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The potential for predicting Australian wool supply using remotely sensed data

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Abstract

This paper examines the potential of using remote sensing data to make forecasts of Australian wool production more reliable. At present AWI's Production Forecasting Committee relies heavily on expert opinion and consensus. A model of the Australian flock at a regional scale is critical to enable reliable forecasts. Given technological advances and proven applications like the CSIRO's Pasture from Space program, remote sensing has considerable potential to reduce uncertainty in production forecasting. It can be used to differentiate regions on the basis of the predicted quantity and quality of pasture available for sheep grazing throughout the year. Integrating estimated pasture productivity, flock size and flock structure into a simple simulation model should provide an improved and more precise forecast of wool production across the Australian continent.

Introduction

Wool growers are exposed to market forces and respond predictably to changes in supply and demand. The world market has an impact on wool production in Australia. For example, as the relative value of wool has declined so has the size of Australia's flock; when a higher premium is paid for low fibre diameter wool so wool growers change their management programs, including breeding, to meet this market.

In Australia there is a need to improve forecasts of wool and sheep meat production. At present forecasting is carried out four times a year by the Australian Wool Innovation (AWI) Production Forecasting Committee. In the past this Committee has relied on analysis of information (e.g. state level expert assessment, broker returns, livestock slaughters and rainfall distribution), expert opinion and consensus of committee members (James *et al.* 2004). More recently a flock model driven by survey data has been used in the forecasting process to predict flock numbers at the state level. The committee forecasts the overall production and the fibre diameter profile of the clip from flock numbers and assessment of the season (AWI Production Forecasting Committee 2006). To reduce the level of uncertainty in current forecasts a more detailed, regional level flock model is required, as well as the development of a model which predicts wool cut per head in different regions of Australia.

Two important elements for improving agricultural commodity forecasting are better knowledge of the regional distribution of the industry and more robust information on the production status of those industries in near real time. Remote sensing has made a strong contribution in these areas, particularly in broad acre crop production where remotely sensed metrics are now used routinely for national crop production forecasts. The challenges in applying remote sensing in grazing systems arise because of the more diverse nature of pastures and extending the approach to predict animal product yield. The focus of this paper is the potential remote sensing has to improve forecasts of wool production in Australia by classifying wool growing regions in Australia and predicting their wool production.

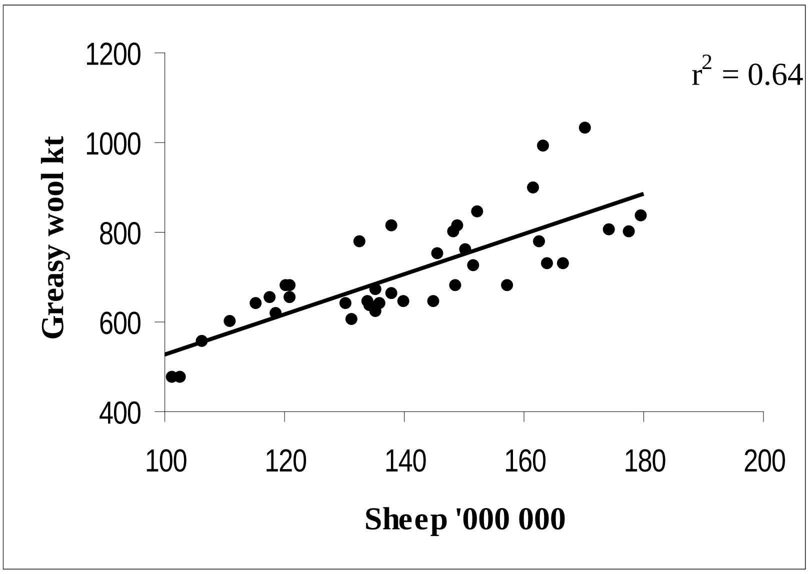
Forecasting Production

Bauer (1975) put forward three reasons for improving forecasts of production; 1) price stability; 2) optimum use of storage, transport and processing facilities and; 3) as an aid to the formulation of government policy. For the wool industry in Australia usage of storage, transport and processing infrastructure is less of an issue as wool volumes have declined.

