Ministry for Primary Industries
Manatū Ahu Matua

Evaluation of the values for pasture ME and N content used in the National Greenhouse Gas Inventory

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Executive Summary

The values for metabolisable energy (ME) and nitrogen (N) content of pasture used by the National Greenhouse Gas Inventory and described by Pickering (2011) were reviewed and assessed for their accuracy and relevance to current New Zealand conditions.

Pasture ME and N values from eight research studies and a commercial testing laboratory were collated, analysed and compared with the national monthly average values used in the current model.

The collated database contained a total of approximately 19,300 samples collected from 1996 to 2011 from dairy, sheep and beef farms all over New Zealand. One sample was identified as originating from a deer farm.

Where sufficient data was available, regional variation in pasture ME and N content was also examined and compared with the national monthly average values used in the current inventory model.

CONCLUSIONS

Due to inconsistencies between the individual databases in terms of experimental objectives, methods and data presentation, the data available in the collated database were not sufficient to provide scientifically validated estimates of monthly ME or N means on either a regional or New Zealand-wide basis for either dairy or sheep/beef farms.

However, some salient observations are:

1. **Dairy ME –** In terms of an overall national average, the dairy ME values from the current database analysis are in reasonable agreement with those of the current inventory model.

2. **Sheep/beef ME –** In terms of an overall national average, the current inventory model appears to overestimate ME content of beef pastures in summer compared to values from the data collated in this report.

3. **Dairy N –** The single annual average value for N used in the current inventory model is inappropriate. The data reported here shows that pasture N follows a seasonal curve with monthly N values significantly greater than in current inventory value (3.7% DM) for 6 out of 12 months.

4. **Sheep/beef N –** The single annual average value in the current model is inappropriate. In the data reported here, pasture N follows a seasonal curve with monthly N values that are significantly different from the current inventory value (3.0% DM) for all 12 months of the year.

5. **Deer ME and N** – Suttie (2012) refuted the assumption in Pickering (2011) that deer pasture ME is the same as for dairy pastures and proposed values similar to those of sheep/beef pastures. It seems reasonable to assume that pasture N values are also similar to

those of sheep/beef pastures. However, deer ME and N values cannot be confirmed as we have been unable to find published or unpublished data relating to deer.

6. **Regional variation** – The data in this report demonstrates clear evidence of regional variation in both pasture ME and N for both dairy and sheep/beef pastures. This requires further investigation.

7. **Improved values** – Although it is not possible to suggest regional values for pasture ME and N, the NZ overall values generated by the current statistical analysis are likely to be an improvement on current values:

Proposed improved values for national average pasture ME and N content suggested by the current review

Season	Winter		Spring			Summer			Autumn			Winter
Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Pasture ME content (MJ ME/kg pasture DM)												
Dairy	11.95	11.91	11.95	11.92	11.50	11.20	10.92	10.74	11.20	11.62	11.53	11.90
Beef/sheep	11.06	11.89	11.08	11.17	10.66	9.61	9.26	8.34	8.99	8.94	10.60	10.89
Deer (Suttie)	10.6	10.5	11.2	11.2	11.2	9.6	9.7	9.6	9.0	9.1	9.1	10.5
Pasture N content (% of the diet)												
Dairy	4.0	3.8	4.0	3.9	3.5	3.5	3.8	3.9	4.2	4.3	4.2	4.0
Beef/sheep	3.5	3.4	3.4	3.3	2.7	2.5	2.5	2.3	2.7	2.6	3.3	3.3
Deer	3.5	3.4	3.4	3.3	2.7	2.5	2.5	2.3	2.7	2.6	3.3	3.3

RECOMMENDATIONS

That a nationwide survey of dairy, sheep/beef and deer pastures be biometrically designed and conducted to provide scientifically valid and representative pasture quality data for dairy, sheep/beef and deer farms on a regional basis.

In such a large scale survey it would also be prudent to consider other potentially valuable pasture quality parameters that could be evaluated concurrently (e.g. botanical composition, slope of pasture, farm class etc.).

Furthermore, in view of the potential for the Inventory Model to become ‘regional’ it may be important to consider the appropriateness of redefining ‘regions’ which are currently based on NZ Statistics political regional authorities, in favour of a system based on more relevant agricultural, geographical/geological factors: for example, those used by Beef+Lamb NZ in their farmer economic surveys.

Until better data is available it is recommended that the model adopts the values generated by the current statistical analysis for improved NZ_Overall values for pasture ME and N for dairy, sheep/beef and deer pastures.

Introduction

New Zealand's National Greenhouse Gas Inventory (NGGI) calculates monthly methane (CH_4) and nitrous oxide (N_2O) emissions in cattle, sheep and deer based on their estimated dry-matter (DM) and nitrogen (N) intake. A mathematical inventory model has been devised which uses the estimated ME (metabolisable energy) and N (nitrogen) content of pasture to predict an individual animal's pasture DMI and N intake for dairy cattle, beef cattle sheep and deer (Pickering 2011).

Each animal's energy requirement and, therefore, its DM intake, changes over the year according to its species, sex and physiological state, i.e. whether it is growing, reproducing, lactating, etc.

Similarly, the ME and N content of pasture changes over the year depending on pasture species, stage of growth, soil fertility, climate, farm topography and the species of grazing animal. CH_4 and N_2O emissions for each animal species will, therefore, vary in response to change in DM and N intake and seasonal and regional variation in pasture quality.

The calculation of CH_4 and N_2O emissions, therefore, requires relevant, accurate and reliable information for pasture ME and N.

The purpose of this project is to:

1. Evaluate the pasture ME and N values and sources of information used in the current inventory model (Pickering, 2011).
2. Identify, collate and analyse additional data to provide improved ME and N values for the inventory model.
3. Recommend new values for use in the model and if any further data needs to be collected to improve the model.

CURRENT MODEL VALUES FOR PASTURE ME AND N

The current inventory model applies standard values for all animals of each species nationally with monthly figures for dairy animals and three-monthly figures for sheep and cattle for ME (Table 1, Figure 1) and a constant figure for N (Table 1, Figure 2).

Table 1. Values for pasture ME and N content used in the current model (Pickering , 2011)

Season	Winter			Spring		Summer			Autumn		Winter
Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Pasture ME content (MJ ME/kg pasture DM)												
Dairy	12.582	11.530	11.686	12.007	11.637	10.817	11.084	10.611	10.690	11.329	11.936	11.655
Beef/sheep	10.8	10.8	11.4	11.4	11.4	9.9	9.9	9.9	9.6	9.6	9.6	10.8
Deer (Pickering)	-	-	-	-	-	-	-	-	-	-	-	-
Deer (Suttie)	10.6	10.5	11.2	11.2	11.2	9.6	9.7	9.6	9.0	9.1	9.1	10.5
Pasture N content (% of the diet$^{\phi}$)												
Dairy	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Beef/sheep	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Deer (Pickering)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

$^{\phi}$Though not specified in Pickering (2011), It must be assumed that this is expressed in the same units as ME (i.e. pasture dry matter).

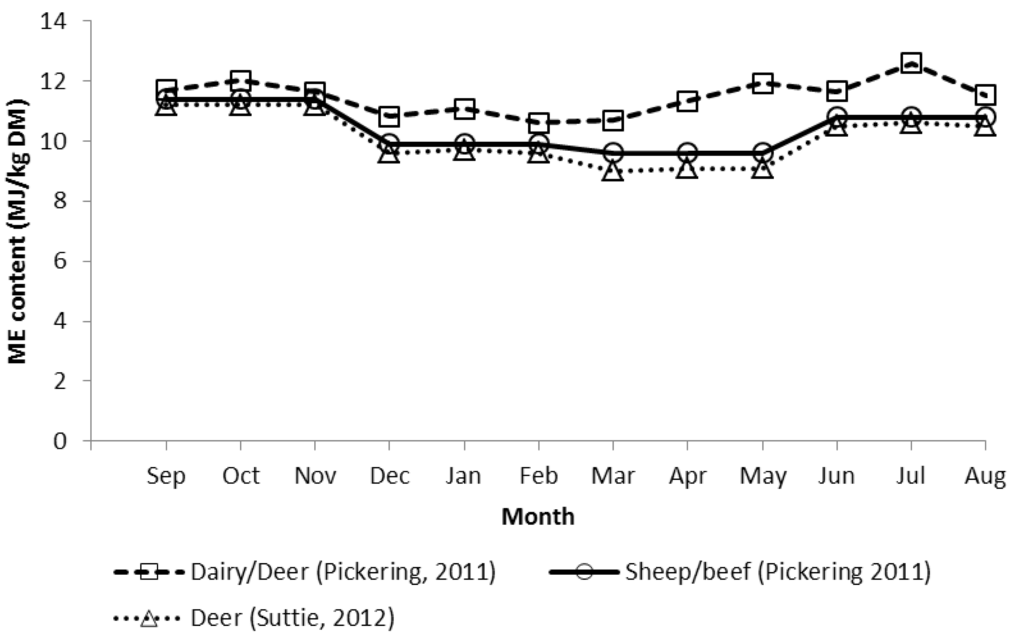
There is no ME value for deer in Pickering (2011) as the current model calculates deer ME requirements using a different method to sheep and cattle. However, pasture ME is required to convert the ME intake into DMI. The Pickering (2011) model assumes the pasture ME for deer is the same as for dairy cattle.

Suttie (2012) comprehensively reviewed deer production systems in New Zealand and confirmed that since 2000, deer have been predominately farmed on land more typical of that grazed by sheep and beef animals than dairy animals. Suttie (2012) proposed monthly pasture ME values estimated from population, production and land class statistics specific to deer farms (Table 1). These new ME values for deer have subsequently been incorporated into the New Zealand inventory model (S. Wear, *pers. comm,* 2013).

ME values used in the model

The current model pasture ME values follow a characteristic seasonal cycle for both dairy and sheep/beef farms (Figure 1). For dairy farms, the ME content is lowest in late summer (Feb) and peaks in late winter (Jul) and spring (Oct). For sheep/beef farms, ME content is lower than for dairy with lowest and highest ME values occurring later in the season than for dairy farms.

Figure 1. Pasture ME values used in the current model (Pickering, 2011)



Sources for these values

Monthly pasture ME values for dairy/deer pastures were derived from unpublished results of a 12 month study in 2001-2002 from 10 dairy farms (locations not known). Therefore, it is not possible to confirm if these values are representative nationally.

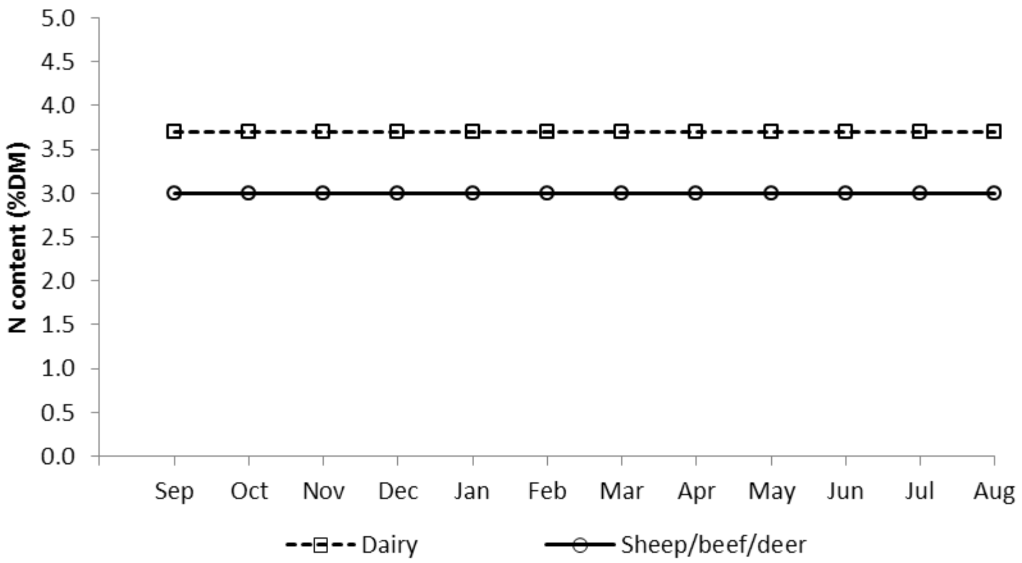
For sheep/beef farms, ME values were derived from a national survey of 19 beef and sheep farms (in Waikato, Tararua, Canterbury and Southland) in 2001-2002 (Litherland *et al.* 2002). The current model values are expressed as seasonal means rather than monthly values. The original publication presented monthly values graphically.

It is not possible to confirm that these four regions or the farms within them were representative of the pastures grazed by sheep and cattle nationally and there is no indication as to what land class these farms represent.

Nitrogen (N) values used in the model

The current inventory model assumes N remains the same throughout the year with higher values on pastures grazed by dairy animals than sheep and beef animals (Figure 2). Pasture N for deer farms is assumed to be the same as for sheep/beef farms.

Figure 2. Pasture N values used in the current model (Pickering, 2011)



Sources for these N values

Pasture N concentrations were derived from a database compiled in 2002 containing approximately 6000 pasture samples (2638 sheep/beef and 4198 dairy) collected between 1992 and 1999 from farms from 16 regions of New Zealand (Ledgard *et al.* 2002). Although the authors proposed the average figures adopted by the current inventory, their original analysis identified pasture N concentrations by month, by region and by topography (slope) (see Appendix 5).

Suttie (2012) did not estimate pasture N values for deer farms.

FACTORS AFFECTING PASTURE ME AND N CONTENT

There is a complex relationship between pasture quality and stage of growth, pasture species, soil fertility, climate, farm class, grazing species and grazing pressure. These have been comprehensively reviewed, with emphasis on New Zealand farming conditions, by Cosgrove and Edwards (2007) and Litherland and Lambert (2007). The main factors influencing pasture ME and N are summarised here.

Seasonal patterns in pasture quality

It is widely known that in any one location, pasture ME and N content changes cyclically and seasonally in response to climate and seasonal plant growth cycles (Litherland & Lambert, 2007).

ME and N content of pasture follow similar seasonal patterns. Typically, ME and N concentrations rise during winter and reach a peak in spring (Figures 3 and 4). Pasture quality begins to fall again around November (earlier in warmer regions, e.g. North Island, later in cooler regions, e.g. South Island) to reach a minimum in February. Minimum values for ME and N are lower in warmer environments.

Effects of sward composition (stage of growth) on pasture quality

Seasonal changes in pasture quality (Figures 3 and 4) are caused by changes in sward composition over the year. Sward composition refers to the proportion of green grass leaf, green grass reproductive stem, clover, and dead plant material in the sward. These proportions reflect the different stages in seasonal plant growth cycle over the year. Figure 5 (reproduced from Litherland & Lambert, 2007) show how these proportions change over the year.

Figure 3. Metabolisable energy concentration of pastures from North of Taupo (NNI, n=2628), Southern North Island (SNI, n=2545) and the South Island (SI, n=1115) throughout the year (reproduced from Litherland & Lambert, 2007).

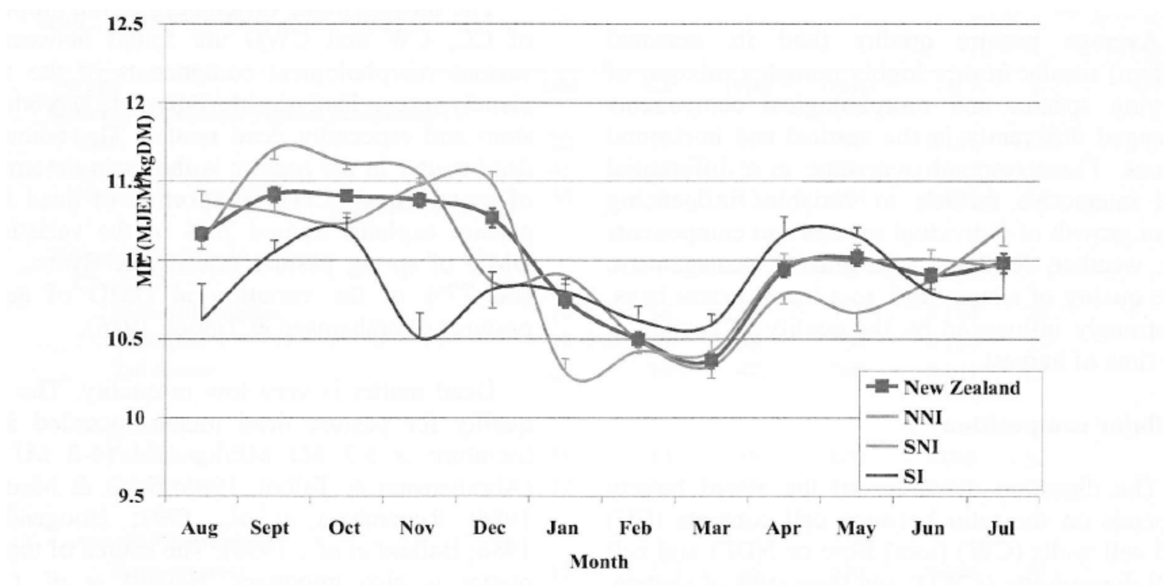


Figure 4. Crude protein concentration of pasture tested North of Taupo (NNI, n=2628), Southern North Island (SNI, n=2545) and the South Island (SI, n=1115) throughout the year (reproduced from Litherland & Lambert, 2007).

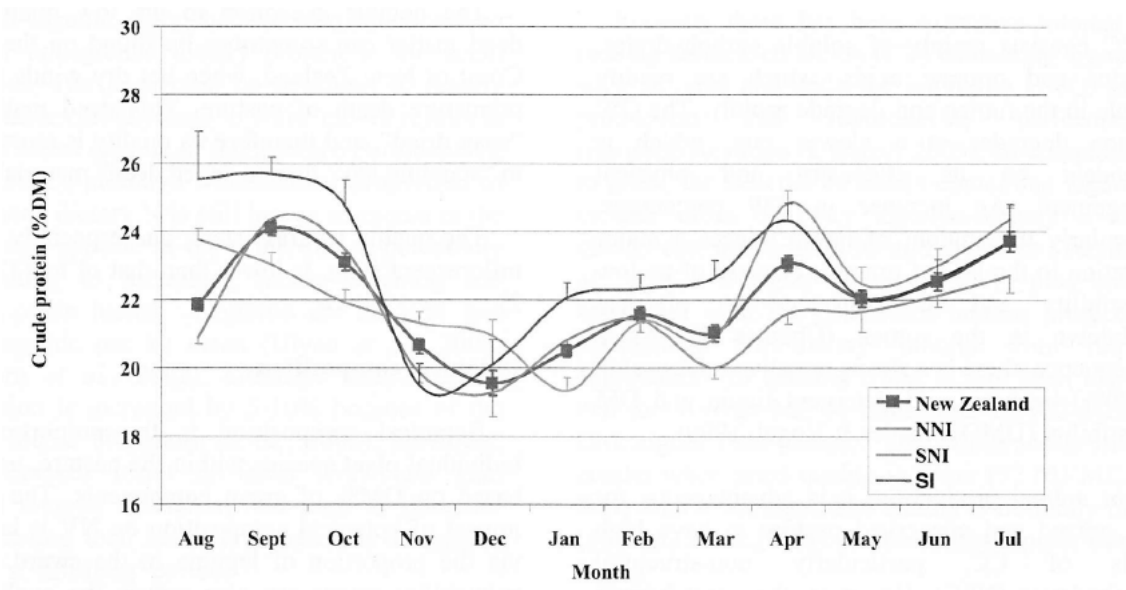
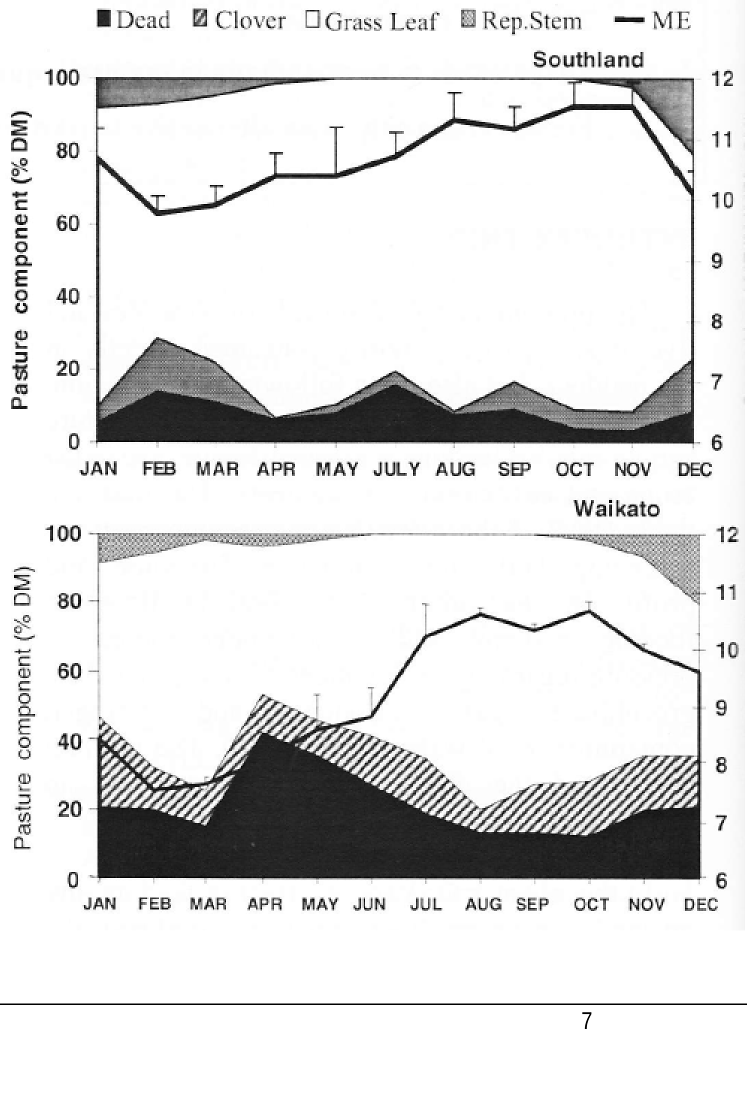


Figure 5: Seasonal patterns of the composition (dead, clover + herbs, green grass leaf, green grass reproductive stem) and ME concentration in pasture on offer on commercial sheep and beef farms in two regions (reproduced from Litherland et al. 2002).



Each of these sward components varies in digestibility, ME and N content. Generally, green grass leaf and clover have the highest digestibility, ME and N content, and dead matter has the lowest. The quality of reproductive stem is intermediate. Peak ME corresponds with greatest proportion of green grass leaf and lowest dead matter content. Clover differs from grass in that the proportions of clover leaf to stem and overall digestibility and nutritive value varies less than in grass.

When a pasture starts to go to seed/reproductive in late spring/early summer the proportion of grass reproductive stem and dead leaf increases, and overall pasture quality declines. This often coincides with the driest part of the year. Both temperature and rainfall affect the proportions of the different sward components. These vary regionally as a result of New Zealand's east to west rainfall gradient and north to south temperature gradient.

Effects of botanical composition (pasture species) on pasture quality

Botanical composition is the proportion of different plant species in the sward and is usually measured in terms of green sward components.

The main impact of botanical composition on pasture quality is the proportion of green grass (e.g. perennial ryegrass) to legume (e.g. clover). This is because clover has a higher crude protein content and higher digestibility than green grass leaf. Therefore, a pasture with high clover content generally has a higher quality (higher ME and N content) than pasture with low clover content. The proportion of clover in the sward varies seasonally and is generally greater in Waikato (warmer, wetter climate) than Southland (colder, drier climate (Figure 4).

In some cooler, drier regions and on steeper land, alternative grass species to ryegrass are often used, e.g. cocksfoot and tall fescue. Cocksfoot has a higher N content (approximately 4%) than tall fescue and ryegrass (both approximately 3%).

In warmer, drier regions (e.g. Northland) drought tolerant C4 species (e.g. paspalum and kikuyu) often dominate pastures. These have a similar N content to ryegrass but are lower in digestibility and therefore nutritive value.

On less fertile country, pasture often have a high proportion of native or poor quality grasses (e.g. reeds, rushes, browntop) with generally low digestibility and low ME and N content.

Botanical composition is also important in terms of palatability to grazing animals. For example, both cattle and sheep will eat clover in preference to grass or young actively growing leaf. As a result, the diet stock select is often of a higher quality than the average feed quality on offer. Sheep have the ability to do this to a greater extent than cattle.

Effect of soil fertility and N fertilisers on pasture quality

In most areas of New Zealand, soil nitrogen is the main limiting nutrient for pasture growth and quality. This is influenced by soil type, pasture clover content, fertiliser management, topography (mainly slope of land), grass species and animal species (via effects on urine deposition and leaching).

Generally, soil N affects grass growth (production) rather than the ME and N content of the grass. Clover can 'fix' N from the atmosphere and is not directly affected by the N content of the soil. The main influence of N content on pasture quality is through its effect on the proportion of grass and clover.

There is wide regional variation in soil fertility due to New Zealand's geology and topography. An extreme comparison is that between the organic-matter-rich, fertile soils on river flats (typical of dairy farms) and at the other extreme, thin stony soils, typical of South Island hill country sheep farms. Pasture composition and quality is very different on these contrasting farm types.

On extensive sheep and beef farms 'high quality pasture' is usually a combination of ryegrass and white clover. Clover fixes N from the atmosphere, some of which diffuses into the soil where it can be absorbed and used by grass and other pasture species. N fertilisers are used less in hillier regions as it can be lost rapidly by leaching or in runoff before the pastures can benefit. It is more usual to use cheaper phosphate fertilisers to boost clover growth which, in turn, provides N for the grass species.

In high production grazing systems (e.g. dairy pastures) N fertiliser is often used boost grass growth. This can increase the overall ME and N content in the sward through an increase in the proportion of grass green leaf. However, the more rapidly growing grass can in turn shade out and reduce clover growth and this can depress pasture N content. Thus the relationship between N fertiliser status, sward composition and pasture quality is complex.

Effects of climate on pasture quality

The main climatic effects on pasture quality are temperature and rainfall which affect pasture growth rate.

Effects of farm class on pasture quality

Farm class covers a range of variables which affect pasture quality. These include:

- Slope (e.g. flat, easy, steep). This determines pasture species, choice of cultivation, pasture renewal and fertiliser practices.
- Altitude and aspect (direction the land faces in relation to sun and prevailing wind and rain).These can affect temperature and rainfall which determine pasture growth rates and composition.
- In turn these affect which animal classes are run on these farms. For example, South Island high country farms will typically only have breeding cows and ewes whereas flatter terrain may have dairy or intensive sheep or beef finishing.

Effect of species farmed and stock class on pasture quality

Dairy pastures are generally higher in ME and N due to more intensive management of pasture and greater N fertiliser use than extensive sheep and beef farms. The more intensive management on dairy farms allows higher quality species to be used, higher level of pasture replacement, better weed management, reduction in the amount of dead matter in the pasture and the amount of time plants spend in a reproductive state.

Different stock classes are given different grazing priorities according to their physiological status, nutrient demands and relative profitability. For example lactating dairy cows will be grazed on the highest quality pastures to maximise milk production; likewise for intensively finished lambs and bull beef. Beef cows are often used to clean up poor quality pasture that is left behind after higher priority stock have grazed the pasture.

