Art or science? Heuristic versus data driven grazing management on dairy farms

Eastwood, C[1] and Kenny, S[2]

[1] Rural Innovation Research Group, Melbourne School of Land and Environment, The University of Melbourne
[2] Department of Primary Industries, Victoria
Email: callumre@unimelb.edu.au

Abstract. Grazing management practice is a central component in Australian pasture-based dairy systems and is largely based on application of tacit rules. This approach often conflicts with the quantitative decision making promoted in the scientific community. The development of pasture measurement and software tools have historically had a minimal or short-term influence on grazing management practice across the industry. The potential role of objective data in dairy farm management was examined using a five month, 18 dairy farm, trial of satellite-derived pasture data as a case study. The findings showed that when assessing sources of pasture data farmers looked at the accuracy and timeliness of data, in addition to the fit of data within existing information networks and its impact on uncertainty in planning. A tension existed between the grazing management approaches farmers preferred (simple, cost-effective, and fitting with their routines and goals) and the scientific worldview (objectivity and structured decision making) of those developing new means of gathering pasture data. To avoid continued underutilisation, future development of pasture measurement tools needs to provide greater consideration to the processes used by dairy farmers.

Keywords: Pasture measurement, objective data use, decision making processes, worldviews

Introduction

Grazing management decision making is an integral component of whole farm planning for Australian dairy farmers. Home-grown feed remains a significant proportion of the diet for Australia's dairy herd however the overall cow diet has increasingly been balanced by other feed supplements. For many years, efficient utilisation of pasture has been consistently shown as a key profit driver for Australian dairy farms (Beca 2008) yet across the industry there is considerable room for improvement in pasture utilisation (Fulkerson et al. 2005). In an attempt to seek higher pasture production and utilisation across the industry, scientists have looked to increase the use of data driven approaches in grazing management decision making. One approach under development focuses on use of satellite-based pasture measurement aimed at saving pasture monitoring time for farmers and adding objectivity and more comprehensive data on available pasture across the farm.

Dairy farmers have been shown to alternate between heuristic-based planning methods for grazing and more formal quantitative approaches (Gray 2001; Ohlmer et al. 1998). Their use of an intimate knowledge of production systems combined with a reliance on visual assessment is driven by an aim for monitoring systems that are timely, rapid, and requiring little capital outlay (Gray 2001). Also, although case study farmers in Gray's study recorded a portion of the pasture data they collected, much of it was stored mentally. These perceptions can be at odds with researchers in the field of grazing management and dairy systems who operate with a worldview involving rationality, structured decision making and objectivity.

The purpose of this paper is to explore the challenges of utilising objective data in grazing management decision making. We will use a recent pilot study into the use of satellite technology to monitor available pasture mass to:

- Investigate key features required for satellite-based pasture data to provide value to dairy farmers.
- Examine the role of objective data in grazing management practice on dairy farms.
- Compare the perspectives of the dairy farming community with those of the scientist community in respect to the form of data required in grazing management.

Satellite based pasture measurement: A case study in delivering standardised objective pasture data

Introduction

The concept of delivering pasture growth and biomass data from regular capture of satellite imagery was developed by a consortium comprising the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of Agriculture and Food Western Australia, and Landgate (Edirisinghe et al. 2000; Hill et al. 2004). In its current form the satellite system has been research proven to be capable of delivering paddock average biomass, and farm average growth rate, for perennial ryegrass dairy pastures in the Gippsland region of Victoria with an accuracy comparable to that achieved through use of a rising plate meter (a hand-held instrument used to estimate pasture biomass through measurement of pasture height).

Despite having encouraging results in concept-evaluation trials in both Australia and New Zealand (Clark et al. 2006) the use of satellite-derived data had not been tested in a commercial farm setting. Therefore a study was conducted by the Rural Innovation Research Group at The University of Melbourne, in collaboration with CSIRO Livestock Industries, to examine the potential value of satellite-derived data in dairy farm systems.

