Department of Agronomy and Range Science
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## PASTURE PROBE EQUATIONS FOR COOL SEASON IRRIGATED PASTURE

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Accurately determining forage levels on irrigated pasture is a critical step to intensive grazing management. It is also fundamental to most pasture and grazing studies. Using a pasture probe to estimate herbage mass on irrigated pasture can save time and is not destructive facilitating repeated measurements.

George (1989) reviewed the operation of the pasture probe. The Pasture Probe (Version MK.3) is a single electrode capacitance meter, measuring most accurately to a radius of 5 cm and to a depth of either 30 cm (12 inches) or 60 cm (24 inches), depending upon the model. The pasture probe is responsive to differences in mass of herbage dry matter rather than to differences in moisture content (Vickery et al. 1980). However, plant and soil moisture must be present to operate the probe.

The user operates the probe as if it were a walking stick, taking successive readings with every step. A corrected meter reading (CMR) is transmitted to an electronic control box, carried either around the waist or over the shoulder. There is memory space for before and after grazing readings from 90 pastures. A digital display allows the user to read the forage level instantly. Data can be downloaded from the control box to a microcomputer for storage.

The control box contains seven pre-programmed equations (Table 1), from which to select depending on the season. These equations were developed in New Zealand by regressing herbage mass (kg DM/ha) on the CMR (Equation 8). Equations 1-4 are similar (Figure 1), while equations 5-7 have increasing slopes. Because the pre-programmed equations were developed on pastures in New Zealand dominated by perennial ryegrass and white clover, it was necessary to determine whether the same equations could be used on irrigated pastures in California. With pooled calibration data from locations throughout northern California, we determined appropriate equations for different seasons of the year.

## 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 $m^2$.

The probe was calibrated by taking 12 readings in a 1 sq. ft. (0.1 $m^2$) quadrat before and after clipping. The dry matter for the clipped forage (kg/ha) was regressed on the CMR (Equation 8) difference before and after clipping. The quadrats were clipped to a height of 1 to 2 inches to reduce the amount of litter in the clipped samples.

Many researchers recommend clipping forage as close to the ground as possible. On irrigated pasture this is sometimes a problem. Due to dead leaves and other debris at the base of the plants, more accurate readings are possible if clippings are taken evenly one to two inches above the ground depending upon the extent of the debris and the height of the forage. Manually removing any dead material and debris will help to improve the accuracy of the readings. Richardson (1984) noted that variation in dead herbage within a set of clippings contributes significantly to the standard error of the regression equation. Some researchers use the before reading for their regression, in which case it would be desirable to clip as close to the ground as possible. They argue that cutting to ground level is more consistent. In the laboratory, weight of dried herbage can be corrected for soil contamination and ash concentration, but this is not feasible for most users. Richardson (1984) and Butler (1986) each agree that the cutting and harvesting technique is not important providing it is consistent between samples.

Ten paired dry matter and CMR estimates were collected on each sample date. Ideally, dates are pooled with others within the same time frame to arrive at seasonal calibration equations. Richardson (1984) recommends 10 samples only for trials using plots of less than 1 ha, and only then when there are minor differences in the pastures. For larger areas 30-40 samples per month should be collected over one or more visits . The larger the number taken, the more chance that data will be unbiased. To be used with confidence, general calibrations to be used for on-farm management usually require several hundred samples (Richardson 1984).

Because the pasture probe responds to plant surface area rather than directly to mass, botanical composition is important to probe calibration as well. Species with different specific area (surface area to mass ratio) will give different calibration equations (Vickery et al. 1980, Richardson 1984, Butler 1984). If calibrations are with green rather than total herbage mass, differences in calibration equations are small between pastures of different composition (Butler 1984). On irrigated pastures, lodged or trampled forage can prevent firm contact between the probe tip and the ground, with the result that the surface area of material in close continuous contact with the ground will be underestimated. Post-grazing samples are likely to contain considerable stubble, stem, and dead material as well resulting in low surface area to dry weight ratios.

Richardson (1984) described the ideal pasture for herbage estimation by the probe as being green and leafy (low dead and stem content), of moderate legume content, having a moderate range of herbage mass (800-3000 kg DM/ha). If pastures have less than 800 kg/ha of dry matter, they are likely to be very short, open, and difficult to cut and difficult to pick up. Additionally the CMR reading on bare ground becomes a significant component when herbage mass is less than 800 kg/ha. If pastures exceed 3000 kg/ha, they are likely to exceed the probe's 12 in. (30 cm) sensing depth, and a buildup of dead or stem material and lodging is generally a problem.

