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ORIGINAL ARTICLE

Pasture growth model to assist management on dairy farms: Testing the concept with farmers

Alvaro Romera[1], Pierre Beukes[1], Dave Clark[1], Cameron Clark[2] and Andrew Tait[3]

1 DairyNZ, Hamilton, New Zealand
2 National Institute of Water and Atmospheric Research, Wellington, New Zealand
3 Faculty of Veterinary Science, University of Sydney, Sydney, New South Wales, Australia

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Correspondence
Alvaro Romera, DairyNZ, Private Bag 3221, Hamilton 3240, New Zealand.
Email: alvaro.romera@dairynz.co.nz

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Abstract

A prototype software tool (Pasture Growth Simulation Using Smalltalk, PGSUS) was developed to estimate herbage mass at an individual paddock level so that farmers can measure herbage mass less frequently. PGSUS was tested on 10 commercial and two research dairy farms in New Zealand. Herbage mass estimations from PGSUS were accurate, with an average residual standard deviation of 252 kg dry matter ha^{-1} across all farms. When interviewed, all farmers gave high ratings to PGSUS, except for the amount of data collection required, and user friendliness, which were given a medium ranking. The extra time dedicated to PGSUS by farmers was 43 min per week on average, which was judged acceptable by farmers. However, in practice, the participating farmers were unable to enter all the information required for the system to work as intended. It is concluded that while it is technically possible to use a pasture model to estimate herbage mass at paddock level with sufficient accuracy to aid decision making, the recording of grazing events proved to be a major obstacle. If the issue of data entry can be overcome, it is envisaged that a full commercial version of PGSUS should appeal to objective-data-oriented farmers, most probably as an add-on to existing commercial farm software.

Introduction

Extension and farmer support agencies in New Zealand recommend that dairy farmers measure herbage mass ideally weekly, on all farm paddocks to inform accurate pasture management decisions (Van Bysterveldt and Christie 2007). This has become known in the industry as "the farm walk". Along with the farm walk, the "feed wedge" technique (sorting the paddock by herbage mass and comparing with a target line in a graph) can be used to analyze the feed inventory for each week (Reynolds 2007). Farm walks (most commonly using rising plate meters, RPM) are time consuming (3–4 h), and this is one of the key reasons preventing more widespread adoption. In a previous paper (Romera *et al.* 2010), a prototype software tool (Pasture Growth Simulation Using Smalltalk, PGSUS) was introduced. The tool was designed to reduce the requirement for physical data collection (i.e. save time) and provide more information from farm walk data. The method involves estimating paddock herbage mass using intermittent observations and supplementing these with a climate-driven pasture model.

The concept of PGSUS is a by-product of the "Pastures from Space" (PFS) project (Mata *et al.* 2007). The PFS project uses satellite images to produce easily accessible pasture cover data on a regular basis at a farm and paddock level (www.pasturesfromspace.csiro.au). In New Zealand, the frequency of the satellite images is limited by cloud cover, and to by-pass this problem a pasture simulation model was adapted to estimate pasture growth and herbage mass and to fill the gaps between images. It was realized that this solution could potentially be useful also for farmers measuring pastures by any means other than satellites.

There are clear advantages in regularly walking and measuring pastures (Van Bysterveldt and Christie 2007) and it would be extremely unwise to replace all farm walks with a model, because they provide information about many aspects of farm operation. PGSUS attempts to make the most out of laboriously collected data and, in fact, the model relies on accurate herbage mass measurements to work (Romera *et al.* 2010). For example, a farmer may miss a farm walk, or walk only part of the farm during busy times. Farmers constantly make intuitive, heuristics-based decisions (Hodgson 1997; Gray 2001), and PGSUS is not intended to replace this judgment, as decision support systems (DSS) frequently try to do (McCown *et al.* 2005). Instead, the idea is to reduce the time to perform a certain task (Lynch *et al.* 2000) so that more farmers would engage in herbage mass assessment. Our reasoning was: if a farmer sees value in doing farm walks and he is using computers, but he is struggling with time management, then he would value a tool that can help him to expend less time and effort doing his farm walks.