Method

An on-farm trial of satellite-based pasture biomass measurement was conducted from July to December 2008 in the Gippsland region of Victoria, Australia. Satellite derived paddock average pasture biomass (biomass) and farm average growth rate (growth rate) data were delivered to 18 dairy farmers within a 60x60 km satellite image 'footprint'. Differences in the satellite image providers used for the two data forms meant that while growth rate data were delivered weekly, biomass data were derived through a more opportunistic system which relied on relatively cloud-free days for successful image capture.

Potential participants were invited to join the study if they were responsible for grazing management on a dairy farm in the study area, and if they exhibited a focus on their grazing management practice. Farmers who met the latter criteria were identified through industry contacts such as extension personnel and farm advisors. Maps of farm and paddock boundaries were created in a geographic information system (GIS) environment, with non-pasture areas such as tracks, trees, and buildings excluded. Biomass and growth rate data were delivered to participant farmers via email, accompanied by a text-message notification. The biomass data were presented in three forms: farm map, feed wedge, and raw data in a .csv file.

Using a framework based on Gray's (2001) representation of information in grazing decision making, we examined the use of satellite-based pasture data in grazing management. This framework acknowledges the use of both objective and subjective information in the grazing management cycle of planning, control, and monitoring. Participants were interviewed prior to the start and at the completion of the study. A semi-structured interview style was used to explore the themes of: expectations of satellite-based pasture data, fit of objective data within existing grazing systems, and value proposition associated with satellite-based data. A grounded theory approach, where theory is driven out of the collected data, was used in the study design and implementation. Grounded theory was appropriate in this study because it allowed issues to be revealed while minimising predetermined bias (Strauss and Corbin 1998). The use of satellite-based data is an innovative approach to dairy grazing management and therefore no previous qualitative studies had been conducted in the topic area. Interviews were recorded and transcribed and later analysed using a thematic coding approach in NVivo7™ software. A final workshop was also run with participants to collect their reflections on findings and examine future options. The results from this data collection and analysis are presented in the results and discussion sections.

Results - Factors affecting use of satellite derived data in dairy farm systems

In this section results from the participant feedback (one-on-one interviews and the workshop) are presented in terms of critical success factors determining farmer acceptance of satellite derived pasture data. These factors included overall acceptance of remotely sourced data, timeliness, ability to fit with flexible information networks, and whether the information added more certainty around available pasture in the short and long-term future. This process also highlighted key features determining dairy farmers' perceptions of using objective data in general for grazing decision making, which forms the basis for the discussion section.

Acceptance of objective data from remote sources

Results from the trial also indicate important factors that determine farmer acceptance of data from a remote source (where farmers are disconnected from the process of measurement). Acceptance of the data was highlighted by participants as an important precursor to its use in their management practice. For farmers in the study, confidence in the satellite derived data was built through trust, understanding the technology, and ability to self-evaluate and these concepts are expanded below.

Trust Trust was an extremely important component for the use of satellite derived data in grazing management practice and the impact of low trust was seen through the trial in participants' preference for their own data over the satellite derived data. Trust in data is influenced by perceived accuracy as well as certainty and consistency. Perception of accuracy was tied up with farmers' perceptions of their own accuracy around pasture measurement, and their comparison with the accuracy of objective data sources. Farmer perceptions were highly important in the decision making around pasture assessment techniques, especially where tacit based methods were currently employed. Farmers in the study perceived their own methods to have a high level of accuracy and therefore demanded even higher accuracy from any new system.

> *'To take it [development of satellite-derived pasture data] to the next step, we're probably looking for accuracy to within 90%, whereas there's times when it's possibly only 70 to 80%. I think if we can get [satellite-derived pasture data] to within 90% accuracy and that's probably the best we can do visually.'* (Farmer F, 2008)

Real proof of accuracy for farmers was obtained via a comparison with their own measurements, as discussed below under 'self validation'.

