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USING THE PASTURE PROBE ON ANNUAL RANGE

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Many indirect forage dry matter assessment techniques have been developed including visual estimation, height and density measurements (i.e., ruler, rising plate meter), and assessment of non-vegetative attributes such as capacitance, beta attenuation, and radiometry. Most early models of the capacitance meter were very sensitive to sample water content. An earth plate capacitance probe developed by Vickery and Nicol (1982) has largely overcome this problem. We have been adapting this capacitance meter for estimating herbage mass in California for several years.

The Pasture Probe (Version Mk III) is an earth plate capacitance meter produced and marketed by Design Electronics of Palmerston North, New Zealand and marketed by Gallagher Power Fence, Inc. of San Antonio, Texas. The Pasture Probe has become a useful tool for estimating herbage mass in ryegrass-white clover pastures in New Zealand. This single probe capacitance meter is mainly responsive to the surface area of the herbage, and it is less sensitive to variations in moisture content of the pasture than previous meters. Thus, it can be calibrated to measure the mass of herbage dry matter to ground level, reducing the need to collect dry herbage samples for frequent recalibration of the instrument.

Herbage mass readings taken by the probe are saved in an electronic control box and can be downloaded to a microcomputer. There is memory space for before and after grazing readings from ninety pastures. Date, time, and pasture size information can be saved in the control box. Computer programs for downloading to a text file or spread sheet are available from the senior author.

The probes's electronic control box can be carried over the shoulder or around the waist with a belt. Readings are taken with the Pasture Probe by walking across a pasture as if the probe were a cane and taking a herbage mass reading each time the probe touches the ground. The average of the capacitance meter readings is converted to dry matter yield using a linear equation developed during calibration. The equations estimate kg/ha, but the probe is set to convert these estimates to lbs/a. The probe's electronics are programmed to convert capacitance to herbage mass using seven conversion equations from which the user can choose depending on pasture growing conditions (Table 1). Equations 1-4 are very similar (Figure 1), while equations 5-7 have increasing slopes. Equation 8 is the corrected meter reading (CMR) which can be used to develop new conversion equations. An air reading taken before and after data collection determines a "standard capacitance" with no herbage present that is used to "correct" capacitance readings (CMR). As capacitance can vary with humidity and temperature the probe automatically "standardizes" the capacitance under current operating conditions.

Because these equations were developed on perennial pastures dominated by perennial ryegrass and white clover, it was not clear whether any of them would work on annual range pastures. The objective of this study was to determine if the existing conversion equations were useful on annual range and to develop new conversion equations for conditions where they were not useful.

CALIBRATING THE PASTURE PROBE

The theory, design, and calibration of the earth plate capacitance meter has been reviewed by Angelone et al (1980), Toledo et al. (1980), Richardson (1982) and Butler (1984). Greathead, Wallace, and Boultwood (1987) determined that for probe calibration quadrat size and shape should be restricted to the circular area within 5 cm of the probe or overlapping probe readings should be collected in larger quadrats. Richardson (1984) recommended a minimum quadrat area of 0.15 m^2 and 15 meter readings per quadrat, and Butler (1986) used 10 readings in a 0.24 m^2 (.3 x .8 m) quadrat. Toledo et al. (1980) found that simple correlation coefficients (r) for the regression of dry matter on probe meter readings increased as plot size increased from .1 m^2 to 0.88 m^2 and changed little at higher plot areas up to 2.4 m^2.

For this study the probe was calibrated by taking 12 probe readings in a 1 sq. ft. (.09 m^2) quadrat. The quadrat was then clipped as close to ground level as possible. The quadrat was probed again after clipping. Dry matter estimates from the clippings were regressed on the difference between CMR before and after clipping. The difference between probe readings before and after clipping is used to remove the CMR contribution of herbage that remains after clipping because it is too short. Other researchers regress dry matter on the CMR before clipping. We found less variation (noise) in our data when the after-CMR was subtracted.

Dry, dead residual forage from the previous growing season was removed from the clipped samples. Richardson (1984) reported that variation in dead herbage within a set of calibration cuts contributes significantly to the standard error of the regression equation. He concluded that the best way to reduce the effect of dead herbage on probe readings was to calibrate the probe to green herbage rather than total.

Ideally the probe should be calibrated with cut samples of consistent composition and structure and extrapolated only to areas of similar composition. In reality this is not practical as pastures are not homogeneous and compositional changes are difficult and time consuming to measure. As with all other techniques used to estimate herbage mass, a compromise must be met between the level of accuracy required and the effort needed to achieve that level of accuracy. Research workers have the facilities to regularly calibrate the probe for trial work requiring a high degree of accuracy. However, Extension workers and farmers who are mainly estimating forage levels to aid in grazing management decisions are likely to achieve better results by using relevant pooled calibration data that reflect the range of pasture composition in their area rather than extrapolating a single set of possibly biased data. However, in pasture research investigating often small treatment responses in herbage mass, precision is required if meaningful results are to be achieved. The probe is capable of producing this precision if calibrated carefully for the specific conditions of the trial.