The elements above, plus encouraging preliminary results in terms of model accuracy (Romera *et al.* 2010), lead to the conclusion that there was a clear case for moving into a prototyping stage with farmers. One of the primary questions we had was, "Would farmers be willing to spend some time on the computer in order to save time in the field?" To answer this question, a working prototype was presented to farmers so they could test it, get a feel for what it would take to operate a system like PGSUS, provide input in the refinement of the tool, and be able to judge whether the concept had merits or not. By involving farmers in the process, there are more chances to develop a DSS that they find easy to use (Lynch *et al.* 2000; Newman *et al.* 2000).

This paper presents results of testing a PGSUS prototype with dairy farmers. Results in terms of herbage mass estimation accuracy, as well as farmers' opinions and suggestions, are presented.

Materials and methods

PGSUS

The PGSUS tool was described in detail by Romera *et al.* (2010). Briefly it involves the use of interpolated daily weather data (Tait *et al.* 2006; Tait 2008), and actual historic herbage mass data to drive a pasture growth model (Romera *et al.* 2009) that predicts daily growth rates used to estimate current herbage mass. The system uses a genetic algorithm function (Meffert and Rotstan 2008) to fit certain model parameters to the data for each paddock individually (model training). It can also be used to forecast pasture growth for 15 days based on daily weather forecast data produced by NIWA (National Institute of Water and Atmospheric Research, New Zealand). The derivation and accuracy of these weather forecasts is described in Renwick *et al.* (2009a,b).

Software testing with farmers

In June 2009, PGSUS was installed on the personal computers of seven farmers in the Waikato region (Farmers 1 –7, North Island of New Zealand). These farmers were asked to collect and enter the information by themselves. In April 2010, all paddocks on three of the Waikato farms were measured with RPM, by DairyNZ technicians and by farmers on the same day to assess the repeatability of the RPM technique and provide a reference point to assess the accuracy of PGSUS. Unfortunately, Farmer 5, 6 and 7 abandoned at different stages.

Two farms in the Canterbury region (Farmers 8 and 9, South Island of New Zealand) and four farms in Southland region (Farmers 10–13, South Island of New Zealand) were included; however, in this case the data collection and entry was done by a DairyNZ technician.

All the farmers in the study were already doing regular farm walks using RPM. In some cases, historical information collected by farmers was imported into PGSUS at the beginning of the process. For this reason the starting date of the data collection period differs between farmers (Table 1).

In the initial visit to the Waikato farmer, the farmers received an introduction to PGSUS, an explanation of the principles behind the model and a demonstration of the operation of PGSUS. The graphic user interface of PGSUS is simple and designed to be self-explanatory, so no training manual was provided. During the 12 months following the initial visit, the farmers were regularly telephoned (approximately monthly) and visited on several occasions to collect feedback and suggestions. Progress was also monitored by looking at the data they were sending using the "send data" feature in PGSUS (Romera *et al.* 2010).

Testing was also conducted at two DairyNZ experimental farms, Scott and Lye Farms (Hamilton, New Zealand). In these cases, pasture measurements were conducted by calibrated visual assessment (Macdonald *et al.* 2008) on Scott Farm and by RPM at Lye Farm. "One-week-ahead" forecasted pasture growth was also predicted for Scott Farm and compared to actual growth.

Preliminary test results on two of the commercial farms were presented previously (Romera *et al.* 2010), in which the observed data for the last three measurement dates were successively estimated using the previous data for model training (i.e. adding one farm walk at a time). This manual process was then automated in the program code, making it possible to repeat the testing for each farm walk date (starting from the fifth farm walk recorded) on all farms (411 farm walks in total) and evaluate the accuracy of estimations. This did not involve weather forecasting, which would have required farmers entering all the planned grazing events into the future. For each farm

Table 1 Average (± standard deviation [SD]) accuracy (residual standard deviation [RSD], Pearson correlation [*r*], slope of the regression line observed versus estimated and proportion of estimations where the estimation error >500 kg dry matter [DM] ha^{-1}) of Pasture Growth Simulation Using Smalltalk (PGSUS) compared to estimated herbage mass at paddock level

