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The Use of Adelaide Technique, to Determine Available Browse of Shrubs

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THE AVAILABLE browse was determined by Adelaide technique through a step-wise regressions in the form of : $Y=a+bx_1+cx_2$, where x_1 and x_2 are the width and height, respectively of the selected shrubs not exceeding 1.5 meters. Results show that the co-efficient of determination (R^2) of these regressions were 0.62, 0.83, 0.60 and 0.80 for the shrubs *Leptadenia pyrotechnica, Acacia nilotica, Acacia raddiana* and *Acacia seyal,* if the estimated weight was used. Hence, the available shrub biomass was found to be 145.7, 282.4, 200.4 and 508.4 gm for the above-mentioned shrubs. On the other hand, when the calculated weight was used, R^2 for the same plants and the same order as above were 0.60, 0.87, 0.72 and 0.95 and available shrub biomass was 54.3, 123.4, 176.8 and 188.0 gm. The Adelaide technique in its simple application was found to be reliable, non-destructive and not time consuming.

Keywords : Adelaide technique , *Acacia nilotica, Acacia raddiana* , *Acacia seyal, Leptadenia pyrotechnica,* Shrubs, Biomass.

Rutherford (1979) in his review: Plant-based techniques for determining Available Browse (shrub biomass) and Browse (shrub biomass) utilization, stressed the difficulties of measuring forage which are peculiar to shrub lands and which are not encountered in grasslands. He observed that "at the present stage of development of techniques it is simply not possible to prescribe to the practical worker a particular browse measurement technique that is assured of succeeding under his particular conditions". To solve this dilemma Andrew *et al.* (1979) and (1981) have discussed three techniques that show promise for estimating shrub biomass non-destructively in the field. These are: Visual estimation, Dimensional measurement and the Capacitance probe.

Visual estimation was developed for use in grasslands and forblands (Pechanec & Pickford, 1937). Woodroffe (1941) described an adaptation of the technique for shrubs which was used in the Yudnabirra grazing experiment in Australia (Trumble & Woodroffe, 1954). Several Australian workers have used versions of a visual estimation technique to assess Chenopod shrub pastures (Leigh & Mulham, 1966; Squires, 1976 and Noble & Totterdell, 1978)

Measurements like height, width, and length of individual shrubs, when combined in various ways, have been shown by different researchers to correlate well with forage of big sagebrush (Neal & Neal, 1973; Carpenter *et al.*, 1973; Rittenhouse & Sneva, 1977; Uresk *et al.*, 1977 and Graetz, 1978).

It is worth mentioning that the dimension measurement and capacitance probe methods were used in comparison to a newly introduced visual estimate called "Adelaide" technique to assess Chenopod shrub biomass (Andrew *et al.*. 1979). As indicted by Andrew *et al.* (1981) all the three methods gave linear relationships between forage and reading method. The Adelaide technique was the best of all.

As described by Andrew *et al.* (1979) the field procedure of the method is as follow: A "unit" is selected. This is a leafy branch of the species to be estimated and typical of the predominant habit, leaf shape and leaf density. The production unit is usually 10 – 20% of average shrub biomass. It may be trimmed to suit the estimator and it is shaken initially to dislodge loose leaves.

Each shrub is then scored for the number of equivalent "units" contained in it. The visual estimation is improved by moving the "unit" around close to the shrub. Operators must be careful that the "units" do not change in size or appearance during use.

The number of "unit" equivalents is then converted to a forage value (gm dry weight) via a calibration curve.

A number of whole shrubs are chosen to span the range of shrub sizes and habits present in the field. At the start and at the end of each session of estimating (*e.g.* a half or a whole day) the numbers of "unit" equivalents of each calibration or standard shrub are estimated using the hand-held unit. The calibration shrubs are protected from grazing and damage during the entire estimation period (usually several days) and thus forage can be constant. At the end of the estimation period, these calibration shrubs are harvested, and the forage stripped, dried and weighed.

The calibration curve is adequately described by a linear regression through the origin as demonstrated below:

F = Actual biomass of a calibration or standard shrub (gm dry weight).
$\bar{F}$ = b* N The calculated forage of a shrub (gm dry weight).
N = The number of "unit" equivalent in a shrub.
B = The conversion factor: F = b*N, obtained as the slope of regression through the origin of F against N for the calibration shrubs (gm dry weight).
U = the forage of the hand-held unit (gm dry weight).

Thus the formula for the conversion factor, b, was:

$$b = \sum_{i=1}^{n} (N * F) / \sum_{i=1}^{n} N^2$$

In the present study a similar procedure of "Adelaide" technique is used to assess shrub biomass, referred to as the available browse, of selected shrub plants in the study area. In addition to that the biomass data will be correlated with the width and height of the selected shrubs to estimate Available Browse.

