Development and commercial use of landsat derived maps as an aid to more effective use of fertilizer

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Summary. Agriculturalists recognise that fertiliser applications should be related to the nutrient status and productivity of individual pastures but until recently these have been difficult to determine. Landsat data from the Northern Tablelands of NSW, Western Victoria and Central Tasmania processed by methods developed at CS IRO Armidale, show pasture growth status or fertiliser response for individual farm paddocks. Maps can be produced allowing farmers to obtain maximum growth from applied nutrients by identifying their most responsive paddocks or those which require maintenance dressings. Calibration with data from the Northern Tablelands is in progress, and a pilot project has commenced to evaluate the method under field conditions.

Introduction

Many agriculturalists have drawn attention to the consequences of spatial variation in nutrient levels and pasture productivity (5). This spatial heterogeneity within farms, combined with the curvilinear nature of the pastures response to added nutrients, causes problems in providing effective fertiliser recommendations for improved pastures on commercial properties. Further, the assumption of spatial uniformity can lead to economic loss through wasteful application of fertiliser and, at times, to acid soils and environmental degradation such as the decline in water quality following algal blooms caused by the run off of excess fertilizer. Soil tests give good results for crops but they often give conflicting or ambiguous results when applied to improved pastures (6). They are costly for large areas of pasture, and not well suited to assessing fertiliser needs *as* they do not give spatial information; plant tissue tests are similar, they require calibration and careful interpretation to allow for internal nutrient recycling and they give no spatial information.

Landsat multi-spectral scanner (MSS) data processed by methods developed at Armidale (12) show spatial variability in potential pasture growth in relation to nutrient status, and these data have the characteristics necessary for use in a pasture management geographic information system. Geographic Information Systems (GIS) are already used in many resource management areas such as rangelands and forestry (3, 8, 1) but they have yet to be applied to the management of improved pastures. The application of GIS technology to agriculture has been discussed (9, 11) and there appear to be a number of cases where the method could be applied to improve the quality of advice on pasture management offered to farmers. However, the development of GIS applications for improved pasture management has been limited by the availability of suitable data ; the processed Landsat data showing potential growth status meet this need.

Methods

Production of GIS maps

Procedures have been developed using data from the earth resources satellites to find which areas of improved pastures are most in need of added fertiliser. Landsat MSS or SPOT multi-spectral (XS) data in the green red and near infrared wavelengths taken on a clear day in spring are corrected for distortions, referenced to the Australian Map Grid and classified with image processing software using methods developed at CS IRO Armidale. An unsupervised classification procedure is used to separate the image into spectral classes which are then aggregated into composite classes for pasture growth status, forest and water. The method makes use of a classification algorithm based on principal components and a set of analytical programmes for the process of spectral class aggregation. It has been possible to calibrate the pasture growth status against sites with known histories of fertiliser treatment. These relationships are then used to predict and map the likely responsiveness of particular areas of improved pastures to additional fertiliser.

Further processing with a PC based geographic information system (EPPL7) allows data for a particular property to be selected and for roads and fences to be added before final colour printing of the map. The procedures make use of databases containing digitised maps showing property and paddock boundaries, soil and geological information, and also data on roads, railways and regulatory boundaries such as Rural Lands Protection Boards. The soil and geological data may be used as masks, so that only satellite data from one soil type or geological parent material are analysed at any one time. The road and boundary data are used as an overlay on the map to allow easy location of properties, and fence lines are included to allow reports on the fertiliser responsiveness of individual paddocks. Classification maps produced by this procedure, would cost approximately $100 per farm although initial commercial releases may cost slightly more depending on the economies of scale in bulk purchasing of the satellite data.

Pasture map details and usage

These maps of the growth status of pasture are suitable for use by agricultural extension officers with minimal training in satellite image interpretation. The maps and associated reports on individual paddocks enable the officer to advise farmers about which parts of their property would be most responsive to fertilisers and which parts require only maintenance treatment. The technology will also identify areas of marginal nutritional status where soil testing would be valuable, thus improving the efficiency of soil testing and fertiliser use on improved pastures.

