remote sensing for domestic crop monitoring which must be addressed in the future include crop separability, yield determination, data availablility, and analysis methods. Some policy related questions which could affect the nature of technical problems are also discussed below.

3.2 Separability

Despite the impression sometimes given that any given temperate crop can be separated from all surrounding crops with Landsat MSS data, this is so only if certain conditions about absence of confusion crops, and date of imagery with respect to growing season (or crop's growth stage) are met. These conditions are rarely met. For example, potatoes were easily differentiated from other crops in New Brunswick (Ryerson et al, 1981), but in southern Alberta, with corn and sugar beets as confusion crops, the separation was less distinct. (Ryerson and Shaw, 1981).

The problem of separability of target crops from their surrounding confusion backgrounds has led to an increased interest in acquiring detailed ground spectral measurements in Canada and further analyzing existing spectral data sets in the U.S. These are useful before new satellite systems are launched (Ahern et al, 1980, Staenz et al, 1980, Tucker et al, 1978, 1979) and before or as new large programs are begun (Brown et al, 1980).

Indications are that existing and planned systems will not provide separations on a routine basis for all crops in all regions. The study of existing data on crop spectra indicate that finer spatial/spectral resolutions will not lead to a general solution to the separability problem, although it will improve the situation for certain confusions in certain areas. In general, in the author's opinion, multitemporal data are more valuable than finer spatial, spectral or radiometric resolution. Thus the repeat cycle and data availability are key elements of the crop separability problem. For a crop which can only be separated from surrounding crops during a one-week window, it is highly unlikely that any existing or planned satellite could reliably provide data at the correct growth stage, especially if the seeding was delayed or spread out over several weeks for any of the region's crops.

Future planning must consider the problem of regional spectral / spatial confusions and the consequent need for research using ground spectral data, supporting aircraft simulations of satellite data, as well as special classification methods and cloud-area estimation procedures (see Section 3.5 below). Regardless of how simple any problem may at first appear, users should always be ready for the possibility that the crop of interest may not be separable from its background or surroundings.

3.3 Yield Determination

Much of the Large Area Crop Inventory Experiment (LACIE) and Agriculture and Resources Inventory Through Aerospace Remote Sensing (AgRISTARS) R and D involves foreign and domestic yield determinations from a combination of meteorological and Landsat data. Although some remarkable success has been obtained, there are still major problems requiring solutions.

The central problems in deriving yield data can be summarized:

1. Satellite data record information (primarily) on the above ground green vegetation. Only for certain crops can this consistently be related through various biomass indices to yield.

2. Yield models now in use are imprecise and tend not to be sensitive to drastic changes from normal conditions nor do they contain a feedback mechanism.

3. Yield models relying on meteorological data use data collected from coarse networks.

4. Regression estimators such as are used for crop area estimates have been applied to yield estimation for some crops in the USA, with but a marginal gain in precision. There has been even less success in the case of foreign crops.

No single satellite available or being planned can provide the information necessary for accurate yield forecasting.

3.4 Data Availability

Data availability and continuity depend upon cycle frequency, cloud cover, satellite failures, ground processing failures and sheer volume of data. Users will not invest in the technology to use the data if they have no guarantees that access will be continuous and at a cost they can afford.

The cycle frequency, or the delay between one satellite pass over the area and the next, has been the subject of a variety of studies. With less frequent coverage, multi-date analysis for crop separation or change detection is not possible. As frequency decreases even more, there is an increased probability that no image will be obtained because of cloud cover. For this reason, satellites like SPOT that look sideways to adjacent cloud free satellite tracks may solve much of this problem. However such a satellite will introduce serious geometric distortion and require a sophisticated decision process for allocating coverage. Moreover, high frequency coverage of one area must be at the expense of less coverage of the adjacent ones.

