Assessment of edible biomass production of Acacia senegal, Guiera senegalensis and Pterocarpus lucens in the Sahelian zone of West Africa

Sanon H.O., Ledin I.

in

Papachristou T.G. (ed.), Parissi Z.M. (ed.), Ben Salem H. (ed.), Morand-Fehr P. (ed.). Nutritional and foraging ecology of sheep and goats

Zaragoza : CIHEAM / FAO / NAGREF
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 85

2009
pages 117-121

Assessment of edible biomass production of *Acacia senegal*, *Guiera senegalensis* and *Pterocarpus lucens* in the Sahelian zone of West Africa

H.O. Sanon* and I. Ledin**

*Institut de l'Environnement et de Recherche Agricole, CRREA de l'Ouest,
Station de Farako-bà, Bobo-Dioulasso (Burkina Faso)
**Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences,
PO Box 7024, SE-750 07 Uppsala (Sweden)

Abstract. The aim of this work was to evaluate edible biomass production (total and accessible to animals while browsing) of three important browsing species in the Sahelian zone of Burkina Faso: *Acacia senegal*, *Guiera senegalensis* and *Pterocarpus lucens*. Biomass production was also estimated using dendrometric parameters. Accessible edible biomass varied according to the animal species (cattle, sheep or goats), the plant species and the height of plants. *G. senegalensis* produced the highest proportion of accessible biomass, but *P. lucens* had higher total edible biomass than the other two species. Goats browsing at higher height had more edible biomass at their disposal than cattle and sheep. Accessible edible biomass was weakly correlated with tree parameters (trunk diameter, crown diameter and height), while crown diameter was the best parameter to predict total edible biomass production, with R^2 varying from 0.90 (*G. senegalensis*) to 0.98 (*P. lucens*), when dependent and independent variables were log-transformed. In conclusion, the single species models developed could be applied in similar agro-ecological zones by taking into account the height stratification of the plants.

Keywords. Edible biomass – *Acacia senegal* – *Guiera senegalensis* – *Pterocarpus lucens* – Browsing.

La production de biomasse ligneuse appétible de* Acacia senegal, Guiera senegalensis *et* Pterocarpus lucens *dans la zone sahélienne de l'Afrique de l'Ouest

Résumé. *La production de biomasse appétible (totale et accessible aux animaux) de trois espèces ligneuses importantes dans la zone sahélienne du Burkina Faso a été évaluée :* Acacia senegal*,* Guiera senegalensis *et* Pterocarpus lucens*. La production de biomasse appétible a été également estimée en utilisant les paramètres dendrométriques. La biomasse appétible et accessible a varié suivant l'espèce animale (bovin, ovin ou caprin), l'espèce végétale et la hauteur des plantes.* G. senegalensis *a produit la plus forte proportion de biomasse accessible, mais* P. lucens *avait la biomasse totale la plus élevée. Les caprins broutant à une hauteur plus élevée, avaient à leur disposition plus de biomasse appétible. Les corrélations entre la biomasse appétible et accessible et les paramètres des arbres (diamètre du tronc, diamètre du houppier et hauteur) étaient faibles, tandis que le diamètre du houppier était le meilleur paramètre pour prédire la production totale de biomasse appétible avec R^2 variant de 0,90 (*G. senegalensis*) à 0,98 (*P. lucens*), suivant une transformation logarithmique des variables dépendantes et indépendantes. En conclusion, les modèles développés sont spécifiques par espèce et pourraient être appliqués dans des zones agro-écologiques similaires, en tenant compte de la stratification en hauteur des plantes.*

Mots-clés. *Biomasse appétible* – Acacia senegal – Guiera senegalensis – Pterocarpus lucens – *Broutage.*

I – Introduction

In Sub Saharan Africa, especially in the Sahel zone, livestock production systems are extensive and based mainly on the utilization of natural resources. During the dry season, browse species constitute an effective insurance against feed shortage, supplementing the quantity and quality of vegetation from pastures. Speedy and Pugliese (1992) estimated that ligneous material in arid

areas in Africa constitute 40% to 50% of the total available feed and Baumer (1992) reported that up to 80% of the dietary protein was provided by plants of the Capparaceae family during the 3 driest months of the year.

