Evaluating satellite-based pasture measurement for Australian dairy farmers

Eastwood, C.R.[1], *Mata, G.*[2], *Handcock, R.N.*[2] *and Kenny, S.*[3]
[1]*The University of Melbourne, Melbourne School of Land and Environment, Parkville, Victoria 3010, Australia,*
[2]*Commonwealth Scientific and Industrial Research Organisation, Livestock Industries, Private Bag 5, Wembley, 6913, Australia,*
[3]*Victorian Department of Primary Industries, Warrnambool, Victoria 3280, Australia*
callumre@unimelb.edu.au

Abstract

Australian dairy farms rely on grazing pastures as their primary and cheapest source of feed. Accurate and timely measurement of pasture biomass is integral for effective grazing management practice, however few Australian dairy farmers record pasture mass or growth rate objectively. A system has been developed using satellite images to measure pasture biomass at a paddock-scale in Australia. The concept was evaluated with an 18 farm pilot study over the spring growth period, July to November 2008. The study focussed on evaluation in terms of technology fit with grazing management practice of participant farmers. Qualitative research methods, including semi-structured interviews and a group workshop, were used to ascertain participant views on issues such as timeliness, accuracy, and value proposition within the context of farming systems. In this paper we discuss preliminary findings from the study, focussing on the farmer attitudes to the use of satellite-based measurement and delivery of pasture biomass information. The findings suggest that a technology such as satellite pasture measurement has potential application in Australian dairy farm systems. However the provision of data alone does not guarantee successful technology uptake. Support structures must also be provided to help farmers interpret the information within the specific context of their farm system. These support structures may include use of private agronomists, producer groups, agriculture extension personnel, or associated software applications.

Keywords: remote pasture measurement, precision dairy, farmer decision making

Introduction

While precision dairying has advanced in the area of individual animal management, there has been less development and uptake of feedbase management tools. In pasture-based dairy systems such as those in Australia or New Zealand, more detailed information on pasture resources and utilisation are the 'missing link' for whole farm precision dairy systems. Pasture measurement tools (rising plate meters and capacitance probes) are available but not widely used. Reasons include: lack of confidence in their accuracy (Li *et al.* 1998; Reeves *et al.* 1996: Stockdale 1984), high labour demand (Dobos and Fulkerson, 2004), and difficulty of use and cost (Lile *et al.* 2001) and at best farmers view them as useful for short-term use to 'calibrate their eyes' in visual estimation. Pasture cover is then estimated visually either during their daily farming activities or as part of a specific farm walk, and few formally record their estimates. Consequently, neither the industry nor individuals have a reliable measurement of the quantity of pasture grown or utilised.

This lack of quantitative measurements can partially be attributed to the management style of Australian dairy farmers being based on a tacit and intuitive approach, with minimal use of information and communication technologies (ICT). Utilisation of computers for farm management tasks is low compared to other industries, with 59 percent of Australian dairy farms using computers for business operations (ABS, 2006) compared to 89 percent in other Australian businesses (ABS, 2007). Reasons for slow uptake of ICT include low computer literacy, farmer perceptions of a lack of benefit, and incompatibility with management systems (Stubbs *et al.* 1998).

Additionally, supplying an appropriate and consistent amount of feed to cows is difficult within dynamic pasture-based grazing systems. However, Fulkerson *et al.* (2005) showed that accurate allocation of feed can result in approximately 10 percent higher milk yield. According to Fulkerson *et al.* (2005) in pasture based dairy farming supplements are often accurately calculated yet 'pasture intake and quality are guessed'.

In response, new tools have recently been developed targeted at achieving an improved fit with farm management systems through greater ease of use and reduced time commitment. These tools include all terrain vehicle- (ATV) mounted pasture sensors and satellite-based pasture mapping. Pastures from Space® (PfS), a consortium comprising the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of Agriculture and Food Western Australia, and Landgate, have developed a number of satellite-based measurements of pastures. These include fine-resolution pasture biomass in an annual system (Edirisinghe *et al.* 2000), and medium-resolution pasture growth rate via a commercialised system termed PGR® (Hill *et al.* 2004). The measurement of pasture growth rate (GR) from this system was developed for extensive Western Australian sheep and beef properties. The concept of remote observation and delivery of pasture observations has subsequently been adapted with the aim of providing timely and accurate paddock-scale pasture biomass (Handcock *et al.* 2008) and farm-scale GR for dairy farmers. Research into the use of high-resolution satellite images to predict pasture biomass has proven successful in perennial ryegrass-based research studies in Gippsland, Victoria, a primary dairy region of Australia (Handcock *et al.* 2007).

