PASTURE YIELD MEASUREMENT WITH THE C-DAX PASTUREMETER

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ABSTRACT

A system of pasture yield measurement was developed for New Zealand's pasture based, rotationally grazed farming systems. Pasture yield measurement is complex because the pasture biomass has to be measured in-situ, pre and post grazing so that pasture consumption and utilisation can be calculated. The "C-Dax Pasture Meter" was initially developed by Massey University and subsequently commercialised by C-Dax Ltd of New Zealand. The pasture management solution has gained traction in the market-place and is considered a valuable management tool for dairy farmers in New Zealand and Australia.

The method of measurement is simple but highly effective and provides reliable measurement of pasture cover in a range of pasture types regardless of weather and light conditions. The measurement unit is pulled behind an ATV and can be used at speeds of up to 20kmh^{-1}. Two technology levels are available, either as a basic system deriving average cover for individual paddocks, or with the incorporation of a GPS to allow pasture production to be mapped. Recent independent calibration results from New Zealand based research organisations have shown the C-Dax Pasture Meter to have a higher level of accuracy than traditionally used methods as well as increased utility. The system has also proved to be reliable in measuring post grazing residual levels which are known as Key Performance Indicators (KPI's) to achieving good pasture management and maintaining pasture quality.

Measuring pasture covers allows farmers to make timely decisions regarding feed conservation, fertiliser use and stocking policies as well as giving farmers greater certainty in budgeting feed resources. The paper examines the KPI's that farmers use to benchmark the success of their grazing management. A

case study is presented to illustrate how the C-Dax Pasture Meter is benefiting dairy farmers in New Zealand and Australia.

Keywords: Pasture measurement, Pasturemeter, yield mapping.

INTRODUCTION

The original pasture meter concept was to provide a method of yield mapping intensively grazed pasture to provide farmers with an accurate means of allocating feed. Pasture yield measurement is complex, repeated harvest events occur throughout the year, measuring the whole crop rather than seed yield, the residual crop after grazing must also be measured. Many dairy farmers used complex feed budgeting software to calculate their cows energy requirements for the day, but estimates of available pasture, which is the major component of the diet, were often crude approximations of pasture cover which could vary considerably between individual operators. Although the measurement scenario is complex, there is a straight forward relationship between nitrogen fertiliser application and pasture biomass growth. Spatial variation does exist and it likely that fertiliser treatments could be more accurately tailored to the pasture growth potential in any area of the farm thereby improving the nitrogen use efficiency of intensive pasture production.

The first pasture yield maps within this project were created in 1999 using a rising plate meter, an example is illustrated in figure 1. In combination with DGPS (differential GPS), samples were taken on a fifteen meter grid, where 15 samples were taken in a 2 m radius circle at each point. The average reading from the rising plate meter was then used to represent that point recorded using the DGPS which had an accuracy level of +/- 0.30 m. Both pre and post grazing measurements were carried out. Although this process was extremely time consuming and laborious, it demonstrated that pasture growth had significant non-random variation as did the level to which pasture was utilised by the grazing animal. Clearly a pedestrian system would not be suitable and was not a long term solution
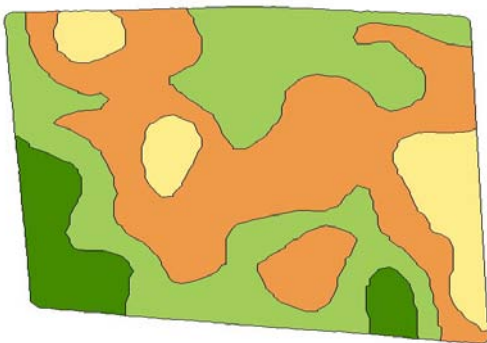
Grass_Utilisation
373 - 589 (0.2 ha.)
589 - 806 (0.9 ha.)
806 - 1023 (0.7 ha.)
1023 - 1240 (0.2 ha.)
1240 - 1457 (0.0 ha.)

Figure 1 Interpolated map of pasture utilisation kg DM ha^{-1} produced from measurements of pre and post grazing pasture covers completed with a rising plate meter and DGPS.

