Pasture utilisation in a pastoral automated milking system

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Abstract
Over the past 5 years a herd of up to 180 cows has been milked by two automated milking systems (AMS) at the Greenfield Project research farm near Hamilton. The performance parameters pertaining to pasture management and pasture utilisation during the 2004/05 season are described. The 54 ha farm had an estimated net pasture accumulation of 16.2 t DM/ha/yr. The estimated pasture consumption was determined using back calculations to be 12.3 t DM/ha/yr resulting in an estimated efficiency of pasture utilisation of 76% (based on consumed vs. net accumulation). The data presented suggest that it is possible to achieve satisfactory pasture intakes, pasture utilisation and to be able to maintain pasture quality with automatic milking in a low-input, pasture-based system.
Keywords: automatic milking, grazing, pasture management, pasture utilisation

Introduction
In New Zealand dairying there is a trend towards larger farms with larger herds and a changing farm ownership structure resulting in more reliance on employed labour (Tipples *et al.* 2004; LIC Stats 2005). When combined with a declining labour pool and the work and lifestyle constraints imposed by fixed-time milk harvesting, this gives rise to a sustainability issue for the New Zealand dairy industry. At the 2001 census, 26,331 people were employed as dairy farmers/dairy farm workers, most of whom are required to milk approximately 4 million cows as part of their daily routine. Data from the 2004/05 Economic Farm Survey show that labour, including unpaid and management labour, is the largest single expense on dairy farms (Dexcel 2006), at a cost of $1.04/kg MS. Labour is expected to become scarcer and more costly as a result of the changing demographics of dairy farmers and the declining labour pool (Tipples *et al*. 2004).

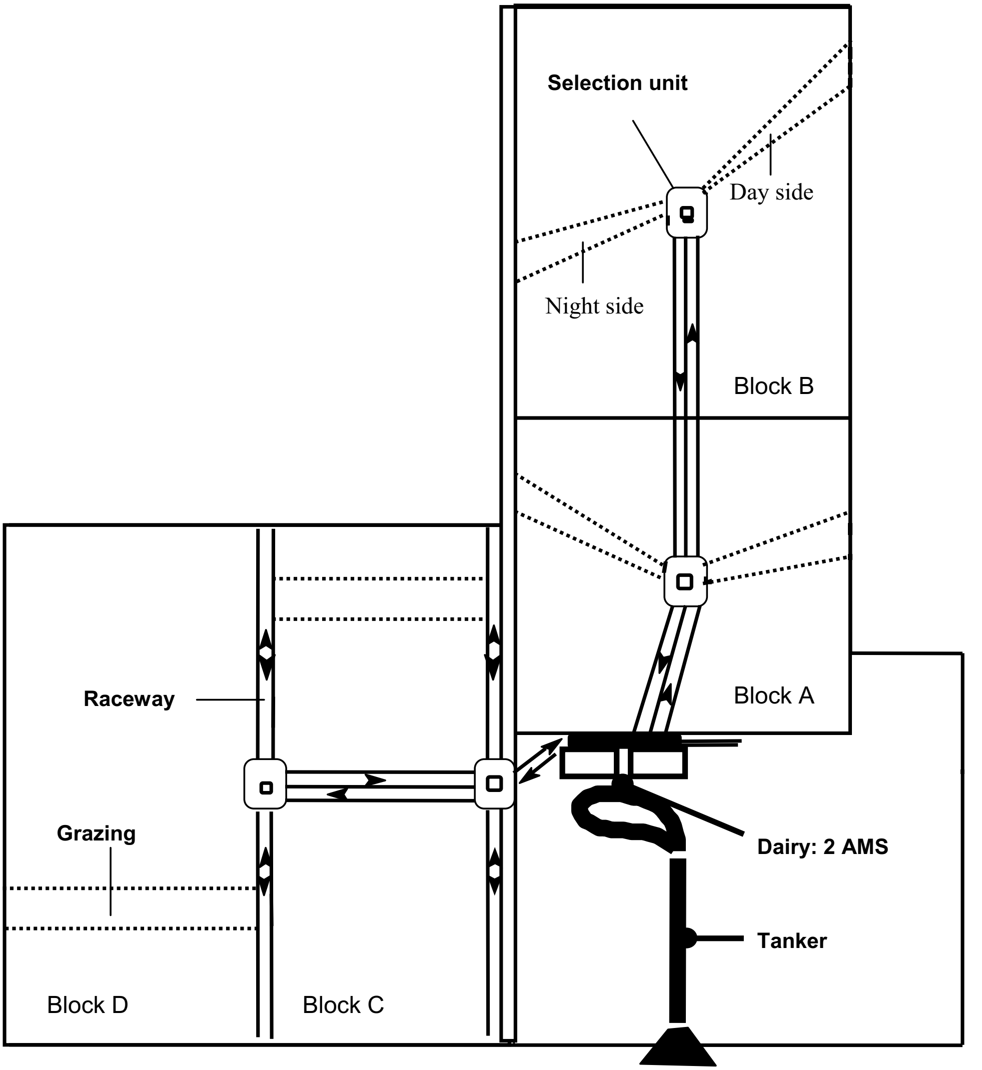
The concept of automatic milking is well-proven in intensive indoor dairying systems. Adoption of the technology has been such that automatic milking is now being used on over 2500 commercial dairy farms in over 20 countries worldwide (de Koning & Rodenburg 2004). These farms are predominantly indoor systems with cows housed for all or most of the year. However, there is interest in determining ways of incorporating fully automated milking systems (AMS) into pasture-based farming (Ketelaar-de Lauwere & Ipema 2000a, b; Salomonsson & Sporndly 2000; Van Dooren *et al*. 2002) with most work focussing on cow traffic between pasture and the dairy and resultant milking frequencies.