However, the evaluation of edible biomass production is rare in pasture assessment. The floristic composition and woody plant cover are usually used to characterise the contribution of woody forage in pasture production. The assessment of edible biomass production can be direct by destructive techniques but indirect methods using regression equations based on more easily measured variables of the trees are frequently utilized for predicting biomass. These approaches are widely used in forestry, either for the estimation of above-ground biomass (wood, branches, leaves) (Ter-Mikaelian and Korzukhin, 1997), or to assess the available browse for wildlife or domestic animals (Patón *et al.*, 2002). In the Sahelian area single regression models for a few browse species have been developed (Cisse, 1980). Most models are focused on total foliage production and do not give any information on the proportion available to animals. The knowledge of browse production is important for the management and for a sustainable exploitation of rangelands. This study aims to evaluate the edible biomass of *Acacia senegal* (L.) Willd, *Guiera senegalensis* J.F. Gmel. and *Pterocarpus lucens* Lepr. ex Guill. & Perrott. and the proportion available for browsing of ruminants (sheep, cattle and goats). Regression models were tested to predict the production of these browse species and estimate their accessibility to ruminants in the area.

II – Materials and methods

The study was undertaken in the Sahelian area of Burkina Faso characterised by a dry climate with low rainfall (June to September) and a long dry season of 8 months from October to May. *Acacia senegal,* family of Leguminosae (Mimosoideae), *Guiera senegalensis,* family of Combretaceae, and *Pterocarpus lucens,* family of Leguminosae (Papilionaceae), three species commonly browsed in the study area as reported by Sanon *et al.* (2007) were investigated. Each species was selected on the pasture type where it is abundant. *A. senegal* was selected in sparse woody steppe, *G. senegalensis* in lowland pasture and *P. lucens* in tiger bush. The study was undertaken during two consecutive years, 2004 and 2005, with different plants of the same species. For each plant species, 4 individuals per class of height [(<1 m), (1-3 m), (3-5 m), (5-7 m) and (>7 m)] were protected from browsing in the dry season by wire enclosure. The accessible edible biomass production, i.e. leaves growing on the trees or shrubs between the soil level and the height reached by animals on pasture was evaluated based on the mean browsing height of sheep, goats and cattle determined in a former study (Sanon *et al.*, 2007): 0.87 m for sheep, 1.47 m for cattle and 1.65 m for goats. The browse biomass was harvested manually in September (leaves, fruits and small branches less than 1 cm diameter) up to the mean height reached by the different animal species, starting from the lower height. The edible biomass out of reach of animals was also evaluated by cutting leafy branches and harvesting the browse components to determine total edible biomass. The edible biomass collected was weighed and air dried and samples were taken for dry matter (DM) determination.

Before harvesting, the dendrometric parameters of each individual were measured to determine their correlations with the browse production. The trunk diameter was taken at the base (for *G. senegalensis* with multiple stems a sum of individual stem basal diameters was made). The diameter of the crown was measured by projecting the edges of the crown to the ground and measuring the length along one axis from edge to edge through the crown centre; then two perpendicular directions were averaged. The total height of plant was measured with a clinometer.

The GLM procedure of SAS software (SAS, 1998) was used to analyse the data. The treatment means which showed significant differences at the probability level of $P < 0.05$ were compared using Tukey-Kramers's pairwise comparison procedures. The following statistical models were used:

$$\ln (y_{ijkn}) = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + t_k + (\alpha t)_{ik} + (\beta t)_{jk} + e_{ijkn}$$

where μ is the general mean, α_i the main effect of species i; β_j is the effect of height class j; t_k is the effect of period (year); $(\alpha\beta)_{ij}$, $(\alpha t)_{ik}$ and $(\beta t)_{jk}$ are the interaction effects and e_{ijk} the error term. The interaction of the three factors was removed from the model as it was not significant in a preliminary analysis.

A regression analysis was performed to test the relationship between the dendrometric parameters of trees and the biomass production. Linear regression, polynomial regressions and $\log_{10}$ transformation were tested and the significant regressions showing the highest regression determination coefficients were retained.

III – Results and discussion

1. Total and accessible edible biomass production

The edible biomass available for sheep (Table 1) decreased significantly from class 1 and onwards for all plant species. The part available to cattle and goats showed a peak in class 3 of *A. senegal* and *G. senegalensis* and class 4 of *P. lucens*. Goats browsing at higher height had more edible biomass at their disposal. Apart from sheep, the accessible edible biomass increase with the height of tree up the point that physical height limit the direct availability to the animals (Kalen and Bergquist, 2004).

Table 1. Foliage production (g DM)† available to sheep, cattle and goat and total biomass production per species and per height class