Design Criteria

A list of ten design criteria was drafted:

1) An accurate, reliable and repeatable measurement system.
2) Used under all reasonable weather conditions, in the presence of cloud or precipitation.
3) Used in any light conditions (day and night).
4) Achieve high measurement speed and provide instant feedback to farmers.
5) Simple to use and operate, can be used by unskilled labour, simple and reliable methods of recording data.
6) Low cost.
7) Versatile in coping with different pasture growth stages and able to measure residual pasture levels after grazing.
8) Provide information to the farmers at inter paddock and intra-paddock levels and provide details of where the measurements had been taken from for audit purposes.
9) Able to cope with rough ground conditions.
10) Robust enough to stand up to daily use by dairy farmers.

Measurement of residual or post-grazing pasture level is important to maintaining yield and quality throughout the growing season. On some farms, the cows will be put back into the same paddock for a short period in order to get the grazing down to the correct level. Occasional measurement of pasture dry matter yield mid-cycle would simply pick up the amount of pasture present which would not discriminate if excessive dry matter in an area was due to optimal growing conditions, or the fact that the grass had not been eaten down adequately when grazed. Measuring post grazing residual presents special challenges due to the presence of large amounts of excreta. Accurate allocation of pasture feed has been estimated to give improve utilisation. Fulkerson (2005) indicated a 12% increase in feed allocated when accurate pasture measurement was applied. In 2004 the financial worth of this improved efficiency was estimated to be NZD $554M, assuming a 10% improvement in pasture utilisation and NZD $871M, for a 15% improvement. Given that there are around 11,500 dairy farmers in New Zealand this translates in simple terms to an increase in revenue of between NZD $48,000 and NZD $75,500 for the average dairy farmer.

Sampling

One aspect which was examined was the sampling rate required, and whether a continuous method was considered desirable. A sampling exercise demonstrates the problem, a 10 by 10 m grid was prepared and 100 cut samples

were taken, yield varied from 1200 to 3440 kg DM ha^{-1}. These dry matter samples were used to estimate the accuracy of various sampling strategies when sampling points were randomly selected over 25 sampling events. The potential for error is illustrated in Table 1, clearly where significant variation is present, small sample numbers have a greater tendency for inaccurate measurements. Although the average cover over the 25 sampling events ended up being reasonably close the range of DM estimates was far greater when fewer samples were taken. When measuring growth rates over short periods of time when differences may be small, then this becomes important, as does the fact that the same sampling lines should be followed in order to achieve consistency.

Table 1 Accuracy of pasture measurement using cut samples over 25 sampling events using different sampling strategies.

Number of samples	Average	Max	Min	St Dev
1	2017	3440	1200	710
5	2199	2908	1704	429
10	2069	2600	1718	264
15	2132	2469	1891	176
20	2110	2355	2026	103
25	2142	2342	1984	103

Table 2. Difference between transect measurement and the mapping approach for pasture mass measurement on individual paddocks

	Transect Measurement		Whole Paddock Map		
Paddock	Number of Readings (1)*	Average Pasture cover kg	Number of Readings (1)*	Average Pasture Cover kg	Percentage Difference
6	640	2739	5040	3170	15.7
7	580	2836	4380	2837	0.0
8	500	3235	4100	2980	7.9
9	460	1849	2720	2946	59.3
10	410	2142	2760	2191`	2.3
11	480	2808	3360	2295	18.3
11a	460	2904	2220	2285	21.3
Average					17.8

(1)*   **Each reading is an average of approximately 200 individual readings.**

Once the first versions of the C-Dax Pasture Meter had been developed it was possible to test different strategies. Many farmers use a simple transect across

the paddock from point A to B, taking a number of samples with the rising plate meter. Two methods of measurement were considered, using transects or mapping on a regular track spacing and using interpolation techniques to estimate pasture yield for the sample area. Due to the spatial variability present, it is important that farmers choose transects that are representative of the paddock. Figure 2 illustrates maps of paddock DM yield, these paddocks were used to compare average pasture cover (using the C-Dax Pasture Meter) derived through mapping with result of diagonal transect lines used by the farm staff. A series of experiments were conducted, the results are presented in table 2.

