Summer pasture yield variation in a central Waikato location from 1979 to 2010: implications for pasture persistence.

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Abstract

Three datasets spanning 31 years (1979-2010) of net herbage accumulation (HA) for Waikato dairy pastures were studied to determine between-year variability in summer HA. In addition, a dairy farm at the same location was modelled with the DairyNZ Whole Farm Model, using climate data for 15 years to predict HA, and milksolids production. Measured extremes for HA over 5 months (1st December to 30th April inclusive) were from 4.7 to 9.1 t DM/ha, with a mean of 7.0 t DM/ha ±1.2 t DM/ha SD. Rainfall during these months had a positive impact on HA, with an extra 849 kg DM/ha (r^2=0.43, p<0.001) grown in December to April for every additional 100 mm of rainfall. December-April rainfall during 1979-1993 was 17% more than December to April 2004-2010. For the modelled farm stocked at 3.1 cows/ ha, December to April HA was predicted to average 6.6 ±1.3 t DM/ha, ranging from 4.7 to 8.7 t DM/ha. In 2 years out of 3, HA was predicted to be below feed demand from December to April. Clearly, managing pastures to recommended post-grazing residuals and pre-grazing leaf stage in summer can be problematic when the variability in HA is large and there is limited capacity to reduce stocking rate and hence feed demand. Repeatedly exceeding pre-grazing herbage mass targets in good summer HA years and post-grazing residual targets in poor summer HA years are both scenarios consistent with the loss of perennial ryegrass plants from dairy pastures and this study examines the historical frequency and size of such events.

Keywords: annual variation, grazing management, *Lolium perenne*, summer herbage accumulation, stocking rate

Introduction

Summer-autumn (December to April inclusive) growth of perennial ryegrass *(Lolium perenne)* pastures in the Waikato is highly variable compared with the winter-early spring period (Baars 1976, Chapman *et al.* 2009). This presents a significant management challenge for dairy farmers to fill feed deficits and achieve satisfactory lactation length. Current pasture management recommendations for dairy farmers to optimise the persistence, growth, utilisation and quality of temperate pasture species are to target 4-5 cm post-grazing residuals and apply a grazing interval based on the 2-3 leaf regrowth stage (Fulkerson & Donaghy 2001, Lee *et al.* 2008). This is difficult because herd feed requirement must be balanced with the variation in herbage accumulation (HA) that may occur between consecutive summer months, and between years. Summer is also considered to be a critical period for maintaining tiller density in ryegrass pastures (Matthew *et al.* 1991, Matthew & Sackville Hamilton 2011, this volume). Combined stresses resulting from severe defoliation, moisture deficit, and insect attack are detrimental to herbage accumulation rates and grazing intensity, and might have consequences for sward persistence.

Farmer decisions for managing feed supply and feed demand during the summer period are not always about optimising pasture and herd performance, since farmers have limited flexibility for adjusting stocking rate. Business decisions and resource prioritisation might mean maintaining a herd size in the short term which could be higher or lower than preferable for balancing feed supply and feed demand. The consequences of stocking rate decisions in terms of risk to future pasture and herd performance need to be considered.

Options for filling feed deficits on non-irrigated dairy farms, allowing for annual climatic variability, have received some attention in southern Australia. For example, Chapman *et al.* (2008 a, b) suggested that a well managed diversification away from perennial ryegrass towards crops and other pasture species, will help smooth out between year variability. In New Zealand the focus has been on strategies for managing the existing perennial ryegrass pastures for milksolids (MS) production during the oncoming summer period (e.g. the More Summer Milk project, Shaw *et al.* (1997); using strategic N applications, Penno *et al.* (1995) and Bahmani *et al.* (1997); managing rotation length, Penno *et al.* (1995); and manipulating grazing management, Matthew *et al.* (1991)).

The aim of this analysis was to determine the annual variation in summer herbage accumulation between years in the central Waikato, and speculate on the possible risks this variation poses to long-term pasture persistence.