New Zealand dairy farming systems are traditionally pasture based with cows grazing pasture year-round. Whilst the number of New Zealand dairy farms using large amounts of bought in feed have increased dramatically over the past 10 years, most still rely on pasture as the main energy source for milk production. Data from the 2004/05 Economic Farm survey show that, on average, 8.0% of total feed is brought in as supplement with a further 5% sourced from crop, hay or maize grown on farm, indicating that New Zealand farms are still predominantly pasture-based.

For automatic milking to be considered a viable option in the NZ dairy industry it is imperative that the system can accommodate low levels of bought in feed and high levels of pasture utilisation. Since 2001 pastured cows have been milked in a voluntary and distributed (throughout each 24 hour period rather than batch milked) manner initially through one and now two automatic milking units at Dexcel's Greenfield Farm, Hamilton. The objective of the 2004/05 season on the Greenfield research farm was to determine the key performance indicators, of which pasture management was a major focus. During this period, the farm and herd size were held stable after 3 years of development and size increases. This paper describes the performance parameters pertaining to pasture management, pasture utilisation and pasture quality. The practical feasibility, focussing on cows ability to learn to milk voluntarily (Jago *et al*. 2004; Woolford *et al*. 2004) and the projected economic viability (Jago *et al*. 2006), of the Greenfield farm have been reported elsewhere.

Methods
Data were collected throughout the 2004/05 production season (1 June 2004 – 31 May 2005). The total herd size peaked at 179 (mixed age, mixed breed; Fr, J and FrxJ) cows, 30 of which calved in autumn 2004 and the remainder in spring 2004. All cows were mated in late 2005 to provide a seasonal spring calving pattern for 2005/06 with no autumn calving cows.

Figure 1 Greenfield milking platform layout showing dairy with two AMS units, raceways (multi and single direction) and selection units for automatic diversion either to the dairy for milking or to the grazing areas (dashed lines).



Pasture management and farm configuration

The farm had a milking platform of 43 ha and a run-off of 11 ha that was used as a dry cow/young stock grazing area. The farm configuration was such that non-lactating stock were able to graze on the milking platform but milking stock were not able to graze the run-off area. The milking platform (Fig. 1) consisted of four blocks of pasture (ranging from 9.2 to 12.7 ha) with limited or no internal fencing. A rotational grazing system was used, based on strip grazing of each block using temporary and back fencing. However, on occasions cow traffic and/or pasture allowances resulted in undesirably high post-grazing residuals. In these instances the size of the next strip was reduced with no back fence to allow cows to regraze the high residual strip.