## MATERIALS AND METHODS

Probe readings and dry weights were collected from irrigated pastures at five locations: 1) the Somerville Ranch in Glenn County, 2) the Madellena Ranch in Sierra County, 3) the Sierra Foothill Range Field Station (SFRS) in Yuba County, 4) the Hunt Ranch in Humbolt County, and 5) the DiBennedetti ranch in Sutter County. Dominant species for each of the pastures are listed in Table 2 and sampling dates in Table 3.

For this study, the double samples from the above five locations were pooled by season to estimate seasonal changes in the regression of herbage mass on CMR. Pooled dates were analyzed to determine whether their regressions were significantly different from the pre-programmed equations developed in New Zealand. Since most of the data was from the Somerville Ranch, we analyzed that separately as well as with the pooled data. Finally we pooled the 1988 and 1989 seasonal data from all ranches to arrive at pooled conversion equations for autumn, winter, late spring, and summer. Equations 1-3 were not used, as they are too similar to equation 4 to consider separately (Figure 1).

## RESULTS

When paired samples from five ranches were pooled and then grouped by season, all but one of the resulting slopes (b) and all of the Y-intercepts (a) were not significantly different from the pre-programmed equation with the closest slope (Table 4). The slope of the summer 1988 calibration equation was significantly greater than the slope for preprogrammed equation 6 and significantly less than the slope of pre-programmed equation 7.

Table 5 shows the results of the Somerville Ranch data alone. The slopes and Y-intercepts of the calculated calibration equations for each season were not significantly different from the pre-programmed equation with the closest slope (Table 5). When 1988 and 1989 seasons for all locations were pooled the spring and summer calibration equations were not significantly different from pre-programmed equation 6, and the autumn and winter calibration equations were not significantly different from equation 4.

## DISCUSSION

Following New Zealand recommendations, we should use equations 1-4 during the fall and winter, switching to equation 5 in late spring and to equation 6 during the summer. Equation 7 is recommended for warm season grasses. Equations 1-4 are very similar (Figure 1). Tables 4 and 5 show that during the hot spring and summer of 1988, equations 6 and 7 should have been used but during the cooler spring and summer of 1989 equation 5 should have been selected. These differences are probably due to differences in plant growth response to weather and grazing. In New Zealand spring and summer temperatures rarely exceed 85 F (29 C). Mild temperatures and close grazing tends to suppress flowering, maintaining a high proportion of leaf in the pastures. In California high temperatures and lax grazing cause flowering to occur earlier, and pastures growing under high temperatures often have a higher proportion of stem. Waghorn and Barry (1987) reported that as grass matures the leaf component becomes a smaller fraction of the whole plant and dead material accumulates during the spring and summer. Increased stem and dead material tends to decrease the leaf surface area sensed by the probe, increasing the slope of the calibration equations. During the winter of 1989 our calibration equations indicated that Equation 5 should have been used rather than the Equation 4. Periodic drought and irrigation water shortages during the winter may have resulted in greater than normal leaf senescence which would have increased the slopes of the calibration equation. Consequently, probe users on California irrigated pastures may find that they need to switch equations in response to changing weather and growing conditions.

## SUMMARY AND CONCLUSIONS

During autumn and winter equation 4 should be used unless dry conditions increase the amount of dead vegetation requiring use of Equation 5. The switch from equation 4 to Equation 5 should normally occur about the time pasture begins to flower, usually in April. Equation 5 should be used until the onset of hot weather, often in June. Equation 6 should be used during the summer. Under extremely hot conditions or when warm season grasses such as dallisgrass are abundant, Equation 7 may be required.

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. County and dominant species for five irrigated pasture data sets used to develop seasonal calibration equations.

| County: | Dominant Species: | Ranch: |
| --- | --- | --- |
| Glenn | Orchardgrass-Strawberry Clover | Somerville |
| Sierra | Timothy-Sedge-Rush | Madellena |
| Yuba | Orchardgrass-Ladino Clover | SFRS |
| Humbolt | Tall Fescue-White Clover | Hunt |
| Sutter | Tall Fescue-Strawberry Clover | DiBennedetti |

Table 3. Sample dates and number of samples collected for each of the five locations locations.

