Gaps and variability in pasture utilisation in Australian pasture-based dairy systems

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Abstract. We used commercial farm data from 4 states of Australia and 9 subsets of data from 4 whole farm system studies conducted in Australia and New Zealand to: (1) explore the relationship between pasture utilisation and farm profitability; (2) identify gaps and causes of both between and within-farm variability in pasture utilisation; and (3) discuss possibilities to reduce these gaps through the application of technology-based solutions. Results confirm that the amount of pasture utilised per ha is a key driver of profitability of Australian pasture-based systems. In spite of this, the gap between potential (research) and commercial reality is huge. Data from whole farm system studies in which the same grazing management rules were applied show a relatively large variability in between-paddock, within-farm (*i.e.* system study in this case) pasture utilisation. The level of variability among datasets was similar, but was higher for systems associated with more variation in water availability compared to fully irrigated systems or studies conducted in high rainfall areas. Factors that can explain within farm variability include differential management of inputs and grazing, even when the 'same' management rules are applied. Given the demonstrated importance of pasture utilisation in profitability of the dairy farms, the key challenge for Australian dairy farmers is to seriously reduce variability in pasture utilisation and pasture wastage. The advancements of automation in agriculture provide new frontiers to assist farmers in reducing variability and gaps in pasture utilisation.

Keywords: Pasture utilisation, farm profitability, technology based solutions, dairy systems.

Introduction

Over 75% of the dairy farms in Australia are pasture-based systems, in which cows graze pasture (including annual pastures, perennial pastures; and/or grazable forage crops) all-year round and are supplemented with low to moderate levels of concentrate and fodders. This reliance on grazed pasture and forages as the main feed source for cows is associated with low-cost milk production, as almost half of the national milk is exported and therefore milk price at farm gate is largely influenced by international prices of commodities.

At an industry level, the link between pasture and cost of production is clearly evidenced by the lower cost of production in countries that produce milk predominantly from pasture-based systems (*e.g.* Australia, New Zealand, Argentina, Uruguay, Chile, Ireland) compared to those that produce milk predominantly from confined systems (*e.g.* USA, Canada and most countries in the European Union) (Hemne 2010). At farm level, however, the relationship between pasture as the key feed source for cows and profitability of the business is commonly assumed but has been less unequivocally evidenced. A recent study (Hauser and Lane 2013) demonstrated a direct reduction in variable costs/kg milk solids produced by Victorian dairy farms as proportion of pasture in the diet increases. However, cost of production is only one part of the profitability equation and sometimes the benefits of producing milk at lower cost through increased proportions of pasture in the diet can be offset by the lower milk yield achieved by those cows, compared with cows fed on total or partial mixed rations (Bargo *et al.* 2002). From a whole system-viewpoint most farms are constrained by land availability, thus if pasture is the cheapest feed source, the more pasture converted into milk per unit of area the higher the chances should be to have a more profitable system. This does not imply that cows must necessarily have a larger proportion of pasture in the diet but rather that the system should convert relatively larger volumes of pasture into milk. The annual amount of pasture harvested (consumed) per ha and converted into milk is the applied definition of pasture utilisation (Garcia and Fulkerson 2005).

In this paper, we combine information from previous studies in Australia with original analyses of commercial farm data from Victoria, Tasmania, South Australia and Western Australia and data from 4 whole farm system studies to: (1) explore the relationship between pasture utilisation and farm profitability; (2) identify gaps and causes of between and within-farm variability in pasture utilisation; and (3) discuss possibilities to reduce these gaps and variability in pasture utilisation through the application of technology-based solutions.

What is known about pasture utilisation on Australian dairy farms

There are several key facts about pasture utilisation in Australian dairy farms that are known from previous research.

First, pasture utilisation in Australia is relatively low with dairy farms in Victoria (mostly based on perennial ryegrass) utilising only ~7 t DM/ha (DIFMP 2012) and those in Queensland (mostly based on kikuyu and annual forage crops) utilising only ~3-4 t DM/ha (Chataway *et al.* 2010; Garcia *et al.* 2013).

Second, these levels of pasture utilisation are well below demonstrated potential. In a recent review that explored the potential of kikuyu (*Pennisetum clandestinum*) for milk production, Garcia *et al*. (2013) brought together Australian and overseas data and demonstrated that the gap between pasture utilisation achieved on whole system studies (research) and commercial farms is literally huge. Based on published data, these authors indicated maximum realistic annual yields of 20-25 t DM/ha for perennial ryegrass (*Lolium perenne*) and 25-30 tDM/ha for kikuyu, thus the gap between research potential and commercial reality varies between 12-14 and 22-25 t DM/ha for ryegrass and kikuyu, respectively (Garcia *et al.* 2013).

