# Indirect measurement of pasture mass and pasture growth rate on sheep and beef pastures

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## Abstract
This study aimed to develop calibrations for the measurement of pasture mass and pasture growth rate on sheep and beef pastures. Herbage within quadrats (0.12-0.2 m$^2$) was measured with either an electronic rising plate meter (RPM) (n=2279), capacitance pasture meter (CPM) (n=693) or pasture ruler (n=2528) for the development of linear and curvilinear seasonal calibrations for pasture mass. Analysis of herbage samples within a subset (n=555) of quadrats, measured for dead matter or dry matter percentage, failed to remove the need for seasonal corrections to prediction equations but did offer a means to measure atypical (e.g. droughted) pastures. Measurements of mown pasture growth rate along with either change in RPM (n=520) or CPM (n=3314) were collected from sheep and beef farms throughout New Zealand. A single, simple multiplier of 157 could be used all year round to predict change in mass from the RPM reading ($R^2$=0.80), whereas the CPM ($R^2$=0.67) required different multipliers for each month.
**Keywords:** pasture mass, growth, rising plate meter, capacitance height, dead, dry matter, sheep, cattle

## Introduction
Feed planning on sheep and beef farms would be enhanced by a rapid, easy to use, robust and accurate means to estimate both pasture mass and growth rate (net herbage accumulation rate). To measure pasture mass in a timely manner, sheep and beef farmers commonly use visual assessment but a calibrated measurement device such as the rising plate meter (RPM), capacitance pasture meter (CPM) or sward stick would be useful for adjusting their eye. Pasture measurement devices use an indirect measure (e.g. height and resistance to compression in the case of the RPM, and capacitance in the case of the CPM) and relate this to pasture mass using either linear or curvilinear calibration equations.

Existing calibration equations provided for the rising plate meter (RPM) and capacitance pasture meter (CPM) were developed on dairy pastures. However, dairy compared to sheep and beef pastures are grazed at and to very different pre- and post-grazing masses. These differences affect the density and composition of the sward as pastures grazed to a lower height or mass are denser and exhibit a higher proportion of white clover (Vipond *et al.* 1997). Curvilinear equations become more appropriate when measuring very short and very long pastures (Gonzalez *et al.* 1990), as may occur on sheep and beef farms. Consequently, RPM and CPM calibration equations developed for dairy pastures may not be appropriate for sheep and beef pastures. Theoretically, sward stick equations should be better calibrated as they were developed using data from sheep and beef pastures at Whatawhata Research Station, near Hamilton (Webby & Pengelly 1986).

Calibrations for pasture mass change with botanical and especially morphological composition of the pasture. On ryegrass/white clover dairy pastures, sward morphology varies with season. This seasonal effect can be accommodated by using different calibration equations for each season (L'Huillier & Thomson 1988) or a single calibration equation that changes continuously with time of year (Thomson *et al.* 2001). Much of the season and pasture type variation in the pasture mass relationships occurs in the base of the pasture, where mass accumulates from August to December and then decays from March to June (Li *et al.* 1998). When measuring pasture growth or feed intake, it is not necessary to measure this non-grazeable pasture base. It was found that when regrowth, i.e. change in mass above the pasture base, was related to change in RPM reading, the relationship was unaffected by pasture type and season and was more accurate than ground level calibration cuts (Davis *et al.* 1998; Devantier *et al*. 1998; Lile *et al.* 2001).

The main objective of this study was to develop more robust sheep and beef calibration equations to measure pasture mass and growth rate. These equations were developed from calibration cuts that were collected on sheep and beef pastures throughout New Zealand. Also explored, was the potential improvement in calibration equations by fitting percentage pasture dry matter (DM%) or dead matter (Dead%). This would account for sward structural differences due to season (Thomson 1983) but also differences generated by poor utilisation, aspect, soil fertility, drought and pasture species (Johns 1972).

## Method

### Pasture mass

The herbage in quadrats (0.12-0.20 m$^2$) were measured using either an electronic RPM (n=2628, supplied by Farmworks, Feilding), CPM (n=470, GrassmasterII) or ruler (HT) (n=2112). The herbage was then cut to ground level with an electric shearing hand piece, before being washed and dried (80$^o$C, 24 hours) for calculation of herbage mass (kg DM/ha). Pastures were predominantly on steep hill country, half were ryegrass based and the remainder consisted of predominantly low fertility tolerant grass species.

