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Methods for estimating forage mass in pastures in a tropical climate

Métodos para estimar a massa de forragem em pastagens em clima tropical

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ABSTRACT

There are various methods to estimate the mass production of forage in pastures, but many are not accurate or unsuitable when used with certain species of fodder plants. Therefore, knowing the uses and limitations of the measurement techniques is important. This review aims to report the primary methods of estimating forage mass in pastures in tropical climates. Tropical grasses have the distinctive characteristic of temperate stem elongation, which influences growth and forage quality and may interfere in some techniques used to estimate the forage production. Measurement techniques of forage mass production that consider this variable are important for research and for the farmers in these regions. Among the various direct and indirect methods, the mass of forage grass species is the factor that determines the most appropriate measurement method. Currently, there is no single method that can be used in all situations; thus, knowing the type of biomass that will be evaluated and the best technique for that purpose is critical.

Keywords: Forage mass, methods of estimation, pasture production

RESUMO

Existem diferentes métodos para estimar a produção de massa de forragem em pastagens, porém muitos não são precisos ou não são adequados quando utilizados em determinadas espécies de plantas forrageiras, sendo importante conhecer as técnicas de medições e suas limitações. Dessa forma, essa revisão foi elaborada objetivando-se relatar os principais métodos de estimar a massa forrageira em pastagens de clima tropical. As gramíneas de clima tropical têm como característica diferencial das de clima temperado, o alongamento de colmo, que influencia no crescimento e na qualidade da forragem, podendo interferir em algumas técnicas usadas para estimar a produção de forragem. Técnicas de medição da produção de massa de forragem que levem em consideração esta variável são importantes para o desenvolvimento de pesquisas e para o produtor rural, alocados nesta região. Entre os diferentes métodos diretos e indiretos utilizados para estimar a massa de forragem, será a espécie forrageira o fator determinante na escolha do método para mensuração. Não existe atualmente um método que possa ser utilizado em todas as situações, dessa forma é importante conhecer a espécie que será avaliada e a técnica utilizada para esse fim.

Palavras chave: Massa de forragem, métodos de estimativa, produção de pasto

INTRODUCTION

Pastures are the main source of food for ruminants and comprise the bulk of the diet because they are less expensive, have a large productive capacity and are easy to grow (Scaglia et al., 2013). Determination of the actual production capacity of pastures and the pressure on land used for livestock production have become major challenges for the development of integrated planning and decision-making in tropical grazing systems (Crestani et al., 2013).

In the tropics, there are differences in the chemical composition of forage, especially when compared to temperate forage. These differences are related to the structure of the tropical pasture itself, which usually has a high percentage of dead tissue due to senescence and stem elongation. However, insufficient consumption of nutrients is one of the main factors limiting animal production and can only be controlled if the nutritional value of forage is not a limiting factor (Gonzaga Neto et al., 2011; Bezerra et al., 2013; Jochner et al., 2013, Santana Junior et al., 2013).

Variability in the morphological characteristics and production of herbage mass of different forage species beyond edaphoclimatic influences and the limits of human and material resources make it difficult to choose the most appropriate method for estimating forage mass. Monitoring the production of forage mass is one of the most effective ways to generate information for management processes and decision-making regarding grazing management (Hietz et al., 2011; Powers and Salute, 2011). Costa et al. (2009) report that the study of current forage production is of primary importance to calculate capacity in pasture management.

Furthermore, research has developed regarding several genetic features. The variability of selection characteristics is important for breeding programs. Characteristics such as the total dry matter, total leaf and leaf percentage require a greater number of samples to be efficiently selected within a species (Braz et al., 2013).

The estimation of forage mass is frequently associated with high experimental error and varies according to the method and the observer. Therefore, the present review discusses the methods used to estimate the mass of forage grazing in tropical climates.