Farm	Period covered	Number of farm walks	Mean (range) number of days between farm walks	RSD (kg DM ha^{-1})	*r*	Slope (kg DM [kg DM]$^{-1}$)	Error >500 kg DM ha^{-1} (%)
Waikato							
Farmer 1	3 August 09–2 February 10	21	10 (8–13)	441 ± 179	0.79 ± 0.14	0.81 ± 0.28	21 ± 19
Farmer 2	21 October 08–6 July 09	17	14 (6–63)	269 ± 103	0.82 ± 0.10	0.79 ± 0.18	16 ± 11
Farmer 3	30 April 09–16 September 09	11	16 (6–35)	369 ± 331	0.79 ± 0.17	0.84 ± 0.30	11 ± 12
Farmer 4	24 November 08–26 April 10	62	8 (6–36)	173 ± 88	0.79 ± 0.19	0.83 ± 0.30	6 ± 9
Canterbury							
Farmer 8	9 January 09–7 January 10	33	10 (4–28)	198 ± 69	0.76 ± 0.20	0.88 ± 0.32	6 ± 8
Farmer 9	9 January 09–8 January 10	35	12 (4–28)	217 ± 105	0.84 ± 0.15	0.93 ± 0.28	7 ± 12
Southland							
Farmer 10	1 September 10–18 May 11	32	8 (6–14)	220 ± 98	0.86 ± 0.08	0.90 ± 0.21	9 ± 13
Farmer 11	15 September 09–17 May 11	72	9 (6–21)	215 ± 75	0.87 ± 0.10	1.03 ± 0.23	8 ± 9
Farmer 12	31 August 10–17 May 11	36	8 (6–14)	221 ± 89	0.84 ± 0.14	0.91 ± 0.28	9 ± 11
Farmer 13	24 February 10–18 May 11	51	9 (6–21)	214 ± 84	0.84 ± 0.11	0.88 ± 0.18	5 ± 8
Research Farms							
Scott Farm	8 December 09–11 May 10	22	7	222 ± 110	0.83 ± 0.08	0.88 ± 0.20	9 ± 15
Lye Farm	24 August 09–29 March 10	19	7	268 ± 97	0.77 ± 0.12	0.81 ± 0.22	15 ± 14

walk date, accuracy was evaluated in terms of residual standard deviation (RSD), Pearson correlation coefficient (*r*), slope of the observed versus estimated regression line and the proportion of paddocks where the estimation error was larger than 500 kg dry matter (DM) ha^{-1}. RSD was calculated as

$$RSD = \sqrt{\frac{\sum_{i=1}^{n}(O_i - E_i)^2}{n}}$$

where O_i and E_i are observed and estimated herbage masses on *i*th paddock, respectively and *n* is the total number of paddocks measured on a farm walk.

Farmer's evaluation

During September and October 2009, six of the seven farmers in Waikato were interviewed by the first author and the technician who had visited the farm on previous occasions. The other farmers were not interviewed because they did not have a direct experience with the PGSUS. A semi-structured questionnaire (Röling 2009) was used with the aim of describing the farmer and his pasture decision-making process, as well as his reasons for participating in the project and expectations. More importantly, the intention was to capture suggestions for PGSUS and an evaluation of the project.

In May 2010 at a final project meeting, all participating farmers were invited to discuss the results of the testing and share their ideas about the concept and their experiences with using PGSUS.

Results

Testing

For most farmers the required information was provided or could be reconstructed (grazing events could be guessed by observing decreases in herbage mass between farm walks) for a portion of the time only for which the software was available (Table 1, second column). The recording of grazing events was the main reason given for farmers stopping using PGSUS in its full capacity.

Herbage mass data to test PGSUS accuracy were collected from four of the Waikato farms (1–4), two Canterbury farms (8 and 9) and four Southland farms (10–13). Herbage mass estimation from PGSUS showed acceptable agreement with observed data (Table 1), with an average RSD of 252 kg DM ha^{-1} across all farms. The coefficient of correlation averaged 0.82 and the slope of the regression line was 0.87 kg DM (kg DM)$^{-1}$. The herbage mass of at least 79% (up to 95%) of the paddocks in all the farm walks was estimated with an error of <500 kg DM ha^{-1}. The 1-week herbage growth forecast by PGSUS at Scott Farm followed the correct trend when compared with actual growth (Figure 1).