Experience in the United States in 1978 during the summer crop season indicates that with one Landsat satellite with an eighteen day repeat cycle, less than 50% of Iowa was covered. With two Landsats having nine day coverage in 1978, eighty-five percent of the state was cloud free at some time in the critical period (Hanuschak *et al*, 1980). Although further consideration must be paid to the periodicity of movement of frontal weather systems across North America, experience suggests that a five or six day repeat cycle would provide coverage of most areas during the key data acquisition windows for crop discrimination. In the meantime, stopgap methods have been developed to estimate crop areas under localized clouds. (Ryerson et al, 1981; Hanuschak, 1976).

With the present satellites long past their design life and now exhibiting some problems, a major fear is lack of data because of satellite failure. This is already a problem with 1981 Canadian work since the ground segment which includes the Digital Image Correction System (DICS) (Guertin et al, 1979) cannot use the degraded Landsat III data as input. (See 3.5 below).

Although less dramatic than satellite failures, ground processing failures can result in delays in delivery or even destruction of data which have been acquired.

For most Landsat receiving stations there is not sufficient redundancy built in to guarantee continuous production under very high demand. Since delays or losses of data to date as a result of ground segment failures have not been high, there may be a tendancy to become complacent. With the turnaround times and volumes of data required for domestic crop estimation, interruptions in data production would lead to failure of crop estimation procedures now in place.

As noted above, turnaround times are critical for domestic crop reporting. Slower turnaround times would be acceptable for raw CCTs (say 20 days) if assurance of image availability could be given to plan data analysis and information flows. The elapsed time between satellite pass and data delivery depends on the volume of data requested for the same time frame, the data's resolution, and the type of processing requested. Guaranteed fast delivery (24 hours) from CCRS of standard computer tapes is possible for Canadian data at a cost of $690 per scene (three times the normal cost). Delivery from the U.S. system usually requires four to six weeks at $200. Geometrically corrected DICS products costing $600 for about one quarter of a Landsat scene require up to 10 days to produce in the rush mode. The system is now close to saturation and continued fast turnaround cannot be guaranteed until new processing equipment now being designed is on stream.

With continued success in domestic crop reporting, it can be expected that the demands on current systems will outstrip their capabilities to produce and analyze data within the next five years. Increased data volume and age of equipment will only serve to exacerbate the problem.

3.5 Methods of Segment Handling and Classification

There are two central differences between the Canada and USA approaches to domestic crop monitoring as outlined in Table 1 which bear further scrutiny. These are the use of geometrically corrected vs uncorrected Landsat data with respect to handling of segments, and the classification methods used.

In both the USA and Canada, sample segments of from one to three square miles in size are ennumerated on the ground by interviewers. In the traditional method, crop areas obtained from these segments are expanded to generate crop area estimates for larger regions. These same segments are used for the satellite based procedures. The segment boundaries do not change, although about twenty per cent of the segments are rotated out of the sample each year. However, in some regions field boundaries do change from year to year.

The USA approach requires digitization of boundaries of both the segments and fields after ground data collection. The Canadian approach takes advantage of the availability of geometrically corrected fast-turnaround data. Segment boundaries can be digitized prior to the current season's image acquisition. When new data are acquired, it is possible to register old and new data and the segment boundaries. Since the field boundaries need not be digitized for use in obtaining training data, as in the USA approach, throughput is potentially faster since less manpower is required during the peak estimation season. The gain is especially important in areas where segments are complex, and after the initial year when only 20% of all segments must be located and stored. There is a further gain to be realized if the data are to be integrated into a place-related information system for multiple use. The use of the geometrically corrected DICS data makes multiple data use a viable possibility. Raw data (P tape, in the USA) however, must go through significant additional processing if they are to be combined temporally or with other data for multiple use.

The questions which must be addressed to evaluate whether or not geometrically corrected data should be used include the following:

1. Are multiple uses to be considered? If so, do they require merging of multitemporal satellite data and / or satellite data and some other data?

2. What are the true operational data costs likely to be for each product?

3. Given these costs, which alternative is most cost effective given number of segments, segment shape and ease of location, classification system used and user requirements?