The RPM calibration data were collected from 2279 quadrats cut in only the North Island, 79% in southern North Island with the remainder equally spread across central and northern North Island. The data were reasonably spread across months (95-485 quadrats per month) and a separate calibration for each month was obtained. For each month, a RPM value of 5 was used to calculate herbage mass and, based on this herbage mass value, months were grouped into similar seasons. In addition, an equation was fitted between slopes and intercepts for individual months to create smoothed, monthly values for both of these parameters.

The CPM dataset contained measurements taken from 470 quadrats (Table 2) matched with a mean of 10 capacitance meter readings per quadrat. A corrected capacitance meter reading was back calculated from the mass using the calibration equation 0.48CMR-300, the default calibration used in the study. The dataset was too small to allow separate monthly calibration data so the same seasonal classifications as the height dataset were used. Half the data were collected in southern North Island with the remainder equally spread between central North Island and central South Island.

Pasture height (HT) was defined as the average height of the free standing grass leaf, not including stem or seed head. The height measurement for the herbage within each quadrat was largely an average of 10 individual ruler height readings per quadrat (n=2472). Seventy four percent of the data came from the historical Whatawhata data (Webby & Pengelly 1986) and the remainder was collected in the southern North Island. The height data were classified according to the following seasons; autumn (March-May), winter (June-August), spring (September-November), and summer (December-February).

Samples within a subset (n=555) of quadrats (0.2 m$^2$) were measured sequentially firstly for height using a ruler, then CPM and finally RPM. The quadrat was then trimmed to approximately 1 cm and a subsample of this pasture was dissected for morphological composition (dead matter, green leaf, reproductive stem, legume and weed) and dry matter determination. The herbage was then cut to ground level, washed and then dried for herbage mass determination. This dataset was collected on predominantly longer and poorer quality pastures in comparison to the main dataset. Because of the small number of samples it was only possible to separate these data into two seasons, namely May to October (cold season) and November-April (warm season).

### Pasture growth rate

Three datasets (A, B, C), where the RPM (n=520) and CPM (n=3314) were used to provide estimates of pasture growth, were used to calculate the relationships between change in meter reading and weight of regrown pasture (change in herbage mass). For all datasets, cages were trimmed to 2-3 cm pasture height, measured with RPM or CPM, allowed to regrow for approximately a month, measured again (change in meter reading calculated) and then re-trimmed to the same height, before being relocated. The accumulated herbage was collected, weighed and a subsample dried (80$^o$C, for 24 hours) to determine change in mass (kg DM/ha) from which daily pasture growth rate was estimated.

For dataset A (n=460), 16 x 1 m$^2$ cages in each of two paddocks were mown (rotary mower) from April to December 2006 on each of two sheep and beef farms located in the lower North Island and two paddocks at Winchmore Research Station in Canterbury. In half the cages, mowing date was offset by 2 weeks. At each cage measurement, a mean of 20 capacitance (GrassmasterII) readings and three electronic rising plate meter readings (Farmworks) were collected. A pooled plucked sample was collected from the cages at each sample date and dissected into dead, grass leaf, clover and weeds.

For dataset B (n=19), three 0.5 m$^2$ exclusion cages, in each of 16 paddocks, were trimmed, using an electric sheep shearing handpiece, from September to July 1996 at Ballantrae Hill Research Station (Devantier *et al.* 1998). At each cage measurement, four mechanical RPM readings were taken.

In dataset C (n=3248), four cages were measured with a CPM (GrassMaster II) in each of two paddocks and then mown (rotary mower) by individual farmers (Clarke-Hill & Fraser 2007) from May 2002 to November 2006 on a total of 80 farms located throughout New Zealand. Pasture composition (legume, green leaf, green stem, dead and weeds) and DM% to mower height was determined.