Changes in pasture quality over time.

Pasture quality, both regionally and nationally, is likely to change over time in response to changes in farming practice and climate. In recent years there has been a dramatic increase in the number of dairy cows. There has also been a major change in the regional distribution of dairy farms, e.g. the rise of dairying in the North Island central plateau (formerly forestry) and Canterbury and Southland (formerly cropping and sheep country). As dairy profitability increases, dairy cows are being farmed on more marginal, steeper country, at the expense of traditional sheep and beef cattle. This has consequences for regional pasture quality profiles. These changes are likely to continue in response to market drivers.

Defining better values

The current inventory model (Pickering 2011) calculates national monthly CH_4 and N_2O emissions for all animals of each species using national average values for pasture ME and N.

The summary of factors affecting pasture quality illustrates a complex relationship between pasture, animal species, environment and farm practice. However, at present the current model can only account for animal species.

To improve the model and make it more relevant, robust and flexible it is necessary to evaluate and characterise variation in pasture quality (both ME and N) according to season, species, region and farm class, with emissions weighted according to the numbers of animals of each stock class within each region.

The main questions to be addressed by this review:

1. Is there data available to better define and update pasture quality (ME and N content) on the basis of:
    a. Animal species
    b. Season
    c. Region
    d. Farm class
2. Is the data valid and relevant?
3. Is it possible to analyse the data to define improved values?

Data collection and analysis

A number of datasets containing pasture quality data were collated from a wide range of both published and unpublished studies (Table 2). These included data for which the raw data is no longer available (see Appendices).

Table 2 lists the source and characteristics of individual data sets obtained for this review. There were 9 different databases and over 19,000 samples although only one sample was identified as coming from a deer farm.

Table 2: A summary of pasture quality databases available for analysis

Database	Date range	Identifiers	Sample no. (n)
Gibbs	2006-2008	Species†, month, region	143
Litherland	2005-2006	Month, region (1)	285
AgResearch	2001-2002	Species, month, region	164
Ausseil 09/10	2009-2011	Species, month, region	659
AgResearch P21	2007-2008	Species, month, region (1)	236
Clark	1995-2001	Species, month, region (1)	974
Dalley and Geddes	2007-2012	Species, month, region	904
Gillingham & Gray	1996-1997	Species, month, region (1)	208
FeedTech	2001-2006	Month, region	≈15,800ᶲ
Total samples			≈19,375ᶲ

† Grazing species (dairy, beef, sheep, sheep/beef, deer)
ᶲ ≈ Not all samples were analysed for both ME and N

Gibbs	– Dairy farms in Southland and Canterbury
Litherland	– Waikato only – species not identified
AgResearch	– Sheep/beef , Waikato, Manawatu, Wellington, Canterbury, Southland
Ausseil 09/10	– Dairy, sheep/beef 11 regions, some farms identify slope
AgResearch P21	– Dairy, sheep/beef, Waikato, Manawatu, Canterbury, Southland
Clark	– Dairy, one farm (No 2 Dairy Ruakura)
Dalley & Geddes	– Dairy, 5 regions over Southland, Otago and West Coast
Gillingham & Gray	– Sheep/beef, Hawkes Bay, slope and aspect
FeedTech	– Data from a commercial testing laboratory, species not identified, samples from throughout NZ

The collection method and type and presentation of data between databases were not consistent:

- Not all samples were analysed for both pasture ME and N.
- The FeedTech database recorded “date of submission” and this was assumed to be the same as the sampling date.
- The category species (dairy, beef, sheep, sheep/beef) was not adequately defined; e.g. did sheep/beef mean pastures grazed by either beef or sheep or by both. The Litherland and FeedTech databases did not identify grazing species.
- The sample collection methods are unknown and likely to vary between databases.
- There was great variability in spread of samples over the year with some seasons having very few data points (see below).
- Databases were inconsistent in identifying farm region/location. Some identified individual farms, others a general region. Regional classifications may not have been consistent between databases. Regional coverage was patchy.
- Only one dataset (Gillingham & Gray, unpublished) identified slope of pasture.

COLLATION OF DATABASES

The raw data sets were collated into a single 'global' database. Because of inconsistency between individual databases, data was standardised as follows:

- All farms identified as sheep farms, beef farms and sheep/beef farms were classified as "sheep/beef". Only 94 samples in the whole database were classified as sheep. Only 2 were classified as beef.
- All farm locations were converted into regions on the basis of New Zealand Statistics Territorial authorities. It is acknowledged that these are political rather than "agricultural regions"
- Regions were also classified as North or South Island.
- Month and season were generated from sample date.

The global database contained 19,633 samples accumulated from 9 sources (Table 3).

Table 3. Sample numbers (n) by identifier

Grazing species	n	Regional Authority	n	Month	n
Dairy	2371	Auckland	38	Jan	1388
Deer	1	Bay of Plenty	124	Feb	1788
Sheep/beef	916	Canterbury	1448	Mar	1483
Not identified	16375	Gisborne	6	Apr	1669
		Hawkes Bay	1565	May	1499
		Manawatu/Wanganui	5761	Jun	2092
		Marlborough	17	Jul	1394
		Northland	224	Aug	1418
		Not in NZ	55	Sep	1405
		Otago	786	Oct	1348
		Southland	701	Nov	2516
		Taranaki	565	Dec	1663
		Tasman	19		
		Waikato	6568		
		Wellington	45		
		West Coast	478		
		Not identified	1263		
Total	19663		19663		19663

SUMMARY OF DATA COLLECTED

Figures 5 to 12 summarise the global database on the basis of monthly raw means and sample numbers. The data from Litherland and Feedtech databases have been omitted as these did not identify grazing species.

Due to the nature of the databases and the studies for which the data were collected, the data is likely to be biased towards "better" farms in terms of greater sampling frequency and sample numbers, i.e. farmers with better management practises and, therefore, higher pasture quality are more likely to collect samples for analysis or co-operate with research studies.

PASTURE ME - DAIRY

There were 2371 dairy samples in the global database. The curves generated from this data were similar to the current model but with a wide variation in the measured values within months (Figure 5) and between regions (Figure 6). Overall sample numbers are lower in winter and in some regions samples are not available for every month of the year.

Figure 5: Mean ME content (±SD) of dairy pastures

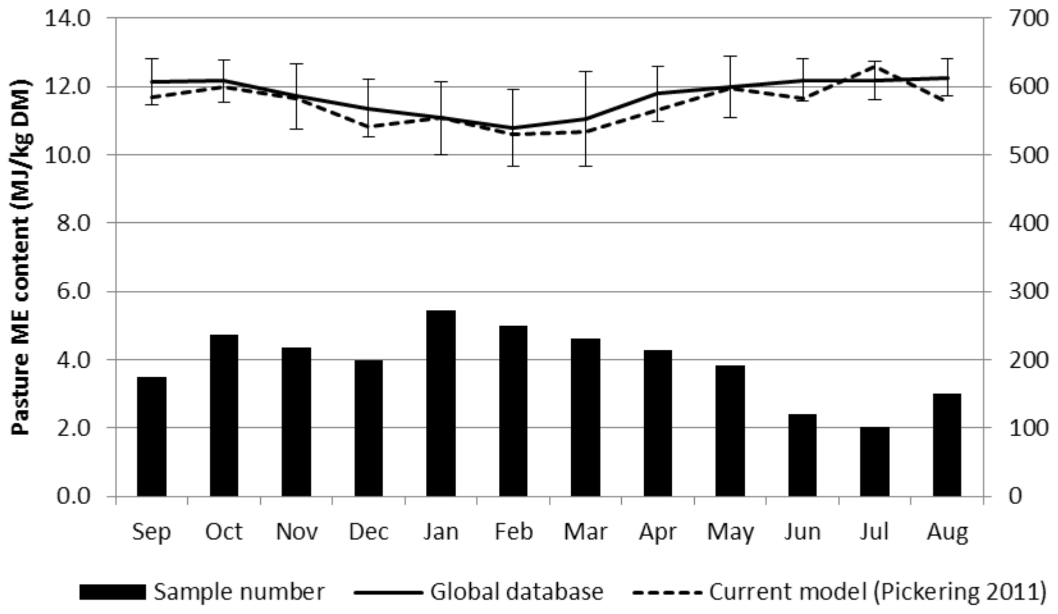
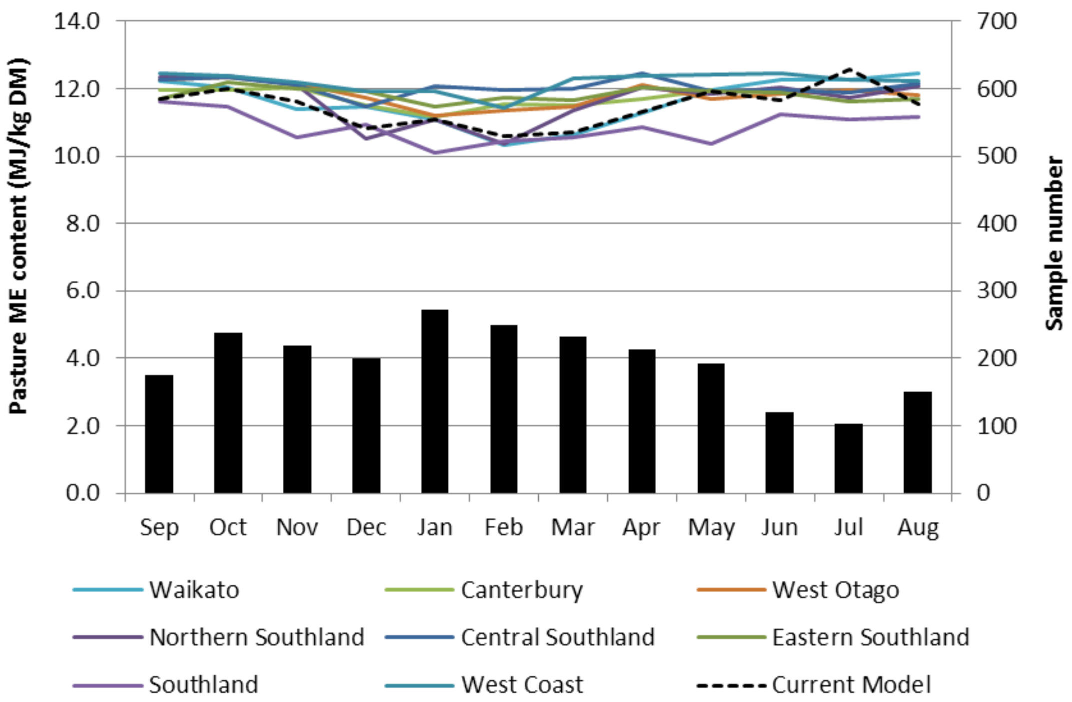


Figure 6: Mean ME content of dairy pastures by region where adequate data is available within a region.



PASTURE ME – SHEEP/BEEF

Only 916 samples were available from sheep and beef farms. This number is small considering the wide diversity farm types from intensive beef and lamb finishing through to extensive sheep production. Overall, the current inventory model appears to overestimate ME content in summer (Figure 7). Sample numbers are very low in autumn and winter. While there appears to be regional variation (Figure 8), few regions have sufficient data to confirm this.

Figure 7: Mean ME content (±SD) of sheep/beef pastures

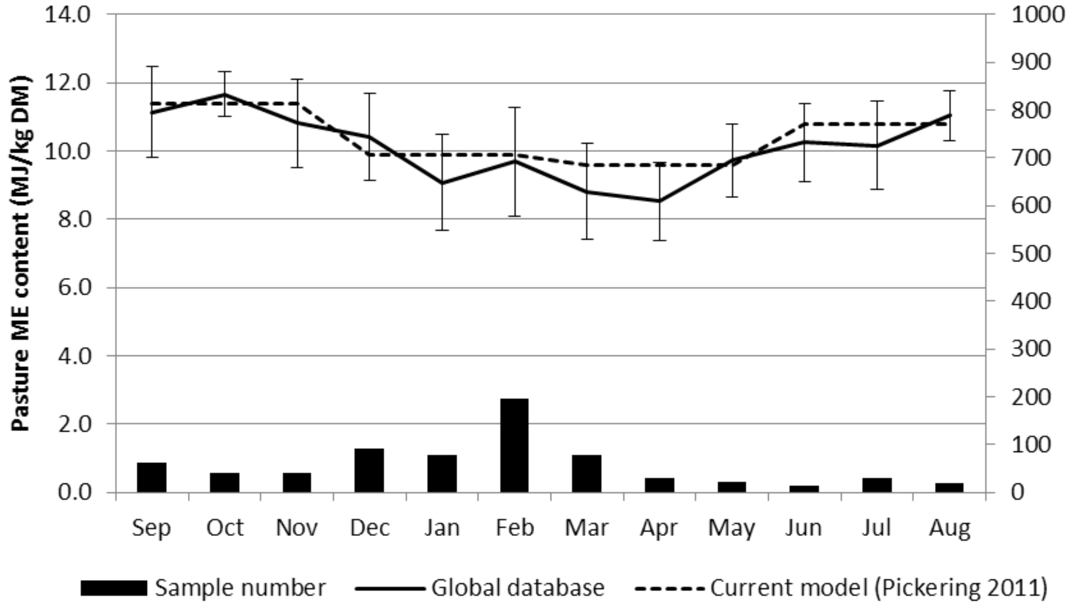
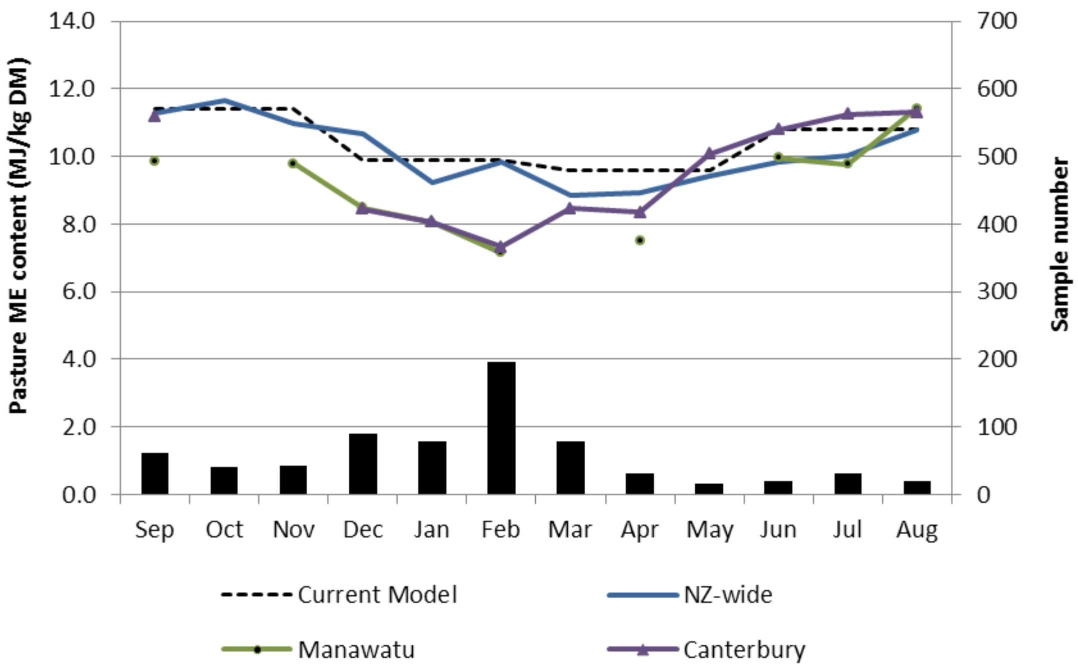


Figure 8: Mean ME content of sheep/beef pastures by region



PASTURE N - DAIRY

Compared with the current database the single value for N used in the current model appears to be inappropriate and a seasonal curve would improve precision (Figure 9 and 10). However, the sample numbers are low over winter and there is considerable regional variation.

Figure 9: Mean N content (±SE) of dairy pastures

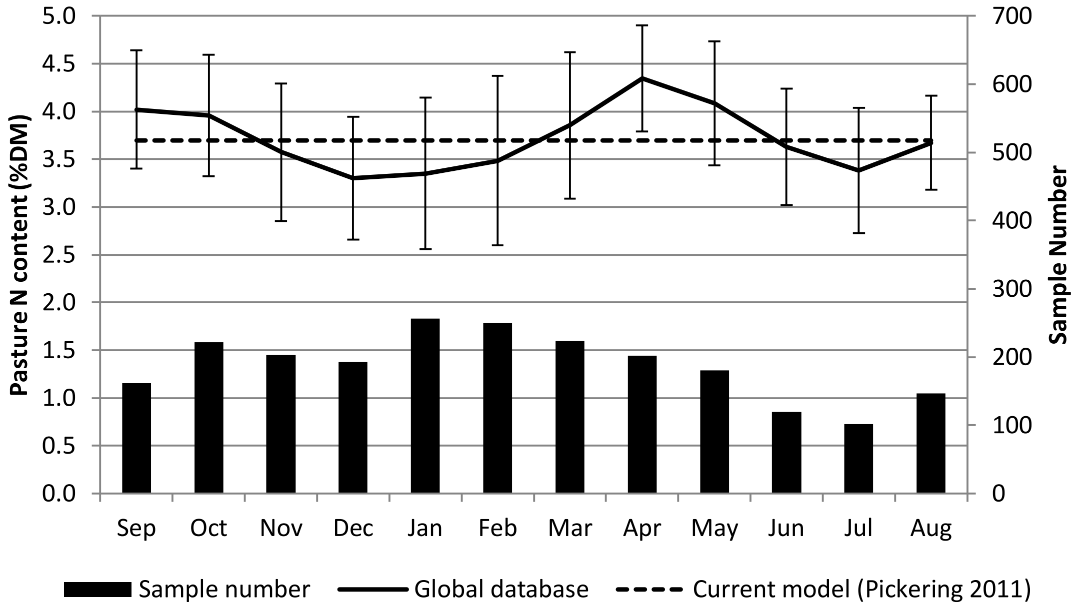
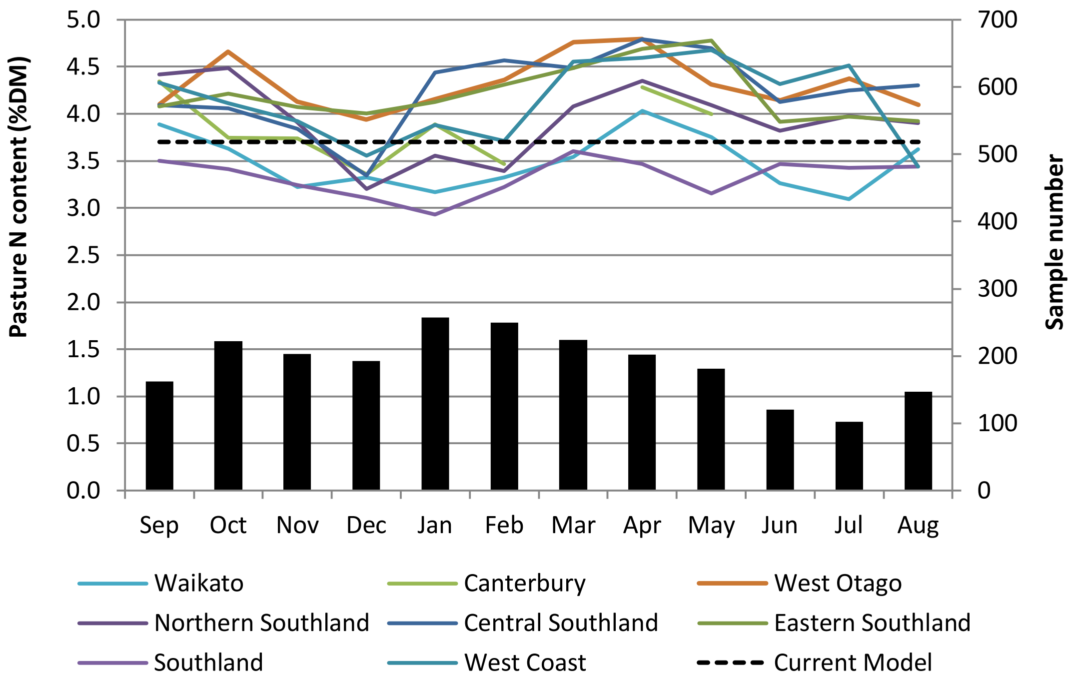


Figure 10: Mean N content of dairy pastures by region



PASTURE N – SHEEP/BEEF

As for dairy, the single value for N used in the current model appears to be inappropriate and a seasonal curve would improve precision (Figure 11 and 12). However, the sample numbers are low over winter and, in spite of limited data, there appears to be wide regional variation. There is evidence of sampling bias towards higher fertility farms (easy/rolling/flat) with poor representation across hill country.

Figure 11: Mean N content (±SE) of sheep/beef pastures

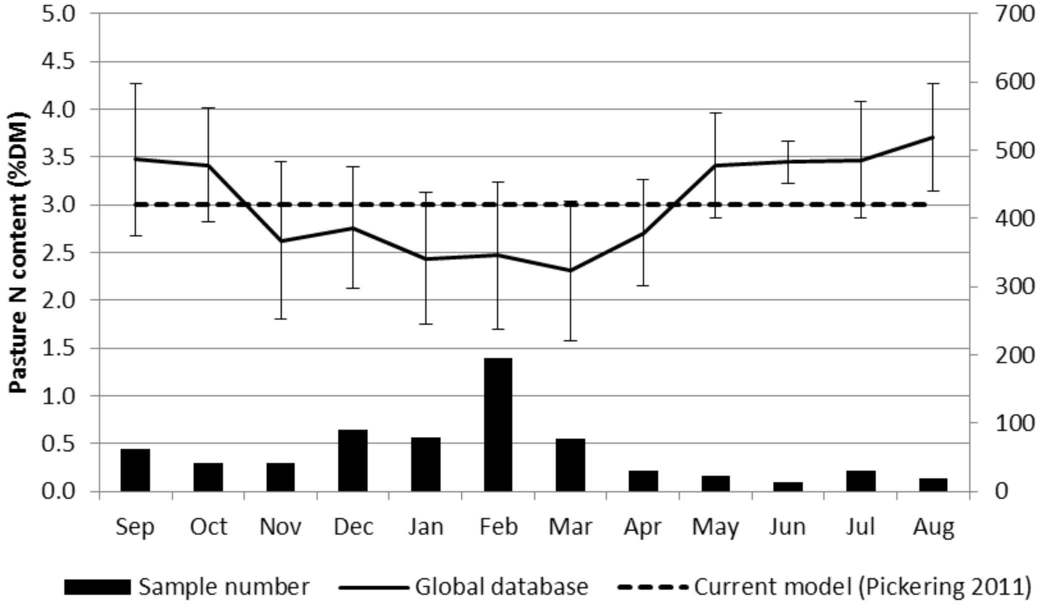
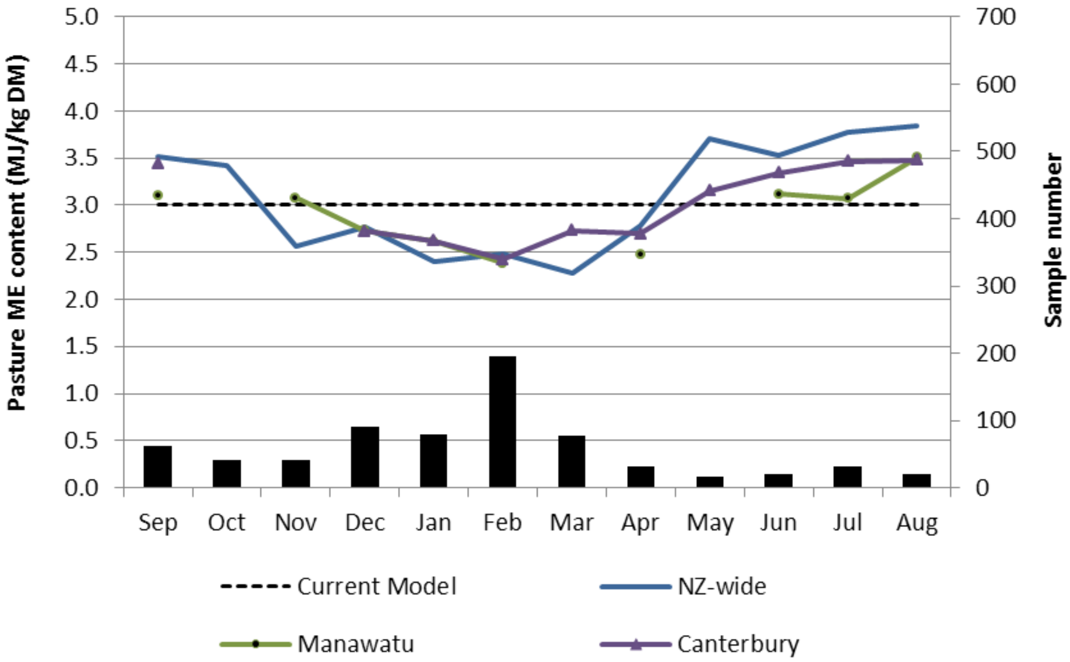


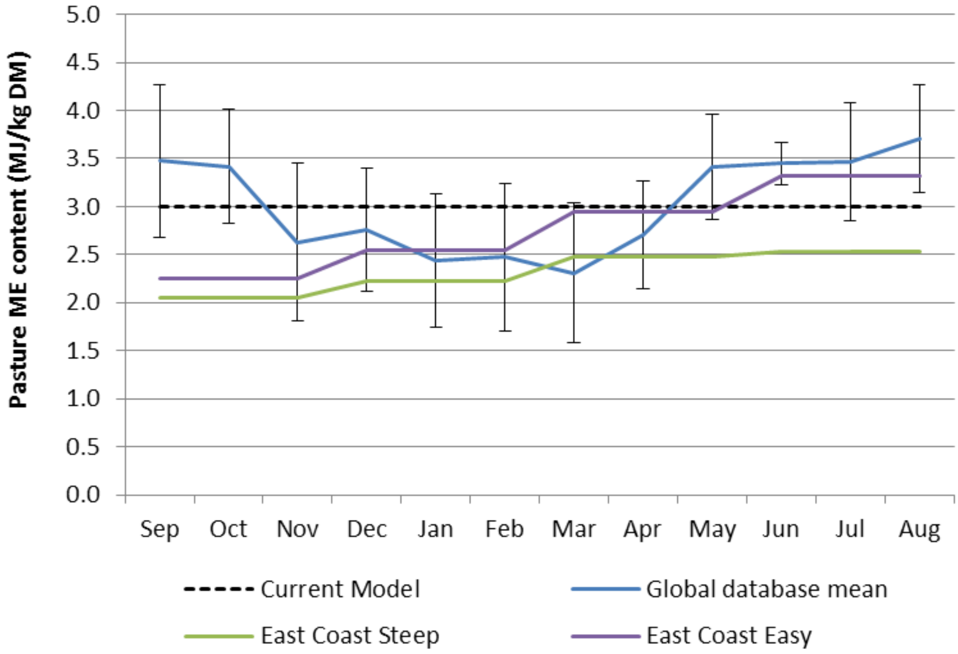
Figure 12: Mean N content of sheep/beef pastures by region



Sheep/beef N - Effect of slope on pasture N content

Only one dataset contained information on the effect of slope on pasture N on sheep/beef farms on North Island east coast pastures – Hawkes Bay (Gillingham & Gray, unpublished; Figure 13). These data suggest that there is a difference in pasture N content between pastures growing on easy and steep slopes with higher quality pasture grown on the easier slopes and lower quality pasture on the steeper slopes. Although this data is from one location it fits with our understanding of pasture quality and provides further evidence that a single average N value is inappropriate.

