Anim. Prod. Aust. 2002 Vol. 24: 81-84

MONITORING PASTURES USING SATELLITE REMOTE SENSING

D.A. HENRY [A] , A.EDIRISINGHE [A] , G.DONALD [A] and M.HILL [B]

[A] CSIRO Livestock Industries, Private Bag 5, Wembley, WA, 6913, Australia.
[B] Bureau of Rural Sciences, PO Box E11, Kingston, ACT, 2604, Australia.

SUMMARY
The strategic use of quantitative pasture information is critical for optimising feed resource utilization for the grazing industries in medium-high winter rainfall regions of Australia. It also offers significant potential to produce agricultural commodities such as wool to a budgeted specification. Satellite technology can provide comprehensive pasture biomass and growth rate information on a spatial basis at a paddock, farm or regional level and national scale, delivered near real time via the Internet or fax. This paper reports the satellite-based pasture products developed by CSIRO Livestock Industries and some of their on-farm applications.

Keywords: feed-on-offer, pasture growth rate, remote sensing, satellite

INTRODUCTION
The utilisation of pastures by grazing animals is low. Estimates by the Department of Agriculture (WA) show that in many seasons the amount of feed grown that is consumed by sheep varies between 20 and 30% (Michael *et al.* 1997). Economic analyses indicate that better utilization of pastures could double farm profit – for every 5% increase in utilization, profit increases by $10/ha/year (J. Young, pers. comm.). In order to better capture the benefits of increased utilisation, producers must be able to feed budget with timely and accurate estimates of pasture biomass and growth rate.

Producers that are able to feed budget and strategically manage their grazing system can also benefit significantly in the quantity and quality of wool produced. Research conducted by the wool program of the Department of Agriculture (WA) showed that controlling feed intake over winter/spring produced more wool per hectare with less variation on fibre diameter which conveyed increased returns via a finer and stronger product. Concurrent studies using the 'measure as you grow' approach are monitoring the pasture production and wool quality throughout the season, and developing new tools that will enable wool producers to produce wool to budgeted specifications (Oldham *et al*. 2002; House *et al*. 2002)

In recognition of the benefits of being able to quantify pasture biomass and growth rate, a number of producer training and education networks have been established (eg WoolPro, Prograze etc). These networks aim to train producers to better evaluate their pastures, and hence change their grazing management to reap the benefits of increased pasture utilization and product specification. However, market research has shown that most producers do not have the time nor the confidence to make estimates themselves. Further, they cannot physically cover each part of every paddock at a regular interval to obtain an accurate measure of the spatial variation in the estimates.

Measurement of feed on offer and pasture growth rate using satellites (Edirisinghe *et al*. 2000) may be the solution for accurate and timely delivery of pasture information on a spatial basis. This technology provides instantaneous mapping of pasture on regional, catchment or paddock scale. In addition to feed budgeting applications, it may also be used to identify areas of poor productivity due to nutrient status, salinity, insect damage, etc and enable timely remedial action. It will also allow precision agriculture techniques typically applied in the cropping industries to be employed in grazing enterprises.

This is the first in a consortium of papers in this volume describing the satellite technology, its delivery and potential on-farm applications and benefits. Oldham *et al*. (2002) describe the 'measure as you grow' technique that monitors changes in fibre diameter of flocks and which is being coupled with the satellite technology to allow producers to increase their pasture utilization and meet budgeted targets for wool quality and quantity. House *et al.* (2002) report on case studies exploring the results of this 'measure as you grow' approach and Sneddon and Mazzarol (2002) report on market research assessing the delivery and application of the remote sensed information for producers.

MATERIALS AND METHODS

Satellite technology

There are numerous satellite platforms available, each with varying overpass frequency, different sensor capabilities and resolutions. Currently we use geo-located satellite imagery that provides a normalised difference vegetation index (NDVI). The NDVI is a measure of the relative use of photosynthetically active radiation by plant canopies. This is a qualitative index that is best explained as a 'greenness' index. The novelty in our technology is the quantification of this NDVI into meaningful measures of feed on offer and pasture growth rate.