### Statistical analysis

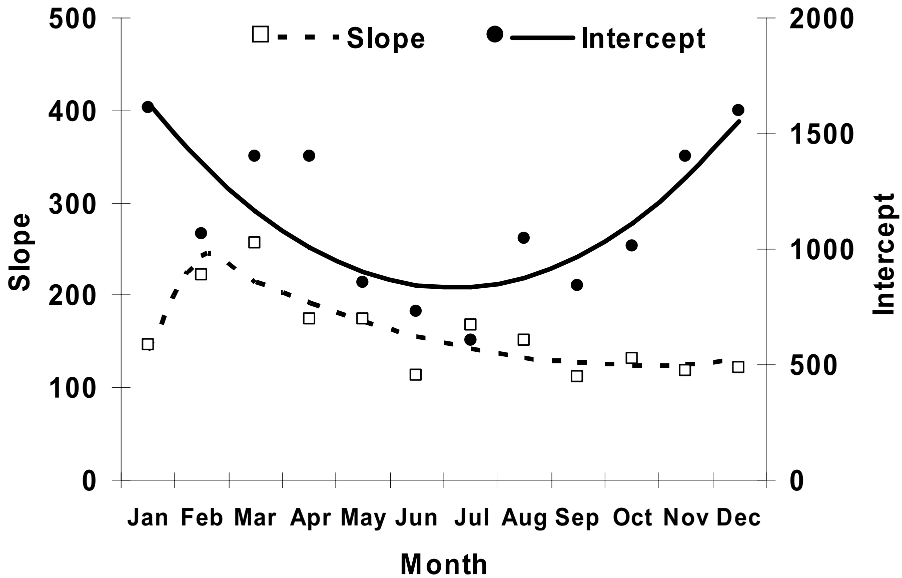
Initially, linear and square root functions of the independent variables (RPM, CPM or HT) were fitted

**Table 1** Annual and seasonal, linear (y = *a* + *b*x) and square root regression relationships ($y = c + e\sqrt{x}$) between pasture mass (y; kg DM/ha) and rising plate meter reading (x) pooled over the year or for individual seasons for sheep and beef pastures.

| | Annual (2279)[1] | | Jan-Apr (560) | | Nov-Dec (492) | | May-Oct (1227) | |
|---|---|---|---|---|---|---|---|---|
| | LSM[2] | SE | LSM | SE | LSM | SE | LSM | SE |
| Linear | | | | | | | | |
| a | 1 034 | 33 | 1 591 | 76 | 1 471 | 56 | 811 | 35 |
| b | 151 | 3 | 166 | 6 | 119 | 4 | 134 | 4 |
| $R^2$ | 0.52 | | 0.56 | | 0.61 | | 0.50 | |
| Significance | | | | | | | | |
| a | *** | | *** | | *** | | *** | |
| b | *** | | *** | | *** | | *** | |
| Curvilinear | | | | | | | | |
| c | -450 | 155 | -247 | 130 | 158 | 95 | -330 | 63 |
| e | 1 003 | 19 | 1 163 | 40 | 838 | 29 | 825 | 23 |
| $R^2$ | 0.55 | | 0.59 | | 0.63 | | 0.52 | |
| Significance | | | | | | | | |
| c | *** | | * | | * | | *** | |
| e | *** | | *** | | *** | | *** | |

[1] n; [2]LSM=least squares mean, SE=standard error mean, * P<0.05,*** P<0.001.

**Figure 1** Monthly intercept and slope values for the rising plate meter on North Island sheep and beef pastures.




to the pasture mass data on an annual basis using a General Linear Model in the Statistical Analysis System (SAS) package. The statistical model was then expanded to include farm and season fitted as fixed class effects. Dead percentage (Dead%) and dry matter percentage (DM%) were fitted as linear regression coefficients using forward stepwise regression. Factors that were not significant (P>0.10) were removed from the model. The relationship between change in RPM and change in kg DM/ha (growth) was determined by regression analysis without fitting an intercept. As fitting regressions without an intercept gives an artificially high coefficient of determination ($R^2$), the $R^2$ presented is the actual versus predicted measure using an intercept.

## Results

### Pasture mass

*Rising plate meter:* Months were grouped into the winter months of May-October, November-December for spring, January-March as summer, leaving April the sole autumn representative so it was included into the summer season (Table 1). The relationship between RPM reading and total mass was highly curvilinear (P<0.001) and slightly improved the correlation coefficient relative to the linear relationship (Table 1). The slope and intercept of the linear equation for each month followed a consistent seasonal pattern (Fig. 1).