Although some transects gave a close approximation to the average yield in the paddock, errors of up to 60% were detected. Clearly this has the potential to misrepresent actual pasture available in the paddock and if subsequent measurements deviate from the transect then differences could occur. This is especially true where different staff are used to carry out this task on larger farms.
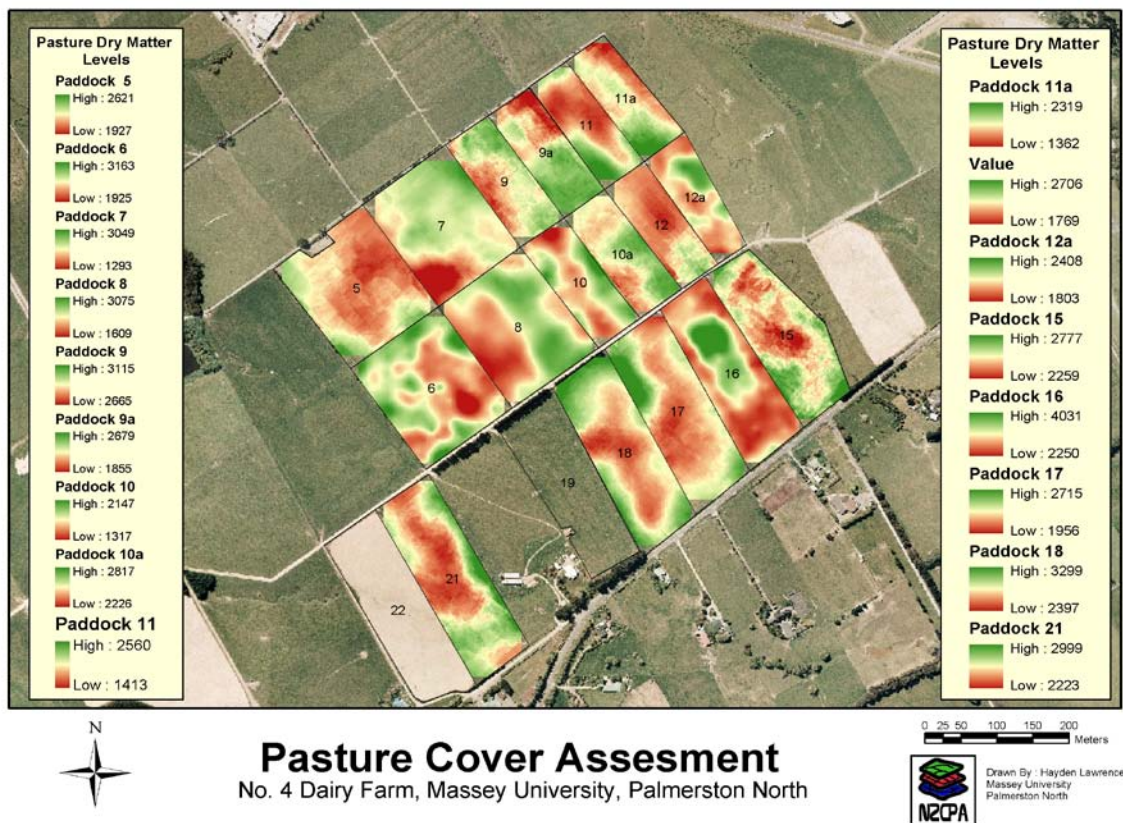

Figure 2 Pasture cover maps of Massey No 4 Dairy Farm, November 2003. Paddocks used for comparison to transect measurement.

Potential measurement methods.

Given the time taken to map pasture with a pedestrian system such as the rising plate meter and given that most dairy farmers had an ATV, it was decided that this would be a more appropriate basis for recording and sampling.

A number of potential methods were explored and these are summarised in Table 3.

Table 3 Methods investigated and/or tested for pasture measurement.

Method	Date	Comments
Mechanical: Mechanical skid, Pendulum	2000 - 2003	Stability was the main issue, highly variable mechanical resistance, speed effects.
Acoustic:	2000 -2002 2010	Problems associated with pasture quality and reliability poor when pasture quality poor. Environmental/meteorological factors also an issue. Revisited 2010 but similar problems experienced.
Satellite: based instruments	2000 - 2010	Traditional dairying areas are high rainfall, hence extensive cloud cover.
VisNIR:	2005 - 2010	Proximal sensors show some promise when higher cover available, problem with residual measurement, soil variability, soil moisture levels and nature of material left after grazing.
Optical:	2000 - 2010	Optical sensors used to measure pasture height. Simple principle but has proven effective.