In this paper we discuss preliminary findings from a 2008 pilot trail to assess the value to farmers of the use of satellite-based measurement and delivery of pasture biomass information. A validation of the algorithm was run concurrently with the pilot with the goal of data delivery to farmers within 72 hours from image acquisition. We present an outline of the study from an end user (dairy farmer) perspective, based on qualitative interviews. We also provide a brief overview of the technical aspects underpinning the satellite measurement of pasture biomass and growth rate, with the focus on implications for practical farm management.

Methods

Research design

The study was based in the Gippsland area in Victoria, Australia, from July to November 2008. Eighteen commercial dairy farmers were selected to take part based on their current pasture management practice and location within a 60x60 km satellite image 'footprint'. The paddock and farm boundaries for each farm were digitised and entered into the PfS database. Two forms of data were provided to study participants; paddock average biomass and farm average pasture growth rate.

1. Paddock average biomass
   SPOT-4 and -5 images were used to provide 20 m and 10 m spatial resolution data respectively for calculating paddock average biomass (kg DM/ha). The pilot study aimed to deliver weekly data to participants for a period of 15 weeks starting July 2008. Images from either of the SPOT satellites were purchased if the image was at least five days from a previously purchased image and had an appropriate view angle and cloud cover. After capturing a successful image it was converted to biomass data using the CSIRO algorithm (Handcock *et al.* 2007). Details of validation from the current research are not yet available as this project phase was still being conducted at time of submission. Paddock-scale pasture biomass was calculated in a geographical information system (GIS) and emailed to participants in three forms: a colour farm biomass map (Figure 1), a .csv file of average biomass per paddock, and a feed wedge graph (a bar chart depicting paddock average kg DM/ha in descending order).
2. Farm average GR
   MODIS satellite images were collected twice daily and used to create a fortnightly 'maximum value pixel composite, updated weekly' from which pasture growth rates were calculated. The PGR® algorithm (Hill *et al.* 2004) also incorporated factors for rainfall, temperature, solar radiation, and evaporation. The spatial resolution of MODIS data is 250m, and is therefore unsuitable for use at a paddock-scale on Gippsland dairy farms where paddock size can range from one to six hectares. A farm-scale average biomass was therefore used. Data were provided weekly to participants in the form of an individualised email showing GR (kg DM/ha/day) for the previous week and predicted GR for the next week. Regionalised GR for the previous week were also provided for participant's interest by grouping farms to calculate an average value.

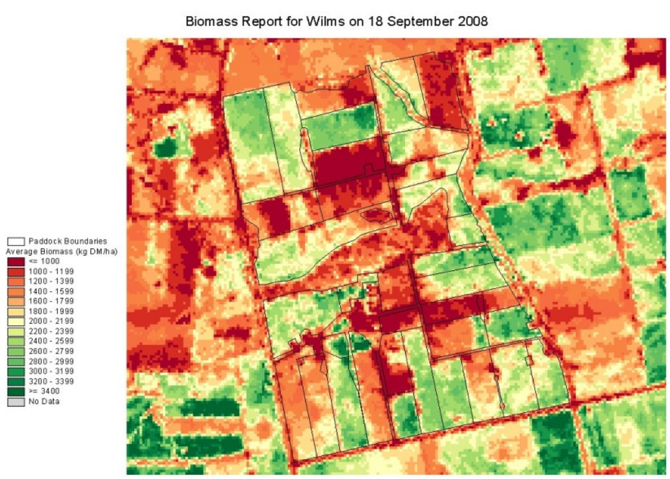

Figure 1. Example of a colour farm biomass map provided to study participants (Note: actual maps provided to farmers use a colour shadeset of red (<= 1000 kg DM/ha) ranging through to green (>= 3400 kg DM/ha).

The spring period was chosen for the study as it represents a key growth period for Gippsland dairy farmers, and is therefore when pasture growth information is paramount. Farmers balance rapid changes in growth with cow feed requirements, pasture quality management, and feed conservation (hay and silage).

Data delivery in this study was kept as simple as possible with minimal computer interaction and no associated software learning. Farmers were left to interpret the data and use it as they deemed appropriate.

Semi-structured interviews were conducted with participants before and after the study. Each interview lasted between 30 and 60 minutes and the themes of expectations, system fit, and value were explored. Interviews were recorded and transcribed, with NVivo7™ used for qualitative analysis. Thematic coding, where interviews are analysed to identify common themes (Strauss and Corbin, 1998), formed the basis of the qualitative analysis process.

