Case studies which demonstrate the financial viability of precision dairy farming

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Abstract. A number of case studies are used to demonstrate the financial viability of precision farming methods for intensively managed pastures. Precision farming has sometimes been criticized as being technology-led where the management goals and desired outcomes are sometimes poorly defined. Case studies presented in this paper demonstrate a strong management approach where appropriate technologies are selected to contribute to the financial success of the farm. The first case study farm has increased milk production by 70% in four years, increased pasture production by 43%, reduced fertilizer costs to 43% of previous levels and has successfully predicted annual production to within 2 to 3% of actual. A strong emphasis on performance measurement is used to support a four stage management approach which consists of Planning, Measurement, Management and Review. The measurement systems in place inform the management at both strategic and operational levels and include twice daily recording of individual milk production and cow weight. The electronic identification (EID) system has been in place since 1996. The second case study farm has demonstrated similar savings in base fertiliser utilisation but has utilised other additional precision agriculture technologies such as the use of crop sensors and variable rate application of nutrients. Again a strong management focus is given, this time expressed as measure, manage, mitigate. This farming partnership also has a very strong environmental sustainability focus and recently received national recognition as the Supreme Winner of the 2013 New Zealand Ballance Farm Environmental Awards, giving further validation to the idea that precision agriculture is profitable as well as environmentally sustainable. Craige Mackenzie has also invested in precision irrigation, and there is a growing body of evidence to suggest that this method can give significant economic and environmental benefits on intensively managed pastures. Further case studies presenting the advantage of variable rate irrigation are also presented.

Keywords: Precision farming, pastures, dairy farming, fertiliser utilisation.

Introduction

There is growing awareness of the potential for precision dairying to improve profitability and resource use efficiency and reduce environmental impacts from intensively managed pastures. It is often difficult to produce hard evidence of the financial and environmental merits of such systems due to the expense of carrying out long term controlled experiments. However, this paper presents real case study evidence from commercial farms to demonstrate these benefits. The areas considered are:

- Nutrient Use Efficiency;
- Pasture management;
- Individual feeding of dairy cows; and
- Precision Irrigation.

Nutrient Use Efficiency

Fertiliser constitutes one of the major working expenses

Table 1. Fertiliser Sales allocated to the dairy industry in New Zealand, 2012

Fertiliser	Tonnes (000)	Cost NZ($) (million)	Cost/Cow NZ($)	Cost/ha NZ($)
Superphosphate products	603	223	46.31	134.29
Potassium products	106	69	14.35	41.62
Ammonium phosphate (s)	138	124	25.70	74.52
Urea	604	449	93.21	270.30
Magnesium	9	6	1.16	3.35
Total	1,460	871	180.72	524.08

Case studies demonstrate that one of the most cost effective measures farmers can take to reduce fertiliser costs and increase nutrient use efficiency is soil sampling in multiple positions for nutrient testing rather than reliance on a single assessment. This can be executed either through a system of paddock by paddock sampling, illustrated in the case study from Hayden Lawrence (Niaruo Dairies), or grid and zonal sampling demonstrated on-farm by Craige Mackenzie, (Three Spring Dairies Ltd). Although there has been considerable interest in variable rate nitrogen, these case studies would suggest that the biggest initial savings can be made when considering base fertiliser needs. This has the further advantage that no significant technology investment is required. In both cases the farms concerned had a history of regular uniform application of required nutrients; in some areas nutrient levels in the soil were elevated beyond the optimum range and other areas were below that range. This approach allowed the areas of excess nutrient to be mined back down to optimised levels while areas of deficiency could be targeted and dealt with in a cost effective manner.

In the case of Niaruo Dairies, the 85 ha milking platform is subdivided into 46 paddocks and a system of paddock by paddock soil sampling used, the paddocks used for rotational grazing were taken as the smallest unit of management. The work was conducted in cooperation with Ravensdown Fertilisers Coop Ltd. Some areas of the farm were found to have elevated levels of the major nutrients N, P, K and S. In these areas the nutrients have been mined back down to recommended levels. This process has been used for 4 years with an average saving of NZ$160/ha/year. Table 2, contains a summary of costs. The sampling cost of NZ$34/ha is included. Although it is anticipated that the long-term benefit will be reduced once elevated levels of nutrients are addressed, there will still be significant financial gain in using this approach to assess fertiliser needs for individual paddocks. During this 4 year period, pasture production, which was intensively measured on a weekly basis, increased from 12.9 t DM/ha to 18.5 t DM/ha. Milk production per hectare has also increased to just over 1500 kg MS/ha.

Although the spreaders used are GPS enabled, variable rate application is not used within individual paddocks, but is used to automatically spread the correct application rate and product in each paddock. The system also prevents the driver from applying the wrong product in a paddock. The first four years of this programme are detailed in Table 2. The only extra cost has been additional soil sampling, the same spreading contractor who already had the on-board technology was used at no extra cost.