The second major difference is in the type of classification algorithm used. In the USA a semi-automatic Maximum Likelihood Decision Rule (MLDR) Classifier on a general purpose main frame computer is used. This classifier assumes a Gaussian distribution of values being classified. Training data are based on field labels which are located from the digitized segment maps and subsequently verified on line printer outputs. In Canada the simpler parallelepiped classifier on the CCRS Image Anlaysis System (CIAS) (Goodenough, 1979) is used. Training data are manually selected by an analyst who uses a cursor on a video display of the data. Results are displayed in real time and can be modified by adding or deleting training pixels from fields known from segment maps to be those of interest (Ryerson et al, 1981). In the Canadian work, thus far involving estimates for single crops such as potatoes and canola, the parallelepiped has proven more accurate for acreage estimates than the MLDR. This may be attributable to the interactive capabilities associated with the parallelepiped as compared to the MLDR. It is assumed that for some separations in the future, more sophisticated classification methods will be required in the Canadian work.

A central question on classification methods arises: is the technology advanced enough to allow batch processing using MLDR for crop estimation without a video display and the human interaction made possible with the simple and fast parallelpiped classifier? There is disagreement on this issue on both sides of the border.

3.6 Innovations in Processing and Integration of Geo-Coded Data

There are two potential developments which may be considered as viable additions to the methodology. The first of these is the possible use of a distributed image processing network feeding into a central data bank. This is receiving some attention in both countries. The second innovation is the possible integration of external data bases to improve an estimate's accuracy or utility. There are three alternatives for domestic crop reporting data processessing: centralized, local or a hybrid of the two.

Central processing has a number of advantages: an identical approach for all regions, justification for a larger single system (likely at less cost than for a number of smaller systems) and hence a higher potential for automation of labor intensive tasks, more efficient use of budgets and the possibility for continued R&D, a concentration of staff in one location (thus less reliance on a few trained individuals) which can focus on problems of a national nature requiring timely solutions, and a central repository which would be able to feed into national decision making more easily than a number of local centers.

Local processing also has advantages: centers would be closer to the problem with more local knowledge and the opportunity to field check inconsistent segments identified during analysis, a regionally tailored individual approach could be used, local problems of a pressing nature (eg. a localized drought over several counties) could be dealt with more easily, local (state or province) data bases may be tapped more easily, local data could likely be made available for earlier estimate dates than would be the case with a central facility, and the less specialized analysis system could serve other local users in the state or province when not required for agriculture to reduce the system's cost to agriculture.

A third, and perhaps the best approach in this area, is to use a central host system with a series of local processing centers with "intelligent" image analysis systems as terminals which could also stand alone. Such an approach combines many of the advantages of each approach.

Another future development which should be considered is the integration of ancillary information into analyses to maximize the utility of the satellite data for decision making. Within the next decade this would involve the use of geo-coded data bases or place-related information systems as well as digital terrain models (DTM). The identification of crops, their locations, and changes from previous years could by themselves form a useful part of the data base for assessing crop rotations, irrigation changes, water use, and their affects on such localized problems as soil erosion and soil salinity. When combined with soils data, slope and cadastral information, the data base could become a powerful extension tool for provinces, states or counties. Looking further into the future, the use of a videotext system by farmers could provide them with a new management tool.

There are a number of exciting possibilities in methods for the future, but optimism must be tempered with the realization that there are problems in methodology, data availability and data costs which must be answered if domestic crop reporting is to become truly operational. In addition, there are policy decisions required which will affect how (and if) the technology will be developed.

3.7 Policy and Economics Questions

The following five policy and economics questions largely determine where the technology will go in the next decade.

First, as noted in Section 3.4, there must be continuity of data for users to feel comfortable with the technology for something as important as crop reporting. At present, continuity of the MSS or Thematic Mapper (TM) is not assured into the 1990's. An important part of continuity is the requirement of a clear understanding of pricing for various products. Above a certain price, there will be changes in methodology and beyond a further threshold there will be resistance and possibly rejection of the technology.

Another area of concern in policy is whether governments (Federal, state/province) or industry will be in control of the satellite data delivery technology, and with what effect? It is assumed that the future analysis of the data would be no different than now, governments, industry and universities would all have the capability to do certain types of analyses.