Maps of individual properties, show the relative responsiveness of the pastures to fertiliser by the use of a colour scale. The pastures are mapped using 1 ha squares where the colour is related to the growth status of the pasture or the degree of pasture improvement. The colour sequence starts with bright green for the most actively growing pastures which require only maintenance applications of fertiliser. Under average rainfall conditions such pastures could be expected to produce up to 10 000 kg/ha of dry matter on an annual basis on the Northern Tablelands of NSW. The next colours in the sequence are lighter shades of green representing the more slowly growing pastures. The pastures with the lowest growth status, coloured yellow, orange and brown may be improved pastures which have become degraded or unimproved native pastures. Such pastures on the Northern Tablelands of NSW are only capable of producing 2500 to 3000 kg/ha in an average season unless improved species are established with added fertiliser.

The maps are used in conjunction with tables which show the proportion of pasture present in each aggregated class, for paddocks larger than 20 ha. Those pastures with a large number of the lighter green squares are particularly responsive to added fertiliser, while those with a large number of bright green squares will require less fertiliser. However, such paddocks should be monitored with the maps and tables for an increase in the number of lighter green squares in subsequent years as this is an early indication of a run-down in nutrient levels. The application of fertiliser to pastures, with a high proportion of yellow, orange or brown squares, without the establishment of improved species, will be unlikely to provide an economic response to those nutrients in many cases. In the initial phases of developing fertiliser recommendations for a particular property, the growth status maps should be used with the recommended soil test for the district. This will provide continuity with existing information and allow for improved calibration of the actual responsiveness of the light green class paddocks on the property in question.

Technology transfer to industry

A pilot project to train officers within the extension services of state departments of agriculture to produce and use these maps has started. Sites for the pilot project are currently in the Central and Northern Tablelands of NSW, and in Central Tasmania. This project will provide a foundation for commercialisation of the technology. There has been considerable interest from both potential commercial partners and from the farming and grazing community. In addition there have been inquiries from associated industries such as forestry where there may be opportunities for adapting the technology. When the GIS computer hardware and software are established at a pilot site departmental officers are given introductory training in its use. This includes the basic use of GIS procedures and methods for digitising roads and paddock boundaries on individual farms. Once the process of digitising has been completed for a particular farm it will not have to be repeated when new satellite data are mapped. We have developed specific software at Armidale to simplify this phase of the work and allow the technology to be used without specialist computing skills. Files for printing the maps and tabular summaries of the individual paddocks are produced automatically from the use of these procedures.

Discussion and conclusion

Significance and direct benefits of the technology

Fertilisers represent 20% of the variable costs for most graziers in temperate Australia, but often the placement of this fertiliser is only determined from subjective knowledge of how responsive individual paddocks will be. Despite the large benefits from tactical use of fertiliser by applying it only where required, the identification of differences in pasture productivity is a major challenge to managers of improved pastures. The satellite remote sensing and GIS methods described in this report can be used to improve this aspect of fertiliser management. In the context of an annual expenditure of $300 to 400 million per year, the cost savings to farmers of a method which maps a pasture's responsiveness and hence need for fertiliser, would be substantial. There are also national financial benefits from such tactical use of fertilisers through savings in the import costs of raw materials for the manufacture of fertiliser.

More efficient use of extension officers' time by directing their attention to pastures with problems of low growth rates, coupled with efficient use of fertiliser applied to pasture by identification of responsive pastures is anticipated from use of the technology. The ability to monitor pastures which only require maintenance applications of fertiliser should avoid the loss of species associated with run-down due to insufficient fertiliser application. Improved efficacy of soil and tissue tests by direction of tests to critical areas and selection of representative monitor sites should also occur. It is important to note that there are significant community benefits from the technology through more responsible use of fertilisers leading towards more sustainable land management and reduced environmental degradation from, for example, soil acidification or declining water quality. This should result in increased protection of the grazing resources of the nation.