PASTURE METER FUNCTIONALITY.

The basic design of the C-Dax Pasture meter is illustrated in figure 3 The unit is towed behind the ATV from it's ball hitch. This was found to give superior handling and stability compared to earlier designs. In the transport position, the wheels are raised and when operating for pasture measurement the wheels are lowered and the C-Dax Pasture Meter rests on it's skids. The wheels form outriggers which helps with stability.

The Pasturemeter measures pasture height, it does so at approximately 200Hz, these 200 measurements are averaged over a second and this reading represents a data point if the unit is being used to map, or forms part of the data that makes up the paddock average when the non mapping version is being used. A speed sensor detects the forward speed of the unit and if the ATV stops then recording also stops, when the GPS detects the unit is moving again then recording recommences. The LED and receivers are mounted on two vertical bars, Fig. 3b, pasture passing between them interrupts the beam and registers the presence of material. The sensors are recessed within the C-Dax Pasture Meter unit to ensure they stay clean even when in heavily soiled post-grazing paddocks. Much of the guarding around the unit is associated with keeping the sensing unit clean.

Experiments were also conducted to find the optimal weight for the C-Dax Pasture Meter which would give good stability for measurement, while not being excessively heavy and impact the ride for ATV's of around 250cc and above, which are typically used on New Zealand dairy farms.
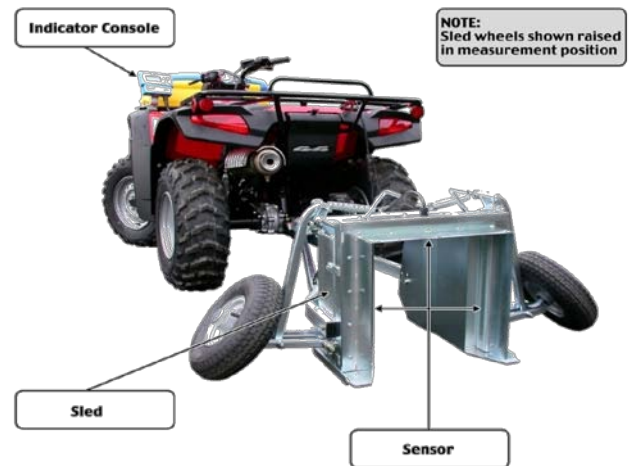

Figure 3 (a) C-Dax Pasture meter in action, (b) C-Dax Pasture Meter components

Calibration

Like any surrogate measurement, a great deal of calibration has to be completed in order to give farmers reliable information. Because many farmers are familiar with the principle of a simple slope and offset(multiplier and constant) of the rising plate meter, it was decided that this form of equation should be

investigated. Others were also trialled, but it was generally felt that any improvement in accuracy was marginal and the simplicity and familiarity of the calibration would be eroded.

Figure 4. Initial field trial work with Pasture cuts.

Initial work was completed by the design team. It was recognised that the dry matter content of the grass varies with the time of year and whether the pasture was irrigated or not. Table 3 shows result from the initial calibration experiments. It was suggested that for irrigated pasture the winter equation should be used.

Table 4 Calibration equations developed from original calibration on Massey University No4 Dairy Farm.

Month	Multiplier	Constant
Winter	18.6	1117
October	15.3	1358
November	16.0	1530
December	18.6	1818
January	21.9	1978
February	24.6	2017
March	22.6	1850

Once this process had been completed, units were placed in different locations where further calibration was conducted. A series of calibration experiments (Table 5) were completed by Fulkerson pers comms (2007) in Australia with 5 grass species through different growth stages. This comprehensive work compared performance with a total of 376 cut samples, the typical r^2 of 0.76. The unit outperformed the rising plate meter on the majority of trials when measuring in direct comparison.

In a further series of experiments conducted in Canterbury, New Zealand on irrigated pasture for the period September to November 2006, the performance of the C-Dax Pasture Meter was compared to the rising plate meter by using transects over 123 paddock, with an average cover of 2162kg DM ha^{-1} 52% were within 100kg DM ha^{-1}, 26% had a difference of between 100 and 200 kg DM ha^{-1}, while 23% had a difference greater than 200kgDM ha^{-1} Franklin pers comms (2007).

