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Crop Monitoring in Australia Using Digital Analysis of Landsat Data

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CROP MONITORING IN AUSTRALIA USING DIGITAL ANALYSIS OF LANDSAT DATA

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I. ABSTRACT

This paper describes on-going co-operative research by the New South Wales (N.S.W.) Department of Agriculture* and IBM Australia Limited. The aims of the project are to investigate if Landsat digital data can be used to map and monitor agricultural resources, particularly crop acreages and production, over large areas.

From the outset, multi-temporal whole scene computation has been a feature of the technical approach. Software modifications for large data volumes were carried out allowing supervised maximum likelihood classification to be used throughout the work. Considerable amounts of agronomic ground truth have been collected over wide latitudes for use in training the computer system as well as for accuracy assessment of classification results.

A number of Landsat scenes have been studied, with three to five acquisitions being registered for each. Preliminary analyses were conducted on historical data of Tamworth (N.S.W.) and Narrabri (N.S.W.) scenes. More intensive studies were undertaken for the 1980-81 wheat season in the Narrabri scene and are currently being undertaken in the Horsham (Victoria) scene. The techniques used and results from these analyses are discussed in this paper. Classification accuracy has been very encouraging showing excellent potential for use in crop area and production estimates.

Various problems emerged which required special attention and these are discussed. They included loss of data because of cloud cover, registration accuracy, training techniques, best combinations of bands and dates for classification, confusion classes, computation of very large volumes of data and classification accuracy assessment.

* New South Wales is the centre State on the east coast of Australia lying between latitudes 29°S and 37°S.

This work is demonstrating valuable applications of Landsat data in Australia. Technology transfer to other users is under way and it is anticipated that further technological development will lead to large scale adoption of remote sensing techniques for monitoring agricultural resources in Australia.

II. INTRODUCTION

Australian agriculture is relatively extensive and therefore has great economic potential for monitoring by satellite remote sensing. The New South Wales (N.S.W.) Department of Agriculture has been investigating the agricultural applications of Landsat data since 1975 and considerable potential has been realised in recent years.

In late 1978 the Department entered into a three year co-operative research agreement with IBM Australia Limited. The aims of the project are to develop techniques for using Landsat data for crop monitoring in Australia. Improved estimates of area and production for wheat are of most interest since Australia is the third largest exporter of wheat, this representing 20% of Australia's primary production.

The project is acknowledged by the Agricultural Remote Sensing Sub Committee of the Australian Standing Committee on Agriculture as the pilot project for wide scale wheat monitoring. Officers from the Queensland Department of Primary Industries and the Victorian Department of Agriculture have also been involved in expanding the analyses to the wheat growing regions of their States.

Under the agreement, IBM Australia Limited has set up an advanced digital analysis facility. It comprises the ER-MAN II software (a derivative of ERIPS) installed on an IBM 3033 computer in Sydney, Australia. The computing aspects of this work are described elsewhere at this symposium by Beach and Dawbin[1].

III. TECHNICAL APPROACH

Multi-temporal whole scene computation has been a feature of the technical approach. Beach[2] considered that advances in computer technology would make the increased computational demands cost effective by the conclusion of the project. Supervised maximum likelihood classification of every pixel across statistical areas (shires) was considered the most powerful approach. Detailed ground truth was easily obtainable allowing accurate training statistics to be derived. Multi-temporal analysis, using up to five registered acquisitions of the one scene, was deemed necessary to achieve good spectral separability of wheat from other agricultural features.

IV. EARLY WORK

Since the Australian Landsat Receiving Station did not become fully operational until late 1980, early work in the project was conducted on historical data of the Tamworth area of north west New South Wales. Three Landsat overpasses were obtained of the 1977 wheat season together with historical ground truth collected from about thirty farmers.

Program modifications within the ER-MAN software allowed whole scene computation and the subsequent registration of the three Tamworth images. A first order registration polynomial using 32 ground control points was used. This gave a maximum overlaying error between the three dates of about 1½ pixels, however, the average error was considerably less than this.

Since most wheat fields in this region are large (over fifty hectares), the misregistration and field boundary effects appeared not to significantly effect the final classification results. The resulting multi-temporal image of an area of 11,500 sq. km. included two channels of ratios,

$$\frac{\text{Date 1 MSS7}}{\text{Date 1 MSS5}} \quad \text{and} \quad \frac{\text{Date 2 MSS7}}{\text{Date 2 MSS5}}$$

as these had been shown to be useful from earlier work[3].

Because of the historical nature and limited quantity of accurate ground truth, detailed classification testing and accuracy assessment could not be undertaken. However, valuable techniques were developed and three major results were obtained:

i) registration and subsequent production of an overlayed image,

ii) all large area modifications to the ER-MAN software were successfully used,

and iii) classification confusion verified an earlier hypothesis that a fallow stage acquisition was required.

It was found that best registration results were obtained when at least thirty-two ground control points (GCP's) were used[4]. Also, these points should be well distributed across a scene and along its edges[5] since the overlaying error was found to increase dramatically outside the GCP's. Further it was found preferable for an identical set of points to be used for each acquisition. Later work indicated improved registration across a scene when second order polynomials were used.

Some confusion resulted in the final classification between wheat and pasture types. This was attributed to non-optimal dates of acquisitions, in particular, the lack of an early acquisition at about pre-sowing or sowing time - May/June. This acquisition would give increased separability between cropland (bare fallow stage) and pastures (green vegetative stage). It was found that the two ratio bands improved the classifications and also gave more consistent results between wheat areas of similar yields.

