FIREWOOD YIELDS OF INDIVIDUAL TREES OF *GUAZUMA ULMIFOLIA* LAM. IN PASTURES IN HOJANCHA, GUANACASTE-COSTA RICA

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SUMMARY

Guazuma ulmifolia Lam. (guácimo), because of its wide distribution, easy handling, and high firewood quality, is a promising native species for firewood production in the wet and dry regions of Central America.

It is possible to make an accurate estimate of the firewood weight of the crown of a guacimo tree that has been periodically harvested, using regression models based on basal diameter of the branches and dbh, crown diameter and age. Several firewood weight tables were developed which can be used to make estimates for periodically harvested individual trees growing in pastures.

RÉSUMÉ

Grace à sa grande aire naturelle, à sa tractabilité et à sa qualité calorifique, *G. ulmifolia* est une espèce idigène prometteuse pour la production du bois de chauffage dans les régions sèches aussi bien qu'humides de l'Amérique Centrale. Il est possible de faire une estimation assez exacte du contenu d'une cime régulièrement exploitée en se basant sur le diamètre des branches, le diamètre à hauteur d'homme, de diamètre de la cime et l'age du sujet. Des tables ont été élaborées pour indiquer le poids du bois de chauffage d'arbres isolés.

RESUMEN

Guazuma ulmifolia (guacimo) a causa de su rango amplio, propagación facil y la alta calidad de su leña, es una especie nativa prometador para la producción de leña en las zonas áridas y húmedas de America Central.

Se puede estimar con precisión el rendimiento de leña de la copa de un arból de guacimo que se ha cosechado periodicamente, utilizando modelos de regressión basados en el área basal de las ramas, diámetro a la altura del pecho, diámetro de la copa y edad. Algunas tablas para el peso de leña fueron desarrolladas para estimar el rendimiento de arboles individuales cosechados periodicamente en pasto.

Introduction

Guacimo (*Guazuma ulmifolia* Lam.) is one of the most widely distributed species in tropical America and the Caribbean, ranging from sea level to 1.200 m. Though the largest populations are found in humid and dry regions, the species also occurs in wet areas having no defined dry season (National Academy of Sciences, 1980; Santander C. y Campos, J. J., 1982).

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There is no available literature on yields of this species, but some information can be gleaned from characteristics of the distribution zones and forms of usage (National Academy of Sciences, 1980; Santander *et al.* 1982)

Among this specie's attributes can be cited: shade and livestock feed, quality firewood, ease of management, and sprouting facility. These characteristics identify it as an ideal species for management in dry zone pastures.

A more thorough understanding of the sprouting capacity and the shifts in use as well as yields will eventually aid the farmer in a more efficient management system.

In Guanacaste, Costa Rica, the farmers have, with time, developed a technique in the management and use of guacimo which grows naturally in pastures. In this region, the cattlemen leave a variable number of trees in the pastures to be used eventually as livestock alimentation, fence posts, and firewood.

The objective of this work is to develop mathematical models, which permit prediction of firewood production in individual guacimo trees growing naturally in pasture.

Sampling

The trees in the sample were cut in Arena de Hojancha, Guanacaste, 10°03′ latitude N, 85°25′ longitude W, and 355 m above sea level. The zone has an annual precipitation of 2223 mm with a dry period from November to May. The annual mean temperature is 27° C. Ecologically, the area is classified as humid tropical forest life zone (Holdridge). The soils of the region are igneous and sedimentary in origin, and according to the map of soil sub-group associations (Haplustalfs), are classified as Alfisols or Inceptisols (CATIE, 1981).

The farm site was selected as representative of the zone and because of its well established use of guacimo for firewood, forage, and shade.

All sprouts of any guacimo tree encountered growing naturally in the pastures are of the same age; and within the same area it is possible to find trees with sprouts one to four years old.

Harvesting is usually done during March, and only trees with three or four year old branches are cut. Branches are generally cut at a height of 2·5 m to prevent brousing by livestock.

A total of 17 trees was sampled, four for each of the age groups and five for age one year. Only those trees with relatively uniform trunks were selected for the sample.

Information from the farmer was used to determine the age of various shoots.

Results and Discussion

Table 1 presents a summary of the dispersion parameters for the 15 variables assessed on the 17 trees sampled. Because the heterogenity of the material in terms of age, the majority of the variation coefficients are relatively high.

