Comparison of methods for estimating herbage mass in small plots

G. M. Lodge and S. Harden

Department of Primary Industries, Tamworth Agricultural Institute,
4 Marsden Park Road, Calala NSW 2340; greg.lodge@industry.nsw.gov.au

Abstract: *Herbage mass (HM, kg dry matter (DM)/ha) of temperate perennial grasses was estimated using four methods: 1. whole plot estimates, 2. subplot (three strata) estimates, 3. BOTANAL estimates (10 per plot), and 4. cutting two quadrats in each of three strata per plot. Methods 1–3 were compared with Method 4 (6 cut quadrats) to identify the method that gave an accurate estimate of HM which could be achieved in a reasonable amount of time. Mean predicted sown species HM ranged from 0–694 kg DM/ha for Method 4 and from 0–1176 kg DM/ha for Method 3. Predicted HM was overestimated by Methods 1 and 2 at values <200 kg DM/ha and while at higher values it was underestimated by both these methods, the underestimates were lower for Method 2. Method 3 consistently overestimated predicted HM and had the highest value of sigma (the square-root of the estimated variance of the random error). The total time taken for pre- and post-processing and field sampling was highest for the destructive Method 4 (~26 hours) compared with 4–5 hours for Methods 1 and 2 and 7 hours for Method 3. Based on these data the best method of sampling for HM in small plots was to use an estimation technique in three strata per plot since its predicted values better covered the range, its estimated variance of random error was intermediate and it required less sampling time than Methods 3 and 4.*

Key words: whole plots, stratification, BOTANAL, cut quadrats, sampling time, sigma, linear regression, correlation coefficient

Introduction

Techniques for estimating pasture herbage mass (HM, Hodgson 1979) and species composition have been comprehensively reviewed and documented by Brown (1954), Tothill (1978) and Mannetje (1978). Generally, these authors reported that the cutting of herbage material in quadrats and its sorting into species or functional group were suitable sampling techniques for comparative studies of species performance. However, quadrat cutting is destructive and may require high time and labour inputs (Mannetje and Haydock 1963). Hence non-destructive sampling techniques are often preferred, since regular close cutting of plant material may also have an effect on persistence (Mannetje 1978). Such techniques are also often less labour intensive, when compared with quadrat cutting as less material is collected and processed (e.g. bagging, sorting and weighing).

Both HM and species composition can vary temporally, as plant growth patterns vary with seasons, and spatially, as swards thin and weed species ingress, so assessment techniques need to be sufficiently robust to reflect these changes. When sampling the HM and species composition of sown species in plots there are three main practical ways to reduce random sampling error; increasing the size of the sample; reducing the size of the sampling unit, or increasing the number of units using stratification (Jolly 1954). For small plots, increasing the size or number of samples may be impractical, but the use of stratification may be appropriate.

Visual estimation is a widely used non-destructive technique. It is usually applied in a double sampling technique in which HM/species composition is estimated in a large number of samples and then determined accurately in a few standard samples (Mannetje 1978). This method is the basis of the calibrated quadrat technique where actual and visual estimates for the same series of quadrats are used in regression to calculate estimates of HM/species composition. For HM, this method was described by Haydock and Shaw (1975) and has been commonly used in agronomic and grazing studies. For estimating species composition (as a percentage of total HM), BOTANAL procedures (Tothill *et al.* 1992) that combined a dry-weight rank method (Mannetje and Haydock 1963) with tied ranks (Tothill *et al.* 1992) and modifications to multipliers for cumulative ranks (Jones and Hargreaves 1979) have also been widely used in grazing studies. Basically, the dry-weight rank method proposed three multipliers with proportional values of 0.702, 0.212 and 0.087 for species ranked 1, 2 and 3, respectively (Mannetje and Haydock 1963). Tothill *et al.* (1992) also described situations where the use of direct estimates of percent species composition was preferable to using the dry-weight rank method.

This paper reports a study that tested the hypothesis that estimates of pasture HM from different assessment methods in small plots would have different mean values, estimates of error and sampling times. This information was then used to identify the most appropriate method that provided accurate HM estimation with efficient use of time.

Methods

The site and experimental plots used in this study were previously described in detail by Boschma *et al.* (2009). Briefly, the experimental site was located 12 km west of Manilla, New South Wales (30.74°S 150.61°E; elevation 400 m). Forty eight plots (6.0 by 1.35 m) were sown in May 2003 in a spatially adjusted randomised complete block design, with three replicates being used in the current study. Sixteen cultivars/lines of the temperate perennial grasses phalaris (*Phalaris aquatica*) and tall fescue (*Festuca arundinacea* syn., *Lolium arundinaceum*) were sown and regularly defoliated or grazed until October 2005. After that time plots remained undefoliated until they were mown in late May 2006. The current study was undertaken on four consecutive days (15–18 August 2006) when all sown grasses were vegetative.