METHODS TO ESTIMATE PASTURE PRODUCTION

Determination of forage availability in pastures is important both for scientific research and for planning the rational exploitation of grasslands in commercial areas. Forage mass can be measured directly by cutting all fodder and determining its mass weight or by cutting samples of known size. It can also be determined through indirect methods using more easily measurable characteristics of herbage mass (Doughertya *et al*., 2013).

To choose a particular method to estimate herbage mass production in a pasture, issues such as the growth of the forage species, equipment costs and labor, and the number of samples required for an accurate measurement must be considered.

As shown in Table 1, one method to estimate herbage mass meets all requirements that should be considered in the choice of the method. The feasibility of a method for estimating forage production in a pasture depends on the assessment of the following: calibration of the method; the cost, including the acquisition of equipment, manpower, time required, and training needs; the difficulty of performing the method; and the accuracy of the method, which is directly related to the number of samples needed.

DIRECT METHOD

Currently, the most commonly used method to determine forage production is the cutting and weighing of forage plants, which is considered by many to be accurate, although it is costly and requires a long time and a large number of samples to obtain reliable estimates in both temperate and tropical regions (Jank *et al*., 2011).

Table 1 - Viability of the methods used to determine production in tropical pastures

Method	Calibration	Cost	Onerous	Accuracy
Direct	No	High	Yes	High
Indirect - Visual estimate	Yes	Low	No	Low
Indirect - Income visual comparison	Yes	Low	No	Medium
Indirect - Height, compressed	Yes	Medium	No	Low
Indirect - Height, uncompressed	Yes	Low	No	Medium
Indirect - Flow biomass	Yes	Medium	Yes	High

When the direct method is used, forage is cut at ground level over a known area and weighed. The amount of biomass available per unit of area is estimated using harvested samples (Carvalho *et al*., 2008). However, if the area to be measured is large, the number of samples required is high, resulting in increased use of skilled labor and higher costs. Lowe *et al*. (2010) used this method to obtain productivity in populations of kikuyu grass (*Pennisetum clandestinum*) in Australia to determine the relationship between phenotypic and genotypic variation.

The best known direct technique for sampling pasture uses a square or rectangular wood, metal or plastic (PVC Pipes - Polyvinyl chloride) frame of known size. The most common shape is square; therefore, this technique is also known as the "Square Method." The square size depends on the uniformity of the area to be sampled and the growth habits of the grass species evaluated. The number of samples required to obtain a reliable estimate depends on how much fodder production costs and the size of the area to be sampled. The cutting height will depend on the grass species and the type and grazing habits of the animals. Normally, the forage is cut close to the ground, but this may not be the most suitable method depending on the selectivity of the animals during grazing, which is an important aspect to be considered in the management of pastures (Salman *et al*., 2006).

Samples obtained by cutting forage close to the ground (full availability), with the exception of organic matter, are not representative of the diet ingested by animals because these not represent how the animal selects its diet. For this reason, the direct method is considered destructive and prevents further studies in the harvested areas due to the removal of forage (Mannetje, 2000). Guzman *et al*. (1992) proposed that the optimal size of the sampling unit for tropical grasses is between 1.0 to 1.75 m^2 in flat relief and from 1.25 to 1.75 m^2 in rugged terrain.

The method of simulated grazing advocated by Aroeira *et al*. (1999) was used by Cóser *et al*. (2003) to estimate the production of elephant grass (*Pennisetum purpureum*). They selected three clumps of elephant grass, representing high (3), medium (2) and low (1) forage production the day before the entry of animals into each of the six paddocks assessed. In each of these clumps, the leaves and stalks were manually removed to simulate grazing. The samples were then oven-dried, and the dry matter determined. After the removal of the animals (or manual removal) the number of plants in the each paddock area was counted. The dry mass of each sample in each paddock was multiplied by the number of plants per paddock, resulting in an estimation of the dry matter yield ($kg.ha^{-1}$).

The direct method also has the limitation that it does not account for the effects of urine and faeces on the pasture or the effects of animal trampling or selective grazing, which may lead to an overestimation of production (Yang *et al*., 2013). In this context, Mannetje (2000) reported that standardization of the cutting height to ground level is necessary and minimizes error because it establishes a consistent reference independent of the operator, crops and/or treatment.