The grade of association between these 15 variables is presented in a simple correlation matrix (Table 3, appendix). It is interesting to note that there is no relation between the number of branches and the trunk dimensions such as dbh, height, and basal diameter; and that these same variables are not associated with any yield variable of the crown. Additionally, it was found that the green wood of the branches had a moisture content of 54% (determined at 105 °C), and that the specific gravity of the large branches green wood was $1{\cdot}28 \pm 0{\cdot}02$ g/cm^3 and of oven-dried wood, $0{\cdot}65 \pm 0{\cdot}02$ g/cm^3.

Table 1
Dispersion parameters for growth variables, by tree

Variable	Average	Standard error	CV (%)
1. Number of branches	13·5	1·4	43·4
2. Average basal diameter of branches (mm)	85·0	7·5	36·5
3. Squared diameter of branches (mm)*	88·4	8·1	37·9
4. Geometric diameter of branches (mm)*	81·3	6·9	34·9
5. Average length of branches (dm)	62·5	4·8	31·4
6. Average commercial length of branches (dm)	46·7	4·7	41·6
7. Total green weight of branches (kg)	399·2	89·0	91·9
8. Commercial green weight of branches (kg)	314·4	77·2	101·2
9. Age of branches (yrs)	2·5	0·3	45·5
10. Total height of tree (dm)	11·2	0·6	23·4
11. Trunk height at sprouting point of branches (m)	2·7	0·2	29·6
12. dbh (cm)	42·2	2·1	20·7
13. Basal diameter of tree (cm)	52·4	3·8	30·2
14. Crown height (m)	8·8	0·8	35·9
15. Crown diameter (m)	10·2	0·9	35·1

* Transformation of the original variable for accuracy.

Estimations per Branch

To evaluate the biomass per branch, it is possible to use the high correlation that exists between commercial weight (2·5 cm minimum diameter) and the total weight. The following regression model allows a very precise estimation independent of the age of the sprouts.

$$A = 2.209 \pm 1{\cdot}1749 \times B$$

A = total green weight of branch (kg)
B = commercial green weight of branch (kg)
$R^2 = 99\%$***
$Syx^2 = 13{\cdot}77$

With the total number of branches and the average commercial weight, total weight of the crown is easily predicted. Determination of commercial weight, though not a complex operation, is a time consuming one. Therefore, the application of any of the following regression models will permit, with satisfactory precision, an estimation of the commercial weight of each branch:

$$LN\ B = 12{\cdot}074 + 2{\cdot}3075 \times LN\ C + 1{\cdot}0668 \times LN\ D$$

$R^2 = 95\%$***
$Syx^2 = 0{\cdot}12$
C = Basal diameter of branch (mm)
D = Total length of branch (dm)
LN = Natural logarithms

Even this model is time consuming in the length measurement of each branch. A more practical model is one which uses only the basal diameter of the branches. The following

simple regression equation has a high degree of accuracy in estimating the firewood weight per branch:

$$LN\ B = -11 \cdot 194 + 3 \cdot 1008 \times LN\ C$$
$$r^2 = 93\%***$$
$$Syx^2 = 0 \cdot 16$$

Table 2 (appendix) summarizes two one-way weight tables. The first is the estimation of commercial weight per branch from its basal diameter; the second is the estimation of the total branch weight from its commercial weight.

Estimation per Tree

To estimate the commercial weight of firewood per tree (crown), the following regression equation can be used:

$$LN\ F = 1 \cdot 8968 + 0 \cdot 0206 \times G + 0 \cdot 0268 + 0 \cdot 0268 \times DAP - 0 \cdot 0198 \times LN\ E + 0 \cdot 13902 \times LN\ H$$
$$R^2 = 80\%***$$
$$Syx^2 = 0 \cdot 05$$

F = Commercial green weight of crown (kg)
G = Avg. branch diameter (mm)
dbh = Diameter at breast height (cm)
E = Age of crown (yrs)
H = Crown diameter (m)