The number of quadrat samples required for probe calibration will increase as pasture variability and precision and accuracy requirements increase. For small plot trials or when there are only minor differences between pastures, a minimum of ten .15 m^2 quadrats should be collected. For larger areas or where pasture variability is greater, 30 to 40 quadrat samples are recommended. To be used with confidence, general calibrations for on-farm management usually require several hundred samples (Richardson 1984).

METHODS

The double sampling procedure was conducted periodically from a few weeks following germination until peak standing crop during the growing seasons of 1987-88 and 1988-89 at three locations: 1) O'Connell Ranch in southern Tehama County, 2) 4-J Ranch in Glenn County, and 3) the U.C. Sierra Foothill Range Field Station in Yuba County. The double samples from these locations were pooled and analyzed by date to estimate seasonal changes in the regression of herbage mass on CMR. Dates with similar regressions were pooled to determine seasonal conversion equations. The regression coefficients and Y-intercepts of the seasonal regression equations were compared to the pre-programmed equations (Table 1) to determine similarity (not significantly different).

RESULTS

Linear regression on a seasonal basis resulted in three conversion equations (Table 2). Equation A (r^2=0.32) is the result of double sampling during seedling establishment and early vegetative growth in the winter. The slope of this equation is significantly lower than any of the pre-programmed equations. The slope and Y-intercept of equations B (r^2= 0.86) and C (r^2 = 0.81) are not significantly different from pre-programmed equations 4 and 5, respectively. Data resulting in Equation B were collected in late winter and early spring after forage levels reached about 700 lb/a and vegetative growth was active. Equation C is the result of samples collected during extended rainless periods in the winter and spring or as annual plants began to flower and mature.

DISCUSSION

Early in the annual range growing season during and immediately following the seedling establishment growth phase when forage mass is less than 700 lbs per acre, all probe conversion equations tend to over-estimate actual herbage mass. Greathead, Wallace and Boultwood (1987) found that linear and curvilinear conversion equations overestimated subterranean clover early in the growing season and recommended a split set of linear equations. Butler (1986) reported that using linear conversion equations can present problems at low CMR values. He found that the Y-intercepts of linear equations have ranged from -600 to 900 kg DM/ha. However, bare ground CMR values are usually between 10 and 20. Therefore at low CMR, linear calibrations can sometimes grossly over or under-estimate the herbage mass actually present. Regressions should ideally be constrained through the bare ground CMR (probably necessitating a curvilinear equation), or extreme care should be taken when interpreting probe readings less than a CMR of 50. Our results concur with Butler's findings, but equation A can be used to estimate low forage levels if great care is taken to reduce sampling error and a large number of estimates are taken with the probe to get an average for the pasture or transect.

We have also tried subtracting bare ground readings from forage dry matter estimates as a means of adjusting winter readings. We found that bare ground CMR is usually 45 to 55 depending on moisture content and how far the probe was inserted in loose soil. This is in contrast to bare ground readings reported by Butler (1986) of 10 to 20. We are uncertain of the reason for this difference. It may be due to changes in the electronics as the probe was perfected and prepared for mass production and marketing. This method of estimating herbage mass early in the season needs further study.

Although the annual range pastures are different from the perennial ryegrass-white clover pastures used to develop the preprogrammed conversion equations in New Zealand, the structure of the swards are similar containing a large grass component and a smaller clover component. The filaree often present in the annual range may have substantial influence on early season calibrations, as it frequently dominates during that period.

Calibration techniques should be refined in future studies. Ancillary data such as phenology of dominant species, air temperature, and soil moisture conditions should be collected. This data should be used to refine recommendations for selecting conversion equations on the basis of phenology or recent growing conditions.

SUMMARY AND CONCLUSIONS

Early in the growing season from seedling establishment phase until forage levels are about 700 lbs/a use the following conversion equation:

$$Y \text{ (DM kg/ha)} = 213 + 6.3(\text{CMR})$$

Early in this period bare ground will be more visible. Forage levels will often begin to exceed 700 lb/a at about a height of 2 in.

When forage levels exceed about 700 lb/a DM equation 4 should be used for forage mass estimates. Late in the growing season as forage moisture declines and flowering becomes prevalent equation 5 should be used for forage estimates. Winter or spring drought may also necessitate switching to Equation 5.

These guidelines for the use of the probe on annual range should be subjected to continued testing and refinement.