*Capacitance meter:* For a given CPM reading the North

**Table 2** Annual and seasonal, linear (y = *a* + *b*x) and square root (y = c +e√x or c + dx + e√x) regression relationships between pasture mass (y; kg DM/ha) and capacitance meter reading pooled over the year or for individual seasons for sheep and beef pastures.

| | Annual (693)[1] | | Mar-May (247) | | June-Aug (91) | | Sept-Nov (268) | |
|---|---|---|---|---|---|---|---|---|
| | LSM[2] | SE | LSM | SE | LSM | SE | LSM | SE |
| Linear | | | | | | | | |
| a | 129 | 99 | -621 | 185 | -232 | 246 | 466 | 116 |
| b | 0.72 | 0.02 | 0.90 | 0.05 | 0.79 | 0.07 | 0.62 | 0.02 |
| $R^2$ | 0.58 | | 0.63 | | 0.60 | | 0.66 | |
| Significance | | | | | | | | |
| a | NS | | ** | | NS | | *** | |
| b | *** | | *** | | *** | | *** | |
| Curvilinear | | | | | | | | |
| c | -3 067 | 202 | -4 768 | 385 | -3 464 | 520 | 1 420 | 1215 |
| d | | | | | | | 0.84 | 0.3 |
| e | 99 | 3.2 | 126 | 6.2 | 103 | 9 | -29 | 37 |
| R2 | 0.58 | | 0.64 | | 0.60 | | 0.67 | |
| Significance | | | | | | | | |
| c | *** | | *** | | *** | | NS | |
| d | NA | | NA | | NA | | *** | |
| e | *** | | *** | | *** | | NS | |

[1] n; [2]LSM=least squares mean, SE=standard error mean,* P<0.05, ** P<0.01, *** P<0.001, NS=Not significant, NA = Not applicable.

**Table 3** Annual and seasonal, linear (y = *a* + *b*x) and square root (y = c +e√x or c + dx + e√x) regression relationships between pasture mass (y; kg DM/ha) and sward height (x: cm) pooled over the year or for individual seasons for sheep and beef pastures.

| | Annual (2528)[1] | | Dec-Feb (389) | | Mar-May (440) | | June-Aug (980) | | Sept-Nov (719) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LSM[2] | SE | LSM | SE | LSM | SE | LSM | SE | LSM | SE |
| Linear | | | | | | | | | | |
| a | 756 | 29 | 662 | 107 | 565 | 103 | 667 | 29 | 1 060 | 43 |
| b | 186 | 4 | 263 | 16 | 243 | 14 | 159 | 5 | 126 | 5 |
| $R^2$ | 0.44 | | 0.43 | | 0.41 | | 0.55 | | 0.42 | |
| Significance | | | | | | | | | | |
| a | *** | | *** | | *** | | *** | | *** | |
| b | *** | | *** | | *** | | *** | | *** | |
| Curvilinear | | | | | | | | | | |
| c | -507 | 53 | 1 275 | 614 | 1 269 | 560 | -241 | 49 | -209 | 81 |
| d | | | 421 | 106 | 376 | 85 | | | | |
| e | 1 023 | 22 | -645 | 520 | -625 | 444 | 795 | 22 | 893 | 31 |
| $R^2$ | 0.46 | | 0.44 | | 0.38 | | 0.56 | | 0.52 | |
| Significance | | | | | | | | | | |
| c | *** | | * | | * | | *** | | ** | |
| d | NA | | *** | | *** | | NA | | NA | |
| e | *** | | NS | | NS | | *** | | *** | |

[1] n; [2]LSM=least squares mean, SE=standard error mean,* P<0.05, ** P<0.01, *** P<0.001, NS= Not significant, NA = Not applicable.

Island pastures contained 800 kg DM/ha more (P<0.0001) than South Island pastures, the difference being greater (interaction P<0.0001) in December-February (1660 kg DM/ha), March-May (1200 kg DM/ha) and September-November (870 kg DM/ha) but the reverse was the case in June-August (-480 kg DM/ha). Both North and South Island functions failed to have a significant relationship between CPM reading and mass during December-February. In the combined North and South Island datasets a significant curvilinear relationship was found for the annual, March-May and June-August relationships but not for September-November (Table 2).

*Pasture height:* Relative to the Whatawhata dataset, the new data collected on farms had longer, poorer quality pastures and approximately 1000 kg DM/ha more mass, while the new data collected at Massey University had 200 kg DM/ha less mass for the same height (P<0.0001). Pastures in December-February and March-May had a higher mass per cm than those in June-August and September-November (Table 3). The relationship between height and mass was linear in December-February and March-May but was curvilinear in June-August and September-November and annually (Table 3).