Methods

The following data were analysed for between-year variability in summer pasture production.

1. Monthly net HA for the 'control' farmlet at Ruakura No 2 dairy from June 1979 until May 1993. Data from 11 of 13 years were available. No nitrogen (N) fertiliser was applied to pastures during this period.
2. Monthly net HA for the 'control' farmlet at Ruakura No 2 dairy from June 1993 until May 2004. During this period annual N fertiliser application to pastures averaged 186 kg N/ha.
3. Monthly net HA for the Control/benchmark farmlet at the DairyNZ Scott Farm, Newstead, from June 2004 to May 2010. During this period, annual N fertiliser applications averaged 182 kg N/ha.
4. Predicted monthly HA from the DairyNZ whole-farm model (Wastney *et al.* 2002) parameterised with 15 years of Ruakura climate data (1990/1991 to 2004/2005) for a farm stocked at 3.11 Friesian cows/ha.

The 'control' farmlet at No 2 dairy was stocked at 3.0 cows/ha. Management decision rules were applied as described by Macdonald & Penno (1998). Little emphasis was placed on using improved pasture cultivars and no N fertiliser was applied until May 1993.

The control/benchmark farmlet at Scott Farm also operated at 3.0 cows/ha, with similar applications of nitrogen fertiliser to the Ruakura No. 2 farmlet. In 1999, 5 years prior to the measurements commencing at Scott Farm, a high proportion of the area subsequently used in the farmlet was re-sown with the perennial ryegrass cultivar Bronsyn with AR1 endophyte.

Monthly net HA data for the farmlets were derived from pasture cover assessments conducted weekly by visual assessment for each paddock, calibrated with ground level herbage cuts. On each occasion, a minimum of 10 calibration quadrats (each 0.2 m^2) covering the range of herbage mass present were set out and visually assessed. After assessment the quadrats were cut to ground level, washed and dried in a forced draught oven at 95–100°C for 48 hr to determine herbage mass. Weekly net HA rates were calculated after using the weekly calibration equations to adjust the visual paddock scores. Herbage accumulation was calculated by difference between the weekly scores where a paddock had not been grazed or made into silage. Monthly HA was calculated as the sum of the average weekly HA rates.

Rainfall Observations

Daily rainfall observations were collected from Ruakura climate station (NIWA 26177 EWS, latitude 37.7757 south, longitude 175.3051 east). The annual variability of total rainfall for December to April of each season, and the impact of this on seasonal HA were examined in the three periods described above.

Model simulations

The DairyNZ whole-farm model (Wastney *et al.* 2002) was used to investigate the impact of climate on HA for 15 different years (1990/1991 to 2004/2005) for a farm stocked at 3.11 Friesian cows/ha. Data from the Ruakura climate station for this period were used to calculate a daily step soil water balance from rainfall and evapo-transpiration, from which daily HA is generated (McCall & Bishop Hurley, 2003). The aim of the modelling was to investigate the impacts of summer variability in HA on MS production and profitability. Nitrogen fertiliser use was limited to 110 kg N/ha/year. Planned start of calving was 15 July with a mean calving date of 31 July. Drying off date for all cows was 30 April. No attempt was made to reduce stocking rate in the summer-autumn period. In the model, pasture silage was fed to the herd when feed demand was not being met from the available pasture. This allowed a modelled lactation length of 273 days /cow/year. Average whole-farm pasture cover on 1 June was set at 2070 kg DM/ha with a pasture silage reserve of 500 kg DM/cow available at the start of each year. Pasture silage made on the farm was used to restore this reserve. In 6 out of 15 years, additional silage was required (purchased) to increase the pasture silage reserve above 500 kg DM/cow in order for cows to be adequately fed. The information reported for each year included: MS/cow, MS/ha, annual and monthly pasture HA, and operating profit/ha (at a payout of $4.00/kg MS).