The farm had a total annual application of 213 kg N/ha/yr (five applications in the form of urea). Potash was applied to the whole farm at a rate of 177 kg/ha in October and a fertiliser blend (89.91% Super Ten, 6.99% Calmag, 3.00% Durasul Sulphur and 0.1% Selenium Ultra) was applied in March/April 2005 at a rate of 670 kg/ha.

The system hardware consisted of a selection unit (SU) made of a concrete base and pipe rails, allocated to each of the four blocks of pasture (Jago *et al*. 2002; Jago *et al*. 2004). The grazing system used two areas of pasture, one on the day side and one on the night side of a block at any one time. On presentation at the exit gates of the SU, a cow was either directed along the race to the dairy if due for milking, or released to pasture, via computer-controlled gates. The SU were used to restrict access to the AMS based on expected yield and production rate criteria set within the AMS software. The herd had a targeted average milking interval of approximately 18.5 h in keeping with maximising milk output by having a high ratio of cows to AMS (90 cows/AMS compared to commonly reported 30-60 cows/AMS). The direction of cow traffic (to day-side or to night-side) was reversed twice every 24 h at 8:00 h and 20:00 h. At 08:00 h any cows that had not voluntarily moved out of the paddock on the day side were moved into the SU while cows returning from the AMS, or diverted "to paddock" when exiting the SU, began to enter a new area of pasture on the day side. Similarly, at 16:00 h, any cows remaining on the night side were moved to the SU and, from 20:00 h onwards, cows returning from the AMS or diverted "to paddock" when exiting the SU began to enter a new area of pasture on the night side.

Pasture data collection

Pasture mass was estimated by visual assessment on a weekly basis. Estimated net herbage accumulation was calculated weekly from the increase in pasture mass on ungrazed paddocks.

Pasture chemical composition was not assessed in the 2004/05 season. From November 2005 to March 2006, pasture samples were collected monthly by hand clipping to grazing height from areas about to be grazed. These were oven dried at 60°C, ground and analysed for chemical composition by NIRS (Ulyatt *et al*. 1995).

Pasture intake calculations

Estimated pasture consumption was determined using back calculations (sourced from I. Brooks, Massey University and P. Hedley, Dexcel Ltd). Calculations were based on an estimated average cow liveweight (LWT) of 455 kg. The herd was 60% Friesian (Fr), 12% Friesian x Jersey (FrxJ) and 20% Jersey (J). The milk production level was calculated using kg milk recorded by the AMS software (Crystal® 1.40, Fullwood Fusion, Holland) and average percent milksolids recorded by the factory. There were also 12 rising 1-year-old heifers and 12 rising 2-year-olds grazed on the dry cow/young stock area. The equations used were as follows:

Maintenance = $(LWT^{0.75})$*0.483*DIM*((((11-Ave MJ ME of feed offered)/1)*0.286)+1)

Pregnancy Requirements = 2222 MJ ME (Fr), 1947 MJ ME (FrxJ), 1672 MJ ME (J).

Milk Production = (Total MS*(68 Fr; 67 FrxJ; 65 J)*1.1) *((((11-Ave MJ ME of feed offered)/ 1)*0.0334)+1).

Walking Energy = ((Ave distance walked per day * 0.0036 * cow LWT) + (average vertical height between farm dairy and hill paddocks in metres/1000 * cow LWT * 0.039)) * ((((11.0 – the Ave MJ ME of feed offered)/ 1) * 0.0286) + 1) * (0.6 for milking frequency of 1.17) * DIM/cow.

Total energy per cow including cost of grazing = (Maintenance + Pregnancy + Milk Production + Walking Energy) * (1 + (0.038 * (1 + ((11.0 – the ave MJ ME of feed offered) * 0.14)))).