The consortium of CSIRO Livestock Industries, Department of Agriculture (WA) and the WA Department of Land Administration has developed and validated two technologies:

1. Feed on offer (FOO)
   This is a measure of green pasture biomass (kg dry matter/ha). It is estimated using an empirical relationship developed between the NDVI and actual feed on offer.
2. Pasture growth rate (PGR)
   Pasture growth rate (kg dry matter/ha/day) is estimated from the same NDVI, combined with coincident climate layers in a light use efficiency model.

Other secondary products such as net pasture production can then be derived from these values.

Table 1. Details of satellite and sensors currently used to measure feed on offer and pasture growth rate

	Feed on offer		Pasture growth rate	
Satellite/Sensor	Landsat Tm	SPOT	NOAA AVHRR	MODIS[1]
Overpass frequency	16 days	3-26 days[2]	Daily	Daily
Resolution	30m	20m	1.1km	250m

[1] MODIS will become available in 2002

[2] Availability of SPOT imagery varies because the sensor on the satellite is tiltable. Orbit frequency is 26 days.

RESULTS

The technology has been developed and calibrated since 1995 in the wool production zone of southwest Western Australia (Edirisinghe *et al*. 2000; Hill *et al*. 1998). This region has an annual rainfall of 500-750mm and consists predominantly of annual plant species. In 2001, we commenced validation of the technology in other regions of southwest WA as well as selected sites in South Australia, Victoria and New South Wales. We aim to expand the technology across temperate and Mediterranean environments of southern Australia, encompassing annual and perennial pasture systems.

All remotely sensed estimates were compared directly with ground-truthed measurements. All sites within WA were established and monitored by the Department of Agriculture (WA). Pasture growth rate was measured using pasture exclosures located along georeferenced transects across the major land management units within a paddock. Growth rate was calculated at 4 week intervals throughout the growing season using NOAA AVHRR imagery. The NDVI was combined with climate variables such as temperature indices, radiation and soil moisture in a light use efficiency model to estimate growth rate (Edirisinghe *et al*. 2000).

The basic pasture growth rate product from the NOAA AVHRR imagery has a resolution of 1.1km. From 2002, use of MODIS imagery will improve this resolution to 250m. When using the coarse resolution NOAA imagery, Hill *et al*. (unpubl. data) devised a method for scaling these large pixel estimates to a farm paddock scale - land management units were classified on the basis of soil and topographic properties and each one assigned an index of relative potential productivity. Pasture growth rate was then scaled for each land management unit according to its relative potential productivity.

Feed on offer was measured in the field along the georeferenced transects using visual estimation - estimates were calibrated against quadrat ($0.1m^2$) samples harvested to ground level using a scalpel, sorted to remove non-green vegetative material, washed and dried at 60^oC. Direct comparisons were made between the ground-truthed measurements and that predicted from the satellite imagery (Edirisinghe *et al*. 2000).

Validity of the satellite estimates

Edirisinghe *et al*. (2000) showed that both pasture growth rate and feed on offer predicted using satellite imagery was significantly correlated with ground-truthing measurements. Figure 1 shows the mean predicted and observed pasture growth rate values for one property in south-west WA. When a number of field sites were combined (five sites each consisting of annual pastures) the generic predictive relationship had an R^2 of 0.7 ($p<0.05$). Feed on offer was predicted with a standard error of ±10%.