As expected there is a strong relationship between the number of sheep and the amount of wool produced in Australia (Fig. 1). Being able to model the Australian flock will be critical to any forecasting system. However, the number of sheep only accounts for 64% of the variation in production. A significant factor is seasonal conditions that affect the fleece weight of individual sheep. For example, two thirds of the reduction in wool production in the forecast of 2006/7 production was attributed to an estimated decline in average clip from 4.33 to 4.08kg per head. Season also affects the fibre diameter profile of the clip (Australian Wool Innovation Production Forecasting Committee 2006). Once the national flock has been modelled it is necessary to separate the national flock into regions that have relatively uniform grazing environments in each year so that the impact that the grazing environment has on wool production can be estimated.

Fig. 1: Relationship between number of sheep and annual greasy wool production.

(Source: ABARE 2005)



Accurate crop forecasts require accurate estimates of the area cropped, its geographic distribution and accurate estimates of yield (Bauer 1975). Many of the established crop forecasting systems used throughout the world rely on mapping the distribution of the industry (e.g. MacDonald and Hall 1980; Maselli *et al.* 1993).

In Australia the distribution of the sheep industry can be mapped using data collected by the Australian Bureau of Statistics. Data on the wool clip, number of sheep shorn and the number of sheep slaughtered is collected once every five years. Although these data cannot be used to forecast production, they can be used to provide a distribution map of the industry and validate forecasts when census data become available.

Being able to forecast wool production over the whole of Australia will require the wool growing areas of Australia to be classified into different grazing environments. Seasonal factors such as temperature and rainfall will impact on production differently in different areas. Dry conditions in Queensland, for example, will have little impact on production in Victoria. At present sheep grazing regions are defined into three very broad classes (High Rainfall, Wheat/Sheep and Pastoral) (Cottle 1991).

Remote sensing

Remote sensing is the science of measuring different characteristics of the energy spectrum emitted from the earth's surface, usually by an orbiting satellite or air borne sensor. One of remote sensing's advantages, when compared to other forecasting tools like surveys or field measurement, is that it provides a map that can summarise conditions over a large area (Roderick *et al.* 2000).

One commonly used product derived from satellite data collected at the near infrared (NIR 0.725 – 1.1 μm) and red (0.58 – 0.68 μm) part of the energy spectrum is the Normalised Difference Vegetation Index (NDVI). The NDVI, or greenness index, is calculated as follows from the red and NIR reflectance bands (Tucker 1979): NDVI = (NIR - Red) / (NIR + Red). NDVI has a strong relationship with leaf area index (LAI) and has been used in remote sensing applications for decades.

NDVI is available at a 1.1 km resolution as fortnightly or monthly composite images from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) satellites, with over 20 years of data available. NDVI and LAI are also available from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellites at 500 m or 250 m resolution since 2001.

Although remote sensing offers the advantage of comprehensiveness, use of remote sensing in agricultural commodity forecasting has some limitations. In the past data acquisition and processing have been too expensive for use in operational seasonal forecasting (Watson *et al.* 1995). At 1.1 km resolution products like NOAA AVHRR NDVI are confounded by mixed pixels. Mixed pixels occur when two land covers (e.g. pasture and forest) contribute to the single value recorded for a pixel. There are also data quality problems: for instance clouds can contaminate the remotely sensed signal and the affected pixels must be identified and masked from the image.

Despite these limitations remote sensing has seen increased use in the monitoring of agricultural landscape over the past decade. This development has paralleled decreased acquisition and processing costs. Some examples from Australia include: the regular monitoring of vegetation condition by the Environment and Resources Information Network using NOAA NDVI[1]; the regular prediction of soil water status by the Normalised Difference Temperature Index and a simple water balance as part of the National Agricultural Monitoring System [2]; continent wide land use mapping which can differentiate between improved and unimproved pasture (Knapp *et al.* 2006); and it has been used for some time in drought monitoring (McVicar and Jupp 1998).