VISUAL ESTIMATES

Methods that employ visual estimates are practical and commonly used in the scientific field. The two best known methods are visual estimation, in which the observer assigns the production of herbage mass for each pasture area visually, and visual comparative yield, in which the observer assigns scores instead of estimating production for the field.

The visual estimation method can be a good choice to determine the production of forage mass because it is practical, fast, non-destructive and inexpensive, which allows the researcher to assess large numbers of samples (Soriano *et al*., 2013). Double sampling can be performed using a combination of visual estimation techniques and direct sampling in which some samples are cut to verify the visual estimates.

According to Costa *et al*. (2009), to use the estimation method the observer must undergo prior training in the field to make visual estimates of weight, followed by cutting and weighing the sample to assess the degree of accuracy. Thus, despite its advantages, this technique has low accuracy and can provide results that do not match reality on the ground.

Zanine *et al*. (2006) considered that the estimation method requires visual assessment of the mass of material present in a given area and comparison with a previous visual reference, which allows the inference of the mass of material in the area. The observer is presented with a series of conditions with known pasture forage masses (determined by cutting and weighing), allowing the observer to develop a reference scale for the forage mass production in the area.

Toperform the visual performance comparison, one should first make a selection of at least five local "standards" representing the pasture as a whole (Salman *et al*., 2006). The samples should then be sorted by grades ranging from 1 to 5 with respect to forage production. After scoring, the local fodder present within the square is cut and the production is estimated after oven drying for the direct evaluation. Then, at least 50 points are chosen and placed in the square for visual evaluation; scores should be assigned to each of the squares using the same criteria as the local "standards".

By calibrating the visual comparative yield, the obtained equation provides the same mass production of forage as the visual estimates according to species, location and situation. The x in the equation represents the scored pasture provided by the observer after calibration and provides the equation using the estimated herbage mass for the given conditions (Table 2).

According to Cóser *et al*. (2003), the visual comparative yield method for elephant grass grazing can estimate the amount of potentially consumable forage in the pasture. These authors also concluded that the pasture estimates obtained by the method of comparative visual performance are more reliable than those obtained by the method of simulated grazing. Orr (2010) evaluated pasture yield and composition of *Panicum maximum* cv. Trichoglume, *Pennisetum ciliaris* cv. Biloela, *Chloris gayana* cv. Callide and *Stylosanthes scabra* cv. Seca, using the methodology BOTANAL proposed by Tothill *et al*. (1992), a visual comparative method.

Paruelo *et al*. (2000) used a photographic method to estimate biomass in semiarid grasslands. The method is based on a relationship between the percentage of "green pixels" in a digital image and green biomass. According to these authors the method needs to be calibrated, and it allows for a dramatic increase in the number of samples compared with the clipping method.

COMPRESSED HEIGHT OF THE CANOPY

The compressed height of the canopy is one of the indirect methods for estimating forage mass. Using the plate meter, rising plate or any equipment that compresses the canopy pasture, the height of the pasture can be determined using a graduated vertical structure.

The disc meter is an indirect method using a discround or square and made of metal of known weight which slides along a central axis (Cauduro *et al*., 2006). According to Fehmi and Stevens (2009), the dish or plate meter are popular because they are easy to use, measurements can be quickly taken and have shown success with various vegetation types. The disc meter evaluates the forage mass based on its height and density as functions of the pressure exerted by the disc.