A third area of policy concern is the nature of the problem which is presently being addressed through the use of satellite data. Satellite data are being used to estimate crop areas for specific regions selected before the current crop season. This approach, while yielding increased precision (for fixed sample size) over the use of ground data alone, essentially duplicates the objectives of the ground survey. If satellite data costs rise substantially, the possibility exists that these data may not be competitive on a purely economic basis. This is particularly so when one considers the current labour intensive budget structures of ground surveys vs the capital costs required for statistical data collection agencies to use satellite data. There is, however, one area to which satellite technology can uniquely contribute - the monitoring of singular or episodic events which can cause major perturbations in planting, harvest and yield. With proper organization and flexibility it should be possible to apply the same general principles used in the LACIE, AgRISTARS and in the Foreign Agricultural Service of USDA to monitor critical areas on an ad hoc basis. Decisions may be required in this area, depending on future data product costs, timeliness of data availability and instability of both weather and markets for crops.

The fourth area for policy discussion is that of central vs local vs a hybrid of the two for image processing, the ramifications of which were discussed in the previous section. The decision as to which approach is best will be a hard one involving complex technical and political questions. Today all data are collected regionally. All data in Canada and part in the USA are sent to a central facility for processing. However results are often returned to the region (province or state) for use in local decision making.

The last policy item presented deals with the user involvement and technology transfer. The decision has already been made in the United States and Canada on the timing and degree of user involvement. A discussion is included here for those in other discipline areas or other countries beginning their work. The question is how should users be involved and how should technology transfer be effected. The answers for both are "from the start". The key element is the schedule for adoption, training and assumption of budgetary responsibilities. All such plans should be fixed in advance during the planning session to specific milestones according to a definite timetable. There must be both management and working level commmitment before beginning. The planning exercise must be thorough even though this may be a long and arduous task as terms are defined and re-defined and mutual understanding is reached among people of quite different technical backgrounds. The remote sensing technical specialist must work directly with the end user. Research oriented individuals in the user area are not the same as the user, the real producer / analyst of crop statistics. Efforts should be made to incorporate remote sensing into existing procedures - not to replace them. Demonstrations must be carefully planned. The initial funding is usually primarily from the technology oriented agency. Clear guidelines on what constitutes success should be specified. Corollary data, such as aerial photography, are often useful for this purpose.

3.8 Problem Summary

Although technical difficulties do remain major advances have already been made in crop separation, yield prediction, data availability, methodology and in developing user awareness. The infrastructure needed to handle both technical and policy related problems which can impede development in domestic crop reporting is developing. The fact that a large number of people (including end users of the data) have been involved and have gained valuable experience bodes well for the future solution of many of the problems. Given this experience, a better understanding of the nature of problems is possible, and identifying options for remote sensing satellite based domestic crop reporting which may be considered in the future can be much more realistic than it was only four or five years ago.

4. OPTIONS FOR THE FUTURE

4.1 Introduction

We now have a history to which we can look back and from which we can project to the future to assess the implications of the various issues discussed to this point. Before the space remote sensing program returned the first satellite images, man had only an imprecise idea of what the earth would look like from space. Although there were a variety of simulations, none could, with any certainty, be viewed as realistic. Even the first Gemini (NASA, 1967) and Apollo 9 images of agricultural areas from 126 n.mi (Colwell et al, 1971) did not prepare us for the exceptional detail available from 565 miles above the earth's surface from Landsat.

Now, however, we have experience with digital satellite data and have even been able to accurately simulate Landsat MSS digital data from an airborne flight at approximately the same time on the same day as the satellite pass (Ahern et al, 1980). Given the accuracy of such simulations, the opportunity for predicting the future utility of specific sensors for specific problems is greatly enhanced (Sigman and Craig, 1981).

Although the future options are discussed here with some confidence, it is still difficult to predict future political decisions - especially those based on that arcane art of economics. The balance of this section therefore attempts to put aside all but the technical issues to arrive at an image, albeit fuzzy, of where domestic crop monitoring is likely to be in the next decade in terms of topical problems addressed, availability of data, the technology likely to be used, operational methods and R and D.