Third, contrary to common belief, the level of pasture utilisation is unrelated to type of production (feeding) system. This was clearly shown by the Dairy Australia's study TasMilk60 (Dairy Australia 2011), in which physical and economic data from 60 farms across different feeding systems varying substantially in the amount of grain fed/cow (low, <1 t; medium, 1to 2 t; and high, >2 t) were collected over 3 years. The analysis showed that the median amounts of pasture used were similar across all 3 groups and years. Similarly, Farina *et al*. (2011b) in a FutureDairy's whole farm system study at Camden, NSW, compared 4 contrasting systems with 2 stocking rates and 2 levels of milk production per cow over 2 years and achieved very similar levels of pasture utilisation across all 4 systems, despite level of concentrate per cow varying from 1 to ~3 t/year.

Fourth, pasture utilisation level varies widely in any feeding system. This again was shown by the TasMilk60 study, as pasture utilisation for farms within each of the 3 groups of concentrate level (<1, 1 to 2 and >2 t/cow) ranged between ~5 and ~15 t DM/year.

What is less known about pasture utilisation in Australia dairy farms

In spite of the above facts and the recognition of pasture management as a 'key profit driver in all pasture-based feeding systems' (Dairy Australia 2011), the relationships between pasture utilisation and profitability, as well as between and within farm variability in pasture utilisation remain unclear. In this section we analyse data from commercial farms and whole-farm system studies to further explore some of these relationships.

Variability in pasture utilisation between-farms

The relationship between pasture utilisation and profitability at the farm level must be strongly demonstrated for the industry to retain its key competitive advantage of being predominantly pasture-based. Profitability of a dairy farm is logically multifactorial but if pasture is truly the least expensive feed, then farms that achieve highest profitability should be, in general, the same farms that achieve higher levels of pasture utilisation. To some extent, the TasMilk60 study showed this, as pasture utilisation had the greatest impact on profit variability at practically all levels of concentrate fed (low, moderate or high). However, this study also found relatively low repeatability in profitability between farms (i.e. farms that achieved high profitability one year did not necessarily achieve high profitability on another year), although the linkage between profit repeatability and variability in pasture utilisation cannot be established from the written report. A more recent report commissioned by Dairy Australia (Hauser and Lane 2013) found that variable costs per kg of milk solids (MS) decreased and operating margin increased as the proportion of pasture in the diet of cows increased. However, the relationship with return on capital and total assets was more variable, with individual farms achieving poor and good economic performance along the whole range (<40% to >80%) of dietary proportion of pasture.

To further evaluate the relationship between pasture utilisation and profitability, we used data from dairy farms monitored regularly by RedSky. The dataset comprised physical and economic information from over 100 dairy farms in Victoria, Tasmania and South Australia for the period 2003 to 2010 (although not all farms were present on all years). This period includes high and low milk prices. All individual farms were classified by economic performance (operating profit, in $/ha). On each year, farms within the top 10% (or 15% for years with less data) of annual operating profit were grouped and their average physical and economic performance compared to the averages of the whole dataset (i.e. including top 10/15%). Mean operating profit across all years was 2 times higher for the top farms (AU$1821.3/ha) than the average of the whole dataset (AU$871.6/ha).

To make all physical and economic data comparable on the same scale, results are presented as the mean for Top farms relative to the Average farm (average farm=mean value of whole dataset, including data from top farms). Physical and economic variables were grouped according to the magnitude of the difference between top and average farms, into similar (within ± 5%, Fig. 1a), greater (>10%, Fig. 1b) or lower (<10%, Fig. 1c) than the respective mean value for the whole dataset.

Overall, compared with the average farm, top performing farms (higher operating profit) were similar (within 5% of average farm) in total effective area, milk price, proportion of pasture and concentrate in the diet of cows, concentrate intake, milk yield/cow and pasture intake per cow (Fig. 1a).

Conversely, top farms had 17% more cows, 18% higher stocking rate, utilised 24 % more pasture/ha, applied 30% more nitrogen/ha and produced 24% more milk/ha than the average farm (Fig. 1b).

As expected, the variables for which the average of top farms were lower than the average of the whole dataset, were predominantly associated with costs, with the exception of forage intake per cow. Total pasture costs (including capital, direct and variable costs) for top farms were ~86% of the cost for the average farm. Similarly, total feed and supplement costs were 92 and 96% of the average of whole dataset. Feed conversion efficiency, expressed as kg DM/kg MS, was also lower for the top farms (96% of average farm), indicating a slightly higher efficiency for top farms (Fig. 1c).