Feedback from study participants indicated that acceptance and use of objective data as an alternative to current methods also depended heavily on certainty and consistency. Certainty relates to availability of data when it's required or scheduled to arrive, which was out of the control of farmers in the on-farm trial. Consistency relates to the data itself, and knowing that even if the data is under- or over-estimating that it is consistent then farmers can mentally adjust for it. Additionally, if the data are to be handed to staff to allocate pasture then the manager must be confident that they are both accurate and consistent

Understanding the technology Participant acceptance of the satellite derived pasture data as a possible management tool was highly contingent on farmers having some background knowledge of the underlying methodology. This knowledge was important for participants to rationalise any errors in the data, or the impact of delays in data capture. Errors or anomalies in the satellite data created disproportionately negative perceptions. Such errors occurred in the study when pasture biomass was outside the calibrated range of the satellite algorithm, or the pasture was predominantly composed of a non-calibrated species. Greater understanding of the underlying methodology could change the perception away from 'errors' to viewing it as an example of the system operating outside its design parameters.

Acceptance will also be aided by evidence of the system working well elsewhere in the farming community. Seeing a neighbour using a new technology, such as satellite derived data, and being able to question them about it, is a powerful means for farmers to build their knowledge and understanding about the system and potential benefits (Eastwood 2008). Several participants suggested the technology would only achieve widespread adoption if farmers could see it operating successfully on other farms first.

Self-evaluation To build initial confidence in remote sensed data participants sought validate the data in their own terms. In the trial this involved participants reviewing the biomass data and comparing it to their own formal or informal data. In this process the occurrence of errors or anomalies had a large impact. This evaluation of a new technology is common, as described by McCown (2002):

> 'A technological innovation also creates another kind of uncertainty because of its newness to the individual and motivates him or her to seek information by means of which the new idea can be evaluated. This innovation-evaluation information leads to a reduction in uncertainty about an innovations expected consequences' (Rogers 1995: cited in McCown 2002 p203).

Timeliness of data

A major target of the research trial was to deliver biomass data to participants at 7-10 day intervals over the three month trial. Persistent cloud cover inhibited capture of clear satellite images and while biomass data were delivered at a 10 day average across the trial, there were two significant periods of 'data drought', one 30 days long and the other 22 days long. The impact of these non-data periods is discussed below. Growth rate data were consistently delivered weekly as they were derived via a methodology separate from pasture biomass.

In their grazing management practice dairy farmers vary information gathering methods depending on the season and time demands (Gray 2001). Higher pasture growth rates necessitate more frequent information in order to maintain control over pasture quality (*ibid*.). The decision making process employed by dairy farmers in this study involved planning their pasture management weeks in advance, with minor changes made closer to the decision point based on current conditions. Satellite-derived data provided during the trial did not match the regularity requirements of farmers who, in the peak growth period of spring, were looking for weekly data updates. While some data were delivered five days apart, the long 'data drought' periods caused farmers to question the value of investing their money and time in a measurement system based on satellite-derived data.

Fitting within the flexible information networks of farmers

In the trial, farmers who conducted formal monitoring in the form of a weekly farm walk also employed other heuristic techniques such as visual assessment of pre- and post- grazing heights on a daily basis to adjust their decision making. This approach matches that found by Gray (2001) where pasture based dairy farmers create information 'networks' which are timely, accurate, and inexpensive. Therefore, in order to be relevant satellite-derived data must fit within this information network approach and act to inform farmers in conjunction with their other information gathering practices. Feedback from participants in this study indicated that satellite-derived data could have a role in the information network as a form of 'foundation' data used for construction of plans for the weeks ahead. Visual data collected day-to-day would then be used to make minor adjustments to grazing plans. However, the satellite data quality does not yet match farmer benchmarks for timeliness and accuracy, and cost may be an issue depending on eventual commercial pricing.

Reducing uncertainty

Study participants faced considerable uncertainty in their grazing decision making due to factors such as climatic influences, variability in projected growth rates, and constant changes in cow nutritional requirements. In their grazing decision making practice they gathered information to reduce the uncertainty, in a constant trade-off with the marginal cost and time required to obtain it. Satellite based pasture measurement is aimed at reducing the uncertainty through objective data delivered from a standardised process. However, in the trial the pasture biomass data delivery was too variable to reduce uncertainty. Participants indicated that if biomass data were able to be delivered at 7-10 day intervals it would aid decision making by increasing their certainty around pasture growth trends and actual feed surplus across the farm. Responses of participants also indicated that they wanted to use satellite derived data to compare against their own measurement methods, with the aim of reinforcing the efficacy of their current approach.