Results

Farm Data

Measured HA for the December to April period averaged 7.0 ± 1.2 t DM/ha for 1979 – 2010, which is 39% of the average annual HA of 18.0 t DM/ha. Summer HA ranged from a minimum of 4.7 t DM/ha in 2004-2005 to a maximum of 9.1 t DM/ha in 2003-2004. Datasets 1-3 were examined for variability in three separate sequences (1979-1993, 1993-2004 and 2004-2010, Table 1). Coefficients of variation (CV) were highest (19%) in the latter period and lowest in the middle period (16%). The CV values for summer HA were larger than those for total annual HA (7-15%) for the same periods (data not shown).

Factors other than farm location and N fertiliser that influence between-year variability in net HA are most likely to be summer soil moisture deficit and spring temperature. Only the relationship between summer

Table 1. Mean herbage accumulation (kg DM/ha ± SD) and mean rainfall (mm ± SD) for the months December to April, for three sequences of measurement during 31 years on the 'Control' farmlet, near Hamilton.

Years	Farm	Herbage accumulation			Summer rainfall		
		Mean	SD	CV%	Mean	SD	CV%
1979-1993(n=11)	Ruakura No. 2 dairy	6834	1248	18	435	83	19
1993-2004(n=11)	Ruakura No. 2 dairy	7369	1169	16	397	87	22
2004-2010(n=6)	DairyNZ Scott farm	6702	1296	19	362	105	29

rainfall and HA was examined here. There was a trend towards lower mean December – April rainfall in each sequence (Table 1), and increased variability of rainfall. Rainfall for December - April from 1979-1993 was 73 mm (17%) greater, on average, than for December - April 2004-2010. Summer rainfall had a positive effect on HA throughout the entire 31-year period, with an extra 849 kg DM/ha grown in summer for every additional 100 mm of rainfall during that period (r^2=0.43, p<0.001, Fig. 1).

Simulated versus observed pasture growth

Simulated HA rates must show a reasonable match to observed rates before confidence can be placed in model predictions. Observed monthly HA rates from 1990-2004 were available for the same location as the climate data used to generate modelled HA for this period. Fig. 2 compares average monthly HA rates predicted by the model and observed in the field, and Fig. 3 presents the correlation between modelled and observed average monthly HA. The correlation coefficient for the relationship between observed and predicted mean monthly growth rates was 0.88, similar to correlation coefficients of 0.71 and 0.81 for simulated and observed HA rates reported for southern Australia by Chapman *et al.* (2008 a, b). Predicted mean monthly HA rates are similar to those modelled for Hamilton, NZ, by Chapman *et al.* (2009).

There was good agreement between the model predictions and the measured data. Over the 15 years included in the analysis, mean predicted summer HA was 6.6 ± 1.3t DM/ha compared with 7.0 ±1.2 t DM/ha for the observed data. The limit placed on N application of 110 kg N/ha in the model, compared with an average application of 145 kg N/ha[1] for the measured pastures, could explain some of the difference in average yield between the measured data and the model predictions.

Modelled dairy farm 1990-2004

Predicted summer HA ranged from a minimum of 4.7 to a maximum of 8.7 t DM/ha. The modelled data also confirmed that HA during the December to April period is more variable (CV = 20.1%) than during winter – spring (June-November) (CV = 6.2%). Mean predicted HA was 44 kg DM/ha/day for December to April, with the average daily feed demand for this period approaching 50 kg DM/ha. Four months of summer feed deficit (HA less than feed demand) was predicted to occur in 1 out of every 3 years, and the deficit months occurred consecutively 1 year in 5. At least 1 month of

Figure 1 Relationship between rainfall and herbage accumulation (HA) in the December to April period for 1979-2010. HA (Dec-April kg DM/ha) = 8.5x (Dec-April rainfall mm) + 3530. (R^2 = 0.43, p<0.001). Regression analysis using GenStat-Release 13.2.