4.2 Topical Problems for the Future

Until now, remote sensing for domestic crop monitoring has focused on crop area estimation. In the future it will also include monitoring of singular or episodic events in an early warning mode.

Although inventories performed by governmental or quasi governmental agencies will continue to be based on states, provinces and (perhaps) smaller crop districts of particular interest, the players will change. There will be increased activity by state and provincial agencies, drawing heavily on Federal / Industrial technical capabilities. Furthermore, there will likely be continued rapid development of the high technology industry selling image analysis systems with specialized agriculturally oriented software and hardware. In addition to systems development there will also be the development of a service industry offering not just data analysis facilities, but information or projections based on traditional as well as remote sensing data - much like those selling weather / crop forecasting systems today. With lower image analysis systems costs in the future, it can also be expected that the grain trade, processors, smaller marketing boards, farmers associations, etc. may buy processing capabilities, and will most certainly buy information.

In addition to new users and general topics, there will be changes in crops assessed. There will be increased attention to crops whose production is volatile and regional perspectives on problem identification and solution.

4.3 Availability of Data

Since availability of data is ultimately within the control of the political decision making process, only limited statements about the future can be made with regard to data availability.

It can be assumed that there will be more redundancy built into the ground segment, ground processing will be much faster and planning for future satellites will be based more on ground spectroscopy and airborne simulations. The shuttle will make it possible to repair and extend the useful life of remote sensing satellites.

4.4 Likely Technology for the Future

As a result of requirements to maintain continuity of data and to keep data rates as low as possible, some of the present satellite technology may still be useful well into the 1990's. However, the ground segment will change dramatically and will become much faster with higher throughput rates.

The MSS Technology will still be useful for much of the work in the U.S. Great Plains and the Canadian Prairies, as well as for some local studies elsewhere. Both the SPOT and TM systems will be useful for finer spatial resolution, and together will contribute to more frequent coverages. The TM will also have an important role to play in making fine spectral separations.

Geometrically corrected imagery will likely be used for all work which incorporates segments since it is expected that such data will be a routine product at high throughput rates as the technology improves. For applications requiring rapid turnaround, say twenty four to forty eight hours, uncorrected data could be used.

Actual processing methodology and organization will be refined considerably in the next few years. It is expected that a network for image processing will evolve. A central facility supported (likely) by the agencies responsible for domestic crop estimates (one facility in each country) will host a number of intelligent stations. There will obviously be more concerns with security as precision and timeliness improve and external access is possible.

The whole area estimation procedure including segment location, training set selection and classification will become more automated. The first step towards automated digitizing and pixel labelling has already been taken (Ozga and Sigman, 1981). Although more automation will be incorporated, it is expected that the video display will remain an important tool for verification and real time class modification in the man-machine interactive approach which has long been a cornerstone of Canadian work in this field (Economy et al, 1974, Mosher et al, 1978). With the power and elegance of the new classifiers, they may gradually replace the parallelpiped classifier in Canada <u>if</u> they become more interactive or under more direct control of the analyst. Although one of the objectives of the R&D effort is to remove as much of man's subjectivity as possible from analyses, it is probable that some agricultural commodity analysts will still value and retain this subjectivity.

Statistical estimates will continue to be important, but two newer products, data base compatible results and maps, will be used increasingly. Depending upon the use, the data base could be local, regional, or national. It is expected that satellite data base updates will also be incorporated into their specific information collection plans by agribusiness interests be they local, regional or national. Maps of crop distributions and changes in distributions in hard copy format or as data in a geo-data base, will be used for applications as diverse as transportation route and site selection and erosion control planning. Maps of changes in distribution may be useful tools for marketing of crops, equipment sales, planning crop storage, processing and shipment, irrigation district development, etc.

These contemplated future remote sensing capabilities in the area of domestic crop statistics should also benefit other types of inventory needs. Joint data collection, facility sharing, and multi-user processing streams by inventory specialists from diverse disciplines are expected.