Theoretical basis

The farming system study was undertaken using a grounded theory approach, which focuses the researcher on collection of qualitative data with an emphasis on theory development (Strauss and Corbin, 1998). Therefore theory is driven out of the data collected, rather than to prove an existing hypothesis.

Results/Discussion

Pasture biomass delivery

Delivery of data commenced on 14 July 2008 and across the spring period twelve sets of paddock-scale biomass data (kg DM/ha) were emailed to participants. In total 13 SPOT images were captured, with data from one image not sent to participants due to problems with image calibration. The time from image capture until email delivery of data to participants was three days on average.

Persistent cloud cover throughout the spring period meant that the target of weekly biomass data delivery was not achieved. The extent to which cloud cover impacted on biomass data delivery is highlighted by the fact that the study was expected to last 15 weeks with 15 images captured, but actually ran for 22 weeks to obtain 13 suitably cloud-free images.

Pasture growth rate (GR) delivery

Pasture growth rate, calculated on a weekly basis during the growing season, was able to be delivered reliably throughout the study. Farm average pasture growth rates (kg DM/ha/day) for the past week were emailed to participants at the end of each week, along with forecast GR for the following week.

Participant feedback: Regularity and timeliness

During the high growth period of spring the participant farmers required regular data at seven day intervals or better. While some biomass data were delivered at five day intervals the overall regularity was not sufficient for farmer's grazing management decision making. However, in 10 of the 12 periods between images the average time gap was eight days (range 5-14). The remaining two periods were 22 and 32 days. In order to replace their current practice the PfS system had to offer farmers more value and a significant part of this value was regularity which could be achieved if gaps in image acquisition were filled by forecasting biomass 7 days ahead based on the current farm GR.

Timeliness was also important for the farmers. Biomass data were delivered on average three days after the image was captured, as per the pre-trial goal. In this time, the image was delivered to CSIRO by the satellite operator, georegistered, biomass calculated and paddock-scale biomass produced including validation and quality control before they were emailed to the producers. Half of the participants expressed concern that considerable changes had occurred on farm in those three days. For example with two grazings per day, up to six paddocks could have been grazed by the time they received the data. One participant said:

'I did look at it a few times and thought, gee, that looks like it was taken a while ago. Yeah, so that's a fairly important point just because of the fact that it's old data; once it comes through three days later, its old. The longest grazed paddocks have already moved on, they're down to the shortest ones again and the ones down the bottom have already moved up a bit. It's a bit like reading a newspaper from a week ago, isn't it? Irrelevant!' (Farmer G, 2008)

Perceptions of inaccuracy in the data because of additional growth during these three days may be overstated. During peak growth the biomass may have changed by between 3 and 10 percent, or about 60 to 300 kg DM/ha over three days in paddocks ranging from 1800 to 3200 kg DM/ha respectively (assuming a maximum growth rate of 100 kg DM/ha/day). This change in biomass is below the limit of accuracy anecdotally reported for visual estimates or RPM. However other participants held the view that it was the relative paddock ranking they were interested in and the paddock with most pasture three days ago would still be ranked highest.

Participant feedback: Accuracy

Preliminary analysis of farmer responses suggests that the participant farmers initially viewed the PfS data with scepticism, as one participant said:

'I'm surprised how accurate it was initially, even initially it was [inaccurate] a little bit; you know, I was pretty sceptical when we first met [at the initial meeting], how can you tell how much grass we've got from up there?' (Farmer J, 2008)

Such comments suggest that scepticism was largely due to concerns over accuracy. While most agreed that the paddock biomass rankings were generally equivalent to their own rankings, any observed anomaly had a highly negative impact on their perception of PfS. Anomalies included paddocks with non-perennial ryegrass species such as weeds, annual pastures, or herb species for which the biomass algorithm was not calibrated. Perceived inaccuracies in data reduced confidence and trust, as described by one farmer:

'It's not quite that accurate yet, I suppose. When I saw an error each time, I thought that this is not ready to replace what I'm doing yet.' (Farmer A, 2008)

Farmer feedback highlighted the value of the study itself, for if PfS was released as a commercial product before expectations of accuracy could be fulfilled or without proper user education as to its limitations it could fail due to such perceptions of inaccuracy.

Participant feedback: Form of data delivery

While all participants had access to email, their frequency of use ranged from multiple times daily to once every two-three weeks. To encourage interaction with the PfS data participants were sent a SMS whenever data were emailed to them.