Despite the accuracy of the herbage mass estimation from PGSUS and the favorable opinions expressed by

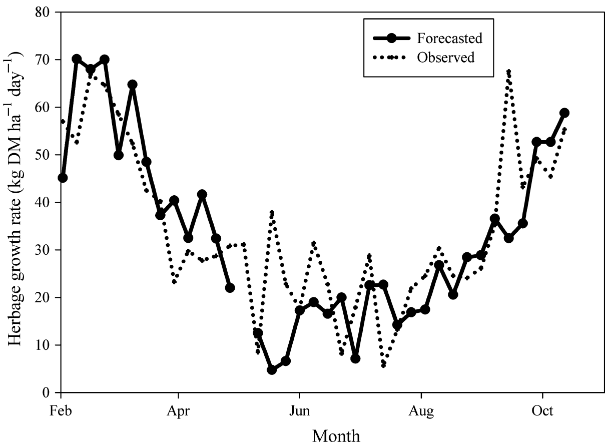

Figure 1 One-week forecasted and observed herbage growth rate at Scott farm during 2010.

farmers (Table 3), only one farmer used PGSUS to make decisions, and just for a brief period (autumn–winter of 2009). The others mostly recorded farm walk data only. The main problem encountered was that farmers did not enter the grazing events accurately into PGSUS; most of the results described above were obtained using farmers' records in some other software (typically Microsoft Excel) and reconstructing grazing events by looking at large decreases in herbage mass from one farm walk to the next.

Some modifications and additions were implemented in response to farmers' feedback, for example: the addition of a different way of entering grazing events; using data exported from other software; a simple feed budgeting page; a page displaying average calculations for the farm; the inclusion of a calculator to help pasture conservation decisions; and a series of new rules to accept/ignore data to be used by the learning algorithm. Ideas that could not be implemented in the prototyping phase included: a page displaying annual and seasonal herbage growth per paddock; entering "clicks" (height) from the RPM instead of herbage masses; a customizable simple, view (html) of outputs; a scroll bar on the bottom of the feed wedge and the ability to modify data through the graphs; color code on the feed wedge (e.g. wet paddock, flat, hill, large size) and generation of print outs.

Farmer's survey and workshop

Most participating farmers were in their early 40s, with tertiary qualifications, and a range of years in farming from <5 to more than 15. All but one were farm owners or dairy herd owners ("sharemilkers"), with high involvement in pasture management decisions, and they were the main users of the farm computer. All the farmers stated that they use the farm computer (mainly to check milk supply and herd data records) almost daily. Internet connection was reliable in all cases (Table 2).

All farmers assigned the utmost importance to grazing management, made regular feed budgets and in general

Table 2 Interview statistics of six Waikato farmers who participated in developing and testing Pasture Growth Simulation Using Smalltalk (PGSUS) (rating: 1 [poor]–5 [good])

	Farmer					
Question	1	2	3	4	5	6
1 Years in farming	>15	>15	<5	>15	<5	7
2 Age group	45	45	35	45	45	35
3 Tertiary qualifications	Yes	Yes	Yes	Yes	Yes	Yes
4 Decision sign off	Yes	Yes	No	Yes	Yes	Yes
5 Management style†	3.5	3.5	3.5	5	4	3
7 Grazing management importance‡	4	4	5	5	5	5
8 Do you have a feed budget?	Yes	Yes	Yes	Yes	Yes	Yes
9 Do you have a reliable internet connection?	Yes	Yes	Yes	Yes	Yes	Yes
12 Are advisors crucial to your business?	No	No	No	No	Yes	Yes
15 Frequency of farm walks (d)						
Winter	10	14	15–20	7	10	10
Spring	10	14	9.5	7	7–14	10
Summer	10	14	25	7	10	14
Autumn	10	14	20–25	7	7	7
18 Time to do a farm walk (h)	1.75–2	3.5–4.5	2.5–3	2.5	3	4
21 Use of feed wedge	Yes	Yes	No	No	Yes	Yes

†1 (intuitive)–5 (objective-data based).
‡1 (low)–5 (very high).