5. SUMMARY AND CONCLUSION

In the past few years domestic crop reporting using satellite data has gone from R&D to demonstration use in the United States and Canada. In the next decade, more experience, advances in methods, new hardware and wider demonstration of the technology should lead to a more mature data collection infrastructure incorporating image processing hardware manufacturers, a service industry, agribusiness and governments, barring political level decisions to delay or stop the satellite remote sensing program, to curtail data availability, or to excessively increase the charges.

It is likely that the same type of statistical procedure now used with satellite data, combined with meteorological satellite data and corollary data from geocoded-data bases will provide the basis of future work. The major changes will come in the organizations using imagery and applying the results, and in the hardware interaction between local and central facilities. As well, there will be a broadening of application to include monitoring singular events.

In short, it will be a most exciting time for those involved in the technology's development and application.

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Table 1

Comparison of USA-Canada Domestic Crop Monitoring Using Satellite Data

Item	USA	CANADA
<u>Crops and Regions</u>		
-regions selected	entire states (1981: Kansas, Iowa, Oklahoma, Missouri)	small province/crop reporting districts
-selection of region based on	10 criteria, such as user needs and interests, previous R&D, land area, cloudiness, % of national crop total	user need, crop separability based on field spectral measurements
-crops	major crops; e.g. winter wheat, corn, soybeans, potatoes.	potatoes and canola/rapeseed (a major oilseed)
<u>Data Used</u>		
Landsat Multispectral Scanner (MSS)	Full frame EROS P-tape (resampled to 79M pixel)	calibrated (Cal 3) $\frac{\sin x}{x}$ geometric correction, one CCT per 4 (1:50,000) NTS maps re-sampled to 50M pixels (See Guertin, *et al*, 1979)
Delivery time after Landsat Pass	6 to 8 weeks (spring 1981)	< 10 days to analysis centre
<u>Corollary Data</u>		
Field Spectroscopy	Via review of research literature. None by user.	Full range of above-canopy spectral measurements.
Current-year airborne imagery	airborne imagery for R&D/demonstration mode only	airborne imagery for R&D/demonstration mode only

Table 1 Continued

Item	USA	CANADA
<u>Field Data</u>	by segment (nominally 0.5 or 1.0 sq. miles in cultivated strata). On (non-current) air photo all fields in segment are delineated. Crop types and areas for all fields recorded from farm interviews.	by segment (variable size for potatoes, 3 sq. miles for canola/rapeseed. On an air photo the crop of interest and confusion crops and their areas are recorded from farm interviews. For canola/rapeseed all crops are recorded, crop stage of growth is reported to the analysis centre by local staff.
<u>User Involvement</u>	work is done by a group within the user agency (USDA/SRS). Procedures developed by research unit with operational state offices taking over more of the necessary steps each year.	-remote sensing portion is done by an agency (CCRS) external to the user agency (Statistics Canada). -the user agency is being trained to do all work in-house.
<u>Methodology</u>		
Segment Handling	-after current-year data received, all field boundaries are digitized	-before current-year data are received segments are outlined for subsequent overlay on new data
Classification Algorithm	-Maximum Likelihood (MLDR). Digitized field boundaries for training data location verified on line-printer output.	-parallelpiped, MLDR may be applicable to other problems. A video display is used to locate training data and verify results.
Statistical Methods	-Regression	-Ratio and Regression
Output	-crop area estimates, some work has been done with Objective Yield Survey data in the regression model.	-crop area estimates

Table 1 Continued

Item	USA	CANADA
Date of Output	winter wheat: Nov. 1 spring-planted crops: Dec. 1 (Final estimates)	late August early September (Second or interim area estimate date)
<u>Software</u>	in place (continual enhancement)	some software under development
<u>Hardware</u>	interactive processing on DECID via commercial time-sharing service. Full-scene classification on NASA CRAY I.	
<u>Satellite Data</u>	-has own program	-relies on US or other programs
<u>Professional Staff In Agencies</u>	Applications: 8 PY (person years) R&D: 7 PY (Funded through Agristars)	5 PY from over 15 people. (Includes rangeland).