| Date | No | Date | No | Date | No |
|---|---|---|---|---|---|
| | | Somerville Ranch | | | |
| 6/3/88 | 10 | 6/8/88 | 10 | 6/16/88 | 10 |
| 6/28/88 | 10 | 7/5/88 | 10 | 7/11/88 | 5 |
| 7/19/88 | 5 | 7/27/88 | 4 | 8/3/88 | 10 |
| 8/10/88 | 10 | 8/24/88 | 10 | 9/7/88 | 10 |
| 9/22/88 | 10 | 10/6/88 | 10 | 10/13/88 | 10 |
| 10/28/88 | 10 | 11/10/88 | 10 | 2/25/89 | 10 |
| 3/27/89 | 9 | 4/12/89 | 8 | 5/3/89 | 10 |
| 5/19/89 | 5 | 6/6/89 | 5 | 6/19/89 | 5 |
| 7/3/89 | 5 | 7/18/89 | 5 | 7/31/89 | 5 |
| 8/15/89 | 5 | 8/29/89 | 5 | 9/14/89 | 8 |
| 9/28/89 | 6 | | | | |
| | | DiBennedetti Ranch | | | |
| 6/16/89 | 5 | 7/3/89 | 5 | 7/10/89 | 4 |
| 7/17/89 | 4 | 7/24/89 | 3 | 7/31/89 | 3 |
| 8/21/89 | 3 | 9/5/89 | 3 | 9/11/89 | 3 |
| 9/24/89 | 3 | | | | |
| | | SFRFS | | | |
| 5/27/88 | 10 | 6/24-28/88 | 18 | 7/26/88 | 6 |
| 8/23/88 | 8 | | | | |
| | | HUNT | | | |
| 8/12-18/8 | 60 | | | | |
| | | MADELLENA | | | |
| 5/11/88 | 5 | 6/2/88 | 10 | 6/15/88 | 7 |
| 7/1/88 | 5 | 7/12/88 | 12 | 9/7/88 | 10 |

Table 4. Comparison of 1988 and 1989 seasonal linear conversion equations (kg/ha) for irrigated pasture from five northern California ranches with preprogrammed conversion equations from New Zealand.

| | | | | | Irrigated pasture Equations | | Preprogrammed Equations | | t-test | | SEASON | DATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equation | n | r | Sb | Sa | b | a | b | a | b | a | 1988 | |
| 7 | 90 | .80 | 1.89 | 2365 | 23.7 | 80 | 25.8 | 232 | N.S. | N.S. | Late Spring (hot) | 5/11 - 6/30 |
| 6 | 164 | .94 | .64 | 3954 | 21.7 | 636 | 19 | 854 | * | N.S. | Summer (hot) | 7/1 - 9/15 |
| 4 | 50 | .62 | 1.39 | 651 | 7.5 | 943 | 10.9 | 212 | N.S. | N.S. | Autumn (pre-rain) | 9/22 - 11/10 |
| | | | | | | | | | | | 1989 | |
| 5 | 27 | .93 | 1.11 | 1496 | 14.2 | 322 | 15.1 | 341 | N.S. | N.S. | Winter (late) | 2/25 - 4/12 |
| 5 | 35 | .87 | 1.51 | 1649 | 15 | 387 | 15.1 | 341 | N.S. | N.S. | Late Spring (cool) | 5/3 - 6/19 |
| 4 | 50 | .52 | 2.41 | 707 | 10.1 | 971 | 10.9 | 212 | N.S. | N.S. | Summer (cool) | 7/3 - 9/5 |
| 4 | 20 | .37 | 5.07 | 539 | 8.6 | 692 | 10.9 | 212 | N.S. | N.S. | Autumn (post rain) | 9/14 - 9/28 |