	Class 1	Class 2	Class 3	Class 4	Class 5
	<1 m	1-3 m	3-5 m	5-7 m	>7 m
A. senegal					
Sheep	21 ± 9 a	5 ± 2 ab	6 ± 2 ab	1 ± 0.2 b	–
Cattle	21 ± 7 a	119 ± 40 bc	204 ± 69 c	28 ± 10 ab	–
Goat	21 ± 10 a	204 ± 66 bc	378 ± 123 c	56 ± 18 ab	–
Total††	21 ± 6 a	1423 ± 380 b	7165 ± 1911 c	11632 ± 3102 c	–
G. senegalensis					
Sheep	90 ± 38	155 ± 64	114 ± 47	67 ± 28	–
Cattle	90 ± 30 a	419 ± 143 ab	468 ± 159 b	324 ± 110 ab	–
Goat	90 ± 29 a	488 ± 159 b	604 ±196 b	447 ± 145 b	–
Total	90 ± 23 a	1030 ± 275 b	3456 ± 922 bc	6118 ± 1632 c	–
P. lucens					
Sheep	16 ± 6	5 ± 2	1 ± 0.4	2 ± 1	2 ± 1
Cattle	16 ± 5 a	57 ± 19 ab	73 ± 25 ab	139 ± 47 b	110 ±38 b
Goat	16 ± 5 a	98 ± 32 b	163 ± 32 b	300 ± 98 b	289 ± 94 b
Total	16 ± 4 a	2104 ± 561 b	6167 ± 1645 bc	11278 ± 3008 cd	26175 ± 6980 d

†Mean and standard error of the mean.
††All edible biomass on the tree (leaves and fruits).
a, b, c,d: Means in the same row with different letters are significantly different (P < 0.05).

Considering the total edible biomass production, *P. lucens* was the most productive species with a maximum production recorded with individuals taller than 7 m, 26 kg, followed by *A. senegal* (11.6 kg mean of individuals from 5 m to 7 m high). Total edible biomass was high compared to the value reported by Bille (1980) on these species. The difference could be due to different ecological conditions and rainfall or maybe the edible components considered in this study that include green fruits. In general, all the leaves from individual plants <1 m are accessible to all the animal species studied. The amount of accessible edible biomass in percent of total edible biomass decreased with increasing plant height for all three species (Fig. 1). If goats are used as the reference, the accessible

edible biomass of *P. lucens* is less than 5% of total edible biomass in all height classes. For *A. senegal* the edible biomass accessible to goats was 14.3%, 5.3% and 0.5%, respectively, of total biomass, for class 2, 3 and 4. The corresponding values for *G. senegalensis* were 47.4%, 17.5% and 7.3%, respectively, for the same height classes. The decrease in proportion of accessible biomass with height of tree has been reported also by Hiernaux (1980) and Ickowicz and Mbaye (2001). However, Breman and de Ridder (1991) suggested that 25% of total biomass could be reached directly by animals, which seems to be an overestimation of accessible biomass. The present study highlights the need to take the height of the plants into consideration. This is very important when determining accessibility, but the crown shape of the species can also have an influence.

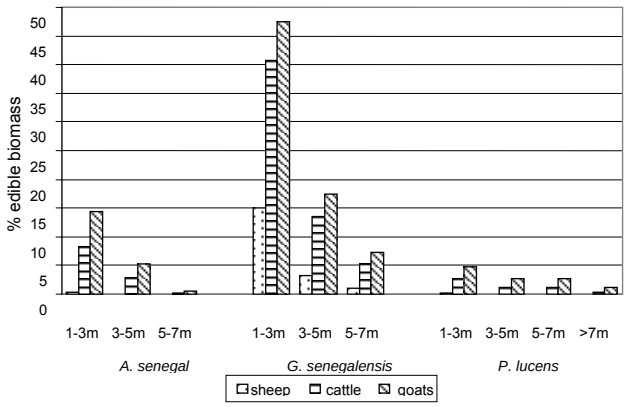

Fig. 1. Percentage of edible biomass available to sheep, cattle or goats according to different heights of the trees.

2. Relation between edible biomass production and dendrometric parameters

Linear regression with $\log_{10}$ transformed data gave the best estimation of total edible biomass production for all species and all parameters. Table 2 gives the matrix of regression coefficients with related equations between dendrometric parameters of trees (trunk diameter, crown diameter, height) and total edible biomass production of the species.

The highest determination coefficients were obtained with crown diameter for all three species, $R^2 = 0.96$, 0.90, 0.98 for *A. senegal*, *G. senegalensis* and *P. lucens*, respectively. Since the edible biomass accessible to animals was only a part of total edible biomass and also varied with the height of the plants, the correlations between dendrometric parameters and accessible edible biomass were lower. The determination coefficients for accessible edible biomass varied with animal species and plant species, from $R^2 = 0.36$ to $R^2 = 0.73$ with crown diameter, $R^2 = 0.31$ to $R^2 = 0.71$ with trunk diameter and $R^2 = 0.37$ to $R^2 = 0.62$ with height. In general the regressions tested had low R^2 values for the edible biomass accessible to sheep. The correlation improved as the accessible proportion increased. For instance, for goats determination coefficients above 50% for all parameters in each plant species were found. The strong relationship between crown diameter and total edible biomass can be explained by the size of the crown that is associated with the number of branches, which in turn is related to LAI (leave area index). The measurement of crown diameter is easy to undertake in the Sahelian area as the trees are sparse and the crowns seldom jointed. The crown can be estimated if aerial photographs of an appropriate scale are available, although field observation will be required to identify different species.