(Abbreviations: Ave = average, LWT = liveweight, MJ ME = megajoules of metabolisable energy, Fr = Friesian, J = Jersey).

Results

The 54 ha farm had a net pasture accumulation of 16,187 kg DM/ha/yr (Fig. 2, total 874.1 t DM/yr). In addition there was 24.4 t DM bought onto the farm in the form of crushed barley/wheat, resulting in a total feed availability of 898.5 t DM. Grazing rotations ranged from 113 days in winter to 14 days through early November 2004.

Surplus pasture was harvested as baled and pit silage

Figure 2 Average monthly estimated net pasture accumulation (kg DM/ha/day) for 2004/05 season on Greenfield farm.

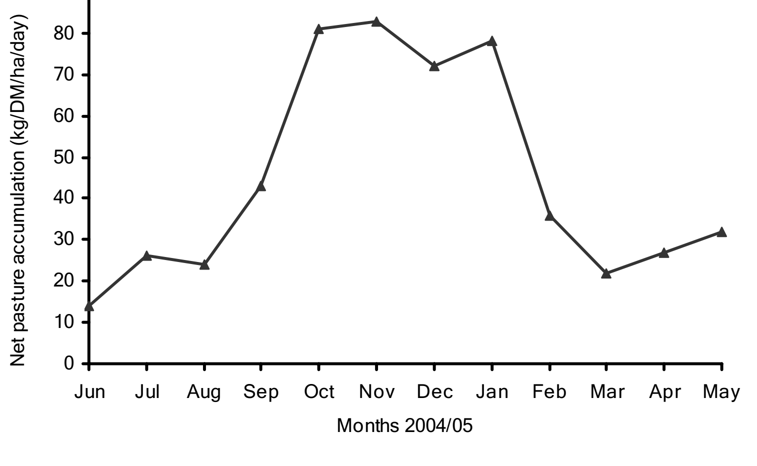


Table 1 Stocking rate, average lactation length, average milk production, estimated net herbage accumulation and pasture consumption levels for season 2004/05 on the Greenfield farm.

	2004/05
Stocking rate (cows/ha)	3.31
Comparative stocking rate (kg LWT/t DM)	96.5
Average lactation length (days)	274
Average annual milk production (kg MS/cow)	281
Average annual milk production (kg MS/ha, all)	936
Average annual milk production (kg MS/ha milking platform only)	1170
Net herbage accumulation (kg DM/ha/year)	16187
Pasture consumption (kg DM/ha/yr)	12272
Pasture consumption (MJ ME/ha/yr)	140637
Pasture consumption (MJ ME/cow/yr)	40484

and was fed back to the cows during periods of pasture deficit. The net accumulation of supplements from 1 June 2004 to 31 May 2005 was zero. No topping was carried out.

The estimated annual energy consumption was 7,278,904 MJ ME. Four percent of this was provided in the form of crushed wheat/barley fed in the bail during milking (24.4 t DM x 12.5 MJ ME/kg DM). Assuming an average metabolisable energy for pasture of 11.0 MJ ME/kg DM, the estimated pasture consumption level was 12,272 kg DM/ha/yr. Expressed as a proportion of the estimated net pasture accumulated, the pasture utilisation rate was 76%.