A more simple equation is:

$$F = -746 \cdot 56 + 9 \cdot 3470\ G + 6 \cdot 5681\ dbh$$
$$R^2 = 96\%***$$
$$Syx^2 = 4782 \cdot 60$$

which permits an estimation of firewood weight per tree using only the average diameter of the branches and the dbh. Table 4 (appendix) presents the commercial green weight of the crown for different combinations of the dbh and average diameter of the branches. Another simple way to estimate the firewood weight per tree uses the crown diameter. The following simple regression equation gives an acceptable degree of accuracy for estimating the firewood weight based on crown diameter:

$$LN\ I = -1 \cdot 2783 + 2 \cdot 853\ LN\ H$$
I = firewood green weight of the crown (kg)
$$R^2 = 78\%***$$
$$Syx^2 = 0 \cdot 41$$

When the age of the sprouts is known, the following linear regression equation can be used to estimate the firewood green weight per tree:

$$LN\ F = 3 \cdot 4522 + 2 \cdot 1367\ LN\ E$$
$$R^2 = 77\%***$$
$$Syx^2 = 0 \cdot 42$$
E = age of crown (yrs)

Table 3 (appendix) indicates a high correlation between total green weight of the crown and firewood weight. The following linear regression model describes in precise form this relation that permits facility of biomass quantification in future evaluations, without the necessity of having to resort to difficult quantification variables:

$$J = 32 \cdot 137 + 1 \cdot 1582\ F$$
$$R^2 = 99\%***$$
$$Syx^2 = 604 \cdot 29$$

Table 5 (appendix) summarizes four one-way tables on commercial green weight and total green weight of the crown estimated from crown diameter and age (yrs). From this it can be determined that a tree with a crown diameter of 10·0 m can produce approximately 198 kg of green firewood.

Conclusions

Both the yield and the growth variables show a high percent of variation. This is a result of using naturally very heterogeneous populations. Thus the average number of branches per tree was 13 ranging from 8 to 35. Normally, one year old crowns have a greater number of branches. This number diminishes after the first year, probably because of competition; in trees of one year the number of branches ranges from 11 to 33, and in trees of four years, the range is from 10 to 15.

Results indicate a high correlation between the age of the crown and its total weight and firewood weight. Equally high is the correlation between these two yield variables and the height and diameter of the crown (Table 3, appendix). This association facilitates estimation of firewood production by each tree.

The logarithmic regression model developed for predicting the total of firewood weight based only on age, will be more accurate if the age of the branches is known. This is not difficult since there is a clear difference in basal diameter of branches by age; the annual increment is approximately 4 cm.

The farmer usually harvests the guacimo sprouts every three years. However, the current analysis has determined that up to 280 kg more of green firewood per tree could be obtained if harvesting was done every fourth year. In the four trees of four years of age that were sampled, an average of 772 kg of green firewood was obtained per tree, with a minimum of 547 kg and a maximum of 982 kg.

Lemckert and Campos (1981) in a study of firewood consumption in the dry Pacific zone of Costa Rica determined that the average family consumption of firewood per year is 5,700 kg. In light of this estimate, one family in Guanacaste could obtain its annual firewood needs from only seven or eight guacimo trees with four years branch growth. This implies that a farmer with 28 to 32 guacimo trees could supply his firewood needs continuously if he maintains a level of use of seven or eight trees per year.

The tables of firewood production per tree give some idea of the firewood weight. This is estimated from dbh, average diameter of the branches, crown diameter and age. These variables are easily measured.

It would be interesting to determine the average number of trees/hectare in the region and the variation between large and small farms. This would permit an estimation of the potential firewood production.

In addition to the trees providing firewood, the foliage and fruit is fed to livestock, the stock appreciate the availability of shade and some of the timber finds a use for fence posts.

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APPENDIX

Table 2

Commercial green weight of branch estimated from basal diameter for *Guazuma ulmifolia* Lam. in kg

Branch diameter (C) (mm)	Commercial green weight of branch (B) (kg)	Total green weight of branch (A) (kg)
30	0·52	2·82
40	1·28	3·71
50	2·55	5·21
60	4·49	7·48
70	7·24	10·72
80	10·95	15·08
90	15·78	20·75
100	21·88	27·92
110	29·41	36·76
120	38·52	47·46
130	49·37	60·21
140	62·12	75·19
150	76·94	92·60
160	93·98	112·63
170	113·42	135·46
180	135·41	161·30
190	160·13	190·34
200	187·73	222·78
210	218·40	258·80
220	252·28	298·62
230	289·57	342·42
240	330·42	390·42
250	375·01	442·80

NOTE: Dry weight was determined by multiplication of green weight by 0·51.