The meter disc compresses the material quickly and easily; however, readings must be performed in many different sites within the pasture to provide reliable data. It is an effective technique for

Table 2 - Forage species and their calibration equations of the visual comparative yield method for the determination of herbage mass

Species	Unit	Equation	R^2	Author
Brachiaria decumbens	MFF ($t.ha^{-1}$)	y = 1.85 + 0.82x	0.83	Costa *et al*. (2009)
Native pasture	MDF ($t.ha^{-1}$)	y = 2.42 + 1.12x	0.98	Cóser & Nascimento Jr. (1991)
Pennisetum purpureum	MDF ($t.ha^{-1}$)	y = -2741.8 + 26113.8 x	0.41	Cóser *et al*. (1999)
Pennisetum purpureum	MDF ($kg.ha^{-1}$)	y = 256.85 + 763.50 x	0.96	Cóser *et al*. (2003)

MFF – Mass production of fresh forage; MDF – Mass production of dried forage.

measuring the herbage mass of medium sized lawns, hardwoods and soft stems (Carvalho *et al*., 2008). It is not suitable for grasses and tender erect stems, including some tropical grasses, as it may provide inaccurate results.

According to Cauduro *et al*. (2006), the height of the material above the ground is measured at the central axis with the graduated scale, and the readings are automatically stored on a portable computer. Thus, the method can produce erroneous measurements in the case of tropical forage, mostly of caespitose growth, and the development of different calibration equations are needed for different seasons, forage species and disc weights.

Interference may occur depending on the type of pasture growth, including caespitose, and the presence of hard stems, and result in low correlation with the herbage mass (leaves) in the field (Edvan *et al*., 2014). It is unfortunate that the technique has not been calibrated for tropical grasslands, which require calibration according to the season. In Table 3, the variation in the values of the calibration equations throughout the seasons can be seen, and the estimated herbage mass values in a pasture whose Media Reading (MR) was 10 cm are presented.

According to Silva and Cunha (2003), the evaluation of fodder mass production using the rising plate meter (time compressed) uses circles of 0.25 m^2 placed in locations that correspond to low, medium, and high experimental points. The experimental unit is assessed before cutting the forage contained within each circle. Thus, the compressed height is determined by the average of the points obtained and, subsequently, the material is cut at soil level to estimate the fodder mass and calibrate the method.

Bransby *et al*. (1977) showed that this provided acceptable estimates of herbage mass using a dish meter (plate meter) in grazing tall fescue (*Festuca arundinacea*). However, the results showed that each species, due to allometric differences, requires a different relationship to convert the height of the plate to the forage mass (Table 4). It is noteworthy that in addition to grass species, soil conditions, climate, time of year and management can change the results of the calibration equation. Therefore, it is necessary to determine the equation for each variable.

Dobashi *et al*. (2001) estimated the mass of Tanzania forage grass using the aluminum plate and the rising plate method. They found that the aluminum plate method was more accurate than the rising

Table 3 - Calibration equations for the seasonal plate meter

Season	Equation	Estimated herbage mass (kg DM ha^{-1} with MR = 10 cm)
Winter / Early spring	125MR + 640	1.890
Late spring / Early summer	130MR + 990	2.290
Midsummer	165MR + 1480	3.130
Early fall	159MR + 1180	2.770
Late fall	157MR + 970	2.540

Source: Adapted of Hodgson *et al*. (1990); MR - Media Reading, DR – Dry matter

Table 4 - Forage species and their calibration equations for the compressed height method to determine the herbage mass

Species	Unit	Equation	R^2	Author
Lolium multiflorum	MFF (t.ha^{-1})	y = 2.32 + 0.009x	0.20	Cauduru *et al*. (2006)
Cynodon spp.	MFF (kg.ha^{-1})	y = 1234.2 + 124.9x	0.70	Paciullo *et al*. (2004)
Cynodon sp. Florakirk	MDF (kg.ha^{-1})	y = 3570 + 120x	0.54	Silva & Cunha (2003)
Cynodon sp. Tifton 85	MDF (kg.ha^{-1})	y = 3055 + 165x	0.73	Silva & Cunha (2003)
Cynodon sp. Coastcross	MDF (kg.ha^{-1})	y = 2480 + 125x	0.49	Silva & Cunha (2003)
Native pasture	MFF (kg.m^{-2})	y = 31.11 + 3.27 x	0.80	Pellegrini *et al*. (2010)
Cynodon nlemfuensis	MDF (kg.ha^{-1})	y = 1226.64+170.97 x	0.64	Arruda *et al*. (2011)
Brachiaria brizantha	MDF (kg.ha^{-1})	y = 1048.7 + 70.3x	0.91	Braga *et al*. (2009)