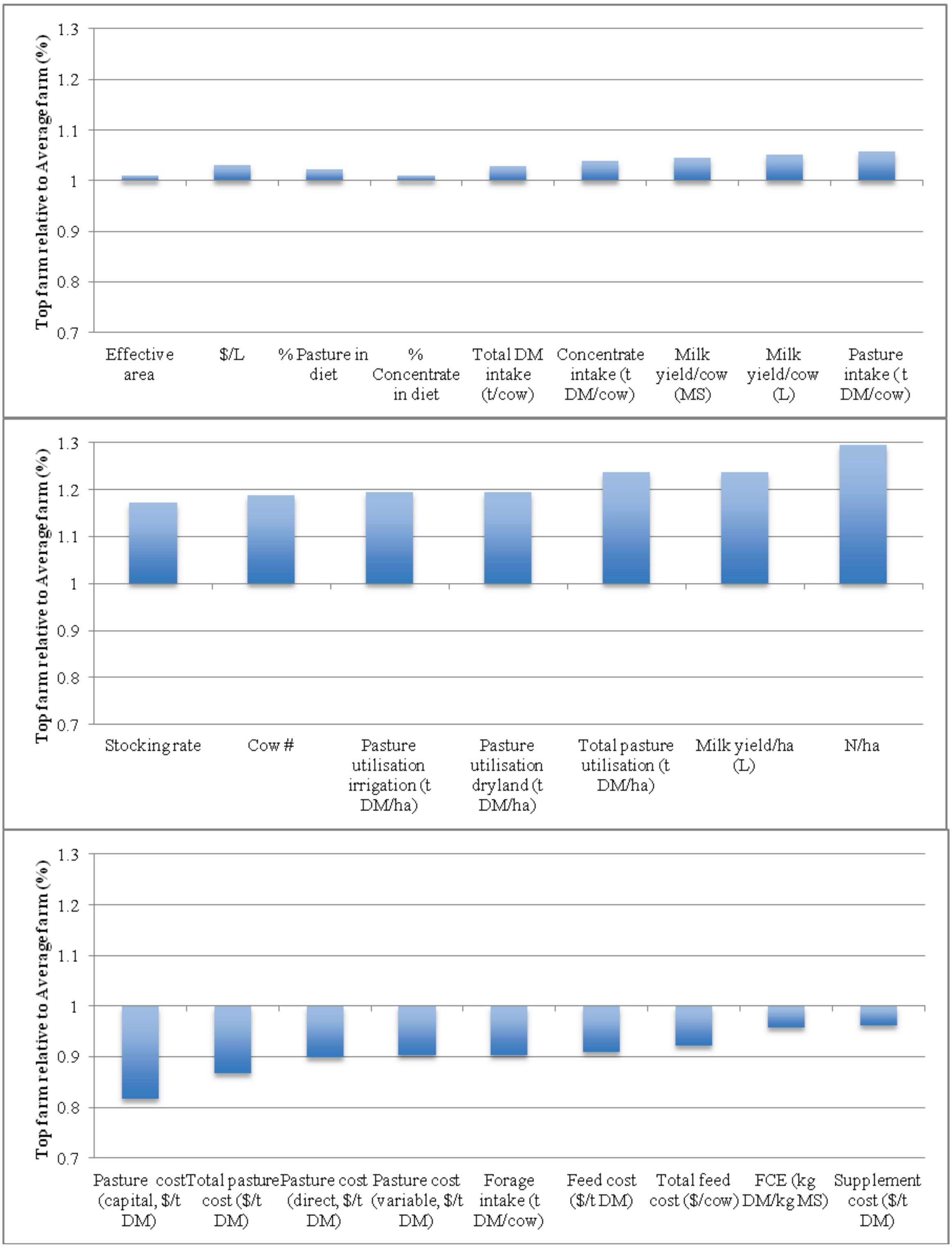

Figure 1. Mean value for Top farms relative to mean value for Average farm (*i.e.* whole dataset AU$). Variables were grouped according to the magnitude of the relative difference into similar (within ± 5%, top graph 'a'), greater (>10%, middle graph 'b') or lower (<10%, bottom graph 'c') than the respective mean value for the whole dataset.

Average pasture utilisation across the whole dataset was 7.2 t DM/ha, remarkably similar to the 7 t DM/ha reported for Victorian farms by the Dairy Industry Farm Monitor project (DIFMP 2012). All together this analysis verifies the relatively low level of pasture utilisation achieved by Australian farms and highlights the importance of pasture utilisation as a key driver of profitability on pasture-based dairy systems.

Pasture utilisation and stocking rate

The analysis of RedSky data suggests that top performing farms in southern Australia have increased pasture utilisation mostly through higher stocking rates rather than by increasing pasture consumption per cow, as indicated by the similar proportion of pasture and concentrate in the diet of cows in both groups.