Table 3 Interview results for quantitative questions from six Waikato farmers who participated in developing and testing Pasture Growth Simulation Using Smalltalk (PGSUS) (rating: 1 [poor]–5 [good])

Item	Average	Mode
PGSUS rating		
Potential to be valuable to me	4.2	4
My understanding of its use	3.3	3
Amount of data collection needed	2.5	1
Level of user friendliness	2.9	2
Its ability to add value to the data	3.9	5
Usability of the PGSUS output	4.2	4
Extra time for PGSUS (min week^{-1})	43	Range, 0–105
Time for PGSUS was 1 (minimal) – 2 (acceptable) – 3 (excessive)	1.8	2
Support provided by DairyNZ	4.8	5
My motivation to keep using it PGSUS	4.2	5

tended to describe themselves as following management styles inclined towards "measuring and monitoring" (as opposed to "based on intuition"). However, there was a range of pasture monitoring methods, including regular farm walks (with a frequency of between 7 and 14 days) and partial farm walks as required to select the next paddocks to graze or monitoring grazing residuals. In four cases, the participating farmer was the one doing the farm walks, whereas the other farmers employed staff. All farmers were storing the pasture data electronically before the survey.

Aligned with the main value proposition of PGSUS, the primary expected outcomes from PGSUS mentioned by farmers in the interviews were saving time spent monitoring pastures and simplifying pasture budgeting. These expectations did not materialize for most of the farmers, given that they were not able to use PGSUS to its full potential. Nevertheless, all farmers gave high ratings to PGSUS (Table 3), except for the amount of data collection required, and user friendliness, which were given a medium ranking. When interviewed, all farmers indicated that they wanted to continue with the project (Table 3). Among the reasons for participating in the project, "helping DairyNZ" received the highest score in the interviews, followed by "improving my farm performance". Expectations included: "make feed budgeting easier"; "reduce the number of farm walks"; "learn to use something interesting"; "be open minded"; and "give me an excuse to walk the farm more often".

The responses to qualitative questions in the interview are detailed in Table 4. For example, when evaluating how the project was conducted, the interviewed farmers suggested a range of ideas including improving the introduction to PGSUS and the training phase and facilitating the exchange of results between participants. They also suggested how to improve PGSUS and add capabilities. Speeding up, or even automating data entry, was one common requirement, along with several ways of presenting the data to reflect differences in management styles. The outcomes farmers expected were in general related to spending less time doing farm walks, and also to have the chance to meet other people.

At the May 2010 meeting, despite the problems of data entry, farmers still showed a positive attitude towards the concept. The farmers were asked to "brainstorm" ways of improving the concept and making it more useful to them, which provided ideas regarding the presentation of results by PGSUS, compatibility with existing software and simplification of data entry. The most relevant comments and suggestion are presented in Table 5.

Discussion

Prototype functioning

The predictions of the model estimation showed encouraging and consistent accuracy across 12 farms located on three contrasting regions of the New Zealand. Considering the limited accuracy of the pasture measuring techniques normally used by farmers, this is remarkable. For example, L'Huillier and Thomson (1988) estimated an RSD of 410 kg DM ha^{-1} with correlation of 0.84 for the RPM, and a RSD of 395 kg DM ha^{-1} with correlation of 0.82 for visual assessment. In general, PGSUS showed similar accuracy on the research farms as on the commercial farm, despite the fact that different pasture measurement methods were used (RPM for Lye Farm and visual scoring for Scott Farm).

To put these results in perspective and provide a reference point, when three of the Waikato farms were measured with RPMs by DairyNZ technicians and farmers, the correlation between both measurements ranged between 0.45 and 0.93. The slope of regression line was between 0.37 and 1.2, the mean RSD was between 268 and 365 kg DM ha^{-1} and the percentage of paddocks with an estimation error >500 kg DM ha^{-1} averaged 7.8% (6.1–9.5%). It could be argued that a farmer using PGSUS could estimate herbage mass almost as well as an independent person measuring the same paddocks with a RPM.

The pasture growth forecast results are also very promising, although more sites and seasons are required to fully test the forecasting accuracy of PGSUS.