MFF - Mass production of fresh forage; MDF - Mass production of dried forage.

plate method, showing coefficients of determination of 0.82 and 0.71, respectively. Silva and Cunha (2003) evaluated the mass production of forage in grazing *Cynodon* spp. using the rising plate method and found that the calibration should be performed with each genotype. In addition, the change in the structure of the canopy over the years requires the method to be calibrated frequently.

Joubert and Myburgh (2014) compared three forage dry matter production methods used in South Africa and reported that phytomass values obtained using the disk pasture meter were significantly higher than that determined using both the PHYTOTAB/Plant Number Scale and the clipping and weighing techniques. PHYTOTAB computer program was developed by Westfall (1992) using data collected by the method Plant Number Scale (Westfall and Panagos, 1988). According to these authors this method consists of determine the canopy cover of all plant species recorded using a quadrat or area-based survey technique.

MEASURING THE UNCOMPRESSED HEIGHT

The direct relationship between sward height and forage production did not provide reliable estimates of availability. However, the measurement of the height of the plant with a ruler has been widely practiced to define when animals enter and leave a given paddock by consulting a table that indicates the best time for the entrance and exit of the animals (Salman *et al*., 2006).

According to Silva and Cunha (2003), to evaluate forage mass production, rulers using circles of 0.25 m^2 were placed in the experimental units that corresponded to the highest and lowest points. Before cutting the material contained within each circle, the height of the canopy was determined through the slit using the mean of the highest and the lowest points with a transparency sheet, commonly used for projection of images, placed on the surface of the forage leaves and cutting at ground level while reading the time.

Costa *et al*. (2009) reported that it is possible to estimate the forage production of *Brachiaria decumbens* using height measurements with double sampling. Silva and Cunha (2003) evaluated the mass production of fodder using two indirect methods, the ruler and rising plate, for a period of 12 months in pastures of *Cynodon* spp. They reported that the two methods do not differ in efficacy and that their prediction accuracies depend on the calibration curves generated with a data set that is sufficiently large to describe the conditions of the pasture to be evaluated. However, as shown in Table 5 and in accordance with what was noted for the other methods, it is necessary to perform the calibration process for each species, region, and season, if applicable, to estimate pasture production.

MASS FLOW OF FORAGE

The analysis of the growth and development of forage plants is an important strategy to characterize

Table 5 - Forage calibration equations using the height method to determine the uncompressed bulk material

Species	Unit	Equation	R^2	Author
Brachiaria decumbens	MFF ($t.ha^{-1}$)	$y = 1.55 + 0.41x$	0.88	Costa *et al*. (2009)
Lolium multiflorum	MFF ($t.ha^{-1}$)	$y = 123.989 + 0.081x - 0.00001x^2$	0.65	Cauduro *et al*. (2006)
Cynodon spp.	MFF ($kg.ha^{-1}$)	$y = 667.7 + 99.9x$	0.59	Paciullo *et al*. (2004)
Pennisetum purpureum	MDF ($t.ha^{-1}$)	$y = 1692.5 + 1843.9x$	0.58	Cóser *et al*. (1999)
Cynodon sp. Florakirk	MDF ($kg.ha^{-1}$)	$y = 3080 + 195x$	0.60	Silva & Cunha (2003)
Cynodon sp. Tifton 85	MDF ($kg.ha^{-1}$)	$y = 2600 + 265x$	0.72	Silva & Cunha (2003)
Cynodon sp. Coastcross	MDF ($kg.ha^{-1}$)	$y = 2590 + 150x$	0.40	Silva & Cunha (2003)
Cynodon nlemfuensis	MDF ($kg.ha^{-1}$)	$y = 987.02+191.95x$	0.56	Arruda *et al*. (2011)
Brachiaria brizantha	MDF ($kg.ha^{-1}$)	$y = 507.4 + 105.1x$	0.93	Braga *et al*. (2009)

MFF - Mass production of fresh forage; MDF - Mass production of dried forage.

the production potential and to define the potential use of the ecosystem for animal production (Glienke *et al*., 2010).