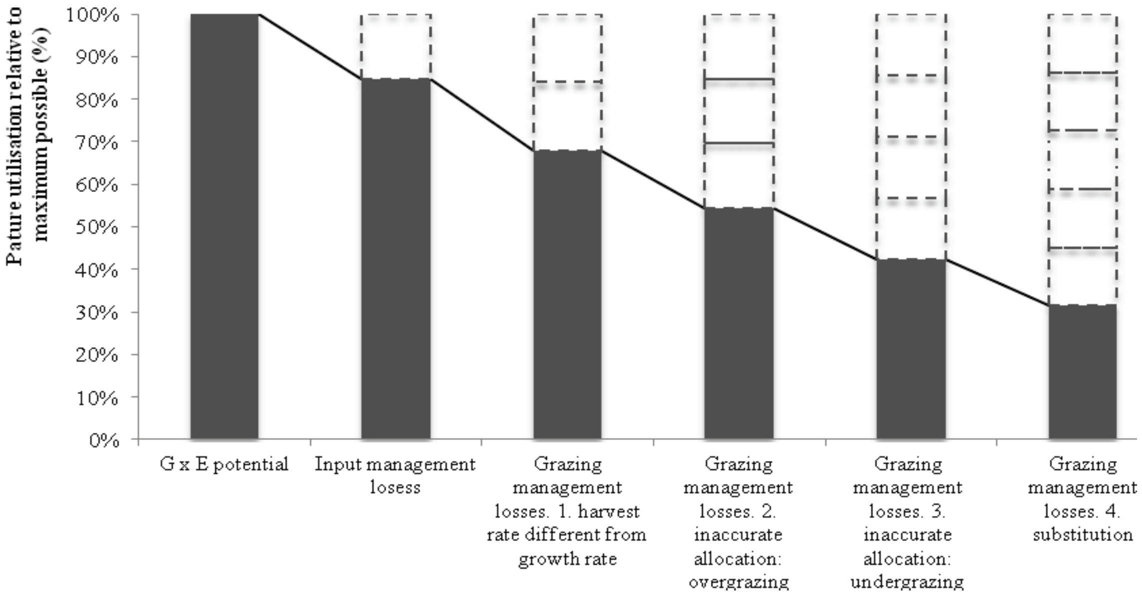

Figure 2. A conceptual model to explain individual and/or cumulative losses in pasture utilisation. For illustrative purposes and due to the lack of data to quantify these losses properly, they are assumed to be all of equal magnitude (from Garcia *et al*. 2013).

Increasing stocking rate is in fact key to increasing pasture utilisation on farms that are well below potential, but it is not, *per se*, the whole solution to reduce gaps in pasture utilisation. Garcia *et al*. (2013) re-arranged data from whole farm system studies compiled by (Fariña 2010) and showed that the increase in pasture utilisation with increases in stocking rate diminishes as basal stocking rate increases. In other words, increased pasture utilisation due to increased stocking rate can occur up to about a point in which the rate of pasture demand matches or exceeds the rate of pasture growth (Garcia *et al*. 2013). When this point is reached it is implied that stocking rate is high enough to generate sufficient demand of pasture/ha; thus further increases in stocking rate should not affect, *per se*, pasture utilisation, although clearly adequate pasture and supplementary feed management would have to be implemented (Fariña *et al.* 2011b).

Where are the losses in pasture utilisation?

Garcia *et al*. (2013) proposed a simple conceptual model of pasture wastage in which losses in pasture utilisation can be grouped within inadequate management of either inputs, grazing or both. This model is schematically shown in Figure 2. In this graph the potential of pasture utilisation is represented by the maximum possible net growth (*i.e.* utilised pasture) that can be achieved by a given genotype (G) in a given environment (E). In other words, this potential represents the true realistic potential of pasture grown as determined –for each genotype- by those factors that cannot be readily manipulated (*i.e*. radiation and temperature and to some extent, soil type).

Garcia *et al*. (2013) explained each of the above levels of pasture losses in some detail. For the purpose of present work, the conceptual model of Figure 2 implies that different level of losses occur due to lack of adequate level and management of key inputs (particularly nitrogen and water), which reduced growth; and due to lack of adequate grazing (and cow feeding) management, which reduce both growth (*e.g.* through overgrazing) and utilisation (*e.g.* by losing material due to excessive rate of senescence).

It is implicit in the graph shown in Figure 2 that each level of pasture loss contributes with a similar amount of pasture wastage. This is of course an oversimplification due to several reasons. First, no data are available to truly account for each level of losses. Second, even if some losses could be quantified, it would be impossible to truly represent the complex matrix of cases given by the interactions of pasture types and species, regions, climates and management. Third, it was not the intention of the review in which this model was proposed to quantify variability associated with each or at least some, losses.

Within-farm variability in pasture utilisation

A generalised quantification of losses across different farms is not possible, as it would require data being collected at paddock level from each individual farm over several years, including specific aspects of pasture and feeding management.