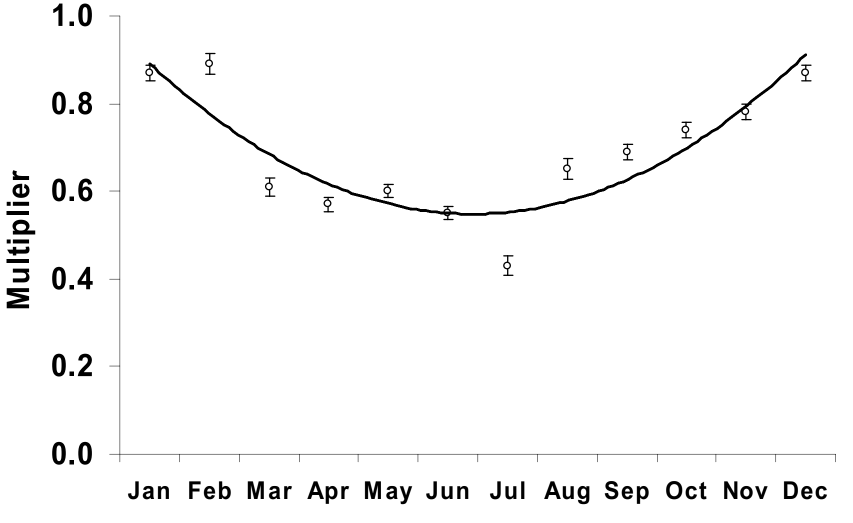
*DM% and Dead%:* Two equations incorporating DM% and Dead% (Table 4) are presented for each measurement device. The first equation gives the forward stepwise

**Table 4** Annual and seasonal, regression equations between pasture mass (y; kg DM/ha) and meter readings along with season, dead% or DM% fitted in order of significance. Season=0 for May-October and season=1 for November-April.

| Parameters | $R^2$ | Equation Number |
|---|---|---|
| $-3413(\pm765) + 2280(\pm395)\sqrt{RPM} + 750(\pm147)\ Season + 11.7(\pm4)\ Dead\%$ $-150(\pm52)\ RPM + 23(\pm8)\ DM\% + error$ | 0.63 | (1) |
| $-4677(\pm746) + 2927(\pm385)\sqrt{RPM} + 22(\pm3)\ Dead\%$ $-230(\pm52)\ RPM + 25(\pm9)\ DM\% + error$ | 0.60 | (2) |
| $-2325(\pm465) + 2442(\pm314)\sqrt{HT} + 858(\pm125)\ Season + 19(\pm5)\ Dead\%$ $-212(\pm48)\ HT + error$ | 0.63 | (3) |
| $-3206(\pm473) + 3050(\pm318)\sqrt{HT} + 32(\pm3)\ Dead\%$ $-303(\pm49)\ HT + error$ | 0.58 | (4) |
| $-4283(\pm500) + 106(\pm60)\sqrt{CPM} + 543(\pm124)\ Season$ $+ 29(\pm9)\ DM\% + error$ | 0.53 | (5) |
| $-9379(\pm2108) + 267(\pm64)\sqrt{CPM} - 1.19(\pm0.49)\ CPM$ $+ 26(\pm11)\ DM\% + 9(\pm4)\ Dead\% + error$ | 0.51 | (6) |

RPM=rising plate meter reading (cm), HT=height pasture (cm), CPM=capacitance meter reading, Dead%=percentage dead matter, DM%=dry matter percentage.

**Figure 2** For the capacitance meter the monthly multiplier (m) for converting change in capacitance meter reading to change in mass over the year.




regression equation with all significant (P>0.05) linear and curvilinear variables included but for the second equation, season was dropped. The measurement methods were: RPM (Table 4, Equations 1 and 2), CPM (Equations 5 and 6), HT (Equations 3 and 4). For both RPM and HT Dead% accounted for more variation in the indirect measure:pasture mass relationship than did DM% with Dead% being particularly important on summer pastures. For RPM and HT a 10% increase in Dead% increased mass by 200-300 kg DM/ha. In contrast, CPM was relatively insensitive to Dead% but was responsive to DM%, with a 10% increase in DM% increasing the estimate of mass by approximately 270 kg DM/ha. The inclusion of Dead% and DM% could not fully negate the effect of season, but removing season only resulted in a small drop in the explained variation.