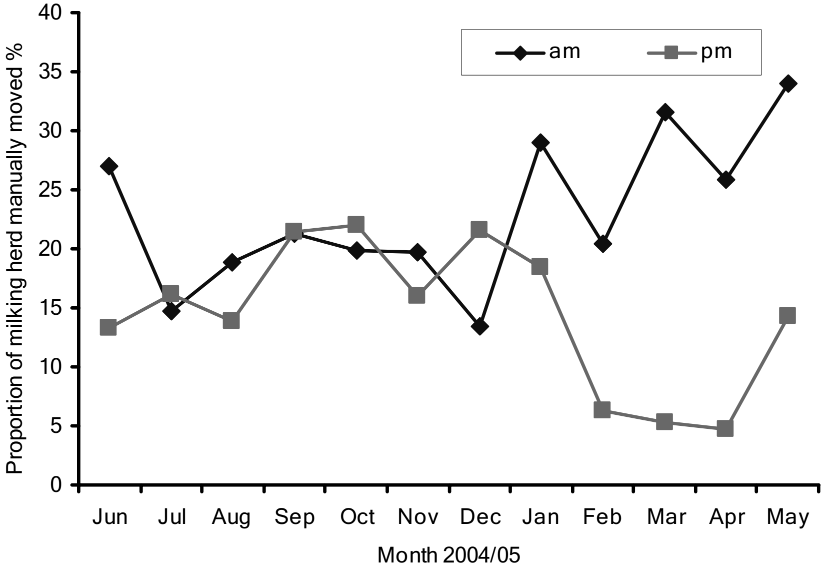
Pasture quality measurements (taken in the 2005/06 season) indicated this was adequate for milking cows, with average ME levels of 11.3 MJ/kg DM, average crude protein of 20.4% of DM, and average organic matter digestibility of 75.6%. Acid detergent fibre and neutral detergent fibre averaged 26.3% and 53.9%, respectively.

Table 1 details the stocking rate and milk and pasture production/utilisation during the 2004/05 season. Whilst the targeted average milking interval was 18.5 h (1.3 milkings/cow/day), the actual annual average milking interval was 20.8 h (1.1 milkings/cow/day). The proportion of the herd that remained in the paddock at 08:00 h (end of day paddock grazing allocation) or 16:00 h (end of night paddock grazing allocation) and had to be moved out ranged from 12-22% from July to December. This changed markedly after that period with a lower proportion of the herd requiring manual movement following the daytime grazing than following the overnight grazing (Fig. 3).

Discussion

Automating milking in a pastoral dairying system is a new concept that presents many challenges to traditional farming methods. Current dairy farm systems in New

Figure 3 Monthly average proportion of milking herd manually moved off the break at the end of the allocated grazing period at 08:00h and 16:00h for 2004/05 season on the Greenfield farm.



Zealand are based upon high levels of pasture utilisation and maintaining pasture quality. The efficiency of pasture utilisation of 0.76 reported here is comparable with 0.70 and 0.72 for farmlets stocked at 76 and 90 kg LWT/t DM, respectively (Macdonald *et al.* 2001). This indicates that voluntary movement on the automated milking farm does not appear to have negatively compromised the efficiency of pasture utilisation, although the higher stocking rate for the Greenfield farm may have assisted in achieving this result. Pasture quality, in the year after pasture utilisation efficiency was estimated, was at the lower end of that reported by Macdonald *et al*. (2001) for farmlets of increasing target stocking rate, although it is still considered to be of an acceptable level. The fact that no topping was required also indicates that pasture quality was able to be managed through grazing pressure.

An essential element of a 24 h milking system is achieving distributed and voluntary movement of cows from the pasture area to the dairy. There are many factors that affect the level of voluntary movement, including stage of lactation (Jago *et al*. 2006), climatic conditions, individual cow experience (J. Jago, unpublished data), location and timing of availability of feed (Jago *et al.* 2004) and water incentives in the system and pasture allowance. Whilst it is difficult to quantify the impact of pasture allowance on cow movement patterns, it has been observed that a low pasture allowance generally results in fewer cows requiring manual movement from allocated grazing areas than when grazing a higher pasture allowance. While the goal is not to have to manually move any cows from the pasture area following a grazing allocation, the time required to do this was not great since it was done at the same time as gates were changed to control the direction of cow flow to fresh grass.

One of the key approaches to incorporating automatic milking technology within low input pastoral systems is to maximise milk output by increasing the ratio of cows per AMS above those typical for international AMS operations. To minimise per cow production losses known to result from extended milking intervals such as once daily milking (Clark *et al.* 2006), the targeted average milking interval for the Greenfield herd was approximately 18 hours (with an average milking frequency of 1.3 milkings/cow/day). The actual average milking frequency ranged from 17.4 to 23.5 h on a monthly basis with an overall annual average interval of 20.8 h (1.1 milkings/cow/day). The level of per cow production (281 kg MS/ha) was 12% higher than the 4-year average production levels reported by Clark *et al*. (2006) for Friesian cows milked once-a-day (252 kg MS/cow) reflecting the 20.8 h average milking interval. Similarly, production of 936 kg MS/ha (1176 kg MS/effective ha) was slightly higher than the 882 kg MS/ha reported for the once-a-day milking trial. Improving production performance will require a shorter milking interval than achieved in the 2004/05 season. A greater understanding of the interactions between pasture availability, time since last milking and cow movement patterns is required.