On Three Spring Dairies Ltd, grid and zonal sampling methods have been used on larger paddocks to map nutrient differences. Variable rate applications of base fertilisers and lime have been used, again with significant savings being achieved. Some of the differences arise from paddock amalgamation as well as soil differences and the recognition of effluent spreading areas. Effluent is spread from a centre pivot irrigator over an area larger than the minimum specified. Zonal sampling has been used to differentiate between effluent and non-effluent areas which are in the same paddock, allowing the nutrient value of the effluent to be fully integrated into the fertiliser programme. Three Spring Dairies Ltd have variable rate application capability and effluent areas within the paddock can be eliminated from the bulk fertiliser application. This approach has achieved significant savings of 45% of base fertiliser inputs to the dairy farm in the first year with no apparent loss in productivity. Again the more intensive approach to sampling will continue and fertiliser prescriptions will be prepared for all parts of the farm.

In this case study farm, N in the pasture has also been sensed using a Greenseeker® sensor, vigorous growth under the effluent irrigator is recognised and additional N in the form of urea can be either reduced or eliminated depending on the sensor response and current application plan. This approach gave a 21kg/ha saving for every 70 kg/ha application of urea, on the 300 ha farm. There was an approximate 30% reduction of urea N input Over one season, with five applications of 70 kg/ha, giving a saving of NZ$90/ha.

The Greenseeker sensing was completed and the nutrient requirement map developed prior to the N application. A further advantage of this approach is that the correct amount of fertiliser can be put in the hopper eliminating waste and reducing the temptation to simply double up if fertiliser remains at the end of the job. The Amazone" Hydro Profis" is self-calibrating through on-board weigh cells, has headland control, border spreading and can vary width of spread preventing application overlap reducing the in-field CV of spread. The economic loss of pasture growth from typical "in-field" CV's of conventional spreaders (presently 40%) while spreading N are known to be around NZ$21/ha, reducing the in-field CV to 20% reduces this economic loss to NZ$3/ha per application (Yule and Grafton 2013). This machine combined with the approach of fully utilising the dairy effluent and sensor-informed N application has reduced urea (N) use by 30%. The greater effectiveness of fertiliser utilisation achieved through even spreading has a value of a further NZ$90/ha. Clearly this approach has significant benefits both in terms of reducing the total N application, and making more effective use of effluent and fertiliser, as well as limiting off target and off application rate application. On both farms, the aim is to increase kgs of DM produced per kg of fertiliser input.

Table 2. Cost comparison of blanket application versus the paddock by paddock approach on Niaruo Dairies, (2009 – 2013).

	2009/10	2010/11	2011/12	2012/13
Fertiliser applied using current programme				
Super P (T)	10.31	7.75	2.05	11.73
KCL (T)	5.12	4.1	4.05	6.47
NZ$ Cost	$8,027	$6,251	$4,213	$9,689
NZ$/ha	$94	$74	$50	$114
Fertiliser applied using blanket programme				
NZ$/ha	$279	$279	$279	$279
Less additional costs				
Soil test cost	$34	$34	$34	$34
Annual programme savings				
NZ$/ha	$150	$171	$195	$131
Total Farm	$12,756	$14,532	$16,570	$11,094

Pasture Measurement

In New Zealand dairy systems, pasture is the cheapest source of nutrition for dairy cattle and as a result accurate allocation of pasture is important in ensuring the cow's nutritional needs are met. Niaruo Dairies uses a C-Dax Pasturemeter® to measure pasture covers on a weekly basis, and this is seen as an important part of the farm management process. Weekly pasture covers are used to accurately allocate grazing as well as select timings for paddocks to be locked up for forage conservation or timing of in-season N application. Great care is taken to ensure adequate pasture is budgeted for the cows. Growth rates for the coming week are also projected, based on the growth rate achieved in the previous week and long term local average, however, this is seen as an area which requires improvement. In the four years that this system has been in place the pasture production has increased from 12.9 t DM/ha to 18.6 t DM/ha, pasture utilisation has also improved. This has allowed dry cows to be grazed on the farm rather than grazed for a period off farm which used to be the practice. This has led to a significant saving, as additional feeds such as maize are also now grown on farm. The feed budget is linked to milk production and feed requirements are updated weekly so that these are constantly being re-balanced.

The Pasturemeter data is also used to calculate the annual production from each paddock which allows poorly performing paddocks to be identified. When this is done these paddocks are often used for winter or summer feed crop production and subsequently re-sown into pasture. During this period soil nutrient issues are dealt with if they are found to be limiting growth. When this approach was developed, the average pasture production was 12.9 tonnes, the range was 8 to 18 tonnes. Clearly having the ability to determine productivity allows better informed decisions to be made and the true range of productivity to be recognised. It has also been found that when the pasture has been re-sown significant increases in productivity have been confirmed and maintained with new pasture species due to the high standard of management.