Figure 13: N content of sheep/beef pastures on North Island east coast pastures on easy and steep terrain



Statistical analysis

Statistical analysis of the global database was completed by D. Saville of Saville Statistical Consulting Ltd. A complete statistical report, including details of methodology and statistical conclusions is appended to this report (Appendix 2). The following summarises the main points of the statistical analysis.

STATISTICAL APPROACH

The aim of the statistical examination was to attempt to isolate data from individual field experiments at specific locations and examine the pattern of ME (or N) values from month to month within each farm year (taken to be Sept 1 to August 31). Data for each pasture type (sheep/beef or dairy) and each region was examined separately. The hope was that several data sets would be available for each pasture type and region.

It was expected that many of these data sets would involve missing months. The proposal for each region and pasture type was to put together these (possibly incomplete) data sets using the statistical method “analysis of variance”, with each dataset being treated as a statistical “block” and with months being regarded as “treatments” (statistical design being a randomised block design). “Missing values” would be estimated by the analysis, and in this manner improved regional means would be obtained for each pasture type.

However, the data available for this review came from a number of separate studies each with different objectives, methodologies and data records. The database did not include information which allowed matching of data with individual experiments at specific locations. Therefore, this biometrical “best practice” approach to analysis of variance could not be implemented without modification. As a result the analysis was based on the individual databases rather than on individual field experiments. This was far from ideal because, in some cases, the number of samples averaged within a farm year varied considerably from month to month; in other cases, this was not a problem.

A detailed description of the statistical approach is presented on page 40.

PASTURE ME AND N – DAIRY

For both ME and N, in only 4 out of 17 regional authorities was there sufficient data to examine regional variation in pasture grazed by dairy animals (Figures 14 and 15). Other major dairying regions (Taranaki, Manawatu/Wanganui, and Canterbury) were not included. For Otago and the West Coast, Dalley/Geddes is the only source of data. For Southland, Dalley/Geddes and Ausseil are the two sources. For the Waikato, Clark is the main source, along with Ausseil and Gibbs. In general, Ausseil estimates of ME and N were lower than estimates from the other sources.

Both ME and N varied significantly from month to month (Figures 14 and 15), although on a percentage basis this variation was less than on sheep/beef pastures (Figures 18 and 19). Dairy ME values fall slowly from October to February, then increase through to June, and then plateau from June to October. Dairy N values dropped slowly from April to December and then increased again.

Figure 14. Mean monthly ME content of dairy pastures by region

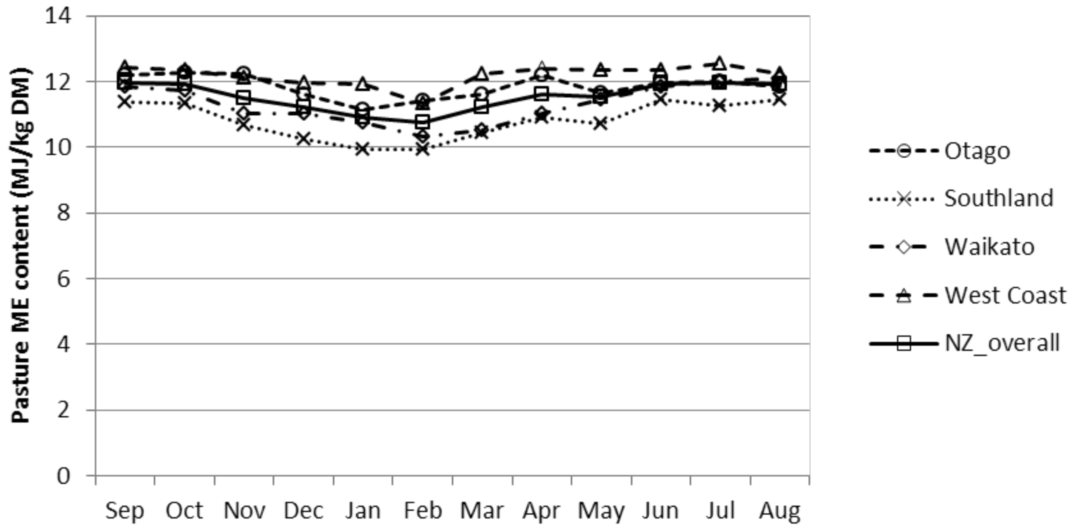
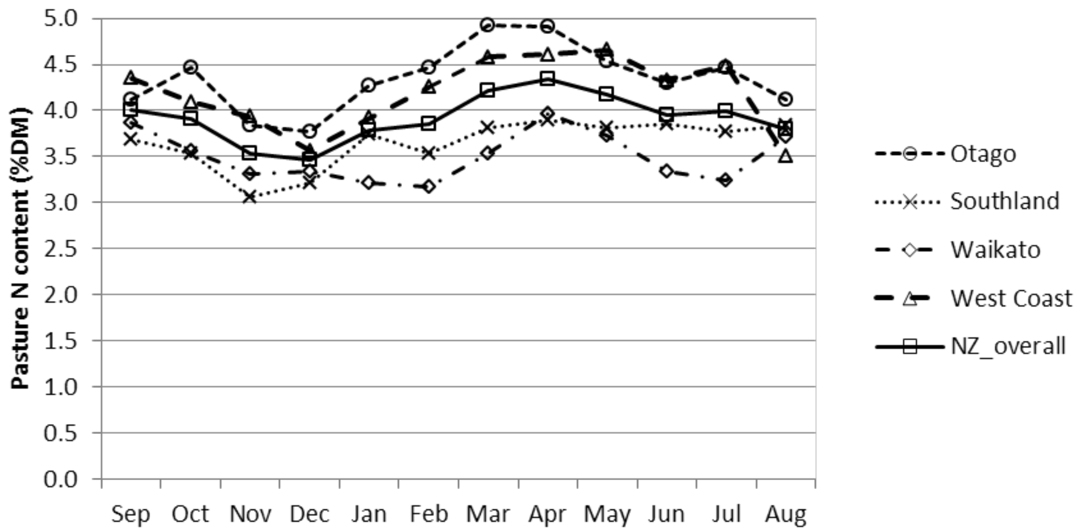


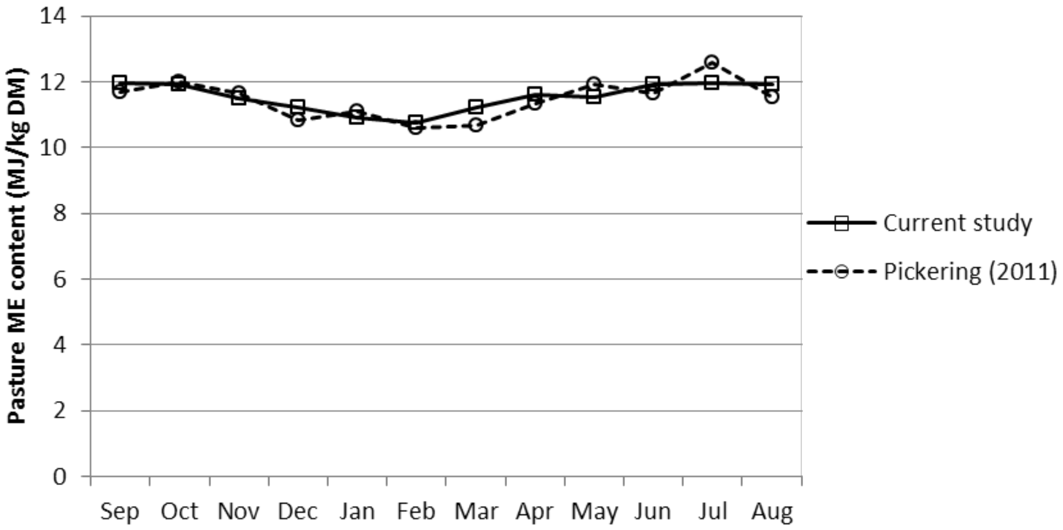
Figure 15. Mean monthly N content of dairy pastures by region



For both ME and N, the four sets of regional figures were used to derive an overall monthly pattern for ME for NZ dairy pastures as a whole (NZ_Overall). The validity of this approach is discussed in the full Statistical Report (Appendix Section 2)

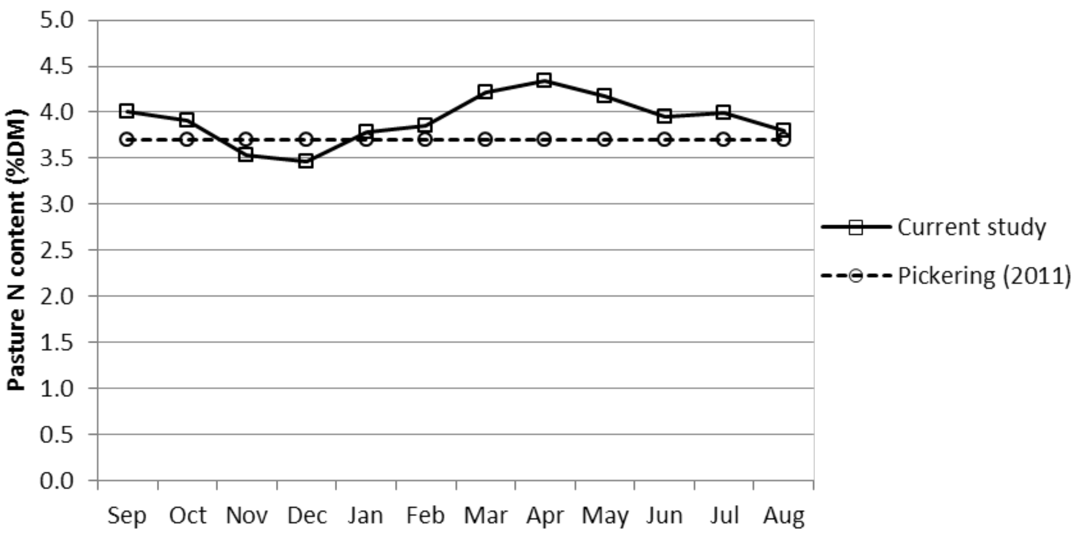
Figure 16 and 17 compare the NZ_Overall data from Figure 14 (ME) and Figure15 (N) with values used in the current inventory model (Pickering 2011).

Figure 16. NZ_Overall mean monthly ME content of dairy pastures



For ME (Figure 16) the current study and the national inventory agree to within 5% for all months (the two ME curves criss-cross each other, and in general, follow each other closely). As a simple average over the 12 months, the two estimates agree to within 0.6%.

Figure 17. NZ_Overall mean monthly N content of dairy pastures



For N (Figure 17) the current analysis indicates that monthly values are higher than the current inventory model for 10 out of the 12 months. On average, the estimate in the current report is 6% higher than that used in the inventory model. A constant N value is clearly inappropriate. For monthly estimate from this report, the Least Significant Difference, LSD (5%) is 0.235. This means that for six months, (months Mar - July and Sep), the estimates in this report differ significantly ($p<0.05$) from the 3.7 value used in the inventory.

PASTURE ME AND N – SHEEP/BEEF

As with dairy, only 4 out of 17 NZ regional authorities had sufficient data to examine regional variation in pasture ME and N on sheep/beef farms (Figures 18 and 19).

Both ME and N vary significantly from month to month, with both variables being lowest from December to April. The extent of the seasonal variation was greater than that occurring on the dairy pasture.

Figure 18. Mean monthly ME content of sheep/beef pastures by region

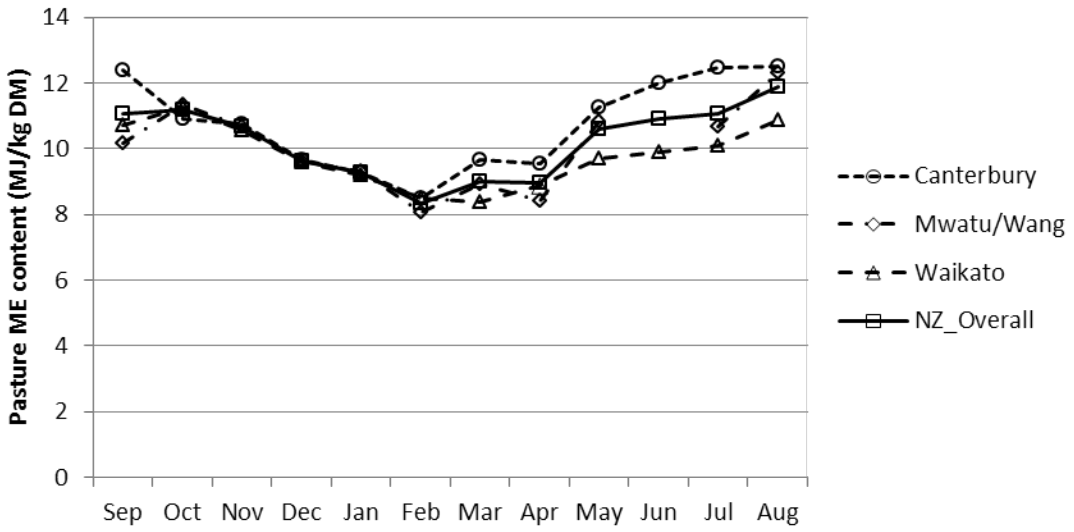
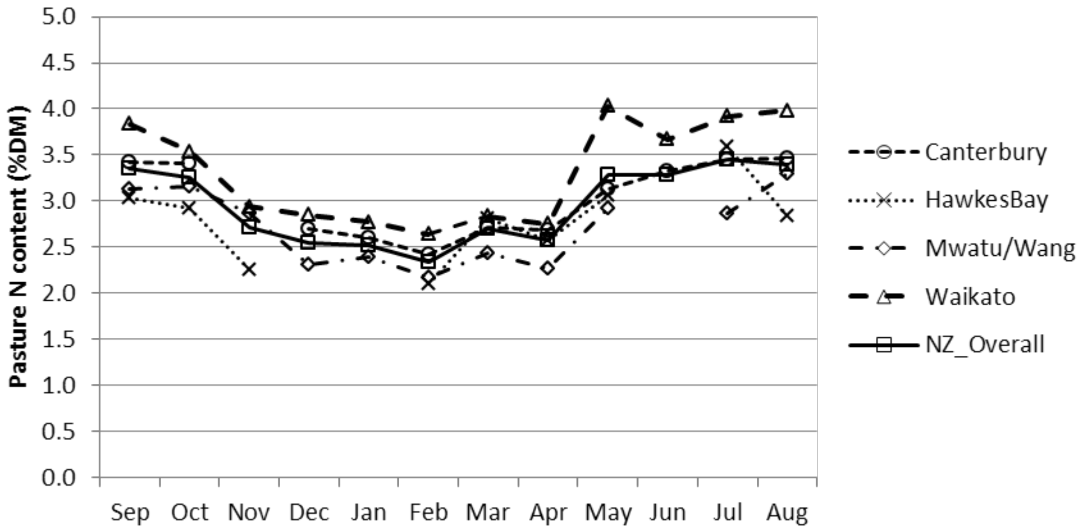


Figure 19. Mean monthly N content of sheep/beef pastures by region



For both ME and N, the four regional sets of figures were used to derive an overall monthly pattern for NZ sheep/beef pastures (NZ_Overall). The validity of this approach is discussed in the Statistical Report (Appendix Section 2).

For ME (Figure 20) the two estimates agree to within 10% except for the months of Feb, May and Aug. As a simple average over the year, the estimate in this report is within 2% of that used in the inventory.

Figure 20. NZ_Overall mean monthly ME content of sheep/beef pastures

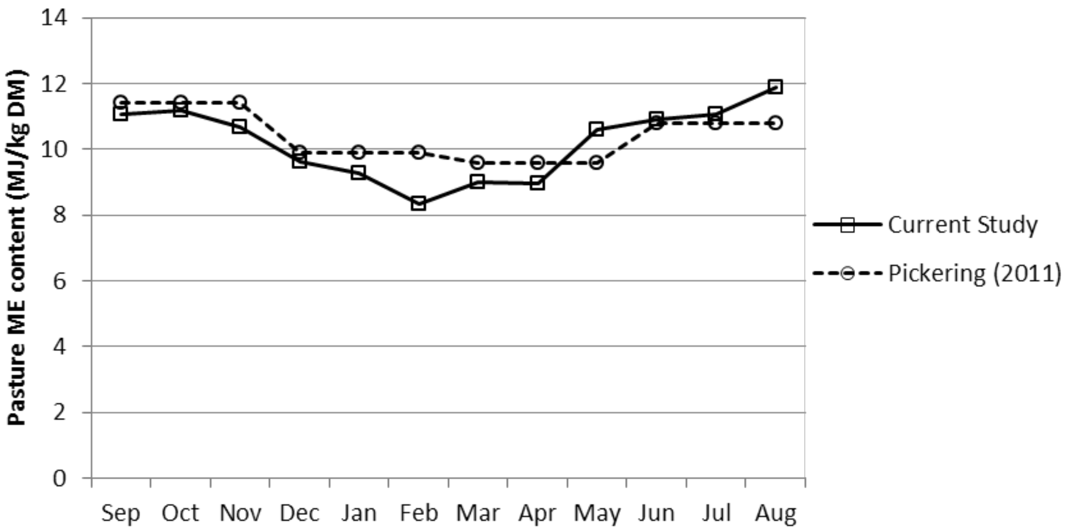
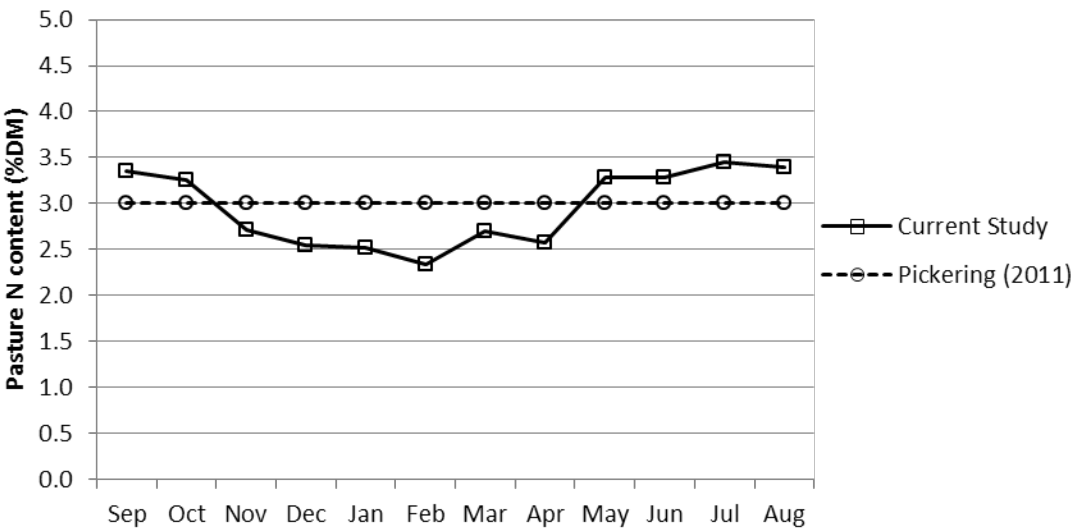


Figure 21. NZ_Overall mean monthly N content of sheep/beef pastures



For N (Figure 21), the two estimates *disagree* by more than 8% across a 12 month period, and disagree by more than 13% for 6 out of the 12 months. As for dairy, a constant N value is clearly inappropriate. In comparing a monthly estimate from this report with the current constant value of 3.0, the Least Significant Difference, LSD (5%) is 0.217. This means that for *all 12 months*, the estimates reported in this analysis differ significantly from 3.0 (p<0.05).

Conclusions

The data available in this collated global database is not sufficient to provide scientifically validated estimates of monthly ME of N means on either a regional or New Zealand-wide basis for either dairy or sheep/beef farms.

However, some salient observations are:

1. Dairy ME - In terms of an overall national average, the dairy ME values from the current global database are in reasonable agreement with those of the current inventory model (Figure 16).
2. Sheep/beef ME - In terms of an overall national average, the current inventory model appears to overestimate ME content of beef pastures in summer compared to values from the global database (Figure 20).
3. Dairy and sheep/beef N – The single annual average value in the current model is inappropriate (Figures 17 and 21).
4. There is clear evidence of regional variation in both pasture ME and N for both dairy and sheep/beef pastures (Figures 14, 15, 18, 19). This requires further investigation.
5. In general there is a sampling bias over season with more samples taken in spring and summer compared to winter. This makes it difficult to develop reasonable seasonal curves.
6. Suttie (2012) refuted the assumption in Pickering (2011) that deer pasture ME is the same as for dairy pastures, and proposed values closer to those of sheep/beef pastures (Figure 1). It seems reasonable to assume that pasture N values are also similar to those of sheep/beef pastures. However, this cannot yet be confirmed as there are no data available in the current global database and no published values in the literature.

Though it is not possible to suggest regional values for pasture ME and N, the NZ overall values generated by the current statistical analysis (and Suttie, 2012) are likely to be an improvement on current values:

Table 4. 'Improved' values for pasture ME and N content suggested by the current review

Season	Winter			Spring		Summer			Autumn		Winter
Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Pasture ME content (MJ ME/kg pasture DM)												
Dairy	11.95	11.91	11.95	11.92	11.50	11.20	10.92	10.74	11.20	11.62	11.53	11.90
Beef/sheep	11.06	11.89	11.08	11.17	10.66	9.61	9.26	8.34	8.99	8.94	10.60	10.89
Deer (Suttie)	10.6	10.5	11.2	11.2	11.2	9.6	9.7	9.6	9.0	9.1	9.1	10.5
Pasture N content (% of the diet)												
Dairy	4.0	3.8	4.0	3.9	3.5	3.5	3.8	3.9	4.2	4.3	4.2	4.0
Beef/sheep	3.5	3.4	3.4	3.3	2.7	2.5	2.5	2.3	2.7	2.6	3.3	3.3
Deer	3.5	3.4	3.4	3.3	2.7	2.5	2.5	2.3	2.7	2.6	3.3	3.3

Recommendations

That a nationwide survey of dairy, sheep/beef and of pastures be biometrically designed and conducted to provide scientifically valid and representative pasture quality data.

This should be carried out for a minimum of three complete years (e.g. Sep to Aug), with a minimum of 1-2 pastures sampled for each grazing species (dairy, sheep/beef, deer) in each region in each season. Pastures sampled should be on different farms each season, so that in total, pastures would be sampled (Sep to Aug) on a minimum of 3-6 different farms per region. The number of pastures sampled per region per season should be determined by "optimal statistical design" calculations (as for any stratified random survey), so that the regions with a high number of stock units will be sampled more intensively than regions with a low number of stock units. Practical details would also need to be carefully considered, such as at what stage of the dairy rotation should a paddock be sampled. Standardisation of field sampling technique and of laboratory methodology would also be required.

The resulting data would enable a "best practice" method of analysis to be carried out involving weighting by total stock units per region, and would result in more robust estimates of NZ-wide and regional averages for ME and N in dairy, sheep/beef and deer grazed pastures.

In such a large scale survey it would also be prudent to consider other potentially valuable pasture quality parameters that could be evaluated concurrently (e.g. pasture mineral content, botanical composition, slope of pasture, farm class etc.).

Furthermore, in view of potential for the Inventory Model becoming 'regional' it may be important to consider the appropriateness of redefining 'regions' based on NZ Statistics political regional authorities, in favour a system based on more relevant agricultural, geographical/geological factors.

Until better data is available it is recommended that the model adopts the values generated by the current statistical analysis for improved NZ-overall values for pasture ME and N for dairy, sheep/beef and deer pastures.

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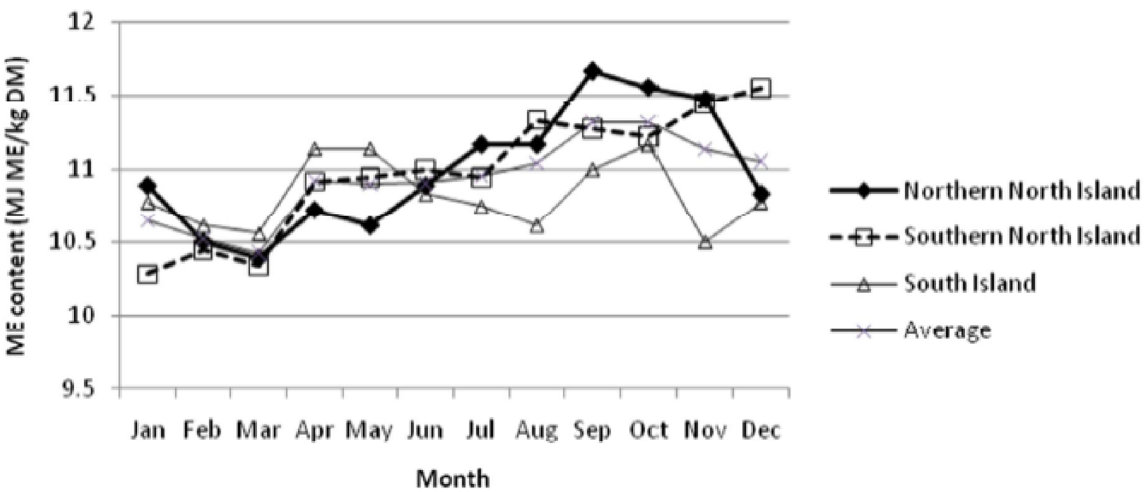
Appendices:

1. PUBLISHED SOURCES FOR WHICH RAW DATA WAS NOT AVAILABLE.

Appendix 1. Published values used in the Overseer program (Wheeler *et al.* 2008)

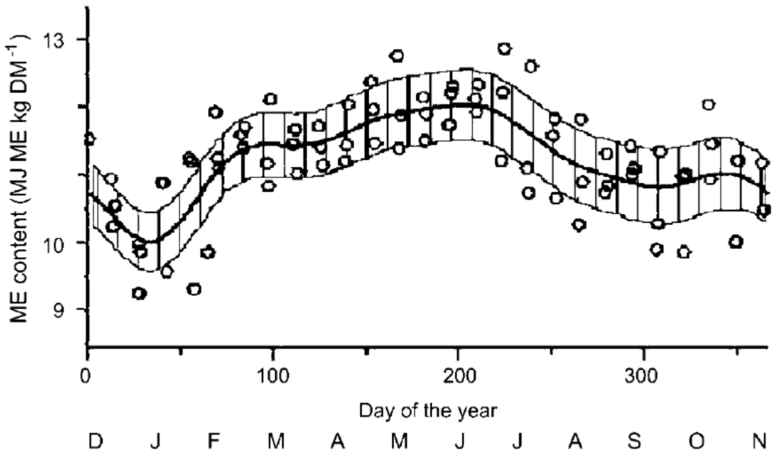
Table 1. Default pasture ME (MJ ME/kg DM) for each region and month.