Evaluation of the technology

During field validation of the growth status maps, a preliminary assessment of their utility as aids to the fertiliser decision process, was obtained by canvassing the views of the farmers on whose properties the technology was being tested. This was done by adding specific questions to a wider survey of pasture improvement and fertiliser problems. Ninety five percent of the farmers who had taken part in the validation experiments indicated that they wished to receive growth status maps on a regular basis. They rated the value of the maps equal to or better than soil tests in the fertiliser decision process.

To date the application of remote sensing technology to farm scale management within the improved pasture based grazing industry has been *ad hoc.* It has usually been applied to solve a specific problem of an individual rather than address a common problem of the grazing community. The technology described here represents a departure from this situation by the establishment a network of pilot sites and consultants with experience in the use of the technology and appropriate computing hardware. They should then be able to routinely use processed Landsat MSS data as one of their tools in farm management consultations. The successful implementation of the technology will represent the first time that an application from satellite remote sensing has been made available to this grazing industry for use *as* a routine resource management tool. The combination of processed Landsat data combined with other ancillary data in a GIS offers anew dimension to current farm management practices. The research in progress will enable the refinement and evaluation of the technology in a semi-operational situation and assist in developing a market for the technology and assist in its commercialisation.

Technical considerations

The technology described was developed from previous strategic research in analysis and interpretation of remotely sensed data gathered by the Landsat MSS (10). Classical image processing methods can be slow and require special skills when applied to the analysis of heterogeneous surfaces such as pastures. A new classification strategy was developed and tested (4) to eliminate the time taken to develop homogeneous training sets. The approach was derived from that used by Jupp *et al. (7)* in mapping The Great Barrier Reef, but it uses a different classification algorithm and analytical procedure. The system we have developed is faster than the classical methods, but similar in performance to these methods when applied to improved pastures (12). An added advantage is that it is easier to use and to train operators to process data.

Considering resolution and cost, Landsat MSS data is the preferred form of remote sensing information for application in areas where the average property size is more than 1000 ha. Most of the calibration work (12, 2) has been done with this form of data. However, should Landsat MSS data become unavailable in the future we have experimental evidence (Reid *et al.* unpublished) that SPOT XS data can also be used effectively for this application. Further, the additional bands which are available with Landsat Thematic Mapper (TM) data provide the potential opportunity to refine the mapping to individual nutrients such as phosphorus or sulphur (Marjoram and Vickery unpublished). We do not propose to use Landsat TM data in the initial phases of the work because our overall philosophy is to keep the system as cost effective and uncomplicated *as* possible. Later in the development of the technology it may become desirable to make use of the advanced scanning systems as experience and requirements of the user community develop.

Place of the technology in agricultural extension

The technology in this project is complementary to the soil and tissue tests currently used for fertiliser management of improved pastures. It has the potential to considerably increase the effectiveness of these testing technologies as well as provide additional management information which can not be otherwise obtained. While the project represents pre-commercialisation development of the satellite technology we recognise some risks in achieving its widespread use. A poor adoption rate might occur if the attitude of agricultural consultants was not favourable. We plan to cover this situation through the use of workshops and field days. The role of NSW Agriculture is significant in this context and their commitment to the project is most important, both through their extension consultants and through their remote sensing section.

Later in the development of the technology it will be necessary to find a commercial partner but as the application is novel this may be difficult in the first instance. However, the market development accomplished through the research should help solve this problem. Finally the attitude of the fertiliser companies must be considered; they might see the technology as reducing fertiliser sales. However, a survey by Vickery *et al.* (unpublished) indicated the financial position of farmers was the main factor in determining the amount of fertiliser purchased. In this context the companies should see the technology as a means of providing farmers with responsible land management information and recommendations for fertiliser applications targeted to those areas where the response will be most beneficial. We have already had discussions with fertiliser manufacturers along these lines and the responses have been favourable.

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