Participants were making grazing management decisions in a highly uncertain environment. The study by Gray (2001) showed that the uncertainty faced by a grazing manager was an important determinant of their perceived limits to control. The value satellite derived pasture data, was shown in this study to be determined by features such as perceived accuracy, data timeliness, fit with information networks, and its contribution to reducing uncertainty in the decision making environment. The value associated with satellite derived data was contingent upon how farmers determined it impacted on their limits to control.

Discussion

The development of satellite based pasture monitoring technology is still in the developmental stage and this trial was designed to highlight areas where improvements could be made. It also highlighted farmers' minimum requirements for objective data in support of grazing management decisions. However, even if the technology overcomes some of its failings, what prospects are there for high quality objective data to improve the grazing management performance of Australian dairy farms? To answer this question we need to take a closer look in this discussion section at what constitutes grazing management practice and what value objective data such as satellite based pasture measurement potentially adds to farmer practice. This discussion section builds on results of the study by comparing the feedback from participants with current approaches to provision of grazing management advice and the worldview underpinning development of pasture measurement tools.

Perspectives on pasture measurement in grazing management practice

Grazing management involves a complex merger of animal, plant, climate, and physical resource systems – all overlain with internal and external farm management influences. Kenny and Paine (2001) described Australian grazing management decision making in terms of a performance triangle model. The three elements of the model involve: a perception of options, a continually occurring feasibility appraisal, and a task specific reality check. Under this model the decision making process is highly influenced by farmer 'intentions' which consist of goals, objectives, and desires. In turn these intentions are in tension with internal and external barriers which are within or outside of the farmers control respectively. The worldview of the farmer permeates and impacts significantly on the performance triangle, and also influences the ability to learn and reflect.

A key feature of effective grazing management is the collection and use of information to feed into the performance model. A recent ABARE study highlighted the pasture measurement practices employed by Australian dairy farmers. Approximately 30 percent of dairy farms indicated that they used pasture height to monitor pasture availability and growth. Alternative methods such as leaf stage or leaf appearance interval technique; pasture growth or quantity; and assigning a standard period of time for particular paddocks, were used by approximately 20 percent of dairy farms respectively (Lubulwa and Shafron 2007). While no specific data is available on the use of tools in Australia, Parker (1999) stated that New Zealand farmers used tools such as rising plate meters for a relatively short time. Tools were replaced with subjective methods once a farmer was confident they had 'calibrated themselves' to the objective standards. Such behaviour speaks to a farmer worldview which rationally places simplicity and time efficiency above relatively minor improvements in measurement accuracy.

In contrast, the worldview of a researcher in grazing management seeks to put a value on pasture measurement which is accurate, objective, and repeatable (Figure 1). Therefore non-destructive pasture yield estimations (visual assessment, plate meter, pasture probe) have been widely used due to efficiency and 'reasonable accuracy' (Li et al. 1998; Fulkerson and Slack 1993; Gourley and McGowan 1991). Plate meters and probes are preferred over visual estimates due to their greater accuracy (*ibid*.).

A divide between the worldviews of farmers and scientists can lead to a disconnection between research and practice. Failure to fit new approaches to the farmer worldview may result in low uptake or short-term uptake of new devices and techniques. Alternatively change can occur by successfully challenging a farmer's worldview (Kenny and Paine 2001).