However, whole-farm system studies that have been conducted over several years can provide insight into some key relationships. We selected 3 whole-farm system studies conducted in Australia and 1 in New Zealand that shared commonalities in pasture management. The Australian studies were all from the FutureDairy program (Garcia *et al.* 2007b) and included data from: a 2-year comparison of 4 systems that differed in stocking rate and milk yield/cow (Garcia *et al.* 2007a; Fariña *et al.* 2011b); a 2-year study of a complementary forage system or CFS, (Fariña *et al.* 2011a); and a 5-year period of a pasture-based automatic milking system (AMS) research farm. The New Zealand dataset was from a 3-year comparison of 3 contrasting calving date systems (Garcia *et al.* 2000; Garcia and Holmes 2005). Two of the studies have multiple treatments (farmlets), thus all together there were 9 individual datasets or subsets.

The common factor of all these studies was the applied pasture management, which was based on a set of similar pre-defined management rules. In all cases, pasture cover

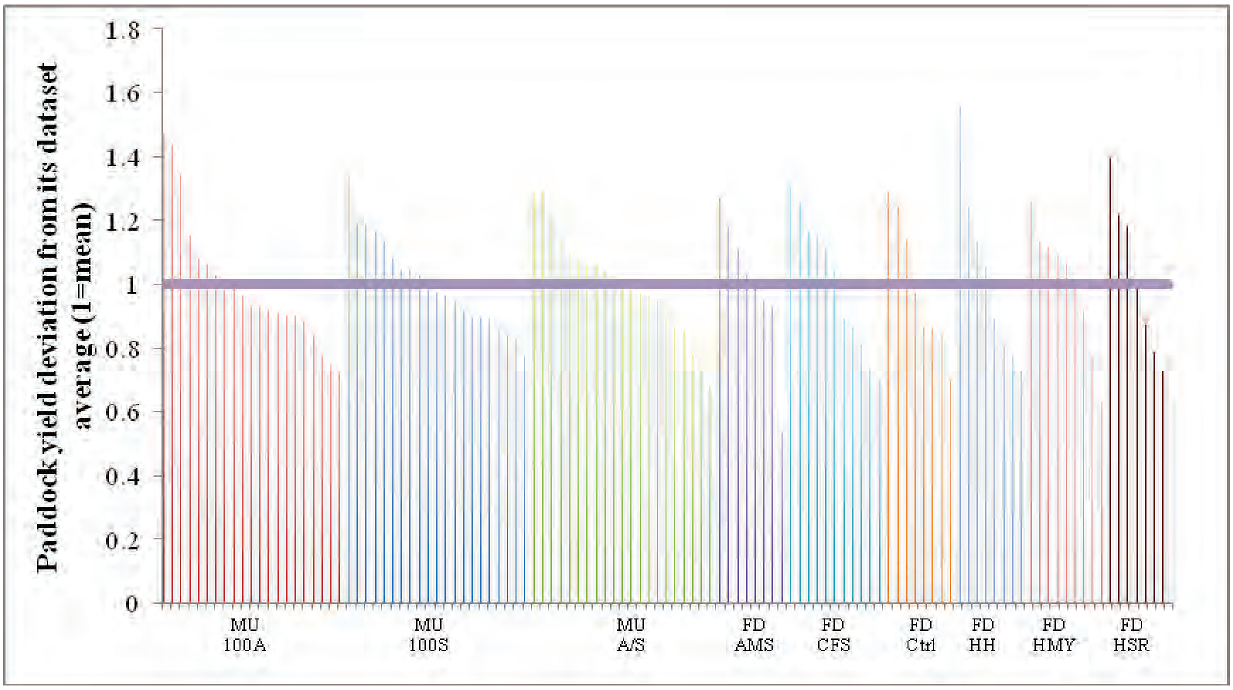

Figure 3. Deviation in pasture utilisation (t DM/ha) relative to the average of each dataset (1=mean for each dataset) for 9 subsets of experimental data taken from 4 whole farm system studies conducted in Australia and New Zealand. MU=Massey University (100A: autumn-; 100S: spring-; A/S: autumn/spring-calving systems); FD=FutureDairy; AMS=Automatic milking system; CFS=Complementary forage system; Ctrl, HH, HMY and HSR=farmlet systems differing in stocking rate and milk yield/cow.

(*i.e.* pasture biomass) was measured weekly and pre- and post-pasture covers of individual paddocks were measured at least 3 times a week. Pasture was allocated to cows on a daily basis with the aim of matching harvesting rate with growth rate (the key principle of pasture utilisation), whilst keeping total farm pasture cover within a desirable range.

The aim here was to analyse the variability in pasture utilisation at individual paddock level for each dataset. As the management applied was similar in all cases, it would be expected that most of the internal variability (between paddocks-within study) could be attributed to non-management factors. As studies varied amply in terms of the level of pasture utilisation achieved (from ~11 to >20 t DM/ha.year on average), individual paddock data were expressed relative to the mean yield (pasture utilised) of the corresponding dataset.