Given this demonstrated potential, technological developments and decreased costs over the last decade, we suggest that remote sensing is in a mature position to make a contribution to wool production forecasting. Such improvements need to focus research and development in two key areas: improving knowledge of the regional distribution of the industry; and in near real-time prediction of wool cut per head.

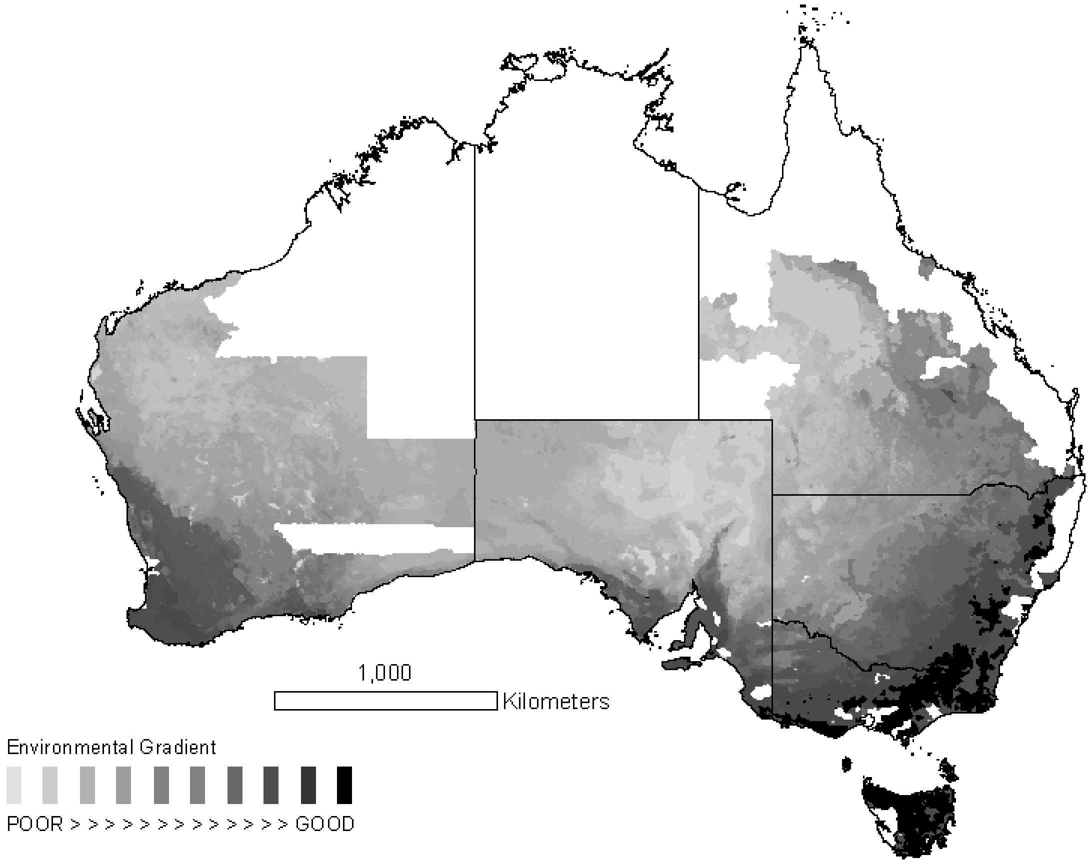
Generating regions for forecasting

Whelan and Cottle (unpub. data) have used two factors to classify sheep grazing environments. Pasture availability was mapped using NDVI derived from NOAA AVHRR satellite data and temperature was used as a predictor of pasture quality.

The Australian continent was divided into a grid of 10km by 10km cells. Each cell contained monthly NDVI data derived from NOAA AVHRR (Holben 1986) for the period (1996-2005) and monthly maximum temperature for a 10 year period (1996-2005). The temperature data were provided by the Australian Bureau of Meteorology (Jones 1999). An unsupervised classification technique that creates clusters of cells with similar attributes (Campbell 1987) was used to produce 25 classes with similar nutritional grazing environments in this period and a map that classifies sheep grazing environments based on pasture availability pasture quality was produced (Fig. 2). The 10km by 10 km grid we have produced could be used to create regions within the sheep grazing areas of Australia. Models of flock demographics could be developed for each of the classes and used to forecast production. Ideally, classes would be generated annually to reflect nutritional differences in the current season.