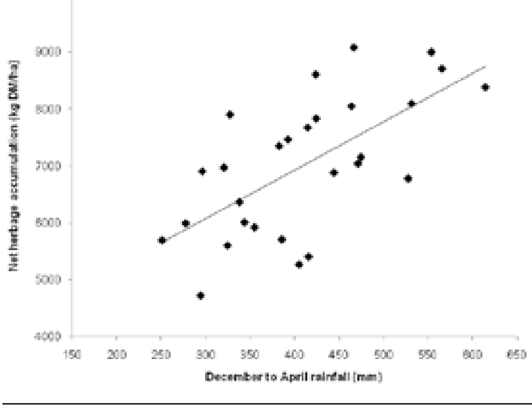
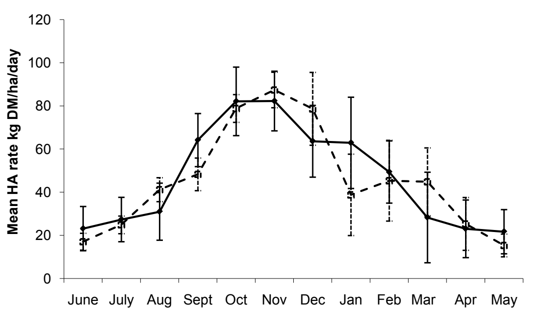


Figure 2 Mean monthly observed (solid line) and modelled (dashed line) pasture herbage accumulation rates (kg DM/ha/day ± SD) for central Waikato during the years 1990-2004. Modelled using the DairyNZ whole-farm model (Wastney et al. 2002).

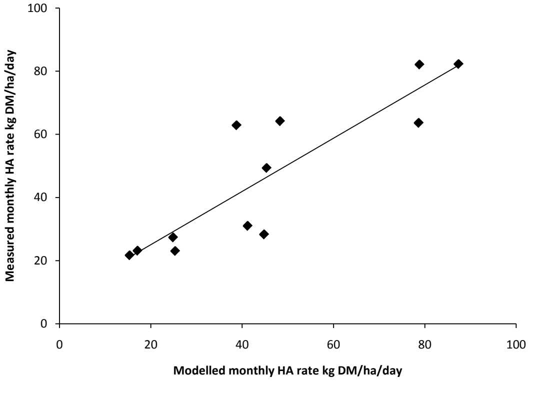


[1]The measured period includes 3 years of zero N applications (1990-1993), reducing the average to 145 from 186 kg N/ha.

Table 2 Mean summer herbage allowance (t DM/cow) for each dataset calculated for a comparative stocking rate of 85 kg liveweight/t DM using mean net HA ± one standard deviation (SD).

Measurement period	Mean herbage allowance for 3.1 cows/ha at mean HA	Mean herbage allowance plus one SD	Mean herbage allowance minus one SD
1979-1993	2.2	2.6	1.8
1993-2004	2.4	2.8	2.0
2004-2010	2.2	2.6	1.7
Modelled:			
1990-2004	2.1	2.6	1.7

Figure 3 Relationship between modelled mean pasture herbage accumulation (HA) rate (kg DM/ha per day) and measured mean HA rate for the summer months (December – April inclusive) during the years 1990-2004 in the central Waikato (r2 =0.7696). Modelled using the DairyNZ whole farm model (Wastney et al. 2002).



feed deficit was predicted to occur in all years during this sequence. The most common summer month for a pasture deficit was February (deficit occurring in 10 of the 15 years).