LN B = −11·194 + 3·1008 × LN C R^2 = 99%***; Syx^2 = 0·16

A = 2·209 + 1·1749 × B R^2 = 99%***; Syx^2 = 13·77

Table 3

Correlation matrix

Var.+	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1·000														
2	−0·462	1·000													
3	−0·456	0·999***	1·000												
4	−0·467	0·999***	0·996***	1·000											
5	−0·495	0·855***	0·845***	0·863***	1·000										
6	−0·495	0·887***	0·875***	0·897***	0·992***	1·000									
7	−0·294	0·959***	0·962***	0·953***	0·775***	0·814***	1·000								
8	−0·279	0·951***	0·954***	0·945***	0·754***	0·794***	0·998***	1·000							
9	−0·483	0·938***	0·939***	0·934***	0·843***	0·849***	0·899***	0·899***	1·000						
10	−0·527*	0·615*	0·610*	0·617*	0·727**	0·715**	0·530*	0·523*	0·643*	1·000					
11	−0·037	−0·329	−0·335	−0·319	−0·437	−0·419	−0·338	−0·326	−0·248	−0·057*	1·000				
12	0·412	0·179	0·182	0·178	0·136	0·172	0·359	0·362	0·172	−0·037	−0·049	1·000			
13	−0·048	−0·269	−0·268	−0·264	−0·421	−0·410	−0·205	−0·177	−0·178	0·024	0·815***	0·194	1·000		
14	−0·510*	0·727**	0·718**	0·734**	0·869***	0·864***	0·634***	0·630*	0·740**	0·896***	−0·276	0·072**	−0·278	1·000	
15	−0·506*	0·922***	0·920***	0·920***	0·855***	0·864***	0·845***	0·844***	0·937***	0·681***	−0·220	0·057	−0·226	0·756**	1·000

* Significant to 5% probability
** Significant to 1% probability
*** Significant to ·1% probability
Variables from Table 1

Table 4

Commercial green weight of crown estimate from two variables for *Guazuma ulmifolia* Lam. in kg

Average diameter of branches (mm) (G)	dbh (cm)						
	30	35	40	45	50	55	60
50	—	—	—	16·35	49·19	82·04	114·88
60	11·30	44·14	76·98	109·66	142·66	175·51	208·35
70	104·77	137·61	170·45	203·29	236·13	268·98	301·82
80	198·24	231·08	263·92	296·76	329·60	362·45	395·29
90	291·71	324·55	357·39	390·23	423·07	455·92	488·76
100	385·18	418·02	450·86	483·70	516·54	549·39	582·23
110	478·65	511·49	544·33	577·17	610·01	642·86	675·70
120	572·12	604·96	637·80	670·64	703·48	736·33	769·17
130	665·59	698·43	731·27	764·11	796·95	829·80	862·64
140	759·06	791·90	824·74	857·58	890·58	923·27	956·11
150	852·53	885·37	918·37	951·05	983·89	1016·74	1049·58

NOTE: Dry weight derived by multiplication green weight by 0·51.
$F = -746{\cdot}56 + 9{\cdot}3470 \times G + 6{\cdot}5681 \times DAP$
$R^2 = 96\%$***; $Syx^2 = 4782{\cdot}6$

Table 5

Green weight of crown estimate from crown diameter and age for *Guazuma ulmifolia* Lam. in kg

Average diameter of crown (H) (m)	Commercial green weight (F) (kg)	Total green weight (J) (kg)
4	14·54	48·98
5	27·48	63·96
6	46·23	85·68
7	71·76	115·25
8	105·04	153·79
9	146·09	202·38
10	198·54	262·08
11	260·58	333·94
12	334·00	418·97
13	419·68	518·21
14	518·49	632·66
15	631·29	763·30
Age (E) yrs)		
1	31·57	68·70
2	138·83	192·93
3	330·17	414·54
4	610·51	739·23

NOTE: Dry weight was derived by multiplying green weight by 0·51.

$LN\ F = -1{\cdot}2783 + 2{\cdot}853 \times LN\ H$	$R^2 = 78\%$***; $Syx^2 = 0{\cdot}41$
$J = 32{\cdot}137 + 1{\cdot}582 \times F$	$R^2 = 99\%$***; $Syx^2 = 604{\cdot}29$
$LN\ F = 3{\cdot}4522 + 2{\cdot}1367 \times LN\ E$	$R^2 = 77\%$***; $Syx^2 = 0{\cdot}42$