Participant feedback on the form of data delivery showed a positive response to the SMS notification as farmers liked knowing when to check their email, especially for the more erratic paddock biomass delivery under the constraints of the pilot. When biomass data were delivered, the majority of farmers commented that they generally looked at the colour farm map first for a visual assessment of within-paddock variability and between-paddock rankings. Feed wedge data were also used for this purpose. The more data-literate farmers imported the raw .csv data into a spreadsheet for further analysis. In respect to the weekly GR data, the provision of regionalised GR averages heightened farmer interest and interaction because it gave them a benchmarking opportunity. One quarter of farmers also suggested that more value could be made of the biomass and GR data through integration with feed management software. Provision of feed/pasture management software was specifically excluded from the research design due to the inherent limitations of the currently available options, and to minimise additional learning and complexity in the study.

Value proposition and fit with system

The uptake of any new technology depends heavily on its fit with the system within which it is to be used. While the concept of providing regular and fine-resolution pasture data via satellite images was impressive to farmers, there was a perception amongst one quarter of study participants that it only delivered them information they already formally or informally collected. In such instances there can be insufficient incentive to change to a new system, as described by one participant:

'*We were doing our own stuff and our own pasture growth estimates and all that sort of stuff, anyway; in the end, you know how you always stick with a tried and true method?' (Farmer I, 2008)*

The original value proposition associated with the PfS approach assumes that appropriate tools will enable regular, accurate monitoring and will be a conduit to improve management practices, in turn resulting in increased pasture use efficiency, driving productivity with less reliance on supplementary feeds. Additional benefits include: reduced labour costs or time demands, progressive build up of detailed farm information with spatial and temporal components, allowing for benchmarking productivity based on an independent, uniform source of data at the same resolution from the paddock to the regional-scale. From this study it appeared that for the value proposition to be achieved and for the dairy farming community to widely adopt these tools, additional support structures may need to be provided to drive achievement of these additional benefits.

During the interviews the value of the PfS concept was assessed in terms of farmer decision making. The grazing management planning timeline for participants was multi-faceted (Figure 2). At any point in time dairy farmers make grazing management decisions using a mix of information which has differing degrees of certainty. Certainty of information, and thus confidence in decision making, generally decreases as farmers look further into the future. Major short term variables include climate, herd composition, current pasture available, and pasture growth rate.

In this study the PfS system provided data in planning for 'today' through the biomass data. Because it is objective and recordable, biomass data can be used to build historical records and trends, providing information for farmers who try to manage the future by reviewing past events, for example 'yesterday', 'last week', and 'last year'. The GR data provides farmers information for 'previous weeks' to the start of the season, the 'next few days' and 'next week' categories. Findings from the interviews indicated that while the PfS concept as delivered provided data across their planning horizon it did not sufficiently reduce uncertainty in the planning process. Lack of familiarity with the data and limited support could have contributed to the uncertainty. The initial PfS development work in WA showed that adoption and successful implementation was enhanced through active participation in regular producer group meetings. The 'Fit of PfS data' outlined in Figure 2 suggests the potential of PfS to provide data at every stage and thus to influence decision making at any point in time. While the initial analysis of farmer response, suggested that data as delivered in the pilot study were too irregular, infrequent, and lacked farmer credibility in terms of accuracy, the farmer response also indicates that they would benefit from greater familiarity with the system and with tools for interpretation to facilitate their use of this data. Further development was required to enhance the certainty and credibility that the PfS system provides to dairy farmers. These developments are within the capabilities of the PfS System to redress producer's concerns.