Rennie et al (2009) expressed concern that C-Dax Pasture Meter had been calibrated for typical temperate pastures and these were not necessarily representative of conditions found in Northland, New Zealand. Experimentation on pasture with changing Kikuyu content found that using the initial calibration produced high standard errors, the same was also true of the rising plate meter. Further calibration as undertaken and this research identified alternative multiplier and constant which better reflected their cut sample results Rennie published a splined calibration curve through the growing year which shows the relationship between height and pasture dry matter.

Table 5 Calibration results from 376 cut samples, over 5 species. Personal communication Fulkerson 2007.

Date	Species	Calibration Ht. (cm)	Stage of growth	Cuts	Y= DM (kg/ha) X= Bike ht. (mm)	r^2
Nov. 2005 pooled	S.R. Rye	Ground	Node development	27	Y=20.57X - 954	0.79
May 1st & 8th 2006 pooled	S.R. Rye	Ground	First grazing	16	Y= 7.92X + 392	0.76
May 29th & July 2006 &july 2007 pooled	S.R. Rye	Ground	Vegetative	76	Y= 13.38X - 332	0.73
Nov. 2005 pooled	Prairie	Ground	Seeding	22	Y=22.97X - 333	0.82
May 1st & 8th 2006 pooled	Prairie	Ground	First grazing	17	Y=17.01X - 510	0.73
May 22nd & 29th 2006 pooled	Prairie	Ground	First grazing	16	Y= 9.79X - 253	0.91
March 29th & 30th 2007 pooled	Prairie	Ground	Vegetative	25	Y= 7.33X + 11	0.63
July 11th 2007	Prairie	5 cm	Vegetative	10	Y= 24.64X - 890	0.7
Jan 27th & 30th 2006 pooled	Kikuyu	5 cm	Vegetative (early)	28	Y=9.55X + 186	0.8
March to April 2007 pooled	Kikuyu	5 cm	Vegetative (late)	40	Y= 5.66X + 52	0.72
June 19th 2007	Paspalum	5 cm	Vegetative	6	Y= 4.62X - 41.2	0.7
Nov. 2005 pooled	Lucerne	5 cm	Vegetative	37	Y= 9.73X + 620	0.7
Jan to Feb 2006 pooled	Lucerne	5 cm	Vegetative	50	Y= 8.74X + 706	0.73
June 19th 2007	Lucerne	5 cm	Vegetative	6	Y= 5.64X + 35. 3	0.89

Functional design

Evolution of the C-Dax Pasture meter has been continued since its market release in 2006 until the present day. In this time there have been improvements to the sensing technology, engineering of the sled, major improvements to the display console and further farm software options and integrations. The latest release incorporates GPS and enhanced filtering algorithms to simplify the data collection process and further improve accuracy. This technology, combined with improvements in spatial farm software, has enabled auto paddock recognition, improved timeliness of data collection and rapid conversion of data into software-based benchmarking and management tools.
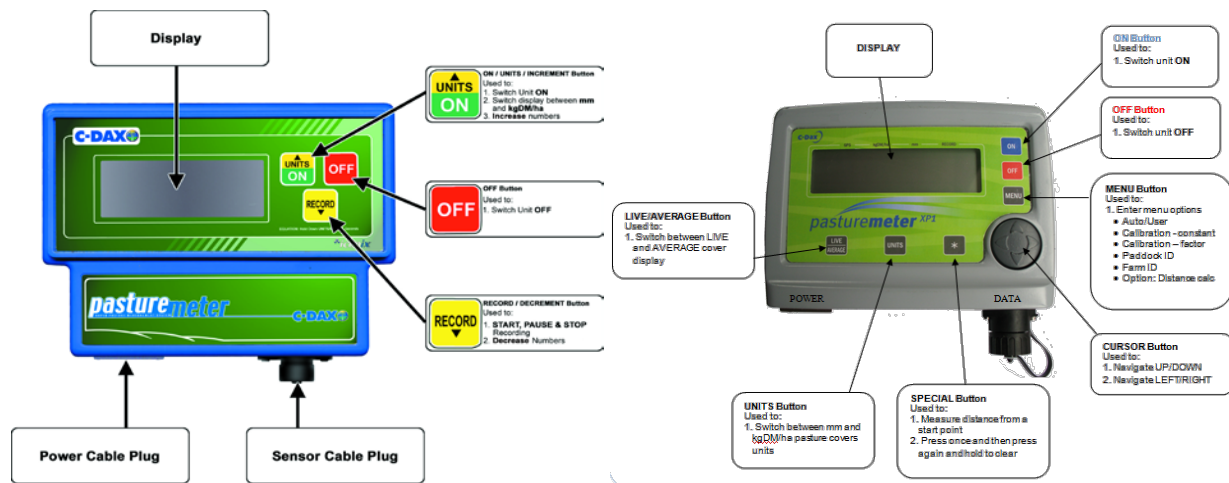