Figure 3 shows key results of this analysis, from which several points are highlighted:

First, without exception, all studies show a relatively large variability in pasture utilisation among individual paddocks, with coefficients of variation in the range of 20-30% in all cases. Clark *et al*, (2010) had previously reported coefficients of variation of 10.8 and 17.5% for research and commercial farms (respectively) in the higher rainfall area of Waikato, NZ.

Second, when expressed in relative terms, the magnitude of such variability was similar for all studies. Across all datasets, pasture utilised ranged from a minimum of ~0.6-0.8 to a maximum of ~1.3-1.5 relative to the average of each dataset. In absolute amounts, the variability between lowest and highest yield was always close to ~100% (*i.e.* top yielding paddock was almost always twice as high as lowest yielding paddock). This range is remarkably similar to inter-paddock variability observed in research farms (Romera and Clark 2008) and in research and commercial farms in NZ (Clark *et al.* 2010).

Third, the average pasture utilisation was always higher than the median in all studies. In other words, there was, in practically all cases, a larger number of paddocks for which pasture utilisation was below the average than *vice versa*. This indicates that, in all cases, a few very high yielding paddocks likely inflated mean values.

To further explore within-farm (study) variability, we separated the data for each year and calculated the coefficients of variation associated with between-paddock and between-year variability.

Figure 4 shows a summary of the results, with two distinct groups being evident. On the right hand side of the graph are the FutureDairy studies conducted at EMAI, NSW (the 4 contrasting feeding farmlets that differed in stocking rate and milk yield per cow and the AMS study). These studies included irrigated and non-irrigated paddocks. On the left-hand side of the graph are the NZ comparison of 3 calving date systems and the CFS study at University of Sydney in Camden. These studies had much less variability in total water received by each paddock, either due to climate (NZ) or irrigation (CFS). As expected, variability was larger (C.V. ~25 to 35%) in the studies with less uniformity in water availability than in the studies with more uniformity in water availability (C.V. ~10 to 20%). Interestingly, variability due to year was clearly reduced by water availability, but variability due to paddock was still high despite the removal (or minimisation) of the water availability factor.

Controlled field research in which a complementary triple-crop forage rotation was grown under 12 levels of

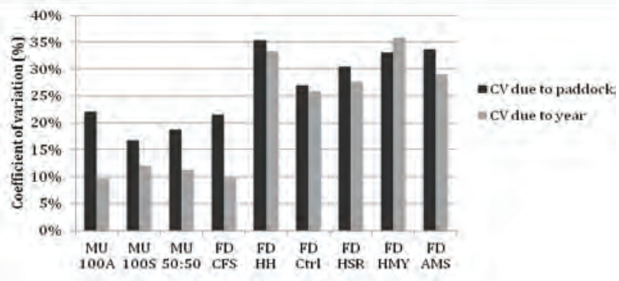

Figure 4. Coefficient of variation in pasture utilisation due to either paddock (for each paddock the average of 2 or more years depending on the dataset; dark bars) or year (for each year the average of all paddocks in the dataset; light-grey bars). From left to right, the first 4 studies had greater and more uniform water availability whilst the other 5 had a mixture of irrigated and non-irrigated paddocks. Data show that between-paddock variability appears to be more constant across datasets than between-year variability (which is more related to water availability). MU=Massey University (100A: autumn-; 100S: spring-; A/S: autumn/spring-calving systems); FD=FutureDairy; AMS=Automatic milking system; CFS=Complementary forage system; Ctrl, HH, HMY and HSR=farmlet systems differing in stocking rate and milk yield/cow.

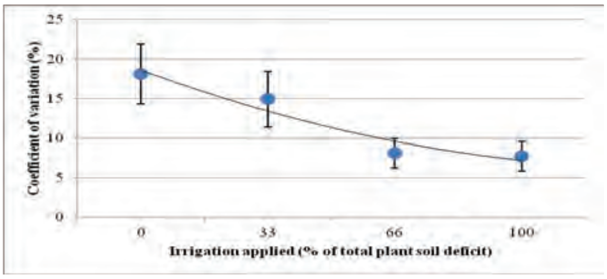

Figure 5. Relationship between coefficients of variation (%) associated with paddock variability and the amount of irrigation water applied (100=full amount of water required to minimise soil moisture deficit at all times) (MR Islam and SC Garcia, unpub. data).

nitrogen and 4 levels of irrigation water regimes (Islam *et al.* 2012) also shows clearly how irrigation reduces variability (Fig. 5). The average coefficients of variation in this study were 9.9% due to year variability and 6% due to paddock variability. This is indicative of the minimum variability that could be expected in forage production, as this was a highly controlled experimental situation. However, in this study the number of replicates per treatment was only 2 due to the large number of treatments (48), thus standard deviations are relatively inflated. Several conclusions can be drawn from this analysis of within-study variability in pasture utilisation.