Figure 1. Differences in farmer versus scientist worldviews

Features of dairy farmer worldviews	*Features of dairy systems scientist worldviews*
- Simplicity	- Objectivity
- Fit to daily routine	- Quantifying
- Time/accuracy tradeoff	- Rationality
- Minimise capital	- Structured decision making

Comparing a data driven approach with heuristic based approaches

While researchers continue to develop and promote tools for collecting objective pasture data, farmers have shown more interest in using methods which closely match their planning and monitoring worldview. The use of heuristic rules in dairy farmer grazing management practice has been recognised in the development of extension programs such as the Victorian Department of Primary Industries 'Feeding Pastures for Profit' (FPFP) program. The FPFP system represents an attempt to fit a grazing management protocol within the existing tacit-based processes of dairy farmers with the goals of implementing the right rotation length and offering cows a consistent amount of pasture. It primarily utilises visual assessment methods such as post-grazing residual, cow behaviour, along with quantifiable aspects such as daily milk production and supplement residue to establish a 'body of evidence' on which to base grazing management. Instead of being based on a quantitative platform such as kg dry matter per hectare (kg DM/ha), FPFP focuses on the principle of pasture leaf stage and a post-grazing target level of pasture residual.

As a planning tool FPFP operates on two levels: information feeds the 'body of evidence' for daily adjustment, and also feeds into a 'rotation right' framework for longer term rotation and pasture conservation decisions. Accordingly the approach guides farmers in their decisions around pasture and supplement allocation with constant feedback mechanisms for adjusting practice.

The FPFP program has had considerable success in facilitating long term management change (Drysdale and Goodrick 2006) and a key part of this program is its flexibility, with participants able to implement it at differing levels on farm, thereby fitting it to their system and personal motivations. By comparison, grazing management based on data derived from satellites as seen in this study, with associated feed management software, could represent a major change for grazing managers.

Both data-driven management and more tacit-based management have strengths and weaknesses based around the different skills required, time input, cost, and end use as summarised in Figure 2.

Figure 2. Comparison between different grazing management approaches

	Feeding pastures for profit	**Satellite based management**
Skills and facilities required	- FPFP requires knowledge of leaf stage, rotation right, and visual observation of signs. - Requires physical presence of user in paddock	- Requires some software/IT skills and confidence with using data, - Requires user to sit inside at computer, needs internet connection.
Time	- FPFP requires constant attention to leaf stage, and body of evidence	- Paddock-scale kgDM/ha data automatically delivered and sorted by software, - Time is required to review data.
Cost	- FPFP includes free training course - More time input doing regular visual check	- Ongoing weekly or annual subscription cost - Only a quantity estimate provided - Users still need to check pasture quality factors
Alignment with existing practice	- Designed to align with an intuitive farm management model	- Requires 'buy-in' of farmers to structured scientific view based on objectivity, accuracy, and independence
Strengths of approach	- Can be implemented at a variety of levels - Uses tacit based tools thereby matching farmer practice	- Track paddock performance over time - Benchmark against other farms
Weaknesses of approach	- Tacit skills require training and consistent use - Unskilled or casual staff are excluded from decision making	- Represents a shift in management approach for many farmers - kgDM/ha is only part of the grazing management picture

The FPFP approach is aimed at making improvements across the grazing decision making process, whereas provision of satellite derived data specifically addresses the aspect of pasture measurement. Concentrating on one aspect of the grazing management process may not lead to major change in practice across the dairy industry because its impact is negated by a lack of control farmers can exert over other facets of grazing management, such as climate. Also, an underlying knowledge and skill base is required in order to effectively utilise data, developing this capability requires an accompanying extension package.