Individual Feeding

The plan, measure, manage, review approach is taken to the management of individual cows on Niaruo Dairies. A walk-over weigh system is used to measure the cow's weight twice a day, any erroneous data is cleaned from the system allowing individual weights to be continuously tracked. Once a cow is in the herd, her condition and productivity is continuously measured. During each lactation her weight is carefully planned and her target weight and body condition score is closely managed. The cows are fed grain in the shed using EID to trigger individual rations based on their peak litres of milk production. The system allows alerts to be quickly put in place if a cow loses weight and/or productivity, she can be drafted for checking. Using this approach the annual production has been predicted to within 2 to 3% of that achieved, this assists in reducing risk and in accurate financial planning.

The weights of the heifers are monitored from the start to ensure large framed, fully developed and productive heifers are brought into the herd. Problems with individuals can be identified early and corrective action taken. Calves are fed on a robotic system.

Precision Irrigation

New Zealand (especially the Canterbury region) is going through a considerable expansion of irrigation with the majority of the land being converted to dairy production. Due to its very low labour requirement and high distribution uniformity, centre pivot irrigation is the preferred option. Traditional centre pivots are however extremely inflexible and a new system called Variable Rate Irrigation (VRI) has been developed. As well as adapting to the water requirement of any area under the irrigator the system gives the user complete flexibility in terms of where and how much water goes on. Exclusion zones can be programmed in and a high level of automation in water application is achieved.

A number of technology platforms have been brought together to enable significant economic savings and improvements in water use efficiency to be made. EM soil mapping has been used in New Zealand since around 2000. Initially the wine and cropping sectors were the main users. Work by Hedley *et al* (2010) demonstrated how the method could be used to assess soil water holding capacity and produce detailed maps of all land areas under an irrigator. This information could be used to derive irrigation scheduling for each point under the irrigator. Around this time a company called Precision Irrigation was working on control methods for irrigation in order to achieve control of individual sprinkler nozzles, when the position of the irrigator is known they were able to control the rate of irrigation at any point. This meant that in any position the irrigator could have nozzles that were applying different rates of water, or were shut off. Shutting off water over race lanes has been found to be very advantageous for cows, reducing the incidence of lameness for example. These advances have meant that centre pivot irrigators have gone from being an extremely inflexible method of water application, to one that offers completely flexibility in irrigation strategy. The irrigator is controlled by a wireless network to give individual control of nozzles, and the system can also be controlled remotely from a smart phone.

Hedley *et al.* (2010) completed a number of case studies which are illustrated in Table 3. These demonstrated the financial and water use efficiency benefits of using this technology in the early days of its development. A further case study demonstrated an overall water saving of 30% under a large irrigator, with reductions of 68% in some areas of the farm. The level of improved water utilisation is site specific but the methods of invest-igation are established to calculate this. Hedley's work did not include the additional benefit from having exclusions zones, it simply looked at the water use in irrigated areas.

Many regions of New Zealand are now fully allocated in terms of freshwater consents, and there is considerable motivation to improve water use efficiency so that a larger area can be irrigated with the same

Table 3. Key Performance Indicators for Water Use Efficiency (WUE) using Variable Rate Irrigation (VRI) (Hedley *et al*. 2010).

Site	Land Use	AWC range (mm)	Irrigation Saved (%)	Drainage & RO saved (%)	Energy saved (kg CO_2/ha/yr)	Reduced N Leaching (kg/N/ha)	Cost saving (NZ$/ha/yr)
Massey	Pasture	77 -132	10	19	27	-	61
Manawatu	Maize Grain	105 - 190	12	22	38	-	86
Manawatu Sand	Maize Grain	85 - 329	21	40	67	0 (22)	150
Canterbury	Pasture	44 - 101	9	55	40	3 (29 - 26)	89
Ohakune	Potato	81 - 186	15	29	30	3 (12 – 9)	68

amount of water. A further capital advantage is that in situations where water shares have to be purchased, this is completed according to water volume, and a 20% saving water can give a significant financial saving. Craige Mackenzie has adapted this technology to a lateral irrigator as well as his centre pivot. This technology is seeing rapid adoption by farmers.

Conclusions

These case studies are intended to illustrate the high levels of improved performance that precision agriculture can bring to the dairy and pastoral industries. Control of our main inputs, fertiliser and water can produce very real savings while increasing yield. This allows much better resource use efficiency which is a key performance indicator for the farmers involved. The assessment of individual paddock or zone base fertiliser needs resulted in large financial savings and farmers are now embracing this approach. N use efficiency can be significantly improved by the use of sensors and the integration of effluent application in the overall nutrient plan and indicated a 30% saving in N applied as Urea.

These case studies demonstrate that precision agriculture is at the leading edge of dairy production and can have a profound influence on productivity, profitability and sustainability. However the most common features are a very strong management focus which harnesses technology where appropriate. Both farmers demonstrate a high level of involvement in the farm and a very high level of knowledge and expertise. Clearly attention to detail (in the form of system measurement) pays dividends.

The case study evidence for VRI has also been consistently positive, each site is different and the benefits will be driven by a number of factors; soil variability being one of them. It is clear that there is scope to significantly increase the productivity of our intensive grazing systems.

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