The number of leaves is a genetic trait that is unlikely to be influenced by edaphoclimatic factors. Cândido *et al*. (2005) evaluated the flow of forage mass in *Panicum maximum* cv. 'Mombaça' subjected to different grazing strategies in a rotational grazing system characterized by three rest periods defined by the time required for the emergence and expansion of 2.5, 3.5 and 4.5 leaves per tiller. They reported no differences in the senescence rates for the evaluated rest periods and greater forage production in pastures with a rest period of 2.5 emerged leaves per tiller. Thus, the number of live leaves of a tiller can be used with parameters that indicate the best time for the entry of the animals into a pasture or for cutting a particular forage species.

Growth and senescence act on individual tillers and when evaluated in the tiller population, establish the production of the pasture. After defoliation, in the early stages of regrowth, little or no death of leaf tissue occurs until the lifetime of the first leaves produced after cutting is achieved. During this period, the rate of accumulation of herbage mass is equal to the gross production of forage. Pasture production is the result of the accumulation of herbage mass in each tiller and the density associated with them.

To estimate herbage mass, the number and average weight of the tillers in a clump can be used. To carry out the necessary measurements, transects in the experimental unit must be marked, and the chosen tiller should be marked with colored telephone wire or another marker. The distribution of transects in the experimental area must be representative. After picking clumps representing this area and marking and recording the number of tillers and the average weight of some tillers, the clump area and number are determined, and the data for the remaining clumps are extrapolated, thus providing the mass production of green fodder.

Another way to determine forage mass production flows is to assess growth and senescence of the leaf blade. To accomplish this, it is necessary to determine the intermediate variables of the leaf elongation rate, senescence rate per tiller, stem elongation rate, tiller density and weight per unit length of the parts of the plant while considering the emerging strip and completely expanded leaf. Thus, in a given period of time, the accumulation of living net weight (DW) of a species is the result of the difference between the gross weight increase due to the formation of new tissue (G) and the decrease due to senescence and the decomposition of older tissues (S) or the consumption of fodder (I). Thus, DW = G- (S + I) (Bircham and Hodgson 1983; Davies *et al.*, 1983).

To extrapolate the weight, gravimetric indices are determined for the lengthening stems, leaves and leaf senescence. At the end of each rest period, the material collected from approximately 30 tillers per paddock sample were taken to the laboratory and separated into stems, expanded leaf blades and emerging leaf blades to determine their dry weight. Thus, the authors estimated the growth rates and accumulation during the rest period from the elongation rate and senescence of the leaf blade, the rate of stem elongation and the tiller density, according to the methodology proposed by Davies *et al*. (1983).

The study and evaluation of morphophysiological and morphogenic responses of tropical forage plants play an important role in planning strategies and management practices of grazing because they define the limits of flexibility and the use of both plants and animals in the composition of livestock grazing systems (Galzerano *et al*., 2012a; Galzerano *et al*., 2012b). In these systems herbage mass of tropical forage legumes is commonly used because the efficiency of ruminant production in pastures requires sufficient levels of nitrogen for the proper functioning of ruminal microorganisms. In addition, nitrogen fixation by legumes is a crucial feature in this environment (Nepomuceno *et al*., 2013; Tucak *et al*., 2013).

CONCLUSIONS

The main difficulty in estimating herbage mass of tropical grasses is due to the elongation of stems, especially for caespitose growing species.

There is no single method to estimate the mass of fodder which can be used efficiently for all types of grass because of the large morphophysiological variability in plants. It is of crucial importance to know which species is being evaluated in order to choose the most appropriate technique for estimating its herbage mass.

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