Farmers' opinion

According to the Technology Acceptance Model (TAM), perceived usefulness and ease of use are key to technology acceptance, although the former is by far the most important (Davis 1993; McCown 2002; Flett *et al.* 2004). Pan-

Table 4 Interviews results for qualitative questions to six farmers who participated in developing and testing Pasture Growth Simulation Using Smalltalk (PGSUS)

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6
Expectation	Make feed budgeting easier	Reduce number of farm walks	"I prefer working on the computer rather than on the field"	Be more open minded	Cut number of farm walks. More time for other areas	Forecast covers, and growth. Filling in the gaps. Walks farm less often
Hoped outcome	Fill data when not able to do the farm walk	Spend less time doing farm walk.	I don't always have a fresh farm walk and I have to make many decisions"	See accurate predictions. This will give him confidence to use it	Fill data when not able to do the farm walk	Spend less time doing farm walk
Problem	N/A†	Farmer 2 was just entering farm walk data	I was expecting more interaction with other farmers	He had not used PGSUS fully.	Finding time for the farm walk was an issue	I probably did not use PGSUS to its potential
Suggestion	Calculate feed requirement for more than one herd	Automate/simplify data entry and view	Improve error cleaning. Show past growth per paddock	Show past growth from each paddock.	PalmPilot to enter data from the paddock	Colour code on the feed wedge (e.g. wet paddock, flat, hill, large size)
Best thing about PGSUS	N/A	Compatibility. Help to choose next paddock	Ranking paddock by covers at any time. Weather forecast	User friendly. "I can see potentially lots of power"	Good snapshot of farm covers. Gives farm averages. Compatibility	Weather forecast, being able to fill the gaps in the data. PGSUS has a huge future
Why continue	I was in PFS from the beginning	"I've been waiting for this technology for a long time. It should already be here"	N/A	Add value to staff, keep up with new technology	Made a commitment with DairyNZ. The potential of the program is good	PGSUS is a valuable tool, would make life easier adding value to business
Idea for running the study	Show it to more farmers	More training	Share information among farmers	Lend old computers to participating farmer	Choose the timing of introduction better (avoid busy times)	Run it in conjunction with consultants

†No comment made by the farmer.

Table 5 Farmers suggestions on the workshop (May 2010)

- More training in the operation of the prototype was required
- In order to gain "trust" in the tool, it should be possible to visualize the accuracy of the predictions immediately after entering new farm walk data
- Any new tool must "fit in" with existing software. There are just a few alternatives in New Zealand, two of which were being used by the participating farmers, and such connection (data sharing) was proven feasible
- Some management actions on the farm last several days (e.g. bulls grazing for many days in the same paddock), and this was not properly considered in the current implementation
- Use some extra information from the user, like planned grazing rotation length, to identify paddocks that are due for grazing, or to capture errors in the data entry
- Evaluate individual paddock performance, preferably seasonally, to help pasture renovation decisions and evaluate past decisions
- Improve data entry, possibly via a touch screen, installed in the milking shed, which is the point where the farmer sends cows to the next paddock

nell *et al.* (2006) also considered relative advantage as a decisive factor determining the ultimate level of adoption of most innovations in the long run.

Although interviewed farmers mentioned "user-friendliness" as an issue, they are more than capable of operating complicated software if it suits their needs and management routines. All of the participants possess a tertiary education and were effortlessly using complex Microsoft Excel spreadsheets and other difficult software packages every day. The extra time dedicated to PGSUS by farmers was 43 min per week on average, which was judged acceptable by them. Considering that a farm walk takes approximately 3 h (from 2 to 4 h), 43 min per week seemed to us to be a reasonable trade-off. At the time of the interviews, 6–7 months into the project, most farmers were highly motivated to continue as they could see potential in the concept (Table 3).