Figure 2: Classification of sheep grazing areas of Australia based on NDVI and temperature (1996-2005).

[1] http://www.environment.gov.au/erin/ndvi/
[2] http://www.nams.gov.au/



Predicting production

The CSIRO Livestock Industries Pastures from Space (PfS) project demonstrates the potential of remote sensing to contribute to near real-time prediction of production. It has shown in the annual production zone of Western Australia (WA) that it is possible to predict PGR by transforming NDVI images using climate information to predict the fraction of photosynthetically adsorbed solar radiation (Holben 1986) and deliver PGR in near real-time over the internet to producers (Gherardi *et al.* 2004). In the WA annual production zone there is a relatively simple species structure and the abundance of green FOO correlates well with digestibility and crude protein. WA work has shown that given this relationship it is possible to utilise relatively simple relationships (Thompson *et al.* 1997) to predict wool cut per head in this grazing system. The next phase of PfS research is the application of this approach to grazing systems of Eastern Australia with possible integration with the classification presented in Fig 2.

Currently, PfS simulation of PGR covers the south-west region of WA agricultural area (Donald *et al.* 2004). Recently, a simulation set of PGR covering an area from Rockhampton in Queensland to Ceduna in South Australia has been developed for 1995-2006 but data for this area has yet to be calibrated and validated. These data are provided weekly over the growing season via: http://www.pasturesfromspace.csiro.au and to Fairport technologies for delivery to producers via the Pasture Watch on-farm pasture utilisation software package. PfS is currently undertaking projects to validate and extend the satellite prediction of PGR for annual and perennial pastures across the Mediterranean and temperate regions of eastern Australia and New Zealand.

Complex simulation models such as GrassGro (Donnelly *et al.* 1997) which account for the interaction between the animal and the sward across a multi-species and tissue pool matrix provide an alternative option for prediction. However, it is difficult to validate this approach at the field level (Freer 2002) and it is not feasible yet to apply it to industry level forecasting.

The Sustainable Grazing Systems Pasture Model has been used to evaluate grazing systems across Australia (Andrew and Lodge 2003). The SGS model has the potential to be used over a wide extent of the continent but doesn't yet have the facility to predict wool production (Johnson *et al.* 2003). Linking close to real time pasture availability from PfS, a regional flock model, with predictive models such as GrassGro or SGS may realise an accurate wool clip at a regional and continental scale.

It may be possible to predict wool fibre diameter profile directly from remotely sensed data. In a Sheep CRC project currently underway the fibre diameter profiles of sheep at 29 sites throughout Australia are being compared with monthly NDVI values within the paddocks. The NDVI data will be collected for cells 250m by 250m at the 29 sites. Prediction of wool fibre diameter profile for a region in addition to wool cut could make a forecasting system a powerful tool to assist marketing wool in the future.

Discussion

There is considerable potential for remotely sensed data to reduce the uncertainty in wool production forecasting. A number of projects have demonstrated this potential; including the PfS program for monitoring production in near real time and studies which improve knowledge of the regional distribution of the industry. However, ongoing research and development is required to fully realise this potential for production forecasting which could occur if the wool industry supports it. Further extension and validation of the PfS program in Eastern Australia is one initiative. Continued commitment to the collection and use of field data is an important aspect of building on the approach.

While the current predictions of FOO and PGR have potential value as inputs to the consensus forecasting approach, further work is required for remote sensing to fully realise its potential in grazing industry forecasting. The ultimate objective is the extension of remote sensing to predict total animal yield including wool cut per head and reproductive output, and coupling this to a flock model that is also sensitive to economic decision making such as sales, purchase and slaughter. On going work is being carried out to evaluate the potential of remote sensing to predict the wool fibre diameter profile of the wool clip before it is shorn. It may also be possible to predict the affects of modelled future climate change on future wool supply, which is a project in the new Sheep CRC commencing in July 2007.

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