Figure 3. Design of Indicator console, (a) circa 2006, (b) 2009

CASE STUDY RESULTS

Case Study - Niaruo Dairies

The C-Dax Pasture Meter was used at the beginning of the 2008/09 production season, it is used every Tuesday to take pasture cover readings in individual paddocks, this takes approximately 1 ¼ hours to cover the 85ha which is subdivided into 50 paddocks. Major benefits of using the C-Dax Pasture Meter include the speed and reliability of measurement between operators. It is on-farm policy that every piece of measured data is used to make management decisions, the data collected from C-Dax Pasture Meter is used to make decisions at the strategic, tactical and operational management levels in the farm business as described in table 6.

The C-Dax Pasture Meter is part of a management strategy to maximize dairy herd production and maintain optimal animal health. In-parlour feeding is used in addition to an automatic weighing system linked to the DeLaval AlPro system. This allows weight targets to be set for the herd at various stages throughout the year and gives an early indication of how cows are responding and assists in projecting future feed demand.

Table 6 On-farm KPI's derived from the use of the C-Dax Pasture meter

Measurement	Management Decisions
Strategic	
Total farm production (T/DM/ha/year)	Data used to measure pasture production performance annually
Total per paddock production (T/DM/year)	Lowest producing paddocks investigated and identified as candidates for following years cropping rotation
Tactical	
Average pasture cover at measurement	Calculate Pre grazing cover required from [1]
Average pasture growth rate for week	Use feed wedge to check current feed position.
Operational	
Paddock growth rates	Use the current available pasture covers in individual paddocks and predicted growth rate.
Pasture demand	Calculate actual daily pasture intake

-[1] Pre Grazing Cover = (Stocking Rate x Target round speed x Target Pasture Intake) + Post Grazing Cover target

Pasture is the cheapest form of feed available for the case study farm, therefore it important to achieve the highest utilisation factor possible. This is associated with many factors including, grass cultivar, age since establishment, soil nutrient status, pre grazing grass height and post grazing grass height. When these factors are combined along with optimal environmental conditions pasture utilisation of greater than 85% can be achieved. The C-Dax Pasture Meter is critical in measuring the KPI's of pre and post grazing heights that vary throughout the year depending on pasture growth and climatic conditions. It is also used to monitor underperforming paddocks which are selected for the cropping rotation and subsequent re-grassing. The current farm management took over the property in the 2008/09 season and began collecting pasture information using the C-Dax Pasture Meter from that point. The previous management regime the farm had produced 78,000kg MS from the same milking platform using similar inputs. Based on this information the farm had a pasture utilisation of 9.8T/ha, using historical pasture growth rates it was calculated that this was a utilisation of 74%. Figure 4 shows the long term annual pasture production cycle, the C-Dax Pasture Meter allowed the actual level of production to be measured and fluctuations in growth as well as the annual production to be closely monitored and trends observed.

In 2008/09, when C-Dax Pasture Meter data was used to make pasture management decisions the utilisation was increased to 81%. With only 1.5 months left in the current production season it is predicted that seasonal utilisation will lift to 85% (Table 7). This 11% increase in utilisation in two years was achieved through improved management of existing pasture, using the C-Dax Pasture Meter measuring and management system described in table 6. The system also assisted in identifying poorly performing areas which were subsequently re-grassed, the combination of pasture renewal and improved growth through superior management

achieves a near 20 per cent increase in pasture production. The farm is now growing more grass and making better utilisation of that grass.