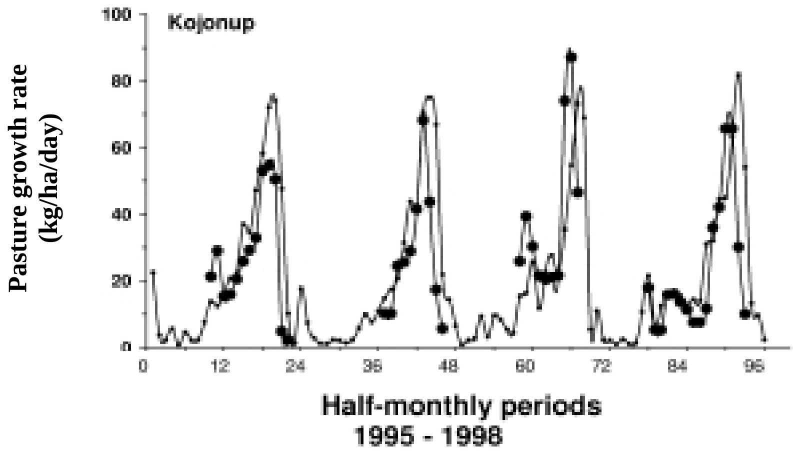

Figure 1. Pasture growth rate (kg/ha/day) measured using pasture cages (•—•) and predicted using satellite imagery (——) over 4 years, 1995 – 1998. Data shown is for a wool property at Kojonup, south-west WA (Hill *et al*., unpublished).

DISCUSSION

The accuracy of remote sensed pasture information is difficult to define due to the marked difference in scale; it is a comparison of 1m x 1m cages (for pasture growth rate) or point estimates of feed on offer versus a minimum of 20 to 30m imagery resolution. Despite this, feedback from producers indicates that many of them do not consider themselves accurate enough to visually estimate either pasture growth rate or feed on offer and are hence enthusiastic about what the satellite technology can provide. It also provides instantaneous spatial mapping of an entire paddock, farm or region, and is a significant time saver.

Remote sensed pasture information such as feed on offer and pasture growth rate can be delivered to the market in a number of ways, whether it be delivered to consultants, advisors or direct to producers. Market research detailing market segmentation, preferred delivery mechanisms, and product composition is being addressed in the accompanying paper by Sneddon and Mazzarol (2002). An example of a farm map product is shown in Figure 2.

One attractive feature of being able to produce farm maps is that each individual pixel is quantified for a level of feed on offer. This enables assessment of within paddock variation and the use of ‘precision agriculture’ techniques that are usually employed in the cropping enterprise.

In 2001, we launched two websites publishing feed on offer and pasture growth rate information in WA. Regional pasture growth rate is shown at a 1.1 x 1.1km resolution at *http://www.pgr.csiro.au*. Delivery of individual farm (paddock scale) information is demonstrated at *http://spatial.agric.wa.gov.au/foo.*