Discussion

The aim of this study was to determine the annual variation in summer HA in the central Waikato and to relate this information to farm management policies and the possible risks for pasture persistence. Managing the interaction between annual variability and stocking rate (feed demand) is a key driver of operating profit in a pasture-based dairying system (Macdonald & Hedley (2010), adapted from Macdonald *et al.* (2008b)). Farmlet studies at Ruakura showed that the optimum operating profit is attained at a stocking rate of 3.1 cows/ha, or 85 kg liveweight/t DM grown. An alternative determinant of stocking rate is how well annual feed requirements are met from pasture. Using average annual HA from this location (18.0 t DM/ha), an annual herbage allowance of 5.8 t DM/cow results at a stocking rate of 3.1 cows/ha. On this basis one could conclude that feed supply and feed demand are well balanced for optimising operating profit on a 100 ha farm with a stocking rate of 3.1 cows/ha, with the modelling data determining that this farm would be self contained for feed for 9 years out of 15 (60%). The variation in summer HA between years found here can alter the feed supply by as much as 4.4 t DM/ha/year, or 1.4 t DM/cow/year, with feed supply variations from other times of the year still to be added. If a farmer could alter the herd size annually to provide a similar herbage allowance/cow each year, then between 270 and 340 cows would be required, with no reliable means of predicting the optimal herd size at the start of each year. In practice, farmers hold a more-or-less constant stocking rate between years, and accept that annual herbage allowance/cow will vary by up to 1.4 t DM between a poor and a good year. This annual variation makes stocking rate in terms of cows/ha less important for operating profit than managing the natural variation of feed supply around this stocking rate (Macdonald & Hedley 2010). Predicted MS/ha of the simulated farm varied by as much as 480 kg contributing to differences of up to $1164/ha in operating profit at a payout of $4.00/kg MS. Hence, annual variability in HA has a large impact on farm profit.

The impact of summer HA variation, one standard deviation each side of the mean, on the summer herbage allowance/cow for an "optimally" stocked farm in the December to April period is shown in Table 2. Typically summer herbage allowance varies from the mean by ± 0.4 t DM/cow, or 18%. For the summer period a dairy farmer can expect to be over (or under) stocked by up to 18%, or ± 0.56 cows/ha, 2 years out of 3. In the remaining years, the extent of over- or understocking could be greater. Management strategies for coping with this have been addressed with varying degrees of success through short term management for MS production (e.g. More Summer Milk, Shaw *et al.* (1997)), for which longer-term effects on cow body condition score at next calving can be estimated (Macdonald *et al.* 2010). However, less is known about carryover effects of variability of summer HA on longer-term pasture production from the accumulating effects of over (and under) grazing of permanent pastures during summer (Macdonald *et al.* 2011, this volume). In addition to varying feed supply, over grazing is more likely to occur due to greater herbage allowances required per cow as a result of improved genetic potential and greater cow size (Macdonald *et al.* 2008a). Increased cow appetite is a factor that needs to be considered in any adaptation to managing summer pasture variation.

Implications for pasture persistence and farm management

Waikato dairy farmers are regularly over- or understocked as they proceed through summer. Hence, their ability to apply the most appropriate grazing frequency and intensity for pasture production and improved pasture persistence is potentially compromised. A consistent post-grazing residual height of 4-5cm in the spring and early summer is currently recommended as a requirement for pasture management to favour ryegrass persistence. Current standard preparation for summer and a diminishing feed supply is to lengthen the rotation, which can result in lowering the post-grazing residual height below target. Alternatively in high growth years the requirement is to conserve surplus feed to contribute to a feed buffer carried forward for poorer years. Both these strategies may conflict with the requirements for maximising ryegrass tiller density and persistence (McKenzie e*t al.* 2006) through post-grazing residuals that are either too low or too high on the grazed areas of the farm. The implications for pasture persistence of sub-optimal post grazing residual heights, in the presence of one or more other stresses such as high summer temperatures, dry conditions and insect pest challenges, are not well documented. If the goal is long term sustainability of perennial ryegrass pastures, farmers require better definition of when, and how, to take action to prevent summer overgrazing or undergrazing of pastures and more information on farm systems that allow them to cost-effectively offer higher total feed allowances in poorer HA years.

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