Table 7 Current production and targeted performance for Niaruo Dairies

	2007/08 (Previous	2008/09 (Actual)	2009/10 (Predicted)	2010/11 (Target)	5yr Target
Milking Platform	93ha	93ha	85ha[1]	85ha[1]	85ha[1]
No of Cows milked	220	220	209	235	240
Production (kgMS)	78,000	90,163	103,000	115,000	135,000
Pasture grown (T/ha)	13.3	13.29	13.62	14	16
Pasture Utilised[2] (T/ha)	9.8	10.7	11.7	-	-
Pasture Utilisation %	74%	81%	85%	-	-

[1] *Milking platform reduced to 85ha to allow all young stock to be grazed on farm*
[2] *Pasture Utilisation calculated using "Pasture Eaten Calculator" (DairyNZ)*
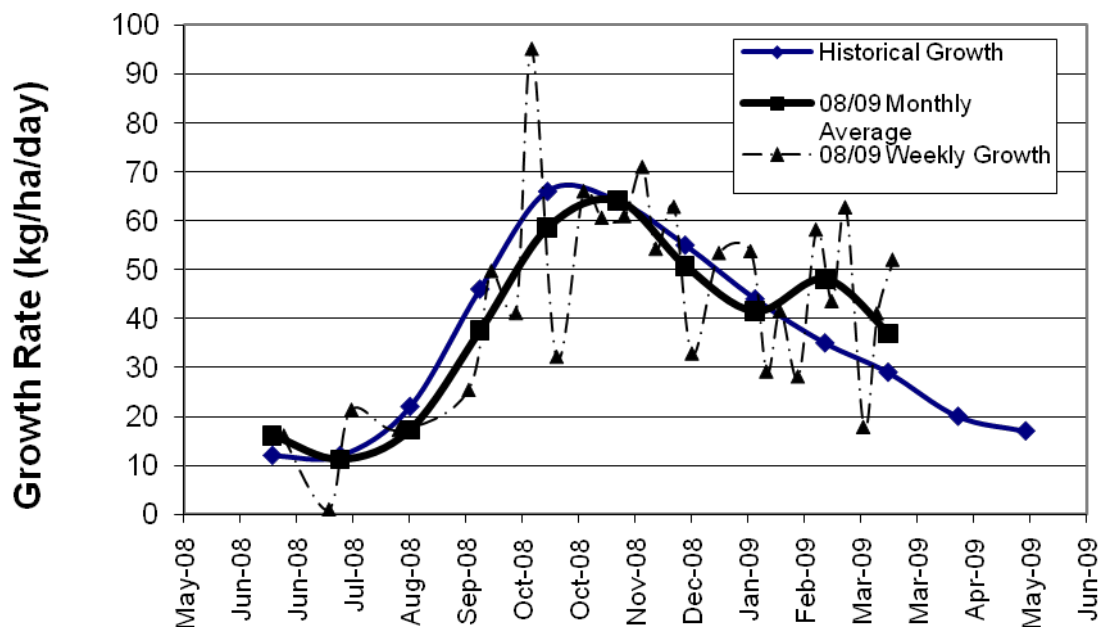

Figure 4 Seasonal pasture growth rates for Niaruo Farms.

CONCLUSIONS

Although the pasture focused KPI's in table 6 are not new, it is only in recent times that NZ farmers have the measurement and reporting tools available to enable them to respond to deviations in their pasture and grazing management plan. As farm management packages become more and more advanced, so to will the measurement devices that provide the relevant data. This provides many challenges for farmers and manufacturers of these solutions. As the complexity of information in the device increases, the ease of use of the equipment must be maintained so it appeals to the mass market.

Pasture measurement has come a long way since the manual plate meter, NZ farmers now have ready access to equipment that can deliver spatially explicit pasture cover information and software that can be used to benchmark farm performance at many different management levels. The case study farm presented in this paper provides an example of how accurate pasture cover information can be used to increase the efficiency of farm production and managerial decision making. The Niaruo Farm has achieved a 9% increase in pasture feed supply to the herd while reducing the milking platform area by 5.4% and using less fertilizer per ha. This has been accomplished with the combination of accurate data and good decision making; these decisions require a robust knowledge of farm performance and a desire to make use of collected pasture cover data.

Significant numbers of C-Dax Pasture Meters have been sold both nationally and internationally and there are many cases of successful integration into geographically diverse farming systems. Many of these successful users have developed benchmarking standards of their own, however the fundamental KPI's remain the same as those presented in table 6. If similar results have been achieved on those farms as Niaruo then the overall impact to New Zealand agriculture is substantial.

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