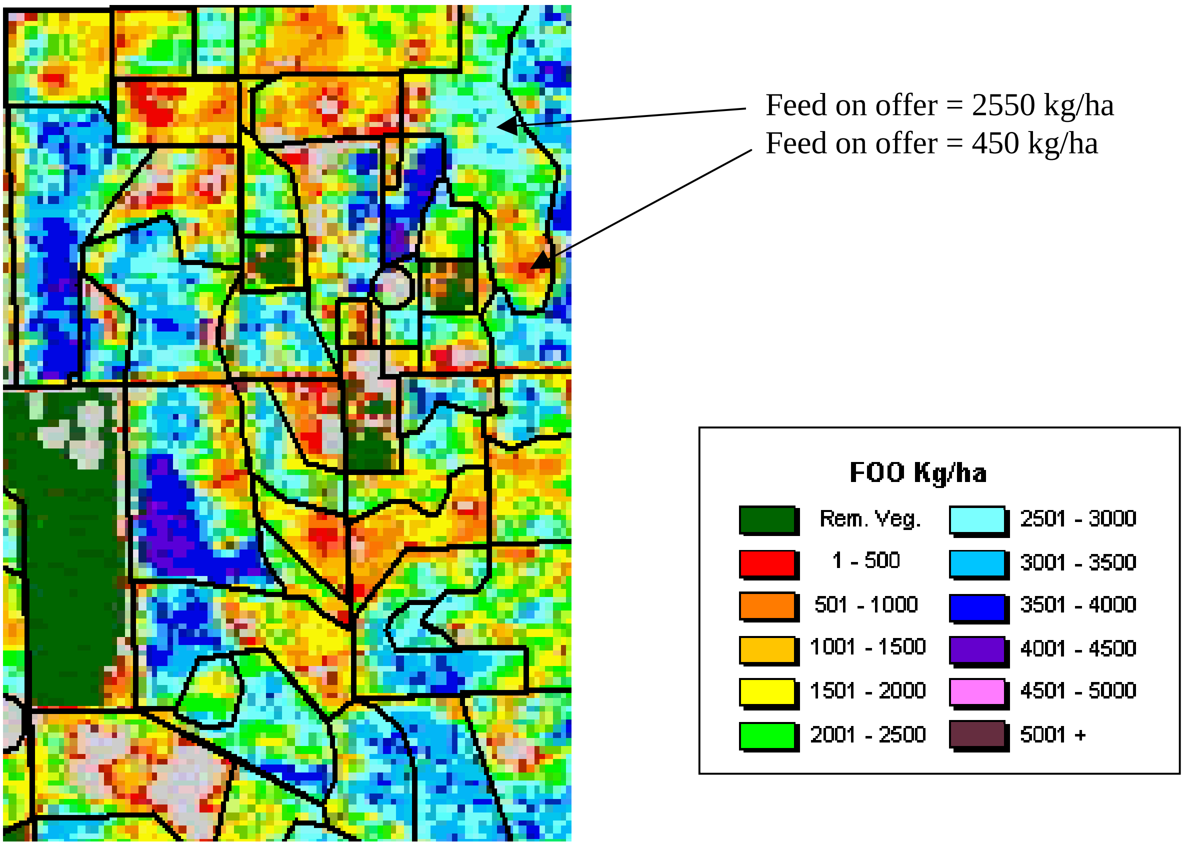

Figure 2. Farm map showing distribution of feed on offer within and between paddocks.

This technology offers significant potential for strategic management of grazing enterprises, including sheep, beef and dairy enterprises. It also has applications in native vegetation planning, strategic land use, finance and insurance applications because it provides quantitative assessment of the productivity of land and hence it's agricultural value. Feed on offer and growth rate are only the first in a suite of pasture-based information tools. We are currently developing hyperspectral technology to estimate pasture quality (such as protein content and digestibility) and botanical composition, and radar-based technology to measure biomass of dry feed and ensure year-round timely delivery unaffected by cloud cover. Remote sensing is a rapidly advancing and innovative field that promises many exciting opportunities. It will be a challenge to keep pace with the developments, and to deliver practical outcomes to a diverse market. Our vision is to deliver, near real time, remote sensed and spatial pasture information directly to producers and agribusiness via the Internet.

REFERENCES

EDIRISINGHE, A., HILL, M.J. and DONALD, G.E. (2000). *Proc. 10th Aust. Remote Sensing and Photogrammetry Conf.* (Adelaide, August, 2000).

HILL, M.J., DONALD, G.E., WHEATON, G.A., HYDER, M. and SMITH, R.C.G. (1998). *Proc. 9th Aust. Remote Sensing and Photogrammetry Conf.* (Sydney, July, 1998).

HILL, M.J., DONALD, G.E., HYDER, W.M. and SMITH, R.C.G. (Unpublished). Estimation of pasture growth in the south west of Western Australia from NOAA AVHRR NDVI and climate data. Unpublished data.

HOUSE, R., BILNEY, R., LADYMAN, D., OLDHAM, C. M. AND YELLAND, M. (2002). *Proc. Aust. Soc. Anim. Prod.* **24**, (these proceedings).

MICHAEL, P.J., GRIMM, M., HYDER, M.W., DOYLE, P.T. and MANGANO, G.P. (1997). *MRC Final Report DAW 048*.

OLDHAM, C.O., GHERARDI, S.G., PAGANONI, B., and YELLAND, M. (2002). *Proc. Aust. Soc. Anim. Prod.* **24**, (these proceedings).

SNEDDON, J. and MAZZAROL, T. (2002). *Proc. Aust. Soc. Anim. Prod.* **24**, (these proceedings).

Email:dave.henry@csiro.au