Region	Average	Northern North Island	Southern North Island	South Island
January	10.65	10.89	10.28	10.78
February	10.55	10.50	10.44	10.61
March	10.43	10.39	10.33	10.56
April	10.93	10.72	10.92	11.14
May	10.90	10.61	10.94	11.14
June	10.91	10.89	11.00	10.83
July	10.95	11.17	10.94	10.75
August	11.04	11.17	11.33	10.61
September	11.31	11.67	11.28	11.00
October	11.31	11.56	11.22	11.17
November	11.14	11.47	11.44	10.50
December	11.06	10.83	11.556	10.78



Appendix 2 . Seasonal changes of herbage quality within a New Zealand beef cattle finishing pasture (Machado *et al.* 2005).

Fig. 1 Seasonal change in herbage metabolisable energy (ME) during the sampling period (by day of the year for each of the 3 years). Plotted confidence bands represent 83% probability.



Appendix 3 . Concentrations of nitrogen, phosphorus, sulphur, magnesium, and calcium in North Island pastures in relation to plant and animal nutrition. (Smith and Cornforth 1982)

Table 3 N concentrations of North Island pastures summarised according to the requirements for active plant growth.

	No. of	% N		% of sites within regions		
Region	sites	Mean±SD	Range	Deficient	Optimal	Safe excess
Waikato	1540	4.23±0.80	1.12–6.22	69	29	2
Taranaki	374	4.20±0.78	1.64–6.01	65	32	3
Wairarapa	512	4.09±0.89	1.45–6.22	65	33	2
Hawke's Bay	472	4.08±0.92	1.30–6.30	67	28	5
Bay of Plenty	312	4.06±0.72	2.00–5.77	71	26	3
Auckland	346	4.05±0.84	1.17–6.06	65	32	3
Central Plateau	627	4.04±0.90	1.25–6.50	70	26	4
Manawatu	122	4.04±0.92	1.76–6.08	70	26	4
Northland	928	3.95±0.83	1.42–6.40	74	23	3
Thames	110	3.83±0.83	1.63–5.78	78	20	2
Wellington	10	3.74±0.62	2.92–4.76	90	10	0
Rangitikei	128	3.69±1.02	1.30–5.74	78	21	1
East Coat	62	3.60±0.81	1.65–5.00	85	15	0
King Country	319	3.55±0.76	1.47–5.47	89	10	1
North Island	5862	3.94±0.83	1.12–6.50	74	24	2

Appendix 4. Seasonal variations in pasture quality on New Zealand sheep and beef farms. (Litherland et al. 2002)

TABLE 1: Chemical and botanical composition (remainder is green grass leaf) of offered pasture collected from commercial sheep and beef farms in four regions and predicted liveweight gain using Q-Graze.

	ME (MJME/kgDM)	CP	ADF	NDF (%DM)	CHO	Dead	Clover	Stem	LWG[1] (kg/d)	LWG[2]
Waikato										
Sum	8.5	17.7	32	55	5.3	24	17	15	0.6	0.5
Aut	8.1	18.8	33	57	6.3	29	10	19	0.3	0.4
Win	9.8	24.2	22	49	7.9	21	13	0	0.8	1.2
Spr	10.3	22.6	28	50	7.1	15	16	2	0.7	1.2
Mean	**9.2**	**20.8**	**30**	**53**	**6.6**	**22**	**14**	**9**	**0.6**	**0.8**
Tararua										
Sum	10.0	18.1	27	47	10.6	11	14	6	0.8	1.0
Aut	9.2	21.9	30	50	7.7	25	10	0	0.7	0.8
Win	10.6	23.3	26	48	10.1	12	6	0	1.1	1.4
Spr	11.6	24.4	22	42	12.1	6	6	0	1.3	1.5
Mean	**10.3**	**21.8**	**26**	**47**	**10.1**	**14**	**9**	**2**	**1.0**	**1.2**
Canterbury										
Sum	9.0	20.2	29	51	6.0	10	18	19	0.5	0.9
Aut	7.6	13.9	33	57	6.5	13	5	39	-0.7	0.0
Win	9.5	19.9	26	49	12.4	21	4	0	1.0	1.3
Spr	10.8	21.5	29	43	11.4	9	13	1	1.1	1.4
Mean	**9.2**	**18.9**	**28**	**50**	**9.1**	**13**	**10**	**15**	**0.5**	**0.9**
Southland										
Sum	10.0	19.7	27	51	7.5	11	14	10	1.0	1.2
Aut	10.0	20.3	28	52	6.8	10	10	10	0.5	1.1
Win	11.3	27.4	25	46	8.8	8	6	5	1.0	1.5
Spr	11.4	24.4	23	44	10.2	6	6	1	1.3	1.6
Mean	**10.7**	**22.9**	**25**	**48**	**8.3**	**9**	**7**	**6**	**0.9**	**1.3**
SED	0.4	1.8	1.5	2.5	1.1	4.8	3.5	5.0		
Significance										
Region	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Season	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Region*Season	0.09	0.02	0.30	0.30	0.004	0.13	0.08	0.001		

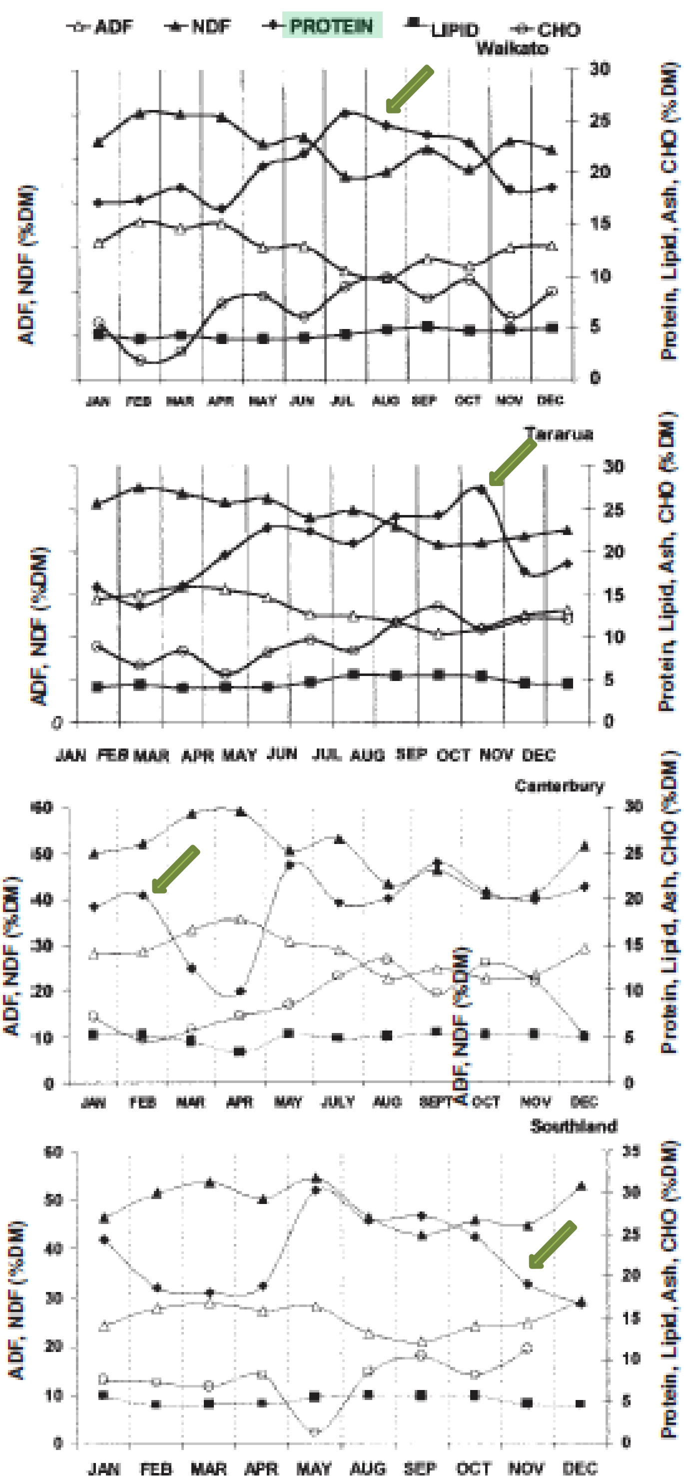
Seasons: Sum - summer; Aut - autumn; Win - winter; Spr - spring
Parameters: ME - metabolisable energy; CP - crude protein; ADF - acid detergent fibre; NDF - neutral detergent fibre; CHO - soluble carbohydrate.
LWG[1] Predicted liveweight gain of 350 kg Friesian bulls grazing paddocks using pre- and post-grazing residuals from Table 2.
LWG[2] Predicted liveweight gain of 350 kg Friesian bulls grazing paddocks from a pre-grazing mass of 2500 down to a residual of 1500 kg DM/ha.

TABLE 2: Pre-grazing herbage mass (PreHM), days since last grazed, post-grazing herbage mass (PostHM) and chemical composition of pasture plucked to simulate animal diet selection on commercial sheep and beef farms in four regions.

	PreHM (kgDM/ha)	Days	PostHM (kgDM/ha)	ME (MJME/kgDM)	CP	ADF	NDF (% DM)	CHO
Waikato								
Sum	2200	23	1800	9.0	21	28	49	6.5
Aut	2060	25	1500	9.1	23	27	48	7.2
Win	1660	31	1160	10.9	28	22	44	9.0
Spr	1600	25	1060	11.1	27	23	45	7.8
Mean	**1870**	**26**	**1390**	**10.1**	**25**	**25**	**47**	**7.6**
Tararua								
Sum	1930	24	1340	10.7	23	25	42	11.6
Aut	1950	30	1380	10.1	25	23	44	7.7
Win	1930	48	1244	10.9	26	22	44	11.0
Spr	1780	23	1200	11.5	27	21	39	13.0
Mean	**1900**	**31**	**1300**	**10.9**	**25**	**22**	**42**	**10.8**
Canterbury								
Sum	1970	27	1300	9.4	24	26	46	6.3
Aut	1960	35	1170	8.1	17	29	53	6.9
Win	1900	69	1300	10.3	21	23	44	12.5
Spr	1800	29	1100	11.3	25	21	38	11.9
Mean	**1910**	**40**	**1220**	**9.8**	**22**	**25**	**46**	**9.4**
Southland								
Sum	2290	24	1110	10.6	23	25	47	7.5
Aut	1980	24	830	11.0	26	23	44	8.4
Win	1680	57	1030	11.2	27	22	46	8.3
Spr	1840	41	1200	11.5	27	21	41	10.3
Mean	**1950**	**36**	**970**	**11.1**	**26**	**22.7**	**44**	**8.6**
SED	230	8	165	0.4	1.7	1.5	2.4	1.2
Significance								
Region	0.9	0.02	0.003	0.001	0.001	0.003	0.004	0.001
Season	0.005	0.001	0.009	0.001	0.001	0.001	0.001	0.001
Region*Season	0.70	0.11	0.22	0.002	0.002	0.06	0.01	0.003

Seasons: Sum summer; Aut autumn; Win winter; Spr spring
Parameters: ME - metabolisable energy; CP - crude protein; ADF - acid detergent fibre; NDF - neutral detergent fibre; CHO - soluble carbohydrate.

FIGURE 2. Seasonal pattern of chemical composition of pasture plucked to simulate animal intake on commercial sheep and beef farms in four regions.



Appendix 5. Summary of research on N concentrations in New Zealand pastures. (Ledgard *et al.* 2002)

Table 7: Summary of published research on N concentration of hill pastures grazed by sheep and cattle

Location/site Site	Fertility	Slope	Season				
			Spring	Summer	Autumn	Winter	Mean[1]
Waikato/West of Hamilton *(Gillingham and During 1973)*	High	Camp	3.5	3.4	4.3	4.5	3.9
	Medium	(<5°)	3.5	2.9	3.7	4.2	3.6
	Medium		3.4	2.8	3.4	4.1	3.4
	Low		3.4	2.4	3.1	3.9	3.2
	Low	Steep	2.9	2.1	2.6	3.5	2.8
Manawatu/ Ballantrae *(Mackay et al. 1995)*	**High**	**Av.**[2]	2.4	2.4	4.3	4.2	3.3
	Low Av.		2.3	2.3	3.6	3.5	2.9
Waikato/Whatawhata *(Espie et al. 2001)*	**High Av.**		3.8	2.6	3.6	3.8	3.5
	Low Av.		3.3	2.1	2.8	3.2	2.9
Seasonal mean[3]			3.1	2.5	3.4	3.8	3.2

[1]weighted for seasonal differences in pasture production
[2]average of different slopes
[3]average of data excluding the Waikato camp area

Table 8: Unpublished research on N concentration of hill pastures grazed by sheep and cattle at the Waipawa research station (Hawkes Bay)

Location/site Site	Aspect	Slope	Season				
			Spring	Summer	Autumn	Winter	Mean[1]
Hawkes Bay/Waipawa *(Gillingham and Gray unpublished)*	North	Easy	2.1	2.6	3.2	4.0	3.0
	North	Steep	1.8	2.2	2.1	2.6	2.2
	South	Easy	2.4	2.8	3.3	3.0	2.9
	South	Steep	2.6	2.5	3.3	2.5	2.7
	North	Easy	2.2	2.6	2.8	3.3	2.7
	North	Steep	1.8	2.4	2.1	2.7	2.3
	South	Easy	2.3	2.2	2.5	3.0	2.5
	South	Steep	2.0	1.8	2.4	2.3	2.1
Seasonal mean[3]			2.1	2.4	2.7	2.9	2.6

[1]weighted for seasonal differences in pasture production

Table 9: Nitrogen concentration of pastures grazed by dairy cows, as affected by season and rate of N fertiliser application

Location	Site	Fertiliser N (kg/ha/yr)	Season Spring	Summer	Autumn	Winter	Mean[1]
Taranaki	Waimate West	0	4.0	4.7	4.9	4.4	4.5
(Roberts 1987)	Stratford	0	4.3	4.5	4.6	4.4	4.5
Waikato	Dexcel No.5 dairy	0	3.3	3.7	4.0	3.5	3.6
(Ledgard 1991)							
Manawatu	Massey No.1 dairy	90	2.6	2.0	2.8	3.9	*(c.2.8)*
(Saggar and Hedley 2001)							
	Seasonal mean		**3.6**	**3.7**	**4.1**	**4.1**	
Taranaki	WTARS	0					3.4
(Roach unpublished)							
Waikato	Commercial farm	0					3.2
(Longhurst unpub							
Waikato	Dexcel No.2 dairy	0					3.4
(Ledgard et al. 2001)		200					3.7
		400					3.9

[1]weighted for seasonal differences in pasture production

Table 10: Average data for analysis of pasture samples from pastoral farms throughout New Zealand sampled during 1992-1999. Data was supplied by Celentis Analytical (now trading as *e*-lab.limited).

Sheep/Beef			Dairy		
Region	**Number of records**	**Average %N**	**Region**	**Number of records**	**Average %N**
BOP	161	3.73	BOP	726	3.96
Canterbury	33	3.75	Canterbury	30	4.07
Gisborne	354	3.12	Gisborne	5	2.88
Hawkes Bay	463	3.16	Hawkes Bay	10	3.40
King Country	115	4.07	King Country	47	4.18
Marlborough	14	3.64			
Manawatu	39	3.94	Manawatu	451	4.39
Nelson	20	3.30	Nelson	21	3.94
Northland	4	2.00	Northland	5	3.92
Otago	89	3.66	Otago	45	3.74
Raglan/Auckland	95	3.56	Raglan/Auckland	241	4.15
Southland	231	3.73	Southland	144	3.75
Taranaki	125	3.78	Taranaki	1612	4.01
Waikato	72	3.72	Waikato	712	3.90
Wairarapa	494	3.42	Wairarapa	61	4.24
Wanganui	329	3.65	Wanganui	55	3.78
			West Coast	33	4.22
Total/Mean	**2638**	**3.49**[1]		**4198**	**4.02**[1]

[1]Mean of the total number of samples

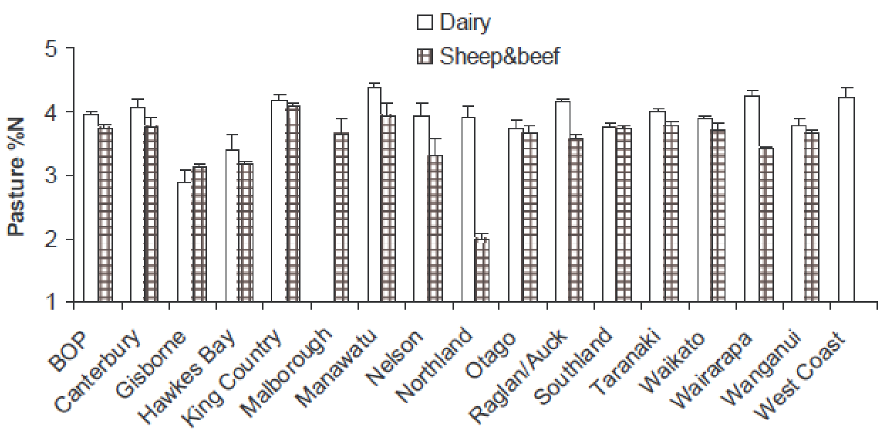


Figure 1: Average N concentrations in pasture from pastoral farms throughout New Zealand which were sampled during 1992-1999. Error bars represent standard errors. Data was supplied by Celentis Analytical (now trading as *e*-lab.limited).

Table 11: Seasonal average data for analysis of pasture samples from pastoral farms throughout New Zealand sampled during 1992-1999. Bracketed values present the range for different years. Data was supplied by Celentis Analytical (now trading as *e*-lab.limited).

Season	Sheep and beef Average %N	Dairy Average %N
Spring	3.47 (3.3-3.7)	4.04 (3.9-4.4)
Summer	3.35 (1.4-3.7)	3.64 (3.3-4.1)
Autumn	3.69 (3.3-4.1)	4.43 (4.0-4.9)
Winter	3.73 (3.5-4.4)	3.96 (3.7-4.9)
Mean	**3.49 (3.3-3.8)**	**4.02 (3.8-4.3)**

Table 12: Nitrogen concentration in pasture samples collected in autumn 2002 from "average" sheep and beef farms throughout New Zealand

		Slope			
Region	**Location**	**Flat (0-5°)**	**Rolling (5-10°)**	**Easy (11-20°)**	**Steep (>20°)**
King Country	Taumarunui	3.34	3.74	3.88	3.09
		3.4	3.53	3.36	3.49
		3.66	3.67	3.75	2.71
		4.1	3.99	3.66	2.63
		3.56	3.38	3.15	3.05
		3.27	3.15	2.37	1.81
	Mean	**3.56**	**3.58**	**3.36**	**2.80**
Gisborne	E. Coast		4.54	3.24	2.86
			3.89	3.50	1.39
Canterbury	Tara Hills	0.93			0.45
high country					0.67
Canterbury	Methven	4.29	3.49	3.13	2.69
foothills		3.21	3.21	3.34	4.45
		3.44	2.72	2.58	2.66
			2.63	2.83	
			3.47	2.94	
North Otago	Ranfurly	3.41	2.11		1.63
Central Otago	Alexandra		2.44		2.02
			3.6		
East Otago	Milton	3.97	2.91		
		2.31	2.78		1.95
Central Southland	Dipton	2.83			
		3.72			
East Southland	Woodlands	4.14			
West Southland	Tuatapere	4.47			
		4.02			
Table mean		**3.45**	**3.29**	**3.21**	**2.35**

Table 13: Nitrogen concentration in pasture samples collected in autumn 2002 from "average" dairy farms in several regions of New Zealand

Region	Location	Pasture %N
Waikato	Hamilton	4.52
		4.57
	Morrinsville	3.76
Mid Canterbury	Lincoln	2.46
		2.01
		4.09
Central Southland	Dipton	4.62
		4.24
		4.26
	Mataura	4.70
		4.81
Eastern Southland	Woodlands	4.85
		4.85
Western Southland	Tuatapere	4.90
		3.83
	Mean	**4.15**

2. STATISTICAL ANALYSIS REPORT – D. SAVILLE.

Statistical analyses and critique of pasture quality (ME and N) review data

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26 August 2013

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Executive Summary

The objective of the current study was to examine the available data on ME and N in New Zealand (NZ) sheep/beef and dairy pastures in relation to the yearly pattern (month by month estimates). The following questions were of particular interest:

- Is there evidence of variation in these parameters from month to month?
- Are the data good enough to provide reliable estimates of the monthly means, *NZ-wide*?
- Are the data good enough to provide reliable estimates of the monthly means for each *region* of New Zealand?

The current study revealed the following:

- Data relating to the yearly pattern in both ME and N monthly values were quite **sparse**, being confined to 3-4 out of the 17 Statistics NZ regional authorities.

  If the data from these few regions are assumed to be representative of New Zealand as a whole, then the resulting pattern in **monthly ME values for dairy pastures** reported herein, is *similar* to that given in the NZ National Greenhouse Gas Inventory (NGGI), due to Pickering (2011), with the two estimates being within 5% of each other for all months, and differing by only 0.6% as a simple average over the months.

- Similarly, the pattern in **monthly ME values for sheep/beef pastures** reported herein, is *roughly similar* to that of Pickering (2011), with the two estimates being within 10% of each other for 9 out of 12 months, and differing by 2% as a simple average over the months.

- **For N**, the NGGI (citing Pickering, 2011) assumes a **constant** value throughout the year for both dairy and sheep/beef pastures. This assumption is **contradicted** by the data presented in the current report, as now detailed:

- For **N in dairy pastures**, the monthly estimates in the current report are higher than the Pickering estimates for 10 out of 12 months, and, as a simple average, the estimate in the current report is 6% higher than the Pickering estimate. The “constancy” model for N is inappropriate, with statistically significant differences observed between the two estimates for six out of 12 months.

- For **N in sheep/beef pastures**, the monthly estimates in the current report are at least 8% *higher* than the Pickering estimates for 6 out of 12 months, and conversely, at least 8% *lower* than the Pickering estimates for 6 out of 12 months. As a simple average, the estimate in the current report is 2% lower than the Pickering estimate. The “constancy” model for N is inappropriate, with a statistically significant difference observed between the two estimates for every one of the 12 months.

- The data reported herein were obtained from various research groups, who may be expected to **vary** in terms of **choice of field sampling techniques and laboratory analytical method**. In particular, it was observed that ME and N values estimated by Ausseil were generally lower than for other researchers, often by appreciable amounts. This brings home the point that methodology needs to be carefully considered in any future work, and methods chosen that are appropriate to the exact purpose of the study.

In terms of the objectives, the answers to the three questions are as follows:

- Yes, there is strong evidence of variation in both ME and N from month to month.
- No, the data are not good enough to provide scientifically tested and validated, and thereby reliable, estimates of the monthly means, *NZ-wide*.
- No, the data are not good enough to provide scientifically tested and validated, and thereby reliable, estimates of the monthly means for each *region* of New Zealand (in fact, for most regions, there is almost no such data available).

To remedy this situation by providing a more adequate basis for analysis, it is recommended that a nationwide survey of dairy, and of sheep/beef pastures be biometrically designed and conducted, with monthly sampling of specific, randomly selected pastures of both types in all 17 Statistics NZ regional authorities (with the possible exception of the Chatham Islands).

For each pasture type (dairy or sheep/beef), this study/survey should be carried out for a minimum of three agricultural seasons (September to August), with a minimum of 1 - 2 pastures of each type sampled in each region in each season. These pastures should be on different farms each season, so that in total, pastures of each type would be sampled (from September to August) on a minimum of 3 - 6 different farms per region. The number of pastures of each type sampled per region per season would be best determined by “optimal statistical design” calculations (as for any stratified random survey), so that the regions with a high number of stock units of dairy or sheep/beef, respectively, would be sampled more intensively than regions with a low number of stock units grazing that pasture type. Further details concerning practical aspects of field sampling design, and the need for standardisation of field sampling and laboratory methodology, are given in the Summary section at the end of the Dairy and Sheep/beef sections of this report.

The resulting data would enable a “best practice” method of analysis to be carried out for each pasture type, as described in section (1) on page 61 below, involving weighting by total number of stock units of dairy or sheep/beef, respectively, per Statistics NZ regional authority. This would result in more robust and scientifically defensible monthly average estimates of ME and N in both dairy and sheep/beef pastures for each region, for South and North Islands, and for New Zealand as a whole.

Objective

The objective of the current study is to examine the available data on ME and N in New Zealand (NZ) sheep/beef and dairy pastures in relation to the yearly pattern (month by month estimates). In particular:

- Is there evidence of variation in these parameters from month to month?
- Are the data good enough to provide reliable estimates of the monthly means, *NZ-wide*?
- Are the data good enough to provide reliable estimates of the monthly means for each *region* of New Zealand?

Database

The data available for use in this study was a database which was assembled for the purpose of correlating (1) estimates of pasture quality parameters (ME and N) obtained using satellites and NIR technology with (2) laboratory-based estimates of actual pasture samples taken from either plots in field experiments or other pastures.

Unfortunately this focus meant that the database did not include information which would facilitate matching of data with individual experiments at specific locations. When the database was compiled, data were accumulated from lots of different field experiments (for which information on pasture type, sheep/beef or dairy, was compiled but most of the other experimental information was not compiled) and also from routine samples as they came through the FeedTech laboratory (in which case pasture type was unknown).

Method of statistical analysis

The basic idea behind the statistical examination of the data was that of isolating data from individual field experiments at specific locations (or individual paddock data if available through time), and examining the pattern of ME (or N) values from month to month within each agricultural season (taken to be Sept 1 to August 31).

Such data would be examined for each pasture type (sheep/beef or dairy) and each region separately. The hope was that several data sets would be available for each pasture type and region (each for a particular location and agricultural season, like 1997/1998 or 2005/2006).

The expectation was that many of these data sets would not include mean parameter values for all 12 months of the season, but would involve missing months. The proposal for each region and pasture type was to put together these (possibly incomplete) data sets using the statistical method “analysis of variance”, with each dataset being treated as a statistical “block” and with months being regarded as “treatments” (statistical design being a randomised block design). “Missing values” would be estimated by the analysis, and in this manner improved regional means would be obtained for each pasture type (these regional means would take account of any differences between the different datasets, and remove any bias caused by such effects).

Plan of attack

The plan of attack was therefore as follows:

- First, take Sheep/beef.
- Then take each Statistics NZ regional authority ("region" for short).
- Then find all experiments (if any) that give ME or N data for that region.
- For the first such experiment, find a "farm-year" = agricultural season (e.g., 1 Sep 2005 to 31 Aug 2006) for which the experiment (or "farm") provides data (for a minimum of two months).
- Then list the months Sep, Oct, Nov, ….. Aug (1 row of excel per month) for that farm-year (like 05/06). Then in the ME column, put the mean of all ME values available for that month (Sep being the first such month) from that specific experiment in that farm-year. If there are none, put an * alongside this month (but have a row for each of the 12 months). Do this for N also in the next column. Note that the * is the missing value code for the statistical program (GenStat).
- Then go to the next farm-year for that experiment, if there is a second year in which data was collected. And a third year if it exists, etc…
- Then move on to the next experiment for Sheep/beef and that region.
- Then move on to the next region.
- The excel headers would read:
Pasture-type Region Experiment Farm-year Month ME N
- When all Sheep/beef regions are done, move on to Dairy and do the same.
- Lastly, repeat the above for Feedtech (pasture-type not specified), for each region and each year.
- When the data compilation as above is complete, the data for each region and pasture type is to be statistically analysed and summarized. Then the regions are to be combined to derive South and North Island and NZ-wide averages.