There were four methods of assessment: Method 1, visual HM estimates of the whole plot; Method 2, visual HM estimates in three subplots (strata) of equal area per plot; Method 3, visual estimates using BOTANAL procedures and, Method 4, cut quadrats. For the first three methods, two experienced assessors were used. Whole plot (Method 1) and subplot estimates (Method 2) were undertaken on day 1 of the study, BOTANAL estimates (Method 3) on day 2 and the quadrats were cut (Method 4) on days 3 and 4. For the whole plot method, each assessor estimated total HM (scores 0–5, (0 = nil, 5 = high, in graduations of 0.1) and overall percentage of sown species. For the subplot method, total HM score and percent sown species was estimated for each stratum. These estimation methods were analogous to the type 3 procedure outlined by Haydock and Shaw (1975) for calibrating a standard yield scale. For the BOTANAL method, HM scores were estimated in 10 quadrats (0.4 by 0.4 m) along the centre line of each plot and dry-weight rankings assessed for five species categories (sown species, annual summer grass, annual winter grass, broadleaf weed and other perennial grass) using the methods described above. For the cut quadrat method, sown species and other herbage were harvested separately in two randomly located quadrats (0.4 by 0.4 m) in each of the three strata. Plant material was cut to a height of ~10 mm above ground level and dried at 80°C for 48 hours before weighing.

For methods 1–3, twenty calibration quadrats (0.4 by 0.4 m) were independently scored by each assessor. Calibration quadrats covered the range of HM and species composition. Species composition estimates and dry-weight rankings were done at separate times to maintain their independence. Calibration quadrats were then harvested, sorted into sown and other species and each portion dried as described above. Scores and percentage estimates were regressed (linear or quadratic R^2>0.80) against actual HM (kg dry matter (DM)/ha) and percentage of sown species to determine the HM of sown species. For Method 3, the 10 estimates of total HM and dry-weight ranks in each plot were used to obtain mean HM for the sown and other species.

Herbage mass estimates determined by Methods 1–3 were compared with Method 4 (cut quadrats) using linear regression analyses. Sigma (the square-root of the estimated variance of the random error) measures the scatter about the regression line and the correlation coefficient (r, the square-root of the multiple R^2 value) indicates the strength of the linear relationship. Visual inspection of graphical plots (not presented) indicated whether or not there was over or underestimation. For each method, the times taken for different operations such as pre-field preparation (e.g. bag numbering), field sampling (e.g. scoring and/or cutting quadrats) and post-field handling (e.g. sorting, processing, weighing, data entry and calculation) were also noted and expressed as the number of hours and minutes/person and the total time taken.

Results and discussion

Mean total and sown species HM for Method 4 (cut quadrats) was 872 and 259 kg DM/ha, respectively and predicted sown species HM values ranged from 0–694 kg DM/ha. Method 1 had the lowest sigma value (Table 1) indicating the least variation when compared with the cut quadrats, but predicted values were in a much narrower range (113–559 kg DM/ha, with only one value being >400 kg DM/ha) than those for the other methods. Both Methods 1 and 2 overestimated predicted HM at values <200 kg DM/ha. At >200 kg DM/ha both methods underestimated predicted HM, although the underestimates were much lower for Method 2. Method 3 consistently overestimated sown species predicted HM (range 0–1176 kg DM/ha) and had the highest value of sigma (Table 1). Overestimation for Method 3 (BOTANAL) was probably associated with a lack of proportional values between 0.333 and 0.702 and the occurrence of species dominance, with about one-third of all proportional values for the sown species being ≥0.702. The lack of mid-range proportional values may have been overcome by using direct estimates of percent species composition (Tothill *et al.* 1992). With a plot length of 6 m some difficulty also occurred for Method 3 in selecting the required minimum of 10 independent quadrats and so it may not be suitable for some small plots.

In this study, Method 4 was the most labour and time intensive, taking an estimated total time of 25 h and 45 min (12 h/person) for pre- and post-processing and field sampling (Table 2). In comparison, Methods 1 and 2 required a total sampling time of 4–5 h (2 h 45 min and 3 h/person, respectively) and Method 3 was intermediate, requiring 7 h total time (4 h 45 min/person, Table 2).