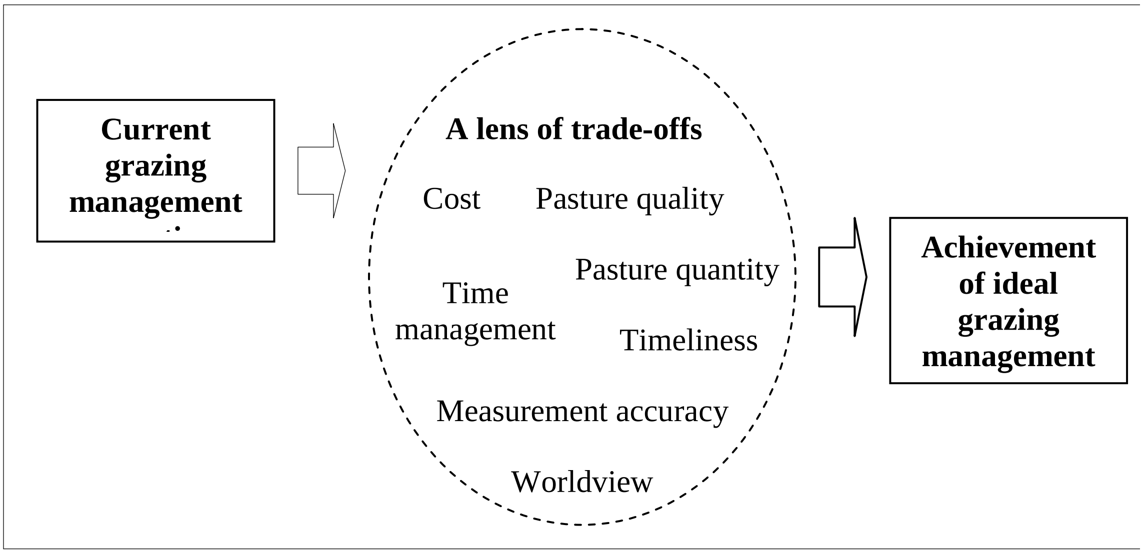
The role of objective data in grazing management - integrating art and science

Satellite pasture measurement is based upon a science-centric worldview of managing farming systems through objective data that is highly accurate and independent. Results from this study indicated that as practitioners of grazing management dairy farmers are focused on the goals of control, efficacy, and trust when deciding on their decision making framework and information sources.

For dairy farmers in the study grazing management and objective data were not necessarily mutually exclusive. However, increased objectivity and accuracy will be traded off depending on the other factors underpinning an individual farmer's worldview. As shown in Figure 3, the path to 'ideal' grazing management will pass through a lens of trade-offs, which will determine ideal practice. Acknowledgement of farmer-specific trade-offs is highly important for development of satellite pasture monitoring because it highlights that data accuracy and objectivity is only one facet assessed by farmers.

In this instance there is a considerable gap between what objective data can currently offer farmers in comparison to the features they desire for grazing management information. In the case of satellite-based monitoring, continuing to focus development on accuracy and frequency of data alone will not provide a system with sufficient value to farmers to justify their long-term use of objective data. This is due to potential errors from changes in the environment (e.g. rainfall) and ineffective plan implementation (e.g. pasture allocation).

Figure 3. Factors affecting the trade-off between current and ideal grazing management



If objective data is to have a place in grazing management decision making on Australian dairy farms, farmers must perceive a value in its use. This has been evident in previous attempts to add objectivity and independence into farmer decision making as identified by McCown (2002) in a review of decision support tools:

> 'Farmers cease to care about (even relevant) tools when they can't see sufficient practical value for action resulting from the output, taking into consideration the costs, including managerial time and attention.' (McCown 2002 p.195)

The original value proposition associated with the satellite pasture measurement assumed 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. In the pilot study many farmers cited the value of data as reinforcing their own methods. This approach to independent objective data mirrors that seen with use of other tools, such as the rising plate meter, where farmers used the tool in the short term to calibrate visual methods and then discontinued use of the tool (Parker 1999). 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 the achievement of significant benefits.

Conclusions

Grazing management can be viewed as an art, with farmers as the artists juggling competing demands for their time and resources with the drive for improved pasture utilisation. Results from this study highlighted key features that dairy farmers look for when assessing the usefulness of objective pasture data. These features include data accuracy, timeliness of data, fit within existing information networks, and ability to reduce planning uncertainty. Dairy farmers approach grazing management with a very different worldview than the science community, surfacing in perceptions around the role of 'data' in grazing management. A tension exists between these worldviews in the search for industry-wide improvements to grazing management practice in Australian dairying. While a science worldview might involve objectivity and structured decision making, dairy farmers look for simplicity, cost, and fit within their established routines and goals. This tension needs to be acknowledged and addressed in any further development of pasture measurement tools. Failure to provide greater consideration of the processes that farmers use in practice may result in the development of concepts such as satellite pasture measurement being misaligned with the needs of farmers and could limit commercial application – a lose: lose situation for researchers and farmers alike.

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