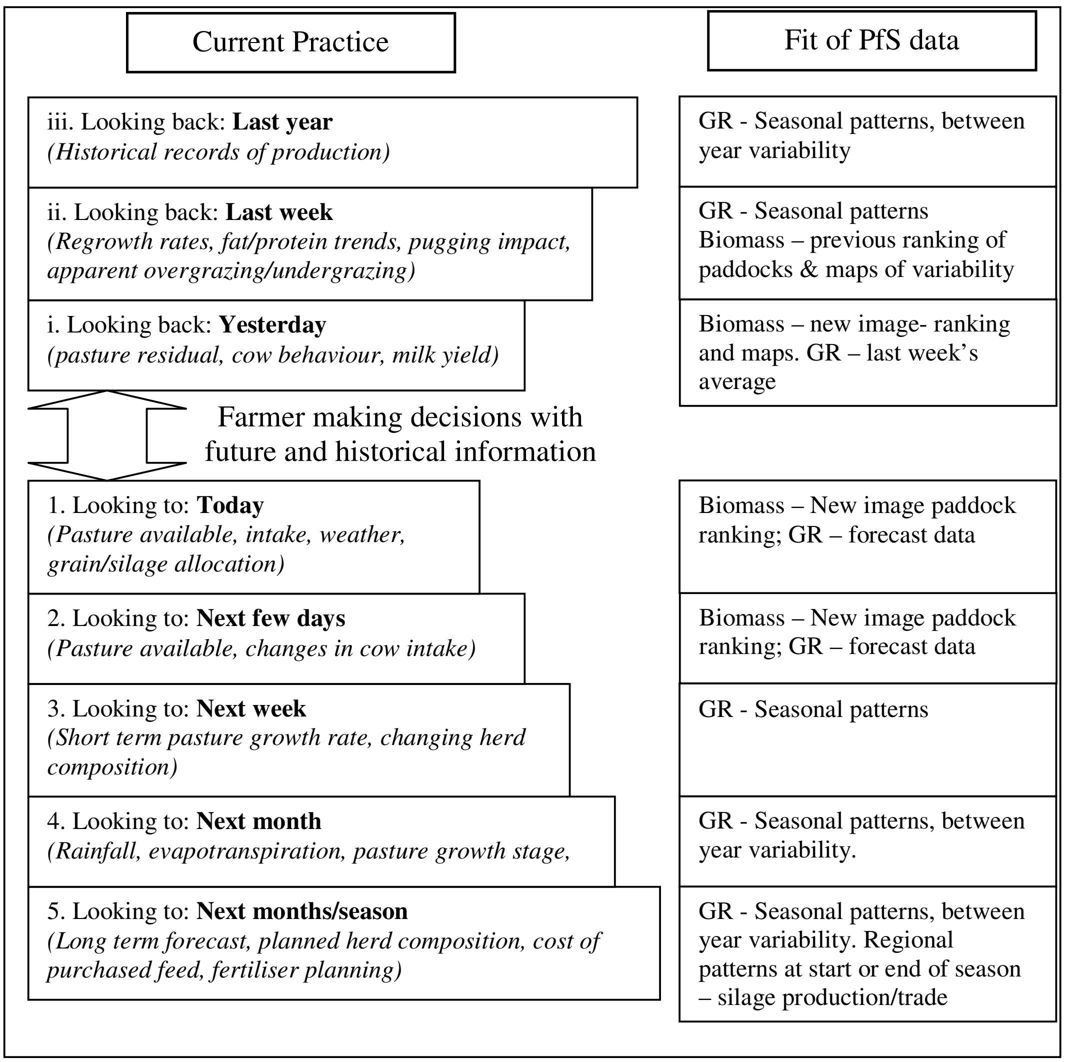

Figure 2. Grazing management planning timeline and information inputs (in italics) and possible fit of PfS data in decision making.

Support structures
Interviews with participants also investigated the potential need for support structures around this new technology. One participant commented:
'You've sort of got to teach farmers how to use the data at the end of the day. There's no good sending them data if here's nobody teaching them management practices.' (Farmer H, 2008)
Farmers participating in this study represented the sector of the dairy industry who are 'pasture-focussed' and who engage with explicit planning practices. For a satellite-based pasture measurement tool to be commercially viable it will need to provide value to the wider industry, including farmers who use minimal grazing planning techniques. A suggestion from participants was that to provide value across the dairy farm market the PfS data should be linked with management software, a feature purposefully excluded from the study as explained previously. It was also suggested that such data could be delivered through a farm consultant network to provide mentoring for farmers less confident with use of data in grazing management.

Conclusion
The value of including commercial farmers in the development phase of new precision farming technologies was highlighted in preliminary results from this study. Farmers were able to test the Pastures from Space®, PGR®, and pasture biomass systems under the practical operating conditions that they encounter daily. Data provided by the Pastures from Space® and pasture biomass systems fitted well with grazing management planning of study participants. While under the constraints of the trial design data were not able to be delivered with sufficient timeliness and regularity to increase the farmers' certainty in decision making, in an operational system it is likely data can be delivered to farmers within the 72 hour goal. The study highlighted possible differences between farmer's perceptions and 'reality' with regards to timeliness and accuracy of the data. Future research and development of the Pastures from Space® GR and pasture biomass systems will focus on increasing certainty in the data delivery, and in investigating associated support structures, which should enable the concept to have industry-wide applicability. The findings discussed in this paper will be further developed in a full analysis of the results from the pilot study, to assess farmer attitudes to the use of satellite-based measurement and delivery of pasture biomass information.

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