Table 1. Values of sigma (square-root of the estimated variance of the random error) and *r* (correlation coefficient) for Method 4 (cut quadrats) compared with Methods 1-3.

Method	Sigma	*r*
Method 1 – whole plot	61.3	0.74
Method 2 – subplot	107.3	0.67
Method 3 – BOTANAL	156.2	0.78

Table 2. Comparative time [hours (h) and minutes (min)] and number of persons required for each of the four sampling methods for field sampling and pre- and post-field processing, together with the total time taken and total time per person.

	Method 1 (whole plot)	Method 2 (subplot)	Method 3 (BOTANAL)	Method 4 (cut quadrats)
		Pre-field		
No. of persons	1	1	1	1
Total time	15 min.	15 min.	15 min.	3 h
		Field		
No. of persons	2	2	2	3
Total time	3 h	3 h 30 min.	5 h 30 min.	14 h 15 min.
		Post-field		
No. of persons	1	1	1	2
Total time	1 h	1 h	1h 15 min.	8 h 30 min.
		Total time taken		
Total time	4 h 15 min.	4 h 45 min.	7 h	25 h 45 min.
Total time/person	2 h 45 min.	3 h	4 h 15 min.	12 h

Selection of the most appropriate sampling method involves the estimates satisfactorily covering the known range of predicted values, having an acceptable variance of random error and comparatively short sampling times. In our study, Method 1 had the lowest sigma value and sampling time/person, but the predicted data occurred over a much narrower range than for those of the cut quadrats (113 to generally <400 kg DM/ha *v.* 0–694 kg DM/ha). Method 3 had the highest sigma value, markedly overestimated the predicted value (0–1176 kg DM/ha) and had sampling times per person that were 140–155% higher than Methods 1 and 2. Hence, in the current study Method 2 (HM estimates in three strata per plot) best met the above criteria.

Acknowledgments

These data were collected as part of the National Plant Evaluation Program within the CRC for Plant-based Management of Dryland Salinity, jointly funded by the Grains Research and Development Corporation and the Department of Primary Industries (formerly Industry & Investment NSW). We gratefully acknowledge the assistance of Brian Roworth, Suzanne Boschma, Mark Brennan and Ivan Stace in collecting the data and processing the herbage samples.

References

Boschma SP, Lodge GM, Harden S (2009) Establishment and persistence of perennial grass and herb cultivars and lines in a recharge area, North-West Slopes, New South Wales. *Crop & Pasture Science* **60**, 753–767.

Brown D (1954) 'Methods of surveying and measuring vegetation'. Bulletin No. 42, Commonwealth Bureau of Pastures and Field Crops. (Commonwealth Agricultural Bureaux: Farnham Royal)

Haydock KP, Shaw NH (1975) The comparative yield method for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15**, 663–670.

Hodgson J (1979) Nomenclature and definitions in grazing studies. *Forage Science* **8**, 1–8.

Jolly GM (1954) Theory of Sampling. Chapter 2 In 'Methods of surveying and measuring vegetation'. Bulletin No. 42, Commonwealth Bureau of Pastures and Field Crops. pp. 8–18. (Commonwealth Agricultural Bureaux: Farnham Royal)

Jones RM, Hargreaves JGN (1979) Improvements to the dry-weight-rank method for measuring botanical composition. *Grass and Forage Science* **34**, 181–189.

Mannetje L t' (1978) Measuring Quantity of Grassland Vegetation. Chapter 4 In 'Measurement of Grassland Vegetation and Animal Production'. Bulletin No. 52, Commonwealth Bureau of Pastures and Field Crops. pp. 63–95. (Commonwealth Agricultural Bureaux: Farnham Royal)

Mannetje L t', Haydock, KP (1963) The dry-weight-rank method for the botanical analysis of pasture. *Journal of the British Grassland Society* **18**, 268–275.

Tothill JC (1978) Measuring Botanical Composition of Grasslands. Chapter 3 In 'Measurement of Grassland Vegetation and Animal Production'. Bulletin No. 52, Commonwealth Bureau of Pastures and Field Crops. pp. 22–62. (Commonwealth Agricultural Bureaux: Farnham Royal)

Tothill JC, Hargreaves JNG, Jones, RM, McDonald CK (1992) BOTANAL – a comprehensive sampling and computing procedure for estimating pasture yield and composition. I. Field sampling. CSIRO Australia, Division of Tropical Crops and Pastures. Tropical Agronomy Technical Memorandum No. 78.