First, despite the large emphasis that is commonly placed on pasture management as key driver of pasture utilisation, it is clear from this analysis that - as the conceptual model implies - other factors severely limit pasture utilisation. This is because the effect of pasture management was minimised in all these datasets, as management rules were very similar both between and within studies.

Second, the magnitude of the variability and the fact that such magnitude was very repeatable across datasets (including different years and even countries) is larger than we anticipated and is of concern. Range of between-paddock variability appears to be more constant than that of between-year variability, as the latter is more related to water availability.

Third, although an even larger variability can be expected in situations where the management applied is less rigorous (*e.g.* most commercial farms), the magnitude of the variability observed in the present analysis is also indicative that the higher levels of pasture utilisation achieved by research (compared to commercial farms) is mostly due to an increase in pasture utilisation on all paddocks rather than to a more uniform level of pasture usage across paddocks. In other words, as researchers we have been successful in ‘moving the whole bell-shaped distribution curve to the right’, but have not yet properly addressed the issue of true within-farm variability in pasture utilisation.

We need to question why research can clearly demonstrate success of better management to push boundaries of pasture utilisation but cannot reduce within-system/farm variability?

If the effect of management is assumed to be largely neutralised (as in the above analysis), then clearly the relatively large between-paddock-within-system variability must be primarily related to input and/or soil limitations.

Within each study, the same rules were used for application of nitrogen and water (for those paddocks that received irrigation). These rules are typically based on the application of a fixed amount of N or mm of water after a given number of grazings (typically 2). It is likely that such management could in fact be exacerbating the lower performance of poorer individual paddocks, as these are less frequently grazed and therefore receive less water and N. For example, the top 3 paddocks for each of the NZ calving date system comparison were grazed, on average 12 times/year, compared to 9.8 times/year for the bottom 3 paddocks (SC Garcia unpub. data). This represents a 22% increase in the number of grazing events and accordingly a similar difference (on average) in total N applied.

Although grazing management effect was certainly minimised by applying the same set of pre-defined management rules, it is also possible that differences in management could still occur. Grazing management rules are based on targets (*i.e.* pasture cover; pre- and post-grazing covers) but in reality all individual paddocks achieve their respective targets ‘around’ the target, but hardly exactly ‘on target’. It is therefore likely that ‘poorer’ paddocks, which have been penalised already for N (and water were applicable), are less likely to achieve the desirable target, particularly in terms of pre- and post-grazing covers. Pre- and post-grazing covers are, on average, linearly related (Garcia *et al.* 2013), thus grazing at consistently lower covers will almost inevitably result in post-grazing residuals being lower than desirable (*i.e.* overgrazing), which has been proved to reduce rate of regrowth (Garcia and Holmes 2005).

Even if nutrient input and management were identical, differences between individual paddocks would still exist due to differences in soil types and soil properties. We know very little about soil macro- and microenvironments in relation to pasture utilisation and how potential growth is being lost because of these factors. This requires further research, as knowledge in this area would likely allow inputs to be applied where most gain is likely to be achieved thereby increasing the efficiency of utilisation of set level of inputs.

Reducing wastage: how can research/technology help farmers reduce the gaps?

It is clear from previous sections that the problem of low pasture utilisation in Australian dairy farms is more complex than previously accepted. Pasture utilisation is not only low; it is also highly variable both between and within farms. Regular monitoring of pasture cover (*e.g.* using existing tools such as plate meters or sensors mounted in a quad-bike) can provide very useful data for improved pasture management, but yet most farmers and managers are reluctant to use them, likely due to the fact that is 'another task in an already busy schedule'.

The key challenge for the future of pasture-based dairy systems in Australia is to truly overcome these limitations. Over the past decade, the industry invested heavily into RD&E programs (*e.g.* 3030, Forage Plus, 1220, FutureDairy) that aimed to lift total pasture (or home grown feed) in dairy farms. Overall these programs were very successful in demonstrating a higher yield potential of pastures and forage crops. However, these achievements have not necessarily translated into overall improvements in pasture utilisation (or home-grown feed) in commercial farms over whole regions, let alone the whole country.

Based on the analysis presented here we argue that an effective way to substantially lift pasture utilisation in commercial farms is by addressing not some but all the different individual 'levels' of pasture wastage (due to poor management of both inputs and grazing) simultaneously. If all the individual levels of pasture wastage could be targeted simultaneously across all pasture areas (paddocks) of a commercial farm, then not only total pasture utilisation should increase but also total variability should decrease. As discussed in this paper the farm would need to have enough stocking rate (*i.e.* harvesting power) to enable significant gains in pasture utilisation.

How can farmers do this in the future?

Theoretically, in order to address all sources of variation simultaneously a famer or manager - or an intelligent software system - would require key information in real time about pasture growth, soil conditions, soil macro and microenvironments, animal performance and intake, among others variables.