Modification to plan

Unfortunately, individual experiments *could not* be identified in the database, so the above plan could not be implemented without modification.

Individual researchers *could* be identified, so the modification was to do the above for each researcher and agricultural season. This was far from ideal. In some cases, it meant that the number of samples that were averaged for a "farm-year" varied wildly from month to month (for example, from 2 to 17 samples, or from 6 to 36); in other cases, this was not a problem (for example, always 10 samples per month, or always 8).

RESULTS

Sheep/beef results by region

Canterbury

As an example (for this first case), the "input" data available for sheep/beef in Canterbury are shown below. Note the variation in sample size in the first dataset, from 3 to 39. In fact, the value of 1.751 for N proved to be highly unusual, so has been omitted from the analysis (this is the only value omitted from the sheep/beef data).

Data for GenStat						
Month	Sample month text	Count of ME	ME	Count of N	N	FarmYear
1	Sep	*	*	*	*	1
2	Oct	17	12.114	17	3.393	1
3	Nov	3	11.934	3	1.751	1
4	Dec	26	10.863	26	2.663	1
5	Jan	*	*	*	*	1
6	Feb	39	9.695	39	2.403	1
7	Mar	*	*	*	*	1
8	Apr	*	*	*	*	1
9	May	*	*	*	*	1
10	Jun	*	*	*	*	1
11	Jul	*	*	*	*	1
12	Aug	*	*	*	*	1
1	Sep	4	11.175	4	3.445	2
2	Oct	*	*	*	*	2
3	Nov	*	*	*	*	2
4	Dec	5	8.440	5	2.723	2
5	Jan	6	8.067	6	2.624	2
6	Feb	5	7.320	5	2.427	2
7	Mar	6	8.467	6	2.730	2
8	Apr	6	8.350	6	2.699	2
9	May	6	10.067	6	3.152	2
10	Jun	6	10.800	6	3.346	2
11	Jul	6	11.250	6	3.464	2
12	Aug	2	11.300	2	3.478	2

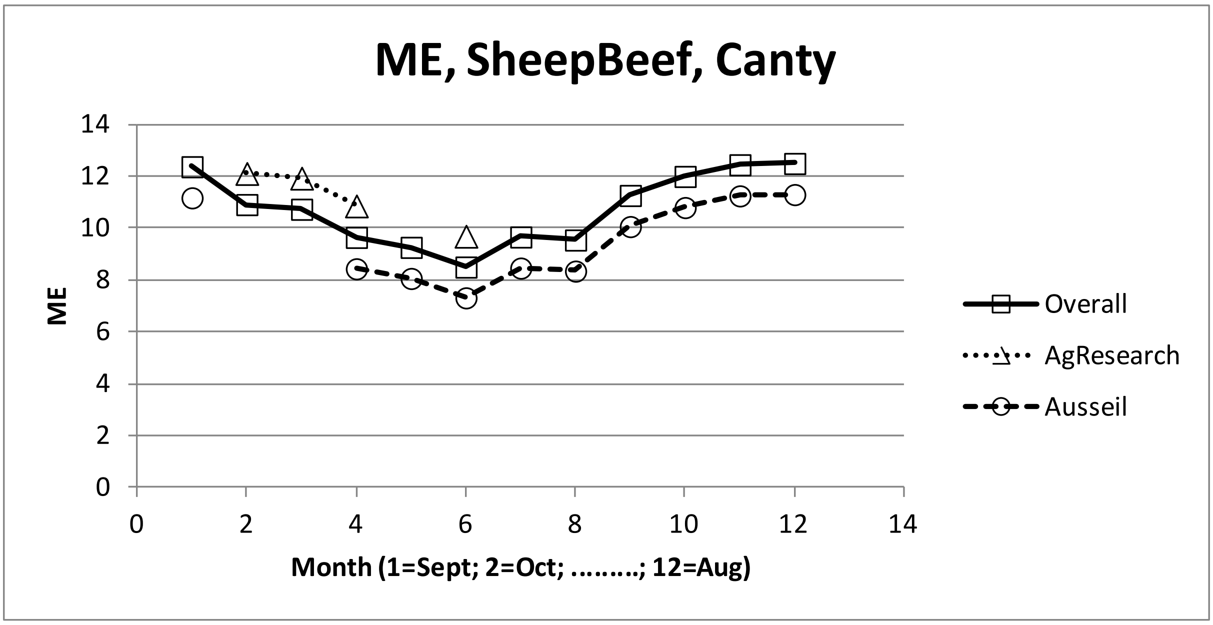
In tabular form, the above data are as shown below. Here the "Overall" Canterbury column gives the adjusted means as output by the statistical analysis (after the two datasets have been "patched" together by the analysis of variance to form a single yearly pattern). These data are also displayed in the graphs below. Note that "Month 1" is September, and month 12 is the following August.

	ME				N		
Month	AgResearch	Ausseil	Overall	Month	AgResearch	Ausseil	Overall
1		11.175	12.374	1		3.445	3.424
2	12.114		10.915	2	3.393		3.414
3	11.934		10.735	3			
4	10.863	8.440	9.651	4	2.663	2.723	2.693
5		8.067	9.266	5		2.624	2.603
6	9.695	7.320	8.507	6	2.403	2.427	2.415
7		8.467	9.666	7		2.730	2.709
8		8.350	9.549	8		2.699	2.678
9		10.067	11.266	9		3.152	3.131
10		10.800	11.999	10		3.346	3.325
11		11.250	12.449	11		3.464	3.443
12		11.300	12.499	12		3.478	3.457

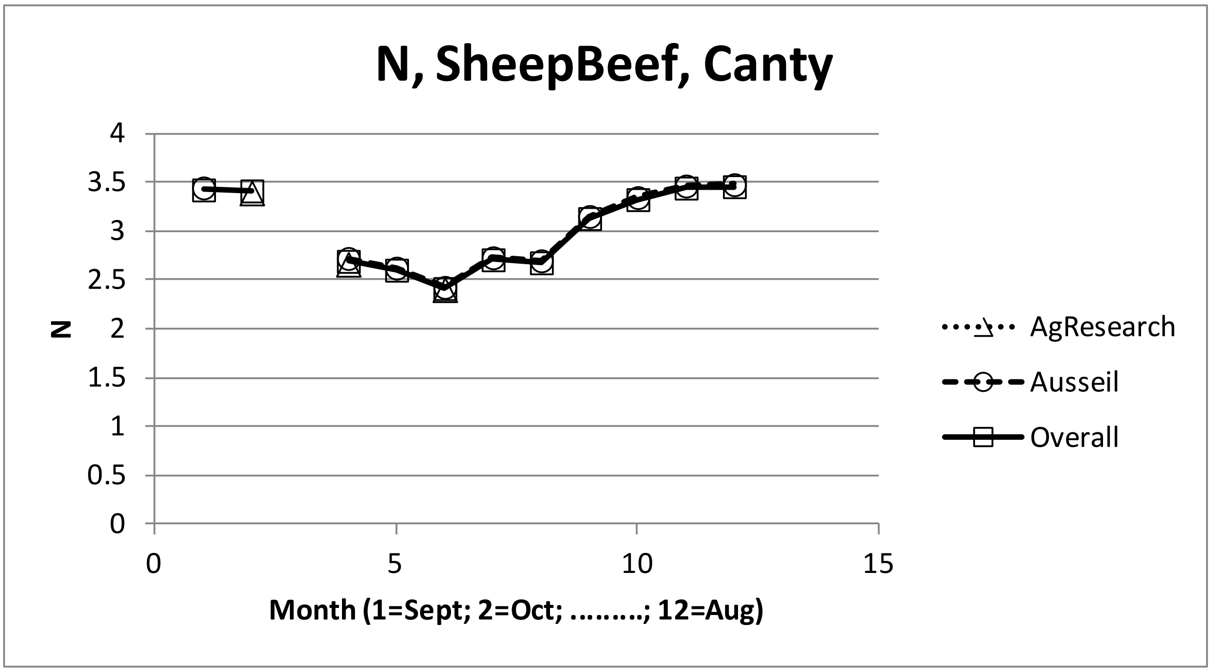
In the graph for ME below, the circles represent one dataset and the triangles represent a second dataset. The two datasets both have values for months 4 and 6; in these cases, the triangles are about 2.4 units higher than the circles. This is taken into account by the statistical program - essentially, it adds half of this difference (2.4/2 = 1.2 units) to the circles and subtracts 1.2 units from the triangles when deriving the adjusted means which are the estimated ME monthly means for sheep/beef in Canterbury.

This first example has proven to be a simple one in terms of the explanation of the method; however, the same basic idea applies throughout this report.

The estimated ME monthly means for sheep/beef in Canterbury are given to greater accuracy in the "overall" column of the table above.



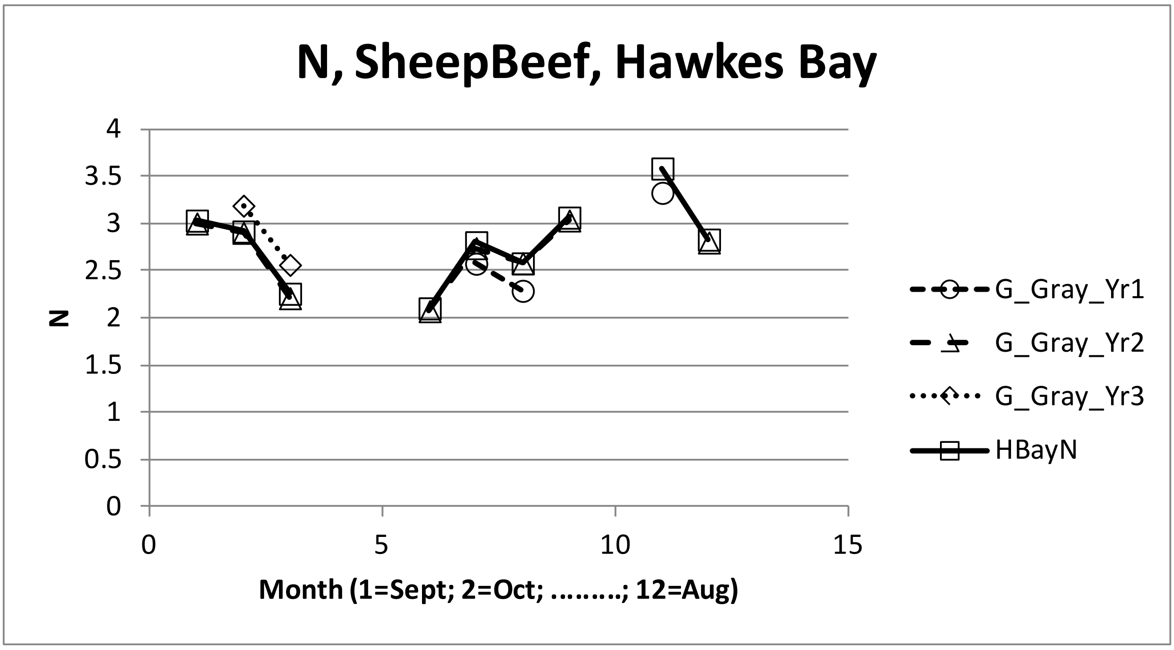
In the second graph, of N data, the circles and triangles lie almost on top of each other. Note that no data are available for month 3 (November).



Hawkes Bay

No useful ME data were only available (samples collected were only for 1 month in 1 year). Also for N, no data were available for months 4, 5 and 10. Regional Hawkes Bay means for N are in the right-hand column of the table, and a graph for N is given below.

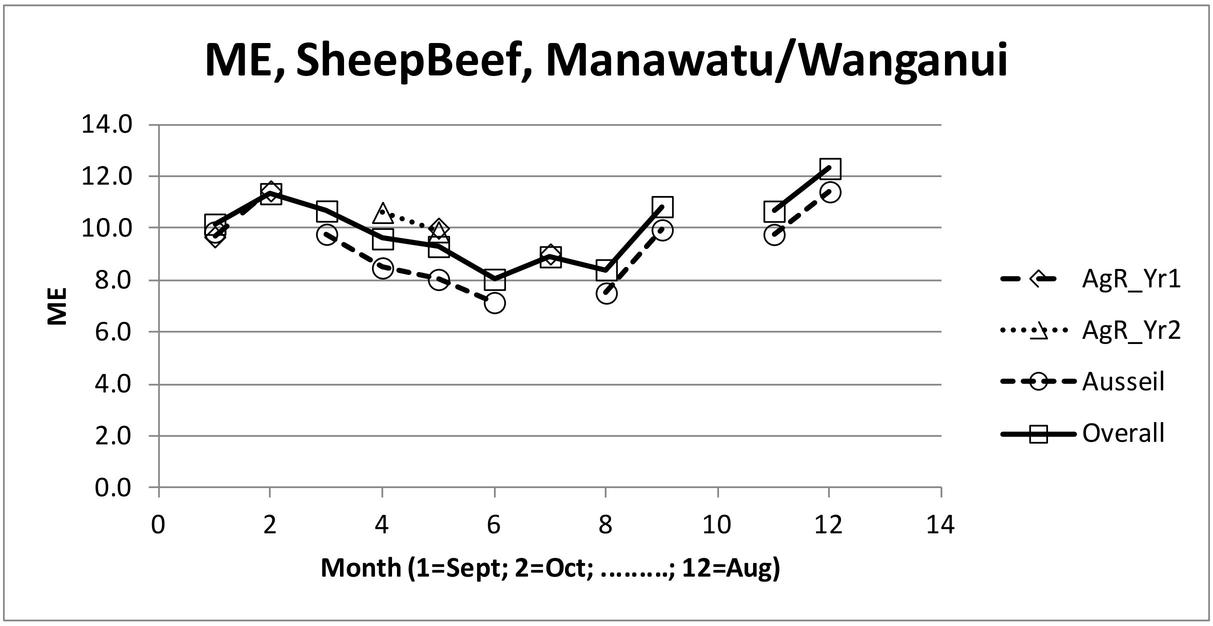
		ME					N		
Month					Month	G_Gray_Yr1	G_Gray_Yr2	G_Gray_Yr3	HBayN
1					1		3.002		3.032
2					2		2.903	3.190	2.917
3					3		2.211	2.563	2.258
4					4				
5		NO ME data!!			5				
6		for Hawkes Bay			6		2.073		2.103
7					7	2.576	2.741		2.803
8					8	2.289	2.581		2.579
9					9		3.034		3.064
10					10				
11					11	3.326			3.584
12					12		2.801		2.831

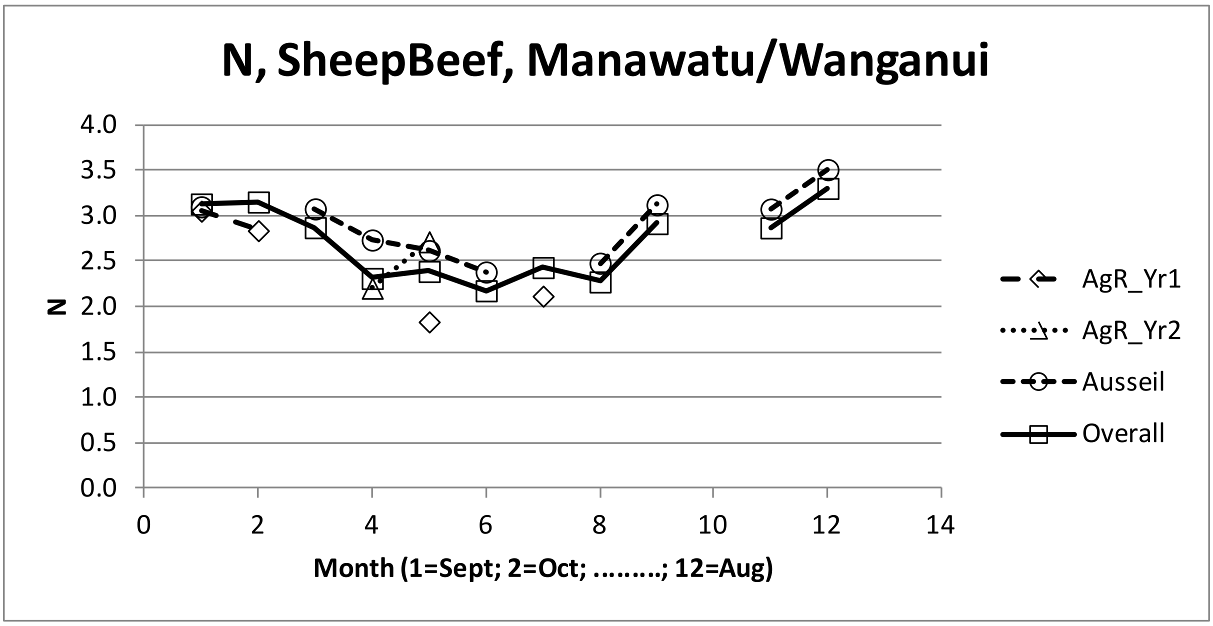


Manawatu/Wanganui

Basic data are shown below. No ME or N data were available for month 10.

	ME				N				
Month	AgR_Yr1	AgR_Yr2	Ausseil	Overall	Month	AgR_Yr1	AgR_Yr2	Ausseil	Overall
1	9.681		9.867	10.168	1	3.051		3.099	3.130
2	11.451			11.344	2	2.837			3.152
3			9.780	10.675	3			3.076	2.870
4		10.623	8.483	9.606	4		2.204	2.734	2.311
5	10.014	9.875	8.040	9.310	5	1.833	2.715	2.617	2.388
6			7.150	8.045	6			2.382	2.176
7	9.021			8.914	7	2.116			2.431
8			7.517	8.412	8			2.479	2.273
9			9.950	10.845	9			3.121	2.915
10					10				
11			9.773	10.668	11			3.074	2.868
12			11.417	12.312	12			3.508	3.302

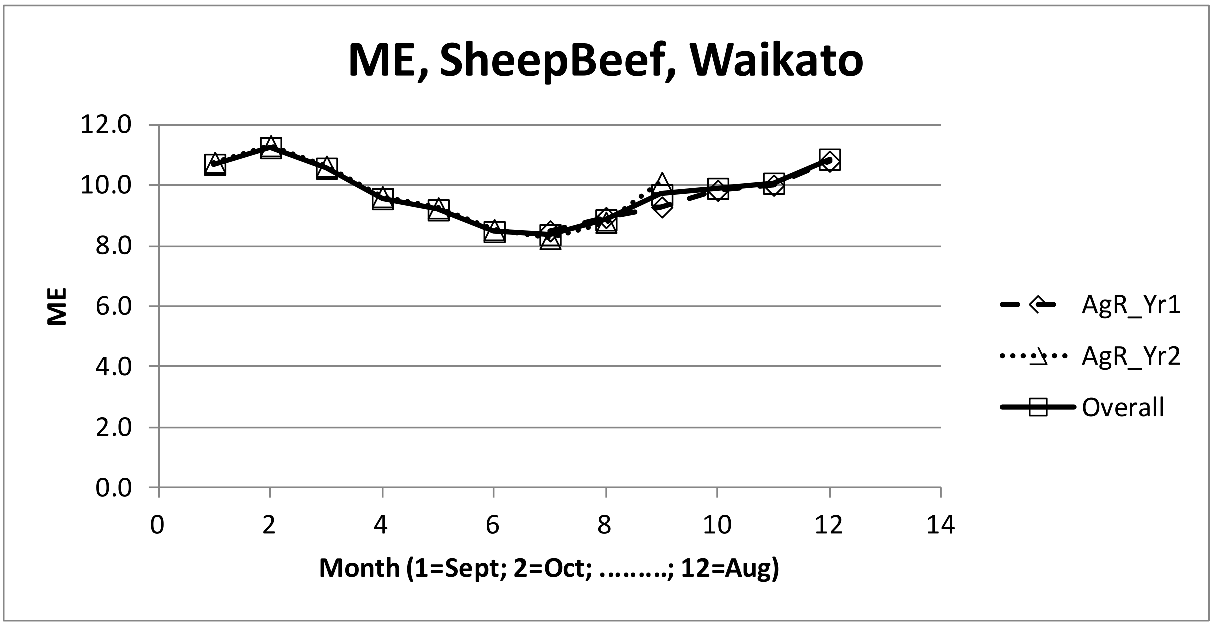


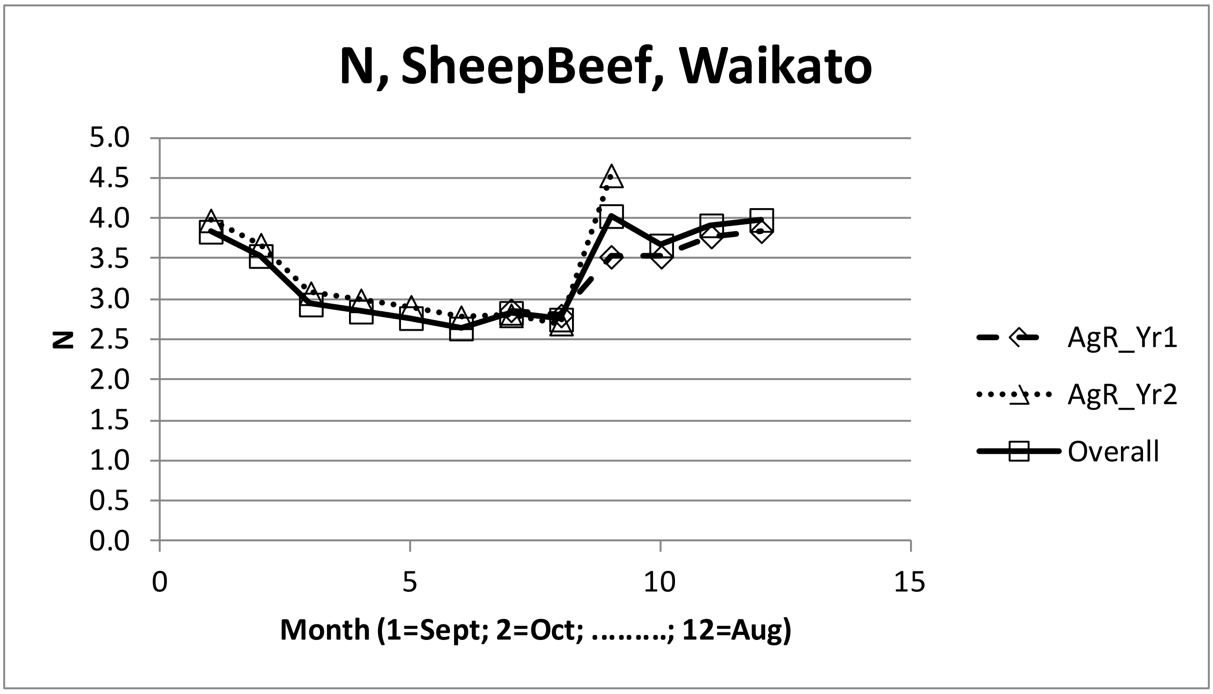


Waikato

Basic data are shown below in a table, and graphs are given below that.

	ME				N		
Month	AgR_Yr1	AgR_Yr2	Overall	Month	AgR_Yr1	AgR_Yr2	Overall
1		10.763	10.696	1		3.978	3.838
2		11.312	11.245	2		3.677	3.537
3		10.636	10.569	3		3.076	2.936
4		9.629	9.562	4		2.988	2.848
5		9.260	9.193	5		2.908	2.768
6		8.542	8.475	6		2.779	2.639
7	8.500	8.250	8.375	7	2.864	2.802	2.833
8	8.940	8.785	8.863	8	2.799	2.700	2.750
9	9.289	10.100	9.695	9	3.527	4.536	4.032
10	9.838		9.905	10	3.528		3.668
11	10.007		10.074	11	3.777		3.917
12	10.800		10.867	12	3.844		3.984





Marlborough

For both ME and N, there are only 2 monthly values, so these are not given here (they are almost no help in terms of establishing a pattern over the season).

Northland

For both ME and N, there are only 3 monthly values, so these are not given here (they are almost no help in terms of establishing a pattern over the season).

Otago

For both ME and N, there are only 5 monthly values, so these are not given here (they are insufficient for establishing a pattern over the season).

Southland

For both ME and N, there are only 2 monthly values, so these are not given here (they are almost no help in terms of establishing a pattern over the season).

Taranaki

For both ME and N, there are only 4 monthly values, so these are not given here (they are insufficient for establishing a pattern over the season).

Wellington

For both ME and N, there are only 3 monthly values, so these are not given here (they are almost no help in terms of establishing a pattern over the season).

Auckland, Bay of Plenty and Gisborne

No monthly values were available for these North Island regions.

Tasman, Nelson, West Coast and Chatham Islands

No monthly values were available for these South Island regions.

New Zealand overall (sheep/beef)

There are three ways in which the available sheep/beef ME and N values could be combined over the regions to form averages for New Zealand overall (and South and North Islands).

(1) If good data had been available for each region, the monthly patterns could be combined over the regions by multiplying each regional monthly ME or N value by the estimated total number of stock units of sheep and beef combined in the region, summing over all regions and dividing by the total sheep/beef stock units in NZ. This would give a weighted average for each month of the ME and N values, with highest weight given to regions with the highest number of sheep/beef stock units (and almost no weight given to data from the Chatham Islands, for example!). This could also be done for South and North Islands separately. Given the sparseness of the sheep/beef data (summarised above for only 4 out of the 17 Statistics NZ regional authorities), however, this "best practice" method is clearly impossible.

(2) A second approach, ignoring the ideas in (1), is to combine ME data from the 8 "farm-years" as presented above, treating these 8 farm-years as a representation of NZ as a whole (for N, this is 10 farm-years).

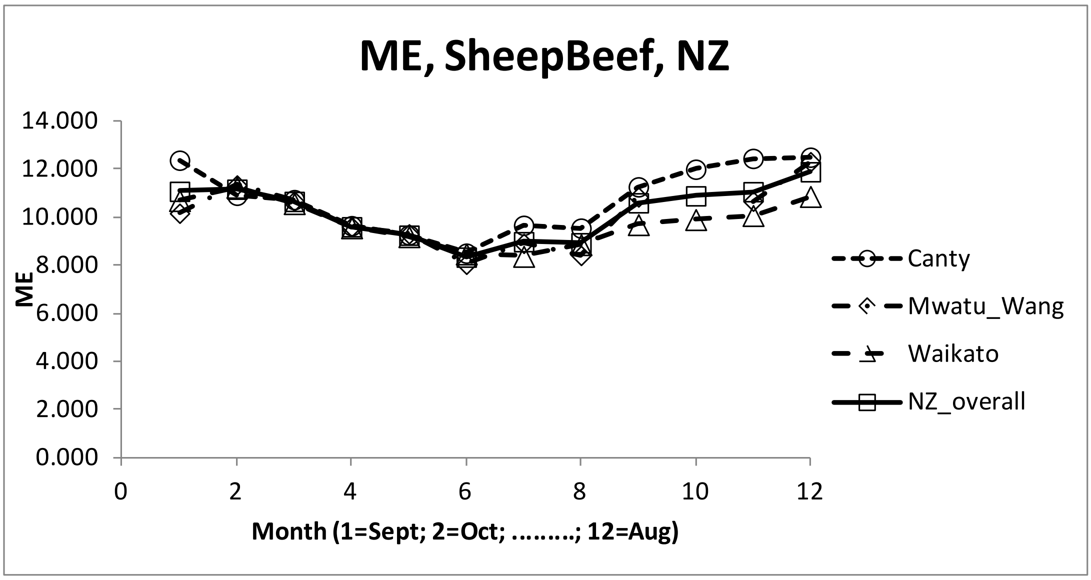
(3) A third approach is to use the three regional sets of monthly means as derived above to derive an overall monthly pattern for ME for NZ, treating these three regions as a representation of NZ as a whole (for N, this is four regions).