**Pasture growth rate**

For the RPM, two statistically different (season P<0.001) seasonal multipliers (d) were found by grouping months using a change in a RPM reading (chRPM) of 5. They were 163.0 (SE 5, $R^2$=0.32) for January-July (n=186) and 156.7 (SE 2, $R^2$=0.79) for August-December (n=375). But the use of these seasonal multipliers only

**Table 5** Annual and seasonal, regression equations between pasture mass (y; Change kg DM/ha) and meter readings along with dead% or DM% (SE).

| Parameters | $R^2$ | Equation Number |
|---|---|---|
| *ChangekgDM 1ha* = 157.1(±2)*chRPM* | 0.79 | (7) |
| *ChangekgDM 1ha* = *m* (*chCPM)* | 0.67 | (8) |
| *ChangekgDM 1ha* = 139.4(±3)*chRPM* + 11.2(±1.5) *DM%* | 0.80 | (9) |
| *ChangekgDM 1ha* = 0.901(±0.009)*m*(*chCPM*) + 8.1(±0.5) *DM%* | 0.67 | (10) |

chRPM=change in rising plate meter reading, m=monthly multiplier (Fig. 2), chCPM=change in capacitance meter reading, DM%=dry matter percentage.

generated differences of 1-2 kg DM/ha/d in pasture growth rate so from a practical standpoint a single multiplier of 157 could be used all year round

For the CPM, the monthly multiplier (m) for chCPM had a consistent curvilinear seasonal pattern and is used to calculate change in mass (Fig. 2).

Stepwise regression indicated that DM% but not Dead% significantly ($P<0.0001$) improved the estimate of change in herbage mass for both meters but gave minimal improvements in $R^2$ (Table 5, Equations 9, 10).

## Discussion

### Pasture mass

For a given RPM reading, North Island sheep and beef pastures contain 300-500 kg DM/ha higher masses than do North Island dairy pastures except during winter when they are similar. Four seasonal calibrations were identified for the RPM, though autumn was only represented by April so this was aggregated into the summer calibration. Five separate seasonal calibration equations were found by L'Huillier & Thomson (1988) with a bigger dairy pasture dataset. For dairy pastures, the intercept and slope change gradually throughout the year (Li *et al*. 1998; Thompson *et al.* 2001) and this pattern was duplicated on the sheep and beef pastures.

The new CPM calibrations for sheep and beef pastures gave 1000-1500 kg DM/ha higher estimates of herbage mass for a given CPM reading than the equations provided with the CPM for dairy pastures. Only 470 cuts were collected on sheep and beef pastures and this is too few for a robust calibration. However, our estimates of mass seem reasonable when compared with a equations presented by Clarke-Hill & Fraser (2007) on sheep and beef pastures based on 3000 quadrat cuts taken 2-3 cm above ground level.

The CPM needs different seasonal calibrations, consistent with the literature (Johns 1972; Michell & Large 1983; Birrell & Thompson 1987). But relative to RPM and HT, the differences in seasonal calibrations were small and, until further data can be collected, it is recommended that the annual calibration equation be used. However, the CPM cannot be recommended for use during summer because once dead matter is dry, it has poor electrical conductivity, and is not recorded by the CPM. For instance, we found no relationship between mass and CPM reading for the summer season and a lack of sensitivity to Dead% in pastures.

The inclusion of new data into the existing Whatawhata height dataset increased the mass estimates on long pastures in summer and autumn by 500-800 kg DM/ha for a given HT but had no other effect. In comparison to other devices, using HT has major advantages due to its ease of use and low cost, but it is prone to operator errors arising from variation in the interpretation of location of the sward surface.

It was hypothesised that sheep and beef pastures, which are generally shorter but at times maybe longer than dairy pastures would be better described with curvilinear calibration equations (Gonzalo *et al.* 1990). On our sheep and beef pastures, in contrast to dairy pastures (Thomson *et al.* 2001), there was a curvilinear relationship between RPM reading and pasture mass in all seasons and for the other measurement devices in some seasons. For the existing commercial RPM and CPM, new curvilinear meter programming would be required before such equations could be used. Mean herbage mass would need to be calculated from each individual reading rather than from the mean meter reading as it is now (Cayley & Bird 1996). This may not be justified as the differences between linear and curvilinear predictions of herbage mass only differ on very short and long pastures. The sward stick, however, has always presented its estimates of herbage mass from HT using curvilinear relationships.