Information about soil macro and micro-environments could be used to create dynamic maps of soil physical, chemical and biological properties and soil health. Dynamic mapping can be implemented to conduct 'dynamic' growing and management of pasture, *e.g.* by better matching plant species to soil-environment and also by mean of 'differential' inputs, *e.g.* differential fertilisation targeting specific needs of a given land area. These concepts have been already developed and are being adopted by different cropping and horticultural industries around the world.

Information about pasture growth will be automatically captured in the future. Our team at FutureDairy is already working with the Australian Centre for Field Robotic (also from the University of Sydney) in this area. These data can also contribute to the concept of 'dynamic mapping', *e.g.* by contributing information about differential growth rates of different areas within a paddock, or between paddocks sown with similar species. Sophisticated models will take and analyse this information to calculate true variability in pasture growth and utilisation and propose/make adjustment to reduce pasture wastage. To a large extent such models already exist. The model PGSUS developed by the DairyNZ modelling team (Romera *et al.* 2010) uses genetic algorithms to optimise pasture allocation based on 'corrected' growth rates for individual paddocks. PGSUS contains a relatively simple pasture model that predicts pasture growth rate from climate and soil data, but 'learns' from previous measurements of pasture cover on individual paddocks to better tailor average growth rate to each paddock in a farm. A commercial version of this model is being developed in New Zealand (A. J. Romera, DairyNZ; pers. comm.).

The availability and amount of data on animal function and performance are increasing at exponential rates. Soon restrictions to manage dairy cows as a herd –until now a *sine qua non* characteristic of pasture-based systems, will be a thing of the past. Automatic milking systems (AMS) are at the vanguard of this. These systems provide large amounts of data on cow performance, milk yield, milk quality, health status, concentrate intake and cow traffic patterns. We refer readers to recent publications from FutureDairy in relation to pasture based AMS in Australia (Kolbach *et al.* 2012; Kolbach *et al.* 2013a; Kolbach *et al.* 2013b). Recently the launch in Europe of the Herd Navigator (DeLaval®) will mean that in the near future dairy farm managers in pasture-based systems will be able to monitor mobilisation of reserve tissue, incidence of mastitis and reproduction status of dairy cows in real time and with great accuracy.

What is then missing?

What is missing in order to increase pasture utilisation (and therefore chances of increased profitability of the dairy farm operation) and overall efficiency is the integration of all the above to improve management of inputs and grazing and reduce wastage.

To date, most of the existing technologies provide lots of data, the majority of which is not only unused by, but also largely unknown to, farmers (Eastwood 2012). Farmers are very busy people and lack of time to properly collate and understand data is arguably at the top of the list of reasons for low adoption of new technologies. In the future we need to be able to transform tonnages of data into simple and meaningful pieces of information that can assist famers and farm managers to make better decisions. To do this, we need intelligent software systems that can integrate data from a variety of sources and provide meaningful information for the decision maker.

We envisage that a true revolution in technology adoption and the consequent improvement in efficiency will occur when pasture-based dairy farmers could acquire new technologies that allow them to 'manage the manager' rather than managing the production system directly. In other words, rather than collecting, collating and analysing soil, cow and pasture data on a daily basis to make decisions on feed allocation, farms will have a number of sensors fitted on soil, cows, pastures or on unmanned vehicles that will automatically collect relevant data and feed these data to an intelligent software/model. It is this model or sophisticated system the one that will analyse, integrate and 'learn' from the different sources of data and provide useful information to the farmer or, in some cases, make changes and adjustments according to the boundaries set by the farmer. Thus, rather than taking away the decision making from the farmer, this means that farmers will in fact have a higher level of decision making, as they will have to decide the boundaries or limits within which they feel confortable to allow the intelligent software to make, on 'their behalf', appropriate changes to the production system. In the future, this will mean the achievement of higher efficiency for Australian dairy systems, therefore at FutureDairy we have called this concept *HEADS*.

Conclusions

The amount of pasture utilised per ha is a key driver of profitability of Australian pasture-based systems. However, the gap between potential (research) and commercial reality remains excessive. Pasture utilisation in Australia is not only low but also extremely variable both between and within farms. The high level of variability within whole farm system studies, in which the influence of management factors can be considered minimal, is of concern. However, this also opens up opportunities to achieve true gains in pasture utilisation (and therefore in possibilities for higher profitability) in the future, if such variability within farm can be addressed and controlled. We discussed factors affecting variability in pasture utilisation and conclude that one way pasture wastage can be avoided is by addressing all the different level of pasture losses collectively. Recent and future technological developments will provide an opportunity to achieve this and we proposed a conceptual model that will integrate data from multiple sensors/sources to transform mostly underutilised data into useful information for timely and more effective decision making.

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