Figure 1. Probe Conversion Equations

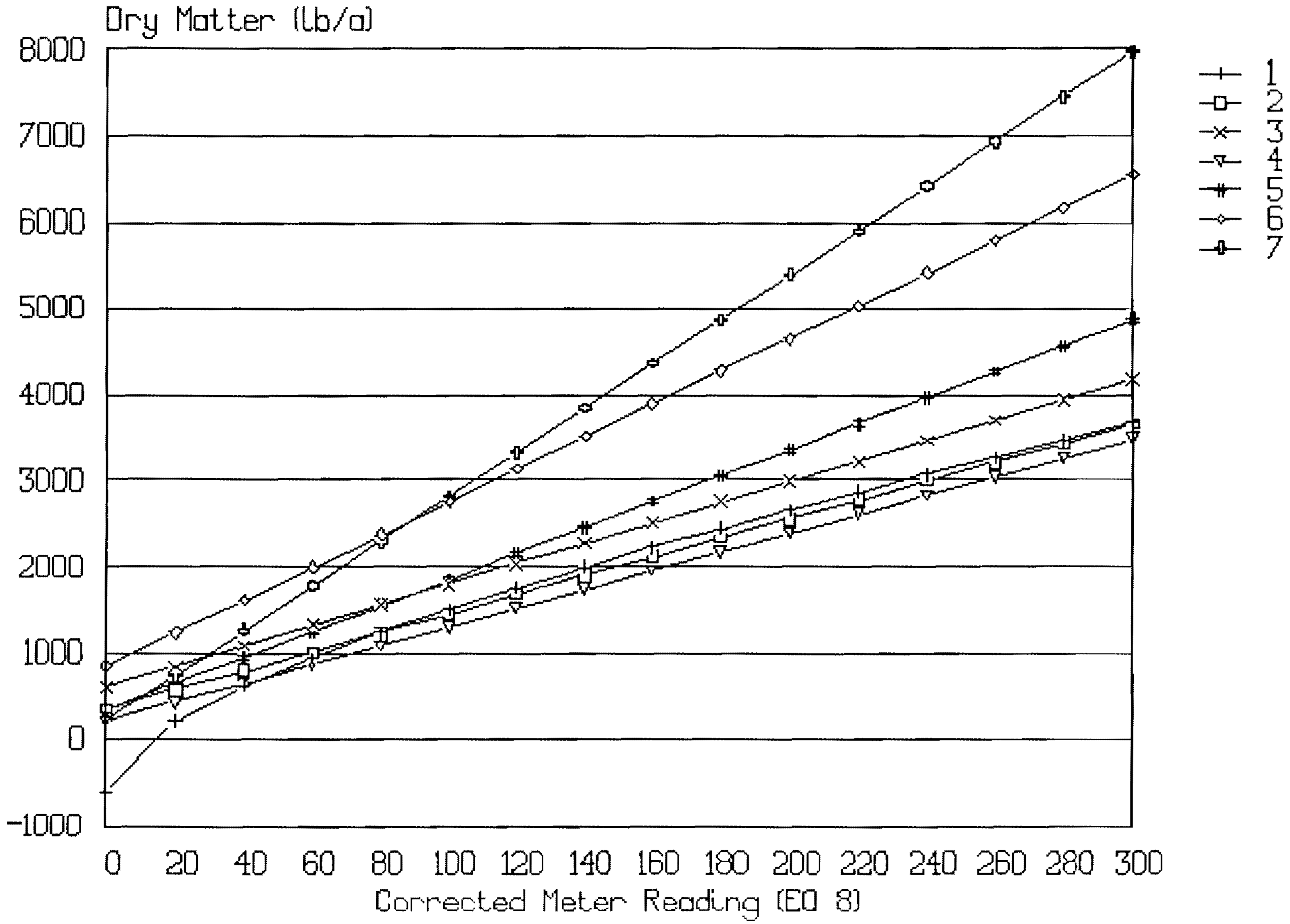

Table 1. Equations used to convert corrected meter readings (CMR) to herbage mass.

Equation		
1	$Y = -609 + 4.82\ CMR + 163\sqrt{CMR}$	Winter-Spring Use
2	$Y = 353 + 11\ CMR$	Early Autumn (before rains, forage green)
3	$Y = 608 + 11.9\ CMR$	Autumn (after rains)
4	$Y = 212 + 10.9\ CMR$	Winter to Early Spring
5	$Y = 341 + 15.1\ CMR$	Late Spring to Early Summer
6	$Y = 854 + 19\ CMR$	Summer
7	$Y = 232 + 25.8\ CMR$	Tropical Grasses
8	Corrected Meter Reading (CMR)	

Table 2. Comparison of linear conversion equations from annual range and pre-programmed conversion equations from New Zealand.

							Pre-programmed Equation		t-test	
Equation	Y-intercept	Slope	n	r^2	Sb	Sa	b	a	b	a
A	231	6.3	60	.32	1.19	324	10.9	212	*	n.s.
B	205	11.6	94	.86	.46	915	10.9	212	n.s.	n.s.
C	199	16.1	114	.81	.73	99	15.1	341	n.s.	n.s.

A -- December to February when forage < 700 lb/a
B -- Jan to March when forage > 700 lb/a
C -- April to May when forage begins to flower, dry and mature

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