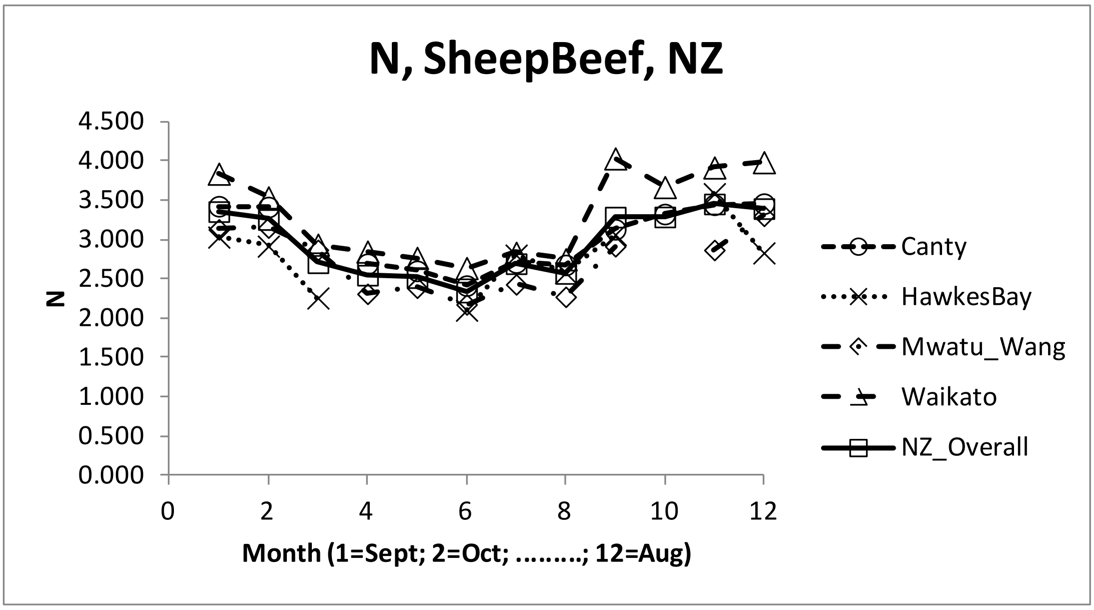
Neither of (2) or (3) is ideal, but we shall now use the third approach. This has the advantage that the consistency of data from region to region can be displayed. Data are as follows, both in a table and in two graphs:

		ME							N		
month	**Canty**	**Mwatu_Wang**	**Waikato**	**NZ_overall**		**month**	**Canty**	**HawkesBay**	**Mwatu_Wang**	**Waikato**	**NZ_Overall**
1	12.374	10.168	10.696	11.079		1	3.424	3.032	3.130	3.838	3.356
2	10.915	11.344	11.245	11.168		2	3.414	2.917	3.152	3.537	3.255
3	10.735	10.675	10.569	10.660		3		2.258	2.870	2.936	2.706
4	9.651	9.606	9.562	9.606		4	2.693		2.311	2.848	2.548
5	9.266	9.310	9.193	9.256		5	2.603		2.388	2.768	2.517
6	8.507	8.045	8.475	8.342		6	2.415	2.103	2.176	2.639	2.333
7	9.666	8.914	8.375	8.985		7	2.709	2.803	2.431	2.833	2.694
8	9.549	8.412	8.863	8.941		8	2.678	2.579	2.273	2.750	2.570
9	11.266	10.845	9.695	10.602		9	3.131	3.064	2.915	4.032	3.286
10	11.999		9.905	10.892		10	3.325			3.668	3.288
11	12.449	10.668	10.074	11.064		11	3.443	3.584	2.868	3.917	3.453
12	12.499	12.312	10.867	11.893		12	3.457	2.831	3.302	3.984	3.394
	Least Significant Difference, LSD(5%)			**0.847**				**Least Significant Difference, LSD(5%)**			**0.307**

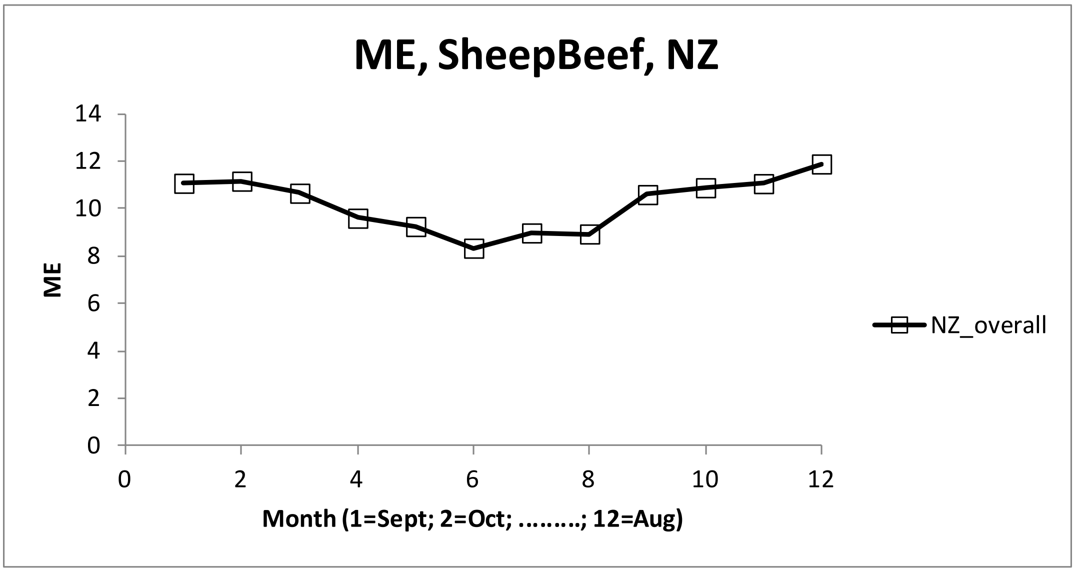
In the above table, a "least significant difference" is given for each variable for the NZ-wide estimated overall monthly means (last column for each dataset). Thus for ME, a difference between two monthly NZ_Overall means is statistically significant at the 5% level of significance if it is greater than 0.847. Hence the mean ME values for months 1 - 3 (Sep - Nov) do not differ significantly from one another (since the differences are less than 0.847), but the mean ME value for month 4 (Dec) is significantly lower than Sep - Nov (since its value of 9.606 is more than 0.847 less than any of the values for Sep - Nov).

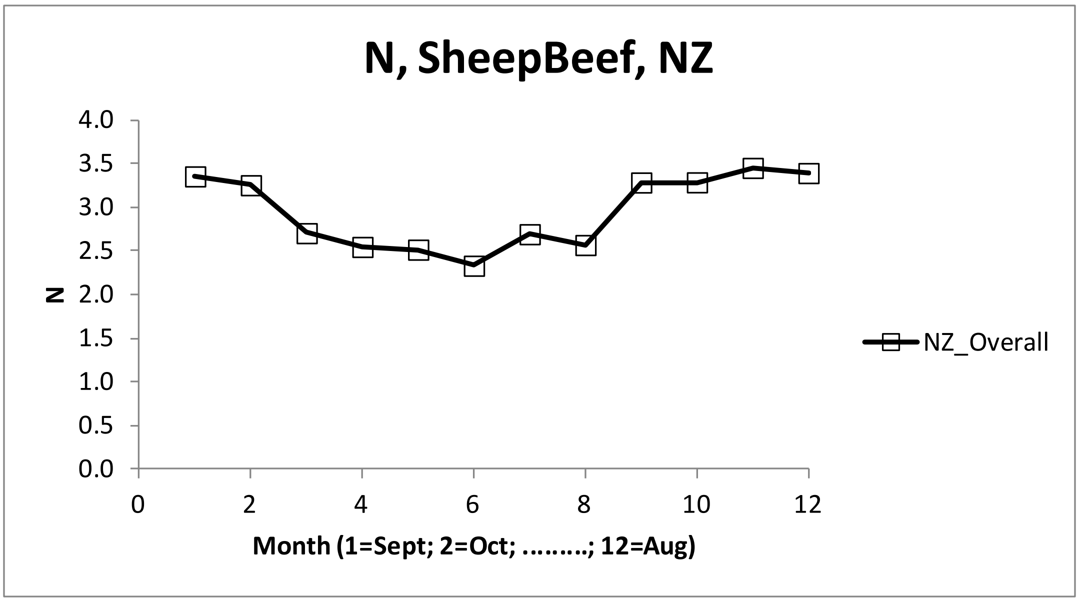
Similarly, for N, a difference between two monthly NZ overall means is statistically significant at the 5% level of significance if it is greater than 0.307. Hence the mean N values for months 1 - 2 (Sep - Oct) do not differ significantly from one another (since the difference is less than 0.307), but the mean N values for months 3 - 4 (Nov - Dec) are significantly lower than Sep - Oct (since both 2.706 and 2.548 are more than 0.307 less than either of the Sep or Oct values).





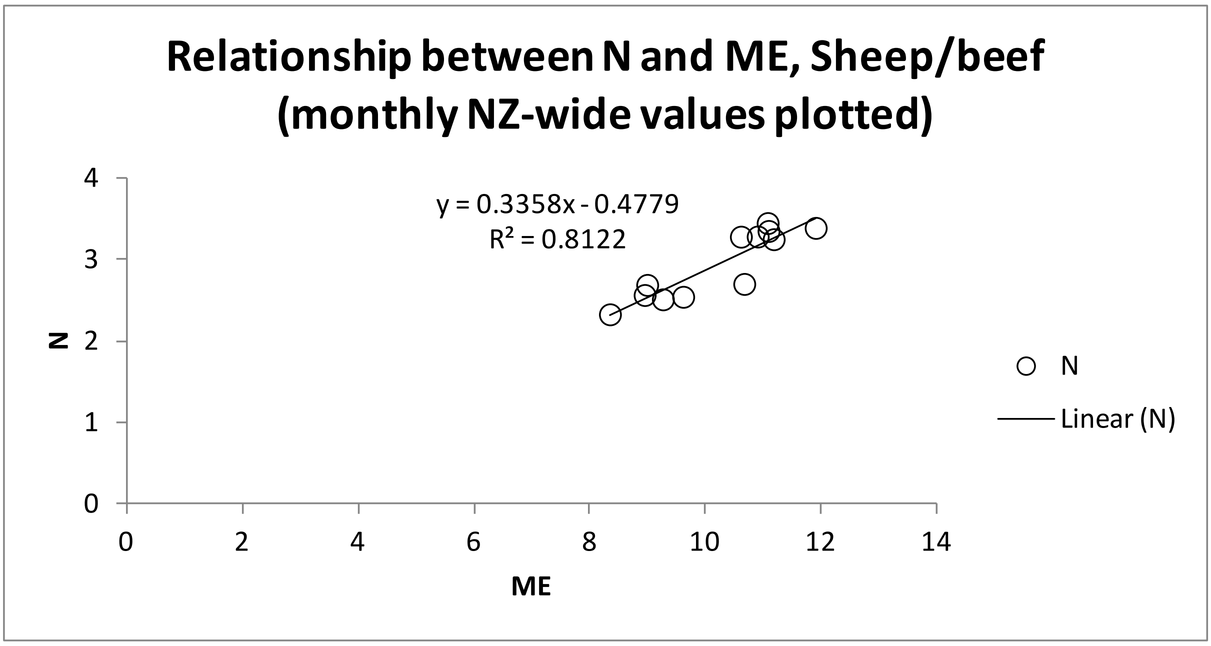
The above graphs are now redone with just the NZ-wide means displayed, for ease of seeing the monthly values:





Relationship between ME and N for sheep/beef pastures

The above yearly patterns are roughly similar, in that the highs and lows of both ME and N seem to roughly coincide. To explore this further, we plot N against ME, using the 12 monthly NZ-wide means for ME and N from the table above.



Overall, there is a statistically significant correlation between N and ME, with a correlation coefficient of r = 0.901 (p<0.0001).

As an aside, the point on the graph which is furthest from the line of best fit is month 3 (Nov), where the N value of 2.706 is perhaps lower than expected (either this, or the ME value of 10.660 is higher than expected).

Summary, Sheep/beef pasture data on ME and N

In summary, several points emerge:

(1) There is surprisingly little useful data available for sheep/beef pastures. For ME, there is data for only 3 out of the 17 Statistics NZ regional authorities, and for N this is only slightly better (4 out of 17).

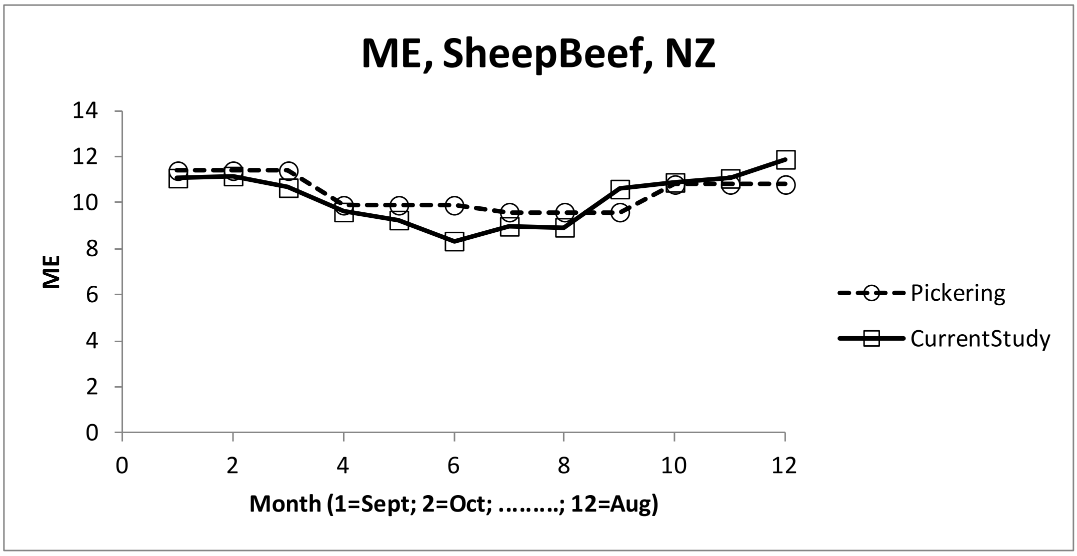
(2) For a more adequate basis for analysis, it is recommended that a nationwide survey of sheep/beef pastures be biometrically designed and conducted, with monthly sampling of specific, randomly selected sheep/beef pastures in all 17 Statistics NZ regional authorities (with the possible exception of the Chatham Islands). This should be carried out for a minimum of three agricultural seasons (Sep to Aug), with a minimum of 1-2 sheep/beef pastures sampled in each region in each season. These pastures should be on different farms each season, so that in total, sheep/beef pastures would be sampled on a minimum of 3-6 different farms per region. The number of sheep/beef pastures sampled per region per season should be determined by "optimal statistical design" calculations (as for any stratified random survey), so that the regions with a high number of sheep/beef stock units would be sampled more intensively than regions with a low number of sheep/beef stock units. (Practical details would also need to be carefully considered, such as whether to sample continuous grazed or rotationally grazed paddocks, the avoidance of pastures closed for hay, and so on. Standardisation of field sampling technique and of laboratory methodology would also be required.)

The resulting data would enable the "best practice" method of analysis to be carried out (as described in (1) on page 48 above, involving weighting by total sheep/beef stock units per Statistics NZ regional authority), and would result in more robust estimates of NZ-wide and South and North Island averages for ME and N in sheep/beef pastures.

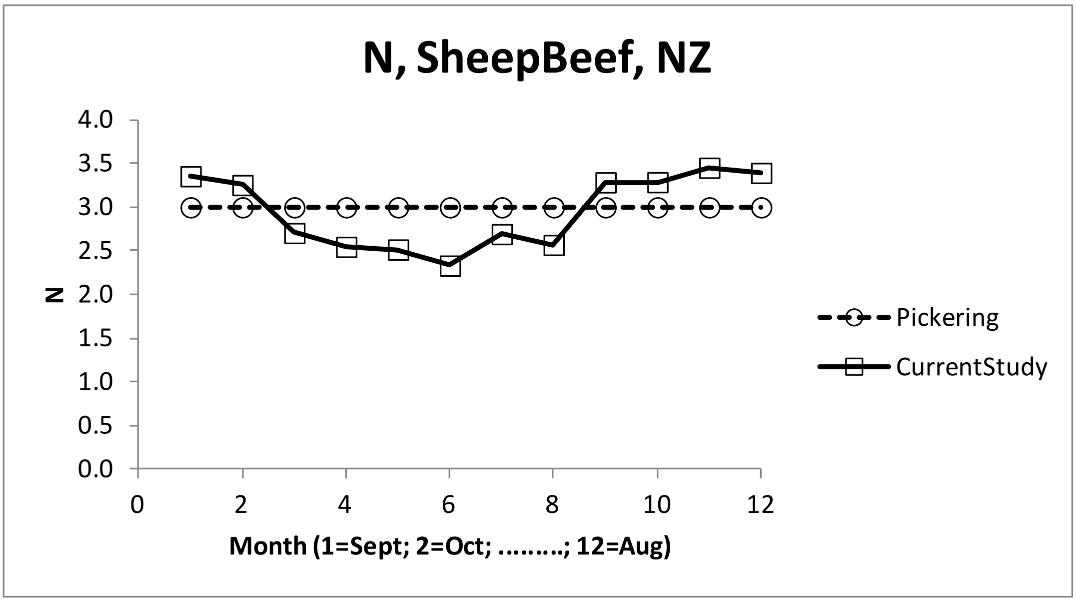
(3) With what little data is available (as reported above), it is clear that both ME and N vary significantly from month to month, with both variables being lowest during the months of December to April inclusive.

(4) The two graphs below compare the estimates from the present report with those currently used in the NZ National Greenhouse Gas Inventory (NGGI), due to Pickering (2011).

For ME, the two estimates agree to within 10% except for months 6, 9 and 12 (Feb, May and Aug). As a simple average over the 12 months, the two estimates agree to within 2%.



For N, the two estimates *disagree* by more than 8% for all 12 months, and disagree by more than 13% for 6 out of the 12 months. Clearly the "constancy" model is inappropriate. Note that for comparing a monthly estimate from this report with the constant value of 3.0, the Least Significant Difference, LSD(5%) is the value reported above (0.307) divided by √2; that is, the LSD(5%) is 0.217. This means that for *all 12 months*, the estimates reported herein differ significantly from 3.0 ($p<0.05$). On the other hand, as a simple average over the 12 months, the two estimates agree to within 2%.



(5) In the NGGI, the N values (%s) are multiplied by the pasture dry matter intake (DMI) when the nitrogen intake is calculated. In addition, the ME values are involved in calculating the DMI. Therefore the annual pattern in pasture DMI must also be considered in relation to the annual patterns in ME and N. In winter, for example, pasture DMI is likely to be lower than at other times of the year, and in spring, pasture DMI may be at its maximum; therefore, the effect of biases in ME or N estimates must be seen in relation to the pattern of pasture DMI.

(6) The estimates made by Pickering and in this report rely upon the same publicly available data, so may both be quite incorrect in terms of nationwide averages. In this report, the inadequacies in the data have been made clear; for example, the three or four regions, out of 17, for which data are available, may not provide an unbiased picture of NZ as a whole. Suggestions for remedying the problem have been made in point (2) above.

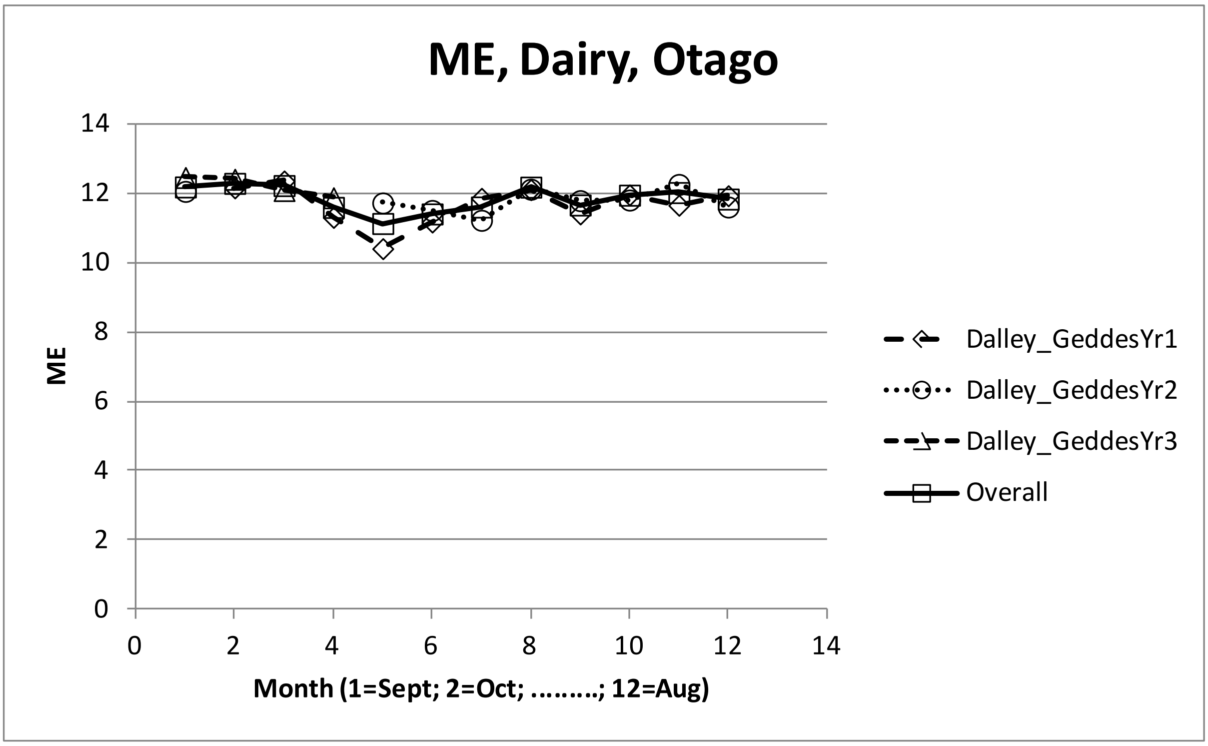
Dairy results by region

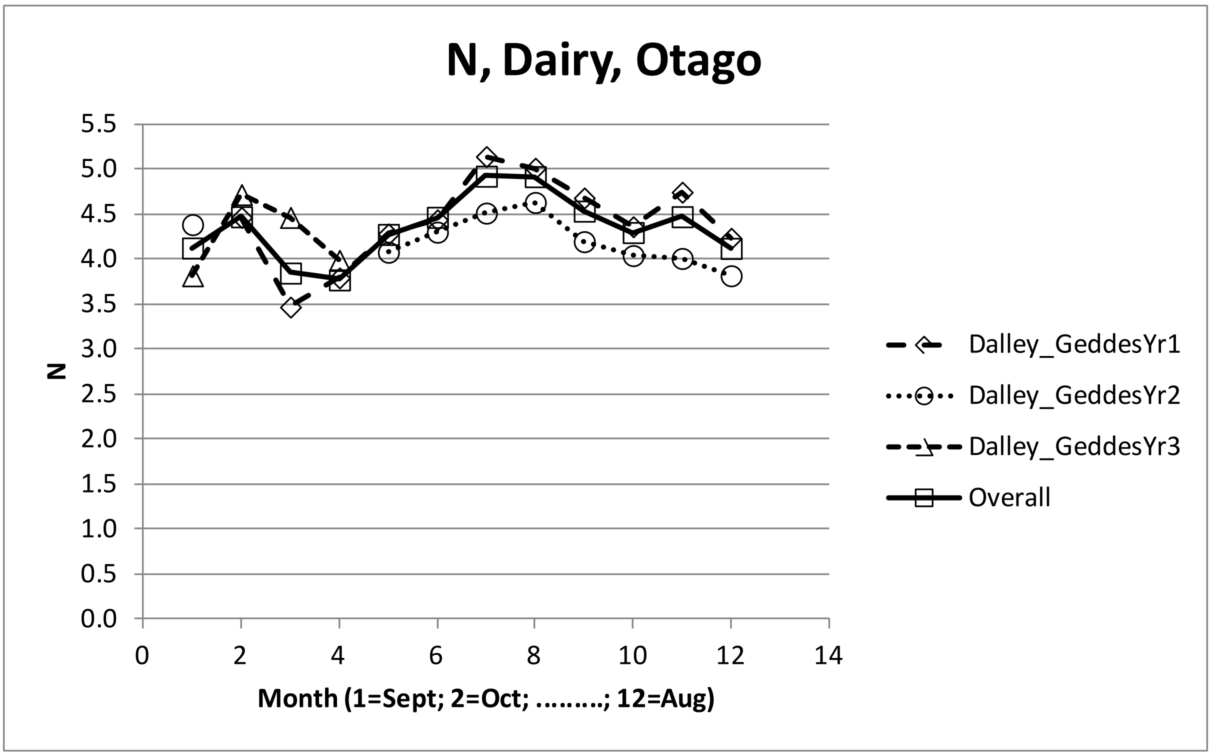
For dairy, the variation in sample size from month to month was not as high as for sheep/beef. Again, however, sufficient data for an analysis were available for only four out of the 17 Statistics NZ regional authorities.

Otago

In tabular form, the data for Otago are as shown below. Here the "Overall" Otago column gives the adjusted means as output by the statistical analysis (after the three datasets have been "patched" together by the analysis of variance to form a single yearly pattern). These data are also displayed in the graphs below. Note that "Month 1" is September, and month 12 is the following August.