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REFERENCES

Clark, D.A.; Phyn, C.V.C.; Tong, M.J.; Collis, S.J.; Dalley, D.E. 2006. A systems comparison of once- versus twice-daily milking of pastured dairy cows. *Journal of Dairy Science 89*: 1854-1862.

de Koning, K.; Rodenburg, J. 2004. Automatic milking: State of the art in Europe and North America. pp 27-37 *In*: Automatic Milking: A better understanding. Eds. Meijering, A.; Hogeveen, H.; de Koning C.J.A.M., Wageningen Academic Publishers.

Dexcel Ltd. 2006. Economic survey of New Zealand dairy farmers, 2004-2005. Hamilton.

Jago, J.; Copeman, P.; Bright, K.; McLean, D.; Ohnstad, I.; Woolford, M. 2002. An innovative farm system combining automated milking with grazing. *Proceedings of the New Zealand Society of Animal Production 62*: 115-119.

Jago, J.; Bright, K.; Copeman, P.; Davis, K.; Jackson, A.; Ohnstad, I.; Wieliczko, R.; Woolford, M. 2004. Remote automatic selection of cows for milking in a pasture-based milking system. *Proceedings of the New Zealand Society of Animal Production 64*: 241-245 .

Jago, J.; Davis, K.; Newman, M.; Woolford, M. 2006. An economic evaluation of automatic milking for New Zealand dairy farms. *Proceedings of the New Zealand Society of Animal Production 66*: 263-269.

Ketelaar-de Lauwere, C.C.; Ipema, A.H. 2000a. Cow behaviour and welfare if grazing is combined with voluntary automatic milking. pp. 289-296. *In*: Proceedings of the International Symposium on Robotic Milking, The Netherlands, 17-19 August.

Ketelaar-de Lauwere, C.C.; Ipema, A.H.; Lokhorst, C.; Metz, J.H.M.; Noordhuizen, J.P.T.M.; Schouten, W.G.P.; Smits, A.C. 2000b. Effect of sward height and distance between pasture and barn on cows' visits to an automatic milking system and other behaviour. *Livestock Production Science 65*: 131-142.

Macdonald, K.A.; Penno, J.W.; Nicholas, P.K.; Lile, J.A.; Coulter, M.; Lancaster, J.A.S. 2001. Farm systems – impact of stocking rate on dairy farm efficiency. *Proceedings of the New Zealand Grassland Association 63*: 223-227.

Salomonsson, M.; Sporndly, E. 2000. Cow behaviour at pasture with or without supplementary roughage in automatic milking systems. pp 192-193 *In*: Proceedings of the International Symposium on Robotic Milking, Lelystad, The Netherlands, 17-19 August.

Tipples, R.; Wilson, J.; Edkins, R. 2004: Future Dairy Farm Employment. A report prepared for Dairy Insight as Project 10015/2003. pp115.

Ulyatt, M.J.; Lee, J.; Corson, D. 1995. Assessing feed quality. *Proceedings of the Ruakura Farmers' Conference 47*: 59-62.

Van Dooren, H. J.; Sporndly, E.; Wiktorsson, H. 2002. Automatic milking and grazing, applied grazing strategies, EU report, www.automaticmilking.nl

Woolford, M.; Claycomb, R.; Jago, J.; Davis, K.; Ohnstad, I.; Wieliczko, R.; Copeman, P.; Bright, K. 2004. Automatic dairy farming in New Zealand using extensive grazing systems. pp 280-285. *In*: Proceedings of the International Symposium on Automatic Milking, Lelystad, The Netherlands.