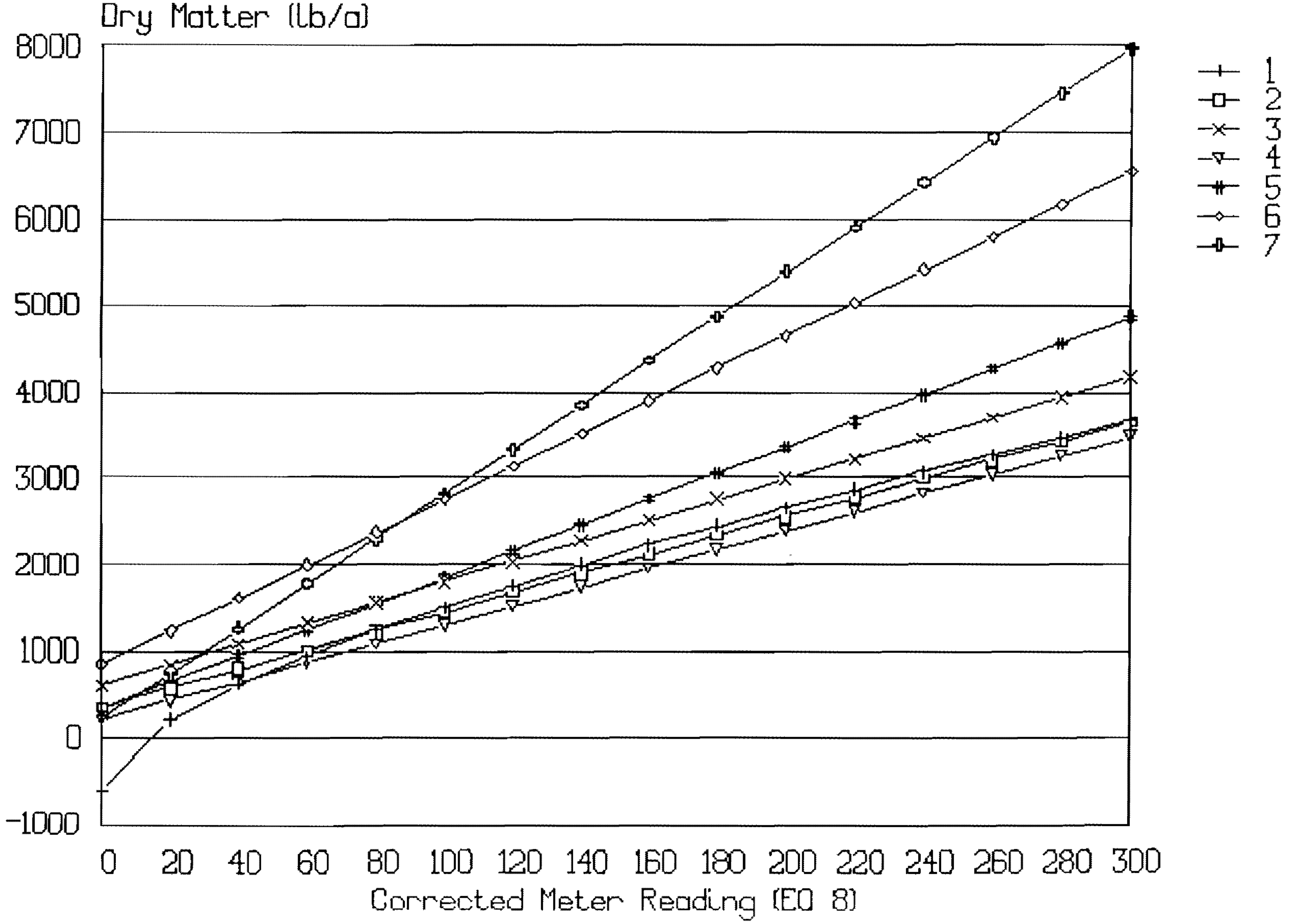
Table 5. Comparison of 1988 and 1989 seasonal linear conversion equations (kg/ha) for irrigated pasture from the Somerville Ranch with preprogrammed conversion equations from New Zealand.

| | | | | | Irrigated pasture Equations | | Preprogrammed Equations | | t-test | | SEASON | DATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equation | n | r | Sb | Sa | b | a | b | a | b | a | 1988 | |
| 6 | 40 | .72 | 3.24 | 2326 | 20.5 | 411 | 19 | 854 | N.S. | N.S. | Late Spring (hot) | 6/3 - 6/28 |
| 7 | 63 | .81 | 2.14 | 2519 | 22.9 | 666 | 25.8 | 232 | N.S. | N.S. | Summer (hot) | 7/5 - 9/7 |
| 4 | 50 | .62 | 1.39 | 651 | 7.5 | 943 | 10.9 | 212 | N.S. | N.S. | Autumn (pre-rain) | 9/22 - 11/29 |
| | | | | | | | | | | | 1989 | |
| 5 | 27 | .93 | 1.11 | 1496 | 14.2 | 322 | 15.1 | 341 | N.S. | N.S. | Winter (late) | 2/25 - 4/12 |
| 5 | 30 | .93 | 1.13 | 1974 | 15.6 | 200 | 15.1 | 341 | N.S. | N.S. | Late Spring (cool) | 5/3 - 6/19 |
| 5 | 25 | .83 | 1.82 | 956 | 13 | 416 | 15.1 | 341 | N.S. | N.S. | Summer (cool) | 7/3 - 8/29 |
| 4 | 14 | .87 | 2.05 | 851 | 12.5 | 110 | 10.9 | 212 | N.S. | N.S. | Autumn (post rain) | 9/14 - 9/28 |

Table 6. Comparison of pooled seasonal linear conversion equations (kg/ha) for irrigated pasture from five northern California ranches with preprogrammed conversion equations from New Zealand.

| | | | | | Irrigated pasture Equations | | Preprogrammed Equations | | t-test | | SEASON | DATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equation | n | r | Sb | Sa | b | a | b | a | b | a | | |
| 6 | 125 | .77 | 1.41 | 1972 | 18.8 | 380 | 19 | 854 | N.S. | N.S. | Late Spring | May-Jun 1988+1989 |
| 6 | 214 | .94 | .57 | 3595 | 22 | 503 | 19 | 854 | N.S. | N.S. | Summer | Jul-midSep " |
| 4 | 97 | .75 | 1.03 | 997 | 11.3 | 603 | 10.9 | 212 | N.S. | N.S. | Autumn & Winter | midSep-Apr " |

Figure 1. Probe Conversion Equations



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