The capabilities of PGSUS would be best used if farmers used their computer for 5–10 min to enter management events each day, while they are still fresh in their memory. This was considered realistic, as all participating farmers switch their computers on daily for other purposes. This could be implemented in a numbers of ways. One farmer suggested that installing PGSUS on a computer in the dairy parlour may have encouraged data entry, because at milking time, farmers are likely to be interacting with a computer to record cow-related data. Cell phone applications allowing the farmer to enter the data while in the field could also facilitate the process. Any form of data entry automation would help, but the farmer would still need to engage with the software to extract information from it. Another possibility could involve the development of third party monitoring services that visit the farm to measure pastures and record management events. Farm walks could be done every 2 or 3 weeks, and software like PGSUS could fill the gaps, eventually making such a service viable and affordable for farmers.

Farmers' views on how to show the model result varied considerably, as some farmers prefer lists, others graphs; some farmers valued the forecasting features, while others put their emphases on data storage, monitoring and retrospective analysis functions. It became clear in the discussions in the last meeting, and by looking at the comments in Table 5, that farmers were talking about different functions that needed to be covered by a software tool, with different emphases from each farmer. Such functions could be summarized into data storage; data analysis; pasture growth forecasting and decision support. The prototype that was presented did cover those functions to some extent, but they were not the main intended purpose. The core focus was on estimating the current herbage mass, mainly as a way to enhance other tools (either dedicated software or self-made Microsoft Excel spreadsheets), and save farmers time by reducing the number of farm walks. The farmers identifying different uses shows the value of having them participate and reinforces the need for PGSUS or other prototypes to be flexible enough to accommodate their suggestions. We could have asked them what they wanted at the start, but it is doubtful that such clear answers would have emerged.

How farmers used PGSUS

The fact that farmers assigned high importance to pasture management, were doing pasture monitoring and budgeting, and were storing the pasture data electronically made them good candidates for PGSUS use. However, only one of the farmers was storing the grazing history in the form of a work log. This had implications later on when using PGSUS, since recording grazing events proved to be the most laborious part of the process and the only truly extra activity (i.e. not part of their normal routine) required from the farmers. An effort was made during the prototyping and testing stage to automate the transfer of data between existing tools and PGSUS, but farmers still had to do some extra work to keep both systems operational.

Farmers' interaction with PGSUS was limited to entering data; therefore they did not reach the point where PGSUS should have become truly useful. Possibly they did not realize that without grazing events, PGSUS could not work. When consulted, farmers argued that they could not find the time to enter the grazing events and use PGSUS properly, although they also stated that the extra time involved in operating PGSUS was acceptable.

We believe that, more than time, it was a matter of modifying routines. The fact that it was "just a research project" may have also played a part in their lack of motivation. The issue of farmers' engagement is not just about the usefulness of the tool, for these farmers it was a short trial with limited actual benefit for their business, therefore their motivation may have been more altruistic than based on an expectation of immediate benefit. Perhaps the farmers participated because they felt it was the right thing to do for DairyNZ and not because they really had a problem they wanted to solve. These issues prevented the farmers gaining confidence in PGSUS, which is unfortunate, given that the retrospective analysis presented in the Testing section showed that the accuracy was good. As commented by Barnett and Sneddon (2005), a more extended experience with a technology may sometimes be necessary for the benefits to become clear.

The rationale behind the current design of PGSUS includes assuming that farmers use the farm walk for short term decisions; therefore the option of having a "fresh" (virtual) farm walk and feed wedge should have been desirable for them. In interacting with and interviewing this small group of farmers, it was observed that not all them were using feed wedges, or were just using the farm walk data for monitoring purposes (e.g. tracking the evolution of the average herbage mass of the whole farm or selecting the next paddock to graze).

Eastwood and Kenny (2009) describe a tension between the worldviews of farmers (based on heuristics) and the science community (emphasis on objective pasture data), in the search for improvements to grazing management. While farmers look for simplicity, cost saving, time management and fit within their established routines and goals; the science worldview focuses on objectivity, quantification, rationality and structured decision making

Table 6 Evaluation of Pasture Growth Simulation Using Smalltalk (PGSUS)