	ME					N			
Month	Dalley_ Geddes Yr1	Dalley_ Geddes Yr2	Dalley_ Geddes Yr3	**Overall**	**Month**	Dalley_ Geddes Yr1	Dalley_ Geddes Yr2	Dalley_ Geddes Yr3	**Overall**
1	*	12.050	12.450	12.178	1	*	4.384	3.816	4.124
2	12.150	*	12.400	12.281	2	4.464	*	4.718	4.471
3	12.350	*	12.075	12.218	3	3.468	*	4.464	3.846
4	11.300	*	11.867	11.589	4	3.792	*	3.987	3.770
5	10.400	11.717	*	11.125	5	4.280	4.077	*	4.275
6	11.167	11.500	*	11.400	6	4.437	4.300	*	4.465
7	11.850	11.217	*	11.600	7	5.140	4.512	*	4.922
8	12.100	12.113	*	12.173	8	5.011	4.630	*	4.917
9	11.400	11.783	*	11.658	9	4.680	4.195	*	4.534
10	11.950	11.800	*	11.941	10	4.360	4.040	*	4.296
11	11.650	12.250	*	12.016	11	4.744	4.008	*	4.472
12	11.925	11.600	*	11.829	12	4.232	3.816	*	4.120



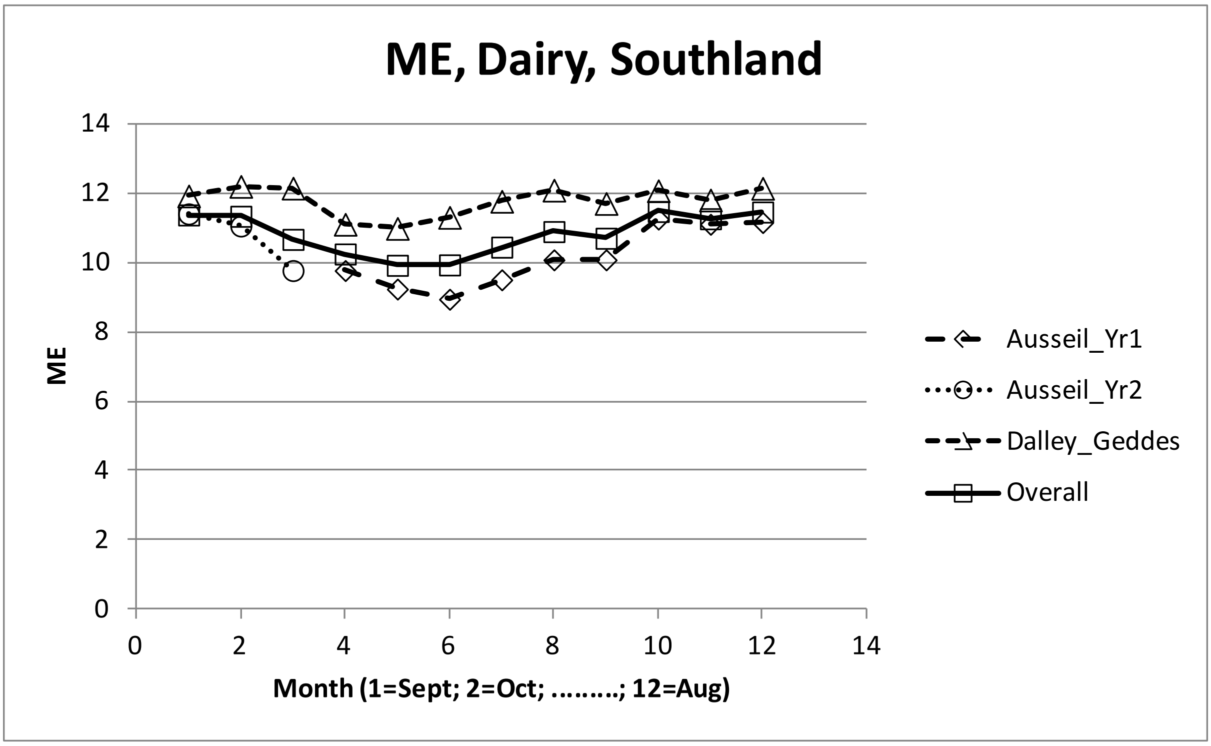


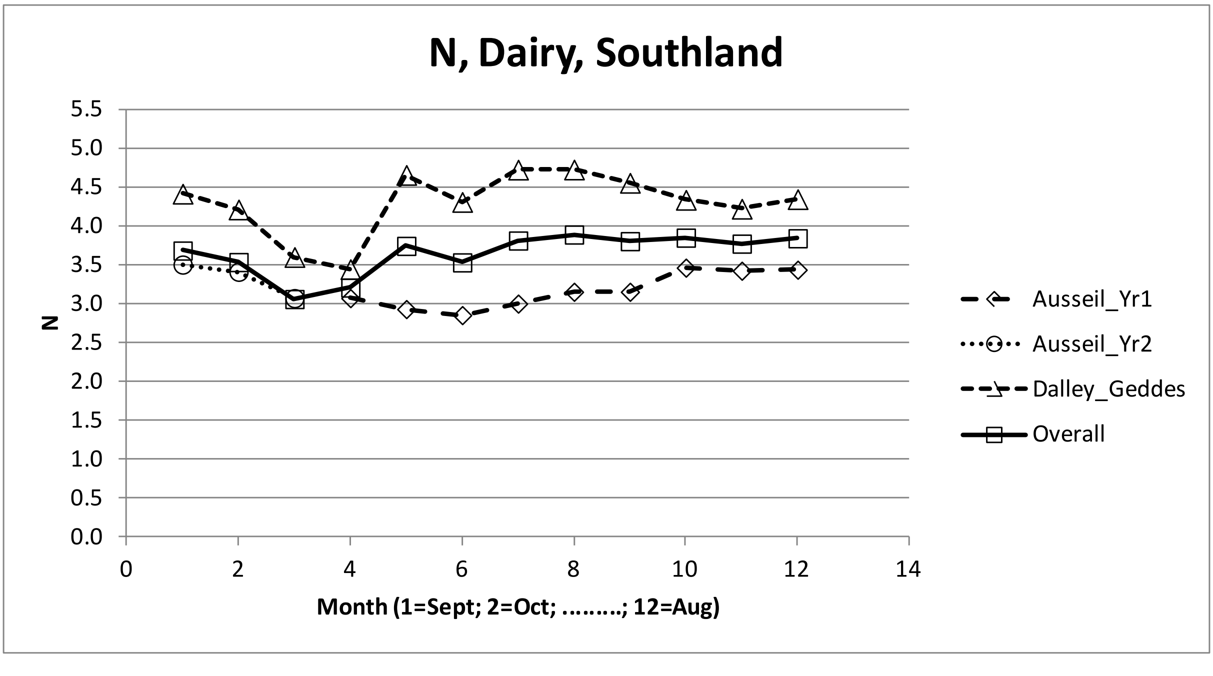
Southland

Basic data are given in the table, and in the two graphs below.

		ME					N		
Month	Ausseil_ Yr1	Ausseil_ Yr2	Dalley_ Geddes	Overall	Month	Ausseil_ Yr1	Ausseil _Yr2	Dalley_ Geddes	Overall
1	*	11.400	11.917	11.369	1	*	3.504	4.415	3.684
2	*	11.050	12.192	11.331	2	*	3.412	4.212	3.536
3	*	9.767	12.142	10.665	3	*	3.073	3.601	3.061
4	9.767	*	11.100	10.244	4	3.073	*	3.445	3.209
5	9.233	*	10.982	9.918	5	2.932	*	4.656	3.744
6	8.940	*	11.300	9.930	6	2.855	*	4.309	3.532
7	9.500	*	11.763	10.442	7	3.002	*	4.724	3.813
8	10.075	*	12.083	10.889	8	3.154	*	4.725	3.890
9	10.075	*	11.700	10.698	9	3.154	*	4.555	3.805
10	11.250	*	12.067	11.469	10	3.464	*	4.336	3.850
11	11.100	*	11.800	11.260	11	3.425	*	4.221	3.773
12	11.150	*	12.136	11.453	12	3.438	*	4.345	3.842

In the two graphs, and in the table, it is interesting to note the differences in ME and N between the patterns observed by the two research groups. For both variables, the Dalley-Geddes values were consistently higher than the Ausseil values. For ME, the difference averaged about 1.5 units, while for N the difference was about 1.0 unit. Both sets of data were from the 2007/2008 season. The difference may be attributable to a difference in field sampling technique, a difference between laboratory methods or techniques, a difference in ME and N levels between the experimental plots (perhaps attributable to the experimental treatments), or a mixture of some or all of the above. This highlights the fact that for future work, the sources of any such differences need to be thought about, and methods standardised in an appropriate fashion.





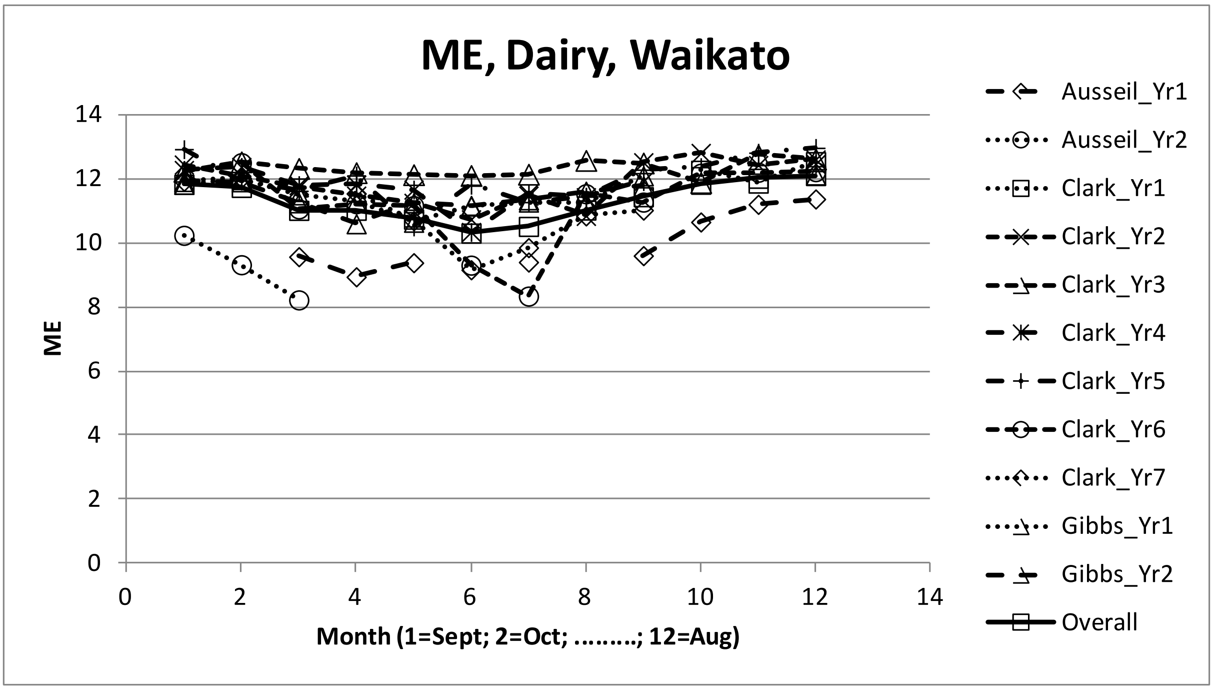
Waikato

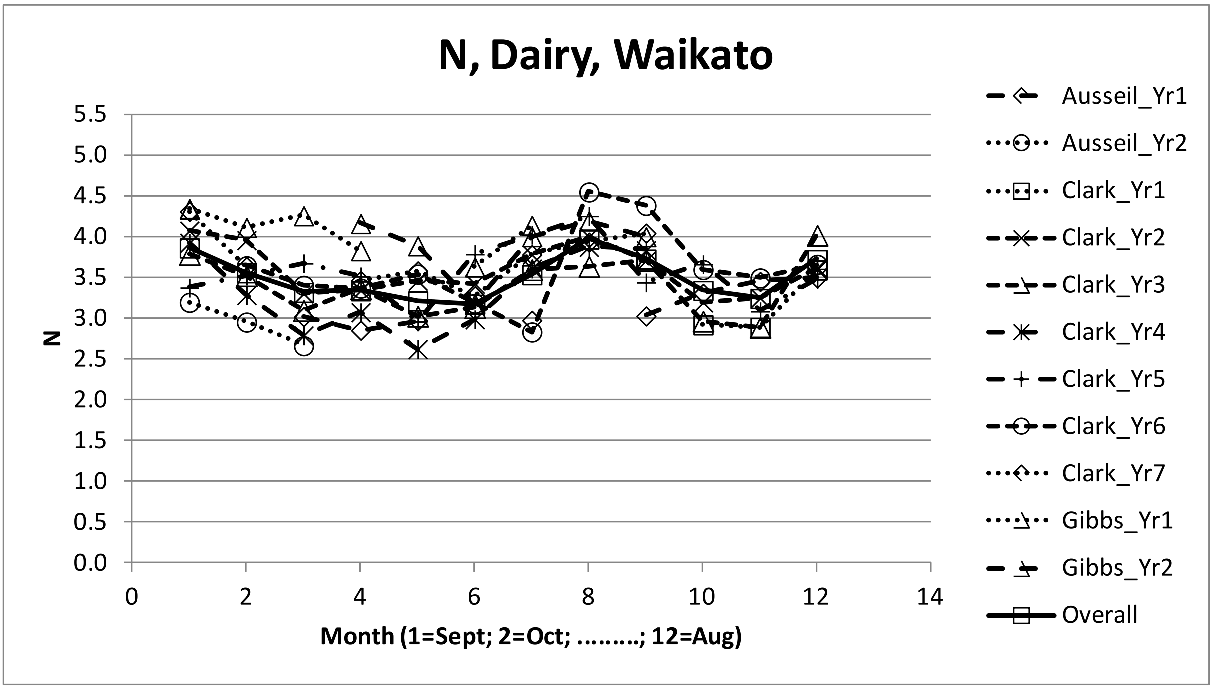
Waikato is noteworthy for the presence of lots of data spread over quite a few years, presumably due to the presence of Ruakura Research Station in the region. There are 11 basic sets of data which necessitate two tables (this page), and two graphs (next page).

						ME						
Month	Ausseil_Yr1	Ausseil_Yr2	Clark_Yr 1	Clark_Yr 2	Clark_Yr 3	Clark_Yr 4	Clark_Yr 5	Clark_Yr 6	Clark_Yr 7	Gibbs_Yr1	Gibbs_Yr2	**Overall**
1	*	10.233	*	12.441	12.230	12.270	12.920	*	11.920	11.821	11.912	11.825
2	*	9.317	*	12.088	12.525	12.367	11.940	12.499	12.020	11.974	11.904	11.728
3	9.567	8.220	*	11.733	12.320	11.800	11.620	11.058	*	11.496	11.247	11.012
4	8.940	*	*	11.471	12.188	11.813	12.100	11.220	11.540	11.281	10.595	11.015
5	9.380	*	*	11.247	12.125	11.660	10.510	11.160	10.690	10.642	11.247	10.738
6	*	*	*	10.733	12.100	10.338	11.810	9.303	9.160	11.145	11.168	10.303
7	9.400	*	*	11.472	12.140	11.540	11.270	8.339	9.850	11.271	11.341	10.512
8	*	*	*	10.841	12.570	11.420	11.440	11.530	10.840	11.260	11.611	11.022
9	9.600	*	*	12.512	12.490	11.925	12.280	11.270	11.020	12.089	11.776	11.438
10	10.650	*	12.263	12.802	11.880	*	12.360	12.170	*	*	*	11.827
11	11.200	*	11.863	12.425	12.742	*	12.810	12.200	*	*	*	12.013
12	11.367	*	12.531	12.600	12.613	12.460	12.960	12.220	*	12.114	*	12.097

						N						
Month	Ausseil_Yr1	Ausseil_Yr2	Clark_Yr 1	Clark_Yr 2	Clark_Yr 3	Clark_Yr 4	Clark_Yr 5	Clark_Yr 6	Clark_Yr 7	Gibbs_Yr1	Gibbs_Yr2	**Overall**
1	*	3.196	*	4.074	3.782	3.926	3.376	*	4.309	4.336	4.344	3.862
2	*	2.954	*	3.957	3.523	3.285	3.523	3.644	3.634	4.112	*	3.558
3	3.020	2.664	*	3.304	3.096	2.790	3.674	3.404	*	4.256	*	3.317
4	2.855	*	*	3.342	3.360	3.074	3.514	3.370	3.464	3.828	4.160	3.337
5	2.971	*	*	3.461	3.025	2.622	2.962	3.541	3.581	*	3.888	3.213
6	*	*	*	3.424	3.131	2.988	3.786	3.183	3.277	3.629	3.180	3.172
7	2.976	*	*	3.780	3.595	3.610	4.024	2.833	3.781	4.139	4.000	3.534
8	*	*	*	3.998	3.635	3.875	4.253	4.547	3.933	*	4.192	3.971
9	3.029	*	*	3.708	3.710	3.834	3.440	4.382	4.043	*	4.000	3.725
10	3.306	*	2.920	3.196	2.965	*	3.662	3.597	*	*	*	3.341
11	3.451	*	2.889	3.249	2.889	*	3.086	3.494	*	*	*	3.243
12	3.495	*	3.593	3.617	4.016	3.600	3.478	3.661	*	*	*	3.720

Individual sets of data are hard to distinguish in the graphs, but for ME, the Ausseil data values can again be seen to be those at the bottom of the scatter of points. This is also the case for the N values, although it is harder to see.

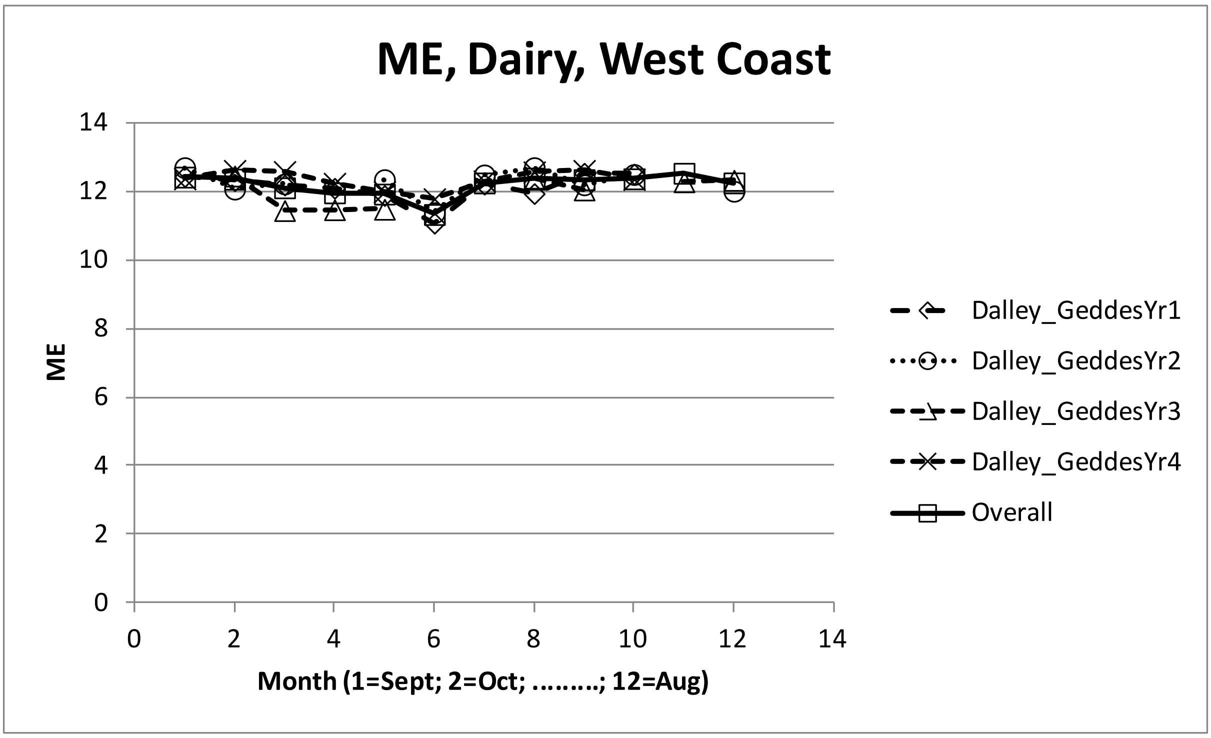


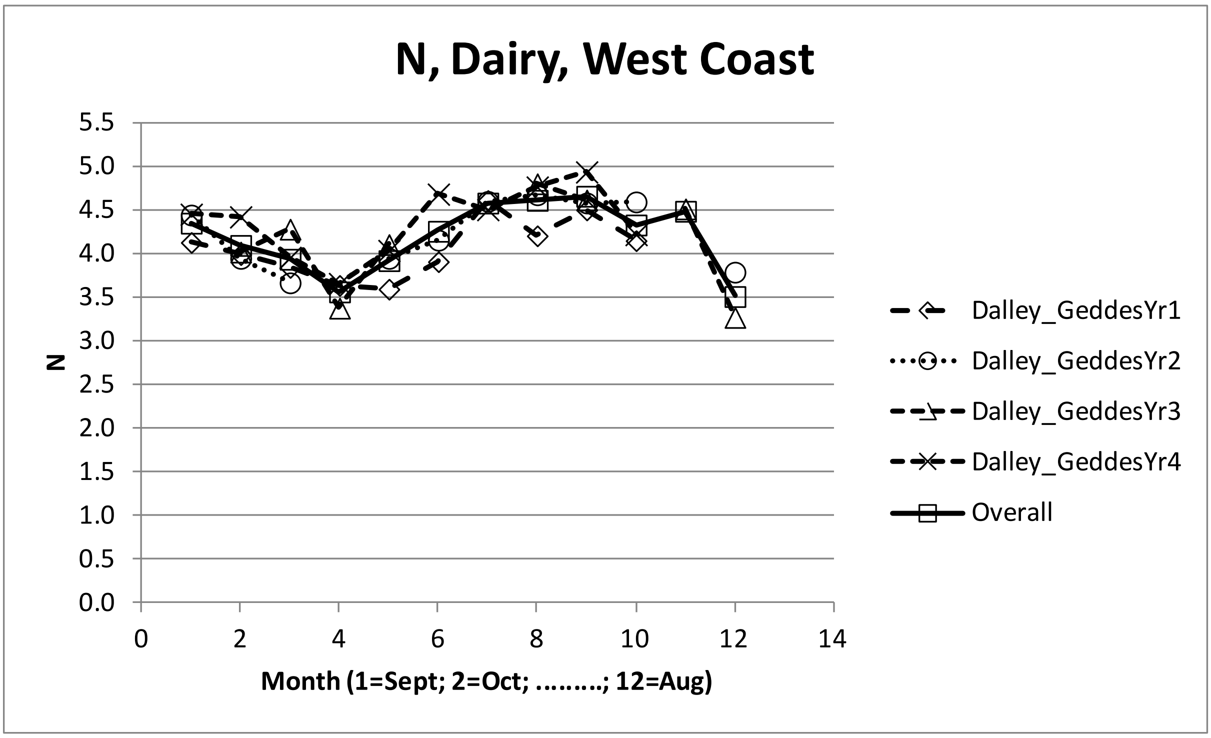


West Coast

Basic data are given in the table, and in the two graphs below.

	ME						N				
Month	Dalley_ Geddes Yr1	Dalley_ Geddes Yr2	Dalley_ Geddes Yr3	Dalley_ Geddes Yr4	Overall	Month	Dalley_ Geddes Yr1	Dalley_ Geddes Yr2	Dalley_ Geddes Yr3	Dalley_ Geddes Yr4	Overall
1	12.429	12.688	*	12.369	12.412	1	4.128	4.442	*	4.451	4.349
2	12.306	12.063	12.444	12.600	12.353	2	3.989	3.946	4.018	4.421	4.094
3	12.181	12.213	11.438	12.569	12.100	3	3.842	3.666	4.280	3.957	3.936
4	12.088	*	11.463	12.225	11.953	4	3.636	*	3.376	3.658	3.562
5	11.875	12.338	11.475	11.981	11.917	5	3.593	3.946	4.104	4.036	3.920
6	11.069	11.375	*	11.775	11.323	6	3.908	4.154	*	4.681	4.256
7	12.206	12.475	*	12.296	12.242	7	4.608	4.598	*	4.504	4.579
8	11.931	12.688	12.350	12.558	12.382	8	4.204	4.674	4.800	4.762	4.610
9	12.525	12.188	12.038	12.600	12.338	9	4.500	4.580	4.614	4.935	4.657
10	12.500	12.488	*	12.350	12.362	10	4.148	4.592	*	4.218	4.328
11	*	*	12.275	*	12.523	11	*	*	4.512	*	4.485
12	*	12.000	12.319	*	12.243	12	*	3.788	3.270	*	3.509





The other 13 regions

For the other 13 regions, there were not enough monthly values to attempt to establish a pattern over the season. For Canterbury, there were only 5 monthly values for both ME and N, for Northland and Manawatu/Wanganui there were only 3 values each, and for Taranaki and Bay of Plenty there were only 2 values each. For the other eight regions, there were *no* monthly values for either ME or N.

New Zealand overall (dairy)

As for sheep/beef above, there are three ways in which the available dairy pasture ME and N values could be combined over the regions to form averages for New Zealand overall (and South and North Islands).

(1) If good data had been available for each region, the monthly patterns could be combined over the regions by multiplying each regional monthly ME or N value by the estimated total number of stock units of dairy cows in the region, summing over all regions and dividing by the total dairy stock units in NZ. This would give a weighted average for each month of the ME and N values, with highest weight given to regions with the highest number of dairy stock units. This could also be done for South and North Islands separately. Given the sparseness of the dairy pasture data (summarised above for only 4 out of the 17 Statistics NZ regional authorities), however, this “best practice” method is clearly impossible.

(2) A second approach, ignoring the ideas in (1), is to combine ME data from the 21 “farm-years” as presented above, treating these 21 farm-years as a representation of NZ as a whole (and for N, similarly). Note that with this approach, there is a strong weighting towards the Waikato region, with 11 out of the 21 farm-years.

(3) A third approach is to use the four regional sets of monthly means as derived above to derive an overall monthly pattern for ME for NZ dairy pastures, treating these four regions as a representation of NZ as a whole (and for N, similarly).