Sheep and beef (and dairy) farmers often use RPM or CPM to estimate herbage mass without changing from default winter or annual calibration equations. The use of the winter calibration, all year round, produces farm cover estimates more related to green, than total mass. While green mass does relate well to animal performance, we speculate that the underestimation of summer/autumn mass contributes to under-grazed pastures, poor utilisation and reduced pasture quality. Lile *et al.* (2001) recommend that when feed budgeting over winter, the winter calibration is used to establish the start average cover in autumn. This effectively removes the dead matter mass from the calculations which is justified because on fertile soils the dead matter will rapidly disappear after rain and therefore should not be included in a winter feed budget.

Fitting Dead% or DM% to RPM and CPM relationship with herbage mass could not fully remove the seasonal effect, possibly because Dead% and DM% were measured only on trimmed pasture. It is probable that greater proportions of dead matter accumulated below trimming height in summer thereby preserving some of the seasonal effect. Dropping season and instead fitting dead% or DM% only reduced the amount of variation explained by 1-5% while allowing a much greater range of pastures to be measured. Using the equations without season, revealed that a 10% increase in Dead% increased mass at the same RPM reading and HT reading by 200-300 kg DM/ha. This was in contrast to the CPM which was non responsive to high levels of Dead%, presumably because the CPM detects dead matter poorly. Following a 10% rise in DM%, RPM and CPM increased the mass estimate by 250 kg DM/ha.

If pastures have the normal structure for a particular season, then it is easier and indeed appropriate to use the standard seasonal calibrations. But for atypical pastures it may be appropriate to use Dead or DM% corrections. For example summer pastures with dead matters of 60%-80%, will have 1000 kg DM/ha more than would be determined using the standard seasonal calibration. In droughted pastures, the DM% rises from the normal 20% DM up to 40-50 DM% and as a consequence mass will be 600 kg DM/ha higher, and if the droughted pasture has both high Dead% and high DM% then mass could be up to 1600 kg DM/ha higher than predicted by the standard seasonal calibration.

### Pasture growth rate

Change in meter reading and change in mass for the RPM could be related with a single, simple, year round multiplier, consistent with findings of Davis *et al.* (1998), Devantier *et al*. (1998) and Lile *et al.* (2001). This was not the case for the CPM which required different multipliers for each month. While the size of the CPM dataset may have increased the chance of significance, it is also probable that capacitance, which varies with pasture surface area, does have a consistent seasonal change due to a seasonal change in the DM to surface-area relationship which is preserved in pasture above trimmed height. In contrast, the RPM has an enhanced capability to cope with differing densities of pasture because it measures resistance to compression.

For both CPM and RPM, DM% but not Dead% significantly improved the fit of change in meter reading to change in mass and even removed the small seasonal effect for the RPM. But for both meters, DM% only gave a minimal improvement in the description of the variation and should be confined to the measurement of atypical pastures. For the RPM, it was pleasing to find that 80% of the variation in actual pasture growth rate was explained by the change in RPM reading. For the CPM, only 67% of the variation in pasture growth rate was explained by change in CPM reading. Given that 80 different farmers collected the data, this level of accuracy is also pleasing.

The RPM offers meter reading as an output option so the multiplier will be easy to implement, but this is not the case for the CPM. For farmers using the CPM, the meter reading will have to be calculated back from the mass estimate using the calibration equation. Once change in meter reading has been obtained, farmers can readily calculate change in mass and then pasture growth rate. Farmers can measure pasture growth rate in ungrazed paddocks or from within exclusion cages. This change in meter reading method has also been used successfully by the primary author to measure pasture intake in rotationally grazed cattle.

## Conclusions

This paper provides calibrations for the estimate of cut to ground mass for the RPM, CPM and HT for both normal sheep and beef pastures and more seasonally extreme pastures via adjustments using Dead% and DM%. This paper provides a method whereby change in meter reading can be used to readily estimate pasture growth rate.

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