Item	Evaluation
Relative advantage criterion	
Short term input cost of the innovation	Nil to low
Impact on profit in the medium–long-term	Low. PGSUS is intended to save time walking the farm
Innovation's impact on other parts of the system	Low
Adjustment costs involved in the adoption	Low
Compatibility with landowner's existing set of technologies, practices and resources	PGSUS is intended to make an existing practice (pasture budgeting/feed wedge) less time consuming (save farm walks), so compatibility was thought to be high for farmers practicing formal feed budgeting. However, collaborator farmers were not always using farm walk data for formal budgeting
Innovation's complexity	The collaborator farmers gave a medium ranking in user friendliness to the prototype, but this could be improved in a release version
Compatibility with existing beliefs and values	PGSUS should be compatible for objective-data-oriented farmers, not for all farmers. For example, all the collaborator farmers identified themselves as following management styles inclined towards "measuring and monitoring"
Trialability criterion	
Divisibility	In its current state PGSUS needs to be adopted as a whole, but future versions could allow for some divisibility
Observability	High. Farmers can see if they save time using PGSUS or not
Response lag time	Farmers need to enter data for 2–3 months (four to five grazing events) before they can see results. While feed wedges are not needed all the time on the farm, data entry is
Certainty about the consequences of adoption	It may be difficult to weight the advantage of saving farm walks against time required on the computer
Cost of the trial	Low monetary cost, but time cost could be considerable if it is only for a trial. Operating PGSUS is more time consuming the first few times it is used
Risk	Relying on inaccurate herbage mass estimations for model training. Although, if this is the case, PGSUS would provide warnings to the user
Information from the trial	PGSUS needs to be properly used to show results. Some farmers could not see the full potential of PGSUS because they did not enter the grazing events
Similarity to a familiar practice	PGSUS is different from existing technologies, although it complements others. For example, PGSUS requires a regular flow of data to function properly, whereas with other farm software the user can enter data sporadically

Criteria and evaluation following Pannell *et al.* (2006).

(Eastwood and Kenny 2009). When asked about their management styles (1 [intuitive]–5 [objective-data based]) the interviewed farmers positioned themselves more towards the objective-data based end of the spectrum, which is coherent with the way they described their approach to pasture management in their own words (Table 2). Both scientists and farmers value objective pasture data; however, farmers place less emphasis on stringent data collection and quality. For example, the findings of Gray (2001) indicate that the reliance on objective data, and therefore the incentive to record data on the computer, changes through the year.

Chances of adoption

Pannell *et al.* (2006) considered two broad categories of characteristics of a technology that drive adoption or non-adoption, relative advantage and trialability. These authors discuss a range of factors upon which these broad categories may depend, and these were used in our study as criteria to evaluate the chances of adoption of PGSUS, based on reflections on the interaction with farmers (Table 6). We believe that PGSUS offers real time-saving advantages, and it would be moderately easy to trial, if the farmer is measuring herbage mass regularly and if the farmer is using formal feed budgeting techniques to make decisions.

The accuracy of PGSUS was acceptable; however, the fact that farmers did not use PGSUS other than just for entering data raises some questions:

- Is there a problem with the user interface? If so, could it be fixed via automation, or improving the look and feel of the graphic user interface?
- Is the concept either simply not useful, or the value proposition not interesting enough to justify any extra effort? According to farmers' opinion, the concept is potentially useful. If there is a value proposition, perhaps it could become more attractive if the effort to collect data could be reduced (e.g. via automation).

Conclusions

We have shown that it is technically possible to use a pasture model to estimate herbage mass at paddock level with enough accuracy for normal farm decision making, given the approximate nature of pasture measuring.

The time required to operate the PGSUS prototype was judged by farmers as acceptable; however, the participating farmers struggled to enter all the information required for the system to work as intended. Particularly, recording grazing events proved to be a major obstacle. More than a time issue, this could have been a question of changing farmers' routines. The way PGSUS is currently designed, the users must commit to data entry every day, even though farmers do not need new herbage mass data every day. Some form of automation or the use of mobile devices for the data entry may solve this problem.

The concept presented here is suitable for farmers that already do regular farm walks, helping them to increase the time between actual farm walks. Farm walks could be done every 2 or 3 weeks, and software like PGSUS could fill the gaps to inform decisions between farm walks. Considering the accuracy of PGSUS and the encouraging comments from the participating farmers, if the issue of data entry is overcome, a full commercial version of PGSUS should appeal to objective-data-oriented farmers, most probably as an add-on to existing platforms.

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