Table 2. Regressions between total edible biomass production and dendrometric variables

	Parameters	Regression equation†	R^2	RSD
A. senegal	Trunk diameter	Log(FP) = –0.12 + 2.64 Log(TD)	0.80***	0.53
	Crown diameter	Log(FP) = –3.48 + 2.49 Log(CD)	0.96***	0.24
	Height	Log(FP) = –2.18 + 2.22 Log(H)	0.87***	0.42
G. senegalensis	Trunk diameter	Log(FP) = 0.55 + 1.89 Log(TD)	0.68***	0.48
	Crown diameter	Log(FP) = –3.02 + 2.46 Log(CD)	0.90***	0.26
	Height	Log(FP) = –2.06 + 2.12 Log(H)	0.87***	0.31
P. lucens	Trunk diameter	Log(FP) = –0.40 + 2.86 Log(TD)	0.75***	0.61
	Crown diameter	Log(FP) = –2.82 + 2.35 Log(CD)	0.98***	0.16
	Height	Log(FP) = –2.51 + 2.30 Log(H)	0.96***	0.25

†FP = foliage production, g; TD =trunk diameter, cm; CD = crown diameter, cm; H = height, m.
***P < 0.001.

IV – Conclusion

Overall edible biomass accessible to animal is low and varied according to species and the height of trees. The most important part of trees edible biomass is not directly accessible to animal. The relations found between the total biomass production and different tree parameters demonstrated the possibility of estimating browse biomass production of pasture. The models developed are species specific and could be applied to similar agro-ecological zones, taken into account the heterogeneous distribution of plant height as well as the degree of accessibility.

References

Baumer M., 1992. Trees as browse and to support animal production. In: Speedy A. and Pugliese P.L. (eds). *Legume Trees and Other Fodder Trees as Protein Sources for Livestock*. Proceedings of FAO Expert Consultation, MARDI, Kuala Lumpur (Malaysia), 14-18 October 1991. Rome, Italy: FAO. p. 1-10.

Bille J.C., 1980. Measuring the primary palatable production of browse plants. In: Le Houerou H.N. (ed.). *Browse in Africa. The Current State of Knowledge*. Addis Ababa, Ethiopia: ILCA. p. 185-196.

Breman H. and de Ridder N., 1991. *Manuel sur les Pâturages des Pays Sahéliens*. Paris, France: Karthala, ACCT, CABO-DLO, CTA. 485 p.

Cisse M.I., 1980. The browse production of some trees of the Sahel: Relationships between maximum foliage biomass and various physical parameters. In: Le Houerou H.N. (ed.). *Browse in Africa. The Current State of Knowledge*. Addis Ababa, Ethiopia: ILCA. p. 204-208.

Hiernaux P., 1980. Inventory of the browse potential of bushes, trees and shrubs in an area of the Sahel in Mali: Method and initial results. In: Le Houerou H.N. (ed.). *Browse in Africa. The Current State of Knowledge*. Addis Ababa, Ethiopia: ILCA. p. 197-203.

Ickowicz A. and Mbaye M., 2001. Forêts soudaniennes et alimentation des bovin au Senegal: Potentiel et limites (Sudanian forests and cattle feeding in Senegal: Potential and limits). In: *Bois et Forêt des Tropiques*, 270. p. 47-61.

Kalen C. and Bergquist J., 2004. Forage availability for moose of young silver birch and scots pine. In: *For. Ecol. Manag.*, 187. p. 149-158.

Patón D., Núñez J., Bao D. and Muñoz A., 2002. Forage biomass of 22 shrub species from Monfragüe Natural Park (SW Spain) assessed by log-log transformation models. In: *J. Arid Environ.*, 52. p. 223-231.

Sanon H.O., Kaboré-Zoungrana C. and Ledin I., 2007. Behaviour of goats, sheep and cattle and their selection of browse species on natural pasture in a Sahelian area. In: *Small Rumin. Res.*, 67. p. 64-74.

SAS, 1998. *Statistical Analysis System. SAS/STAT User's Guide, version 8.02*. Cary, NC, USA: Statistical System Inc.

Speedy A. and Pugliese P.L. (eds), 1992. *Legume Trees and Other Fodder Trees as Protein Sources for Livestock*. Proceedings of FAO Expert Consultation, MARDI, Kuala Lumpur (Malaysia), 14-18 October 1991. Rome, Italy: FAO. 339 p.

Ter-Mikaelian M.T. and Korzukhin M.D., 1997. Biomass equations for sixty-five North American tree species. In: *For. Ecol. Manag.*, 97. p. 1-24.