The main objective of the analyses was to classify wheat pixels correctly over large areas. It was found that many training classes needed to be defined to cover the spectral range of wheat pixels found in a large multi-temporal image.

The second stage of the project involved analyses of a complete statistical area - the Narrabri shire, the state's largest wheat growing shire which has a total area of over 1.2 million hectares (ha) with about 220 000 ha of wheat grown annually.

Again the analyses were of the 1977 wheat season and suffered similar limitations to the Tamworth 1977 work because of their historical nature.

Added to the natural diversity present in the multi-temporal spectral signatures were the effects of drought over most of the shire. Extra training classes were defined and final classifications were encouraging. Results were not conclusive, however, because of deficiencies in the ground truth.

These analyses gave the first indication that Landsat data may give a reliable production estimate over a large area. This was achieved by supervised maximum likelihood classification techniques with the wheat classes based on fields of differing yields.

V. RECENT WORK

A more intensive study was planned when near real-time data became available. It aimed to more fully evaluate the feasibility and accuracy of distinguishing between crops over large and varying areas by checking the classification results before the crop was harvested. However delays in the availability of the appropriate Landsat data meant our processing could not be completed before harvest.

Three separate wheat growing regions were chosen. Narrabri (30°15'S, 149°45'E) and Cootamundra (34°30'S, 148°E) in N.S.W. and Horsham (36°30'S, 142°E) in Victoria. Substantial ground truth was collected throughout the three regions on a number of occasions throughout the 1980-81 wheat season.

However, seven consecutive images of the Cootamundra Landsat scene were all largely cloud covered (i.e. more than 70%). Hence analyses of this area were abandoned and the all too common problem of available, appropriate cloud-free imagery was highlighted.

At the time of writing, analyses of four optimal acquisitions of the Horsham scene were not completed and will not be discussed.

A total of five acquisitions of the Narrabri Shire (11th June, 13th August, 31st August, 18th September, 6th October, 1980) were registered with overlaying error of less than one pixel. All subsequent processing was done on the resulting twenty band sub-image of size 70 million bytes (see also Beach and Dawbin proceedings of this Symposium[1]).

Spectral diversity of agricultural features over the five growth stages recorded was large due to cultural, managerial, soil and climatic effects. Unfortunately, there was a very severe drought and large areas of wheat were not harvested. Project aims therefore included assessments of areas of abandonment and the monitoring of drought effects as the season progressed.

The initial training class definition was based on a set of classes considered necessary from the earlier work. This set consisted of twenty classes. Classifications of trial test areas using these classes showed that additional classes were needed to cater for the increased diversity of drought affected wheat fields. These test areas included farms where detailed ground truth had been collected. If known fields were wrongly classified, further training classes were defined e.g. in areas of crop which were abandoned and grazed. It was found that forty four training classes were sufficient to account for the variability encountered.

Final classifications of all agricultural areas of the Shire (1.7 million pixels) were carried out with combinations of bands selected to address two of the aims of the project. These were to determine the minimum number of acquisitions required and the earliest date on which an accurate crop estimate could be made. Because this data included a fallow stage acquisition for the first time, we have concentrated on using raw MSS bands. The question of the value of using the ratio bands to improve classification accuracy is yet to be investigated.

Test areas for classification accuracy assessment were randomly chosen across the Shire. Detailed ground truth was used to score pixels as classified correctly or incorrectly.

Results to date have been encouraging. Of 30 000 pixels scored over 98% were correctly classified.

Because of the severity of the drought some "crops" died at the seedling stage (less than 5% ground cover). These areas were often classified as "fallow" pixels which was considered correct.

It was found that for these analyses the best classification accuracy was obtained when at least three acquisitions (12 MSS bands) were used. The inclusion of the fallow stage (first) acquisition always improved classification accuracy which again verified the authors' hypothesis. Landsat data up until early September (about two months before harvest) gave very accurate area results. If near real-time data was available in an operational system, this would mean that a first estimate of grown wheat area in the North West of N.S.W. could be produced about a month before current official estimates.

Classifications using later acquisitions included classes that represented wheat areas showing different effects of the continuing drought. This monitoring of the severity of the drought gave area estimates of harvestable hectares of crop. In addition, the classes which represented the potential harvestable wheat were based on known areas with differing yield potentials. At the time of writing of this paper we can report that qualitative assessment suggests that, once again, Landsat MSS data has given a reasonable indication of wheat production in this area. Further quantitative work is underway.

VI. CONCLUSIONS

Landsat technology can give accurate crop area estimates over large areas when classifications use multi-temporal data which include a pre-emergence acquisition. These estimates were shown to be able to be produced using data available two months before harvest.

Indications suggest a potential for deriving production estimates from harvestable areas.

Further work is continuing with the aim of extending the crop monitoring techniques to other areas of Australia.

VII. REFERENCES

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AUTHOR BIOGRAPHICAL DATA

Mr. Ken Dawbin. He graduated as an agronomist from the University of Sydney and has been with the New South Wales Department of Agriculture for seven years. He has been a remote sensing specialist since 1976 and has been the only research officer working full-time on Landsat applications to agriculture in Australia.

Mr. David Beach. Currently he is an advisory systems engineer with IBM Australia Limited. He has been with IBM for approximately 17 years and has worked on Landsat projects full-time since November, 1978.