Neither of (2) or (3) is ideal, but we shall now use the third approach. This has the advantage that the consistency of data from region to region can be displayed. Data are as follows, both in a table and in two graphs:

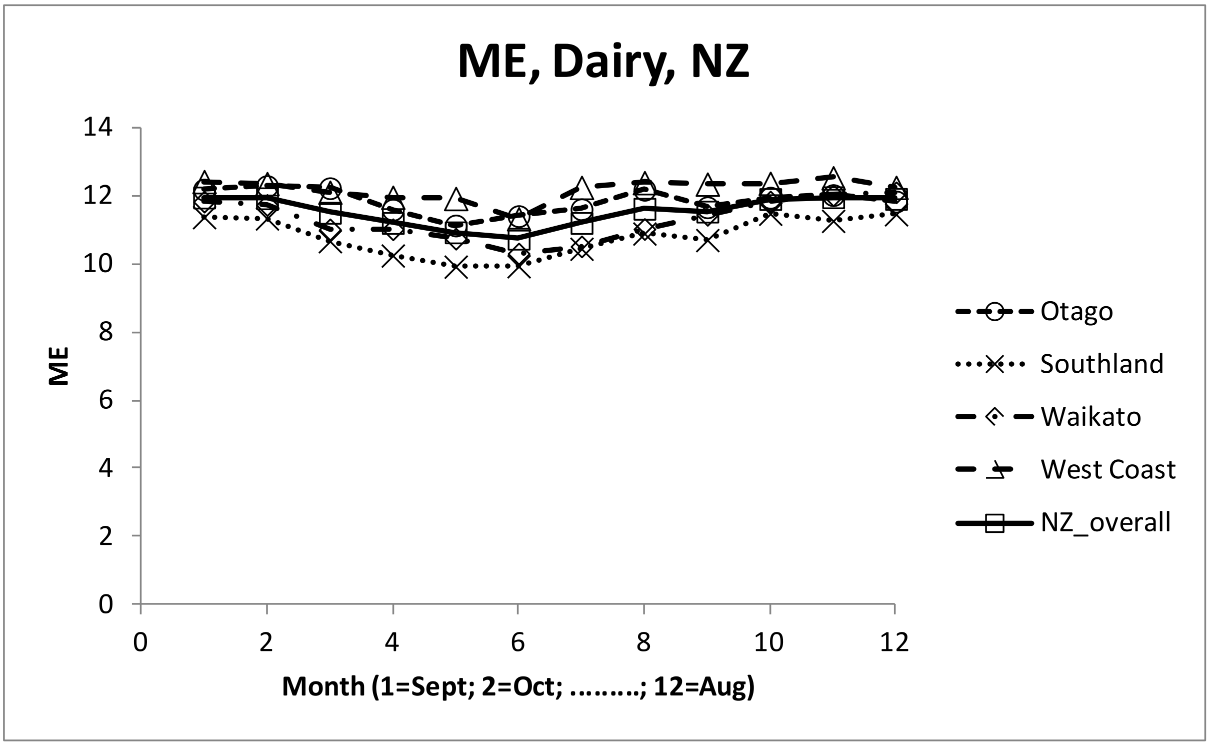
			ME							**N**		
month	**Otago**	**Southland**	**Waikato**	**West Coast**	**NZ_overall**		**month**	**Otago**	**Southland**	**Waikato**	**West Coast**	**NZ_overall**
1	12.178	11.369	11.825	12.412	11.946		1	4.124	3.684	3.862	4.349	4.005
2	12.281	11.331	11.728	12.353	11.923		2	4.471	3.536	3.558	4.094	3.915
3	12.218	10.665	11.012	12.100	11.499		3	3.846	3.061	3.317	3.936	3.540
4	11.589	10.244	11.015	11.953	11.200		4	3.770	3.209	3.337	3.562	3.470
5	11.125	9.918	10.738	11.917	10.924		5	4.275	3.744	3.213	3.920	3.788
6	11.400	9.930	10.303	11.323	10.739		6	4.465	3.532	3.172	4.256	3.856
7	11.600	10.442	10.512	12.242	11.199		7	4.922	3.813	3.534	4.579	4.212
8	12.173	10.889	11.022	12.382	11.616		8	4.917	3.890	3.971	4.610	4.347
9	11.658	10.698	11.438	12.338	11.533		9	4.534	3.805	3.725	4.657	4.180
10	11.941	11.469	11.827	12.362	11.900		10	4.296	3.850	3.341	4.328	3.954
11	12.016	11.260	12.013	12.523	11.953		11	4.472	3.773	3.243	4.485	3.993
12	11.829	11.453	12.097	12.243	11.905		12	4.120	3.842	3.720	3.509	3.798
	Least Significant Difference, LSD(5%)				**0.387**			**Least Significant Difference, LSD(5%)**				**0.332**

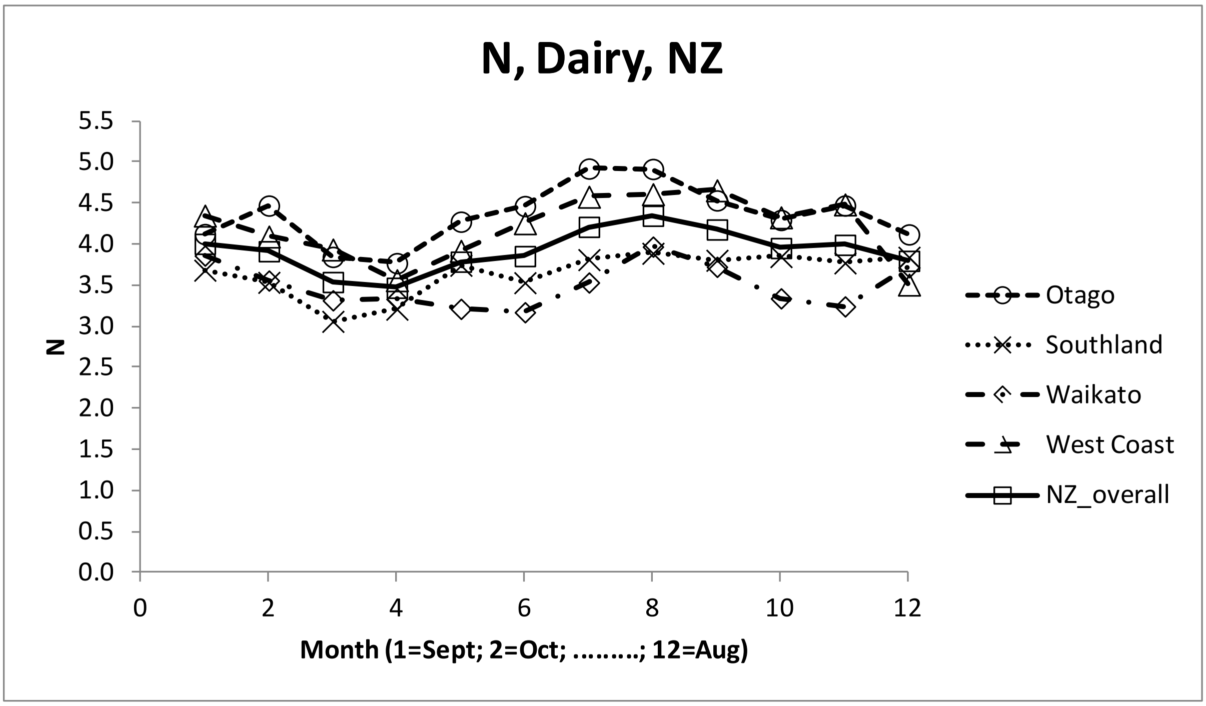
The most striking thing about the dairy pasture data is that ME and N values do not vary as much from month to month as the corresponding values for sheep/beef pastures (compare the dairy pasture graphs on the next page with the sheep/beef pasture graphs earlier in the report, or compare the two tables).

For ME, the minimum monthly value occurs in month 6 (Feb) for both dairy and sheep/beef pastures, but the dairy value is about 2.4 units higher than the sheep/beef value (10.74 versus 8.34). For N, the dairy values are all substantially higher than the sheep/beef values, to the extent that the minimum monthly value for dairy (3.47) is higher than the maximum monthly value for sheep/beef (3.45).

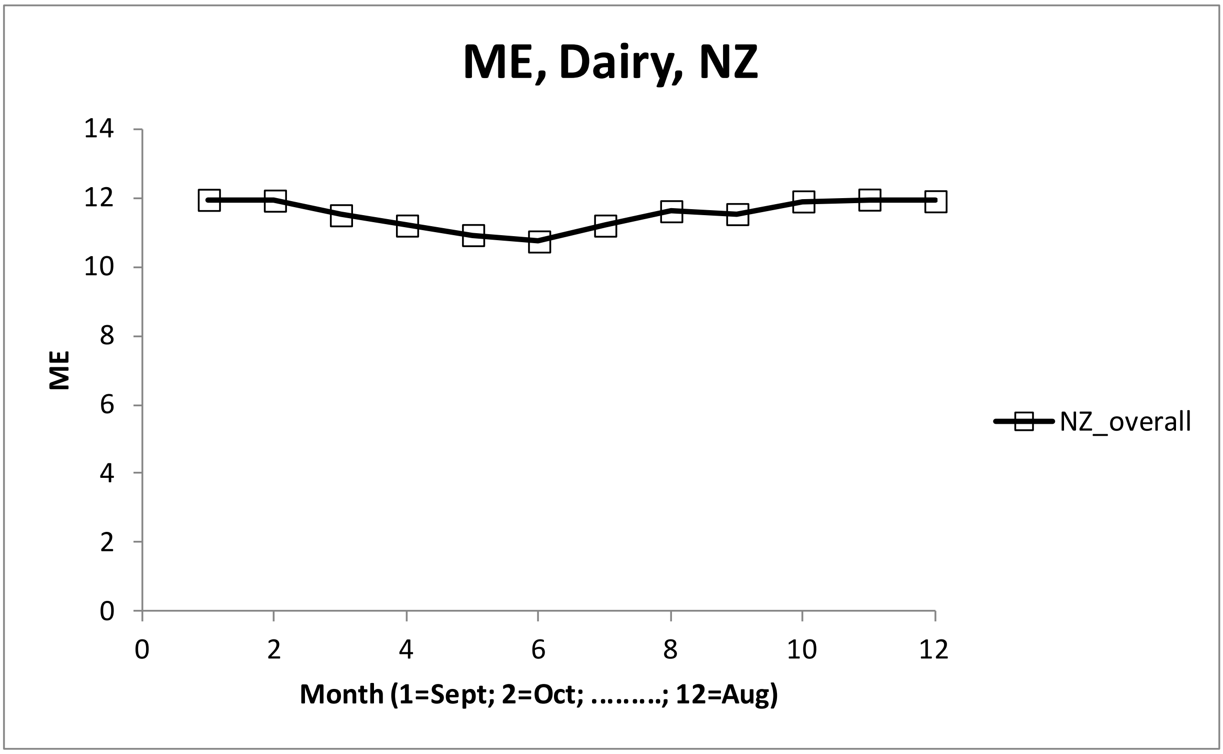
In the above table, a “least significant difference” is given for each variable for the NZ-wide estimated overall monthly means (last column for each dataset). Thus for ME, a difference between two monthly NZ_Overall means is statistically significant at the 5% level of significance if it is greater than 0.387. Hence the relatively high mean ME values for months 10 - 12 and 1 - 2 (June - Oct) do not differ significantly from one another (since the differences are less than 0.387), but the relatively low mean ME values for months 4 - 7 (Dec - Mar) are all significantly lower than for June - Oct. Mean ME values for months 3, 8 and 9 (Oct, Apr and May) are intermediate between these low and high values.

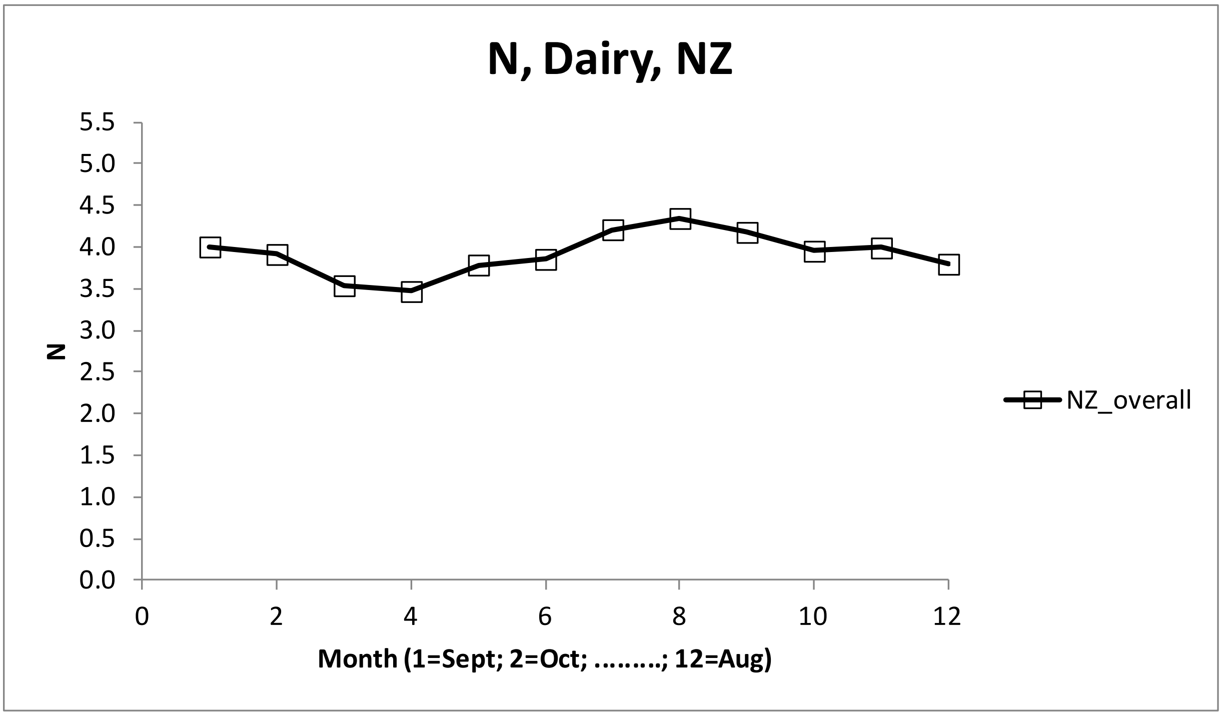
Similarly, for N, a difference between two monthly NZ_Overall means is statistically significant at the 5% level of significance if it is greater than 0.332. Hence the relatively high mean N values for months 7 - 9 (Mar - May) do not differ significantly from one another (since the differences are less than 0.332), but the relatively low mean N values for months 3 - 5 (Nov - Jan) are all significantly lower than for Mar - May. Mean N values for months 10 - 12 and 1 - 2 (June - Oct) are intermediate between these low and high values.


ME, Dairy, NZ
14
12
10
8
6
4
2
0
ME
0
2
4
6
8
10
12
Month (1=Sept; 2=Oct; ....; 12=Aug)
Otago
Southland
Waikato
West Coast
NZ_overall


N, Dairy, NZ
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
N
0
2
4
6
8
10
12
Month (1=Sept; 2=Oct; ....; 12=Aug)
Otago
Southland
Waikato
West Coast
NZ_overall

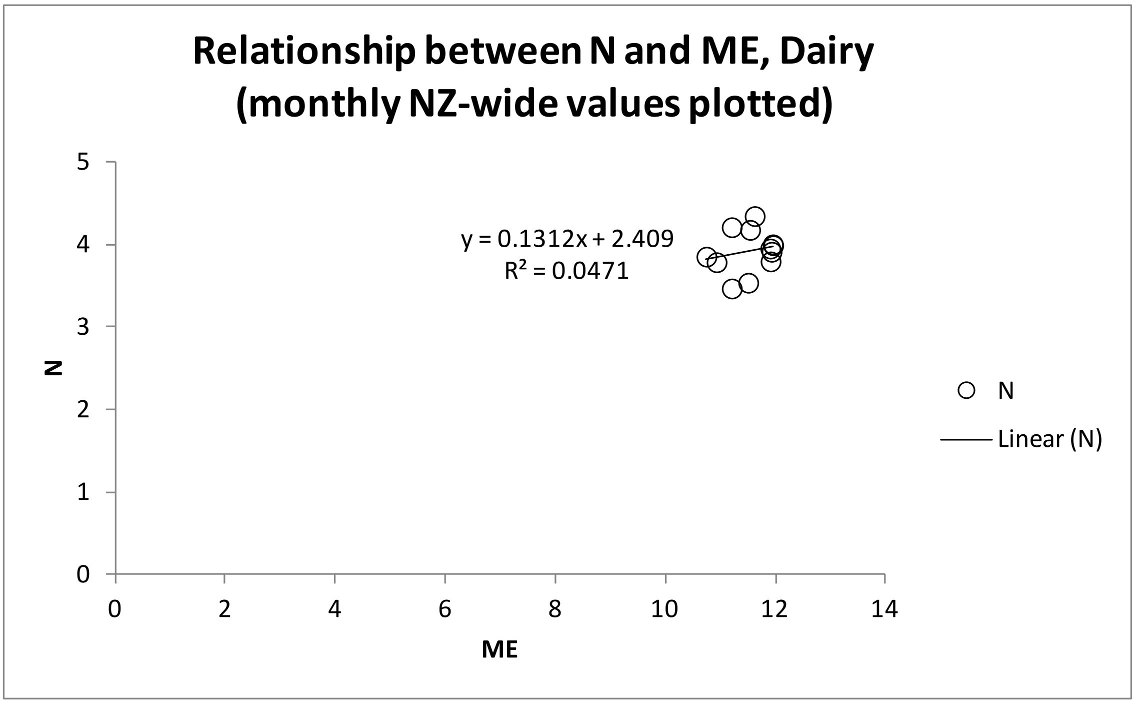
The above graphs are now redone with just the NZ-wide means displayed, for ease of seeing the monthly values:





Relationship between ME and N for dairy pastures

The above yearly patterns for dairy pastures do not look as similar as they did for sheep/beef pastures, in that the highs and lows of both ME and N no longer seem to roughly coincide. To explore this further, we plot N against ME, using the 12 monthly NZ-wide means for ME and N from the table above.



Overall, there is *no* statistically significant correlation between N and ME, with a correlation coefficient of only $r = 0.217$ ($p = 0.50$).

Visually, the points show a lot less variation in both ME and N than was apparent in the corresponding graph for sheep/beef pastures.

Summary, Dairy pasture data on ME and N

In summary, several points emerge:

(1) There is also surprisingly little useful data on ME and N available for dairy pastures (though more than for sheep/beef pastures). For both ME and N, there are data for only 4 out of the 17 Statistics NZ regional authorities. For Otago and the West Coast, Dalley/Geddes is the only source of data. For Southland, Dalley/Geddes and Ausseil are the two sources. For the Waikato, Clark is the main source, along with Ausseil and Gibbs. In general, Ausseil estimates of ME and N are lower than estimates from the other sources.

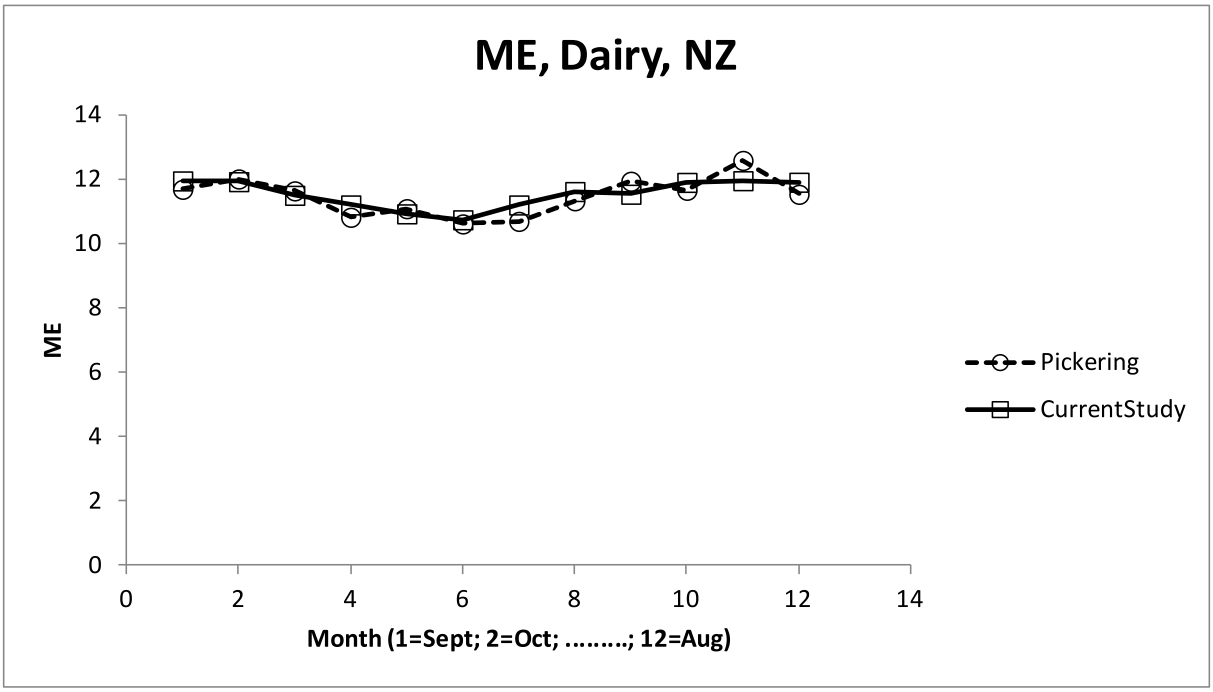
(2) As for sheep/beef, for a more adequate basis for analysis, it is recommended that a nationwide survey of dairy pastures be biometrically designed and conducted, with monthly sampling of specific, randomly selected dairy pastures in all 17 Statistics NZ regional authorities (with the possible exception of the Chatham Islands). This should be carried out for a minimum of three agricultural seasons (Sep to Aug), with a minimum of 1-2 dairy pastures sampled in each region in each season. These pastures should be on different farms each season, so that in total, dairy pastures would be sampled (Sep to Aug) on a minimum of 3-6 different farms per region. The number of dairy pastures sampled per region per season should be determined by "optimal statistical design" calculations (as for any stratified random survey), so that the regions with a high number of dairy stock units will be sampled more intensively than regions with a low number of dairy stock units. (Practical details would also need to be carefully considered, such as at what stage of the dairy rotation should a paddock be sampled. Standardisation of field sampling technique and of laboratory methodology would also be required.)

The resulting data would enable the "best practice" method of analysis to be carried out (as described in (1) on page 61 above, involving weighting by total dairy stock units per Statistics NZ regional authority), and would result in more robust estimates of NZ-wide and South and North Island averages for ME and N in dairy pastures.

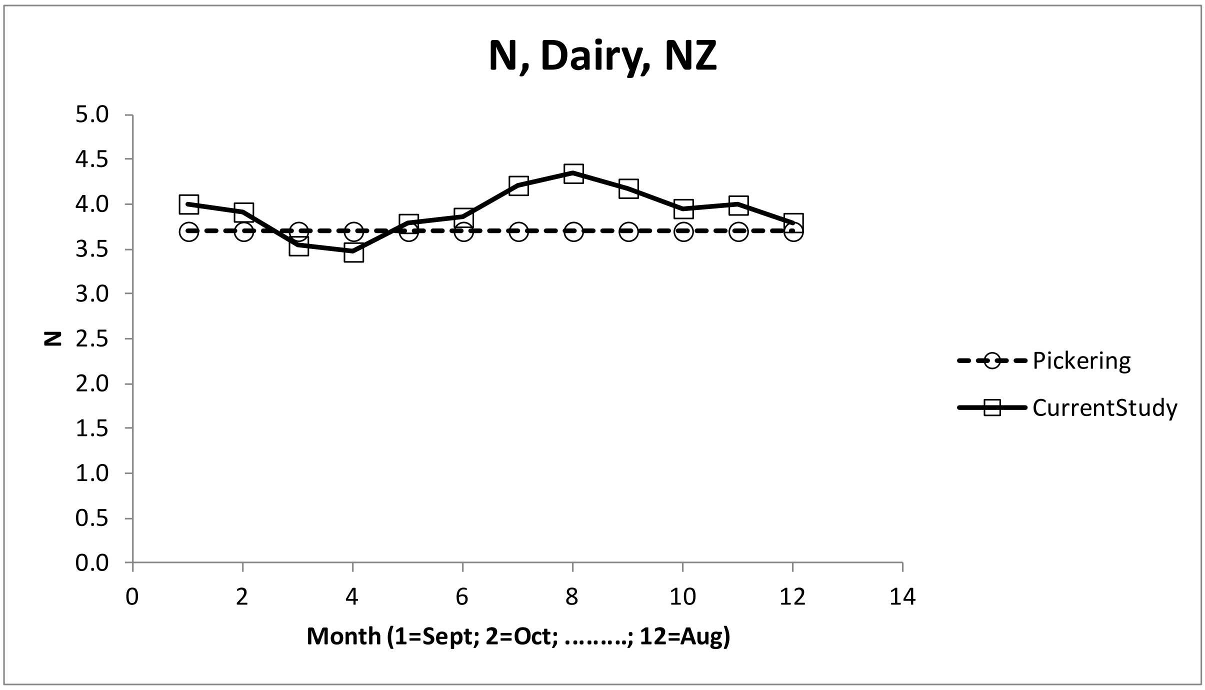
(3) With what little data are available (as reported above), it is clear that both ME and N vary significantly from month to month, although on a percentage basis this variation is much lower than with sheep/beef pastures. In dairy pasture, mean ME values dropped slowly from about Oct to Feb, then increased again to a plateau for the period June to Oct. Dairy pasture mean N values dropped slowly from about Apr to Dec, then increased again until Apr.

(4) The two graphs below compare the estimates from the present report with those currently used in the NZ National Greenhouse Gas Inventory (NGGI), due to Pickering (2011).

For ME, the two estimates agree to within 5% for all months (in the graph below, the two curves criss-cross each other, and in general, follow each other closely). As a simple average over the 12 months, the two estimates agree to within 0.6%.



For N, the estimate in the current report is higher than the Pickering estimate for 10 out of the 12 months (see graph below). On average, the estimate in the current report is 6% higher than the Pickering estimate. As with sheep/beef, the "constancy" model for N is inappropriate. Note that for comparing a monthly estimate from this report with the constant value of 3.7, the Least Significant Difference, LSD(5%), is the value reported above (0.332) divided by $\sqrt{2}$; that is, the LSD(5%) is 0.235. This means that for six months, months 7 - 11 and 1 (Mar - July and Sep), the estimates reported herein differ significantly from 3.7 (p<0.05).



(5) In the NGGI, the N values (%s) are multiplied by the pasture dry matter intake (DMI) when the nitrogen intake is calculated. In addition, the ME values are involved in calculating the DMI. Therefore the annual pattern in pasture DMI must also be considered in relation to the annual patterns in ME and N. In winter, for example, pasture DMI is likely to be lower than at other times of the year, and in spring, pasture DMI may be at its maximum; therefore, the effect of biases in ME or N estimates must be seen in relation to the pattern of pasture DMI.

(6) The estimates made by Pickering and in this report rely upon the same publicly available data, so may both be quite incorrect in terms of nationwide averages. In this report, the inadequacies in the data have been made clear; for example, the four regions, out of 17, for which data are available, may not provide an unbiased picture of NZ as a whole. Suggestions for remedying the problem have been made in point (2) above.

Feedtech (pasture type unknown) results by region

Additional ME and N monthly values are available from Feedtech, but for these data, the pasture type (Sheep/beef or Dairy) is unknown. This means these data are of limited usefulness, since in this report we have seen that pasture type has a large effect on ME, and especially, N values.

Such data are available for the following eight regions (many the same as in this report):
Canterbury
Hawke's Bay
Manawatu/Wanganui
Waikato
Otago
Southland
Northland
Taranaki
(Northland and Taranaki are the two regions for which no data are given in this report)

The data for these regions would provide further information on differences between regions, but this would be confounded (confused) with pasture type; for example, Taranaki values may turn out to be higher than for some other regions, due to the predominance of dairy pastures in Taranaki.

These data have not been statistically analysed for inclusion in this report; this can be done at a later date if so desired.

Conclusions in relation to objective

The stated objective of the current study was to examine the available data on ME and N in New Zealand (NZ) sheep/beef and dairy pastures in relation to the yearly pattern (month by month estimates). In particular:

- Is there evidence of variation in these parameters from month to month?
- Are the data good enough to provide reliable estimates of the monthly means, *NZ-wide*?
- Are the data good enough to provide reliable estimates of the monthly means for each *region* of New Zealand?

The answers to these three questions are as follows:

- Yes, there is evidence of variation in the parameters from month to month.
- No, the data are not good enough to provide scientifically tested and validated, and thereby reliable, estimates of the monthly means, *NZ-wide*.
- No, the data are not good enough to provide scientifically tested and validated, and thereby reliable, estimates of the monthly means for each *region* of New Zealand (in fact, for most regions, there is almost no such data available).

To remedy this situation, it is recommended that a nationwide survey of sheep/beef, and of dairy pastures be biometrically designed and conducted, with monthly sampling of specific, randomly selected pastures of both types in all 17 Statistics NZ regional authorities (with the possible exception of the Chatham Islands). Further details concerning this recommendation are given in the Summary section at the end of the Sheep/beef and Dairy sections of this report.