Materials and Methods

Four shrubs not exceeding 1.5 m in height were selected. These are:

1- *Leptadenia pyrotechnica* "Marrikh".
2- *Acacia nilotica* "Sunt".
3- *Acacia raddiana* "Seyal".
4- *Acacia seyal* "Talih".

a- A procedure similar to that of Andrew *et al.* (1979), the so-called Adelaide technique was followed in assessing Available Browse.
b- Three single observers were used in the assessment.
c- Five calibration or standard shrubs were selected of different height class not exceeding 1.5 m. These shrubs were tagged with masking tape.
d- A hand-held production unit for each shrub was used to estimate the unit-equivalents in each selected shrub. 15 production units- equivalent for the selected shrubs were visually estimated.
e- The standard shrubs production units were visually estimated and then twigs of 2 mm in diameter were cut, oven dried at 70° C, to determine the actual weight of Available Browse.

Results and Discussion

Prior to the derivation of the suitable relationships between Available Browse and the width and height of the selected shrubs, the following conventions had to be considered:

1- The production unit weight is the oven dry weight for each selected shrub. This unit was used to estimate the production unit - equivalents of each shrub.

2- The correction factor is determined by the following formula:

$$b = \sum^{n} (F * N) / \sum^{n} N^2 ,$$

where b is correction factor in grams, F is the actual weight of the 5 standard shrubs and N is the number of production unit – equivalents.

3- The estimated weight of a shrub is derived from multiplying the number of production unit-equivalents by the production unit weight.

4- The calculated weight of a shrub is derived from multiplying the number of production unit-equivalents by the correction factor (C.F).

The estimated weight and the correction factor of the 5 standard shrubs were presented in Table 1.

TABLE 1. The production unit weight and correction factors (C.F.) of the five standard shrubs.

Shrub species	Production unit weight (gm)	Correction factor (gm)
Leptadenia pyrotechnica	18	8.71
Acacia nilotica	10.5	9.35
Acacia raddiana	33	29.3
Acacia seyal	24	8.97

As mentioned earlier, five standard shrubs of each selected shrub were chosen and tagged by a colored plastic tape. The number of unit-equivalents of each standard shrub is estimated using the hand-held production unit. At the end of the estimation period the twigs – 2 mm in diameter – of the standard shrubs are harvested, oven dried and weighed. The mean estimated and mean actual weights of the standard shrubs are presented in Table 2.

TABLE 2. Differences between estimated weight and actual weight for the five standard shrubs.

Shrub spp.	No. of samples	Mean Est. wt.(gm)	Mean act. wt. (gm)	d.f	Significance
Leptadenia pyrotechnica	5	172.8	96.04	4	N Sig.*
Acacia nilotica	5	92.4	85.8	4	N Sig.
Acacia raddiana	5	145.2	133.8	4	N Sig.
Acacia seyal	5	332.8	129.4	4	Sig. P< 0.005

* Statistical analysis: t-test by SPSS

Significant differences between the estimated and actual weights of the 5 standard shrubs were statistically analyzed by SPSS program. A t – test was carried out and the results show that there are no significant differences between the estimated and the actual weight for 3 shrubs. These are: *Leptadena pyrotechnica, Acacia nilotica, Acacia raddiana* (Table 2). However, a significant difference is obtained for *Acacia seyal* at $P < 0.005$. This difference may be attributed to the growth habits of the shrub and to a less extent to personal bias. Although there is a significant difference between the estimated and the actual weight of *Acacia seyal*, however and for consistency, is ignored and the estimated weight of *Acacia seyal* was also used to drive relationships between available shrub biomass and the width and height of the shrub.

Difference between estimated and calculated Available Browse

The number of the unit-equivalents of 15 samples of the selected shrubs, within the grazing level of 1.5 m, is estimated using the hand-held production unit. The estimated and calculated weights were derived using conventions (2) and (3) above and they were presented in Table 3.

TABLE 3. Differences between estimated weight and calculated weight for the selected shrubs .

Shrub spp.	No. of samples	Mean Est. wt.(gm)	Mean cal.wt. (gm)	d.f	Significance
Leptadenia pyrotechnica	15	112.04	54.44	14	Highly Sig.* $P < 0.0001$
Acacia nilotica	15	137.9	123.5	14	Highly Sig. $P < 0.0001$
Acacia raddiana	15	200.2	177.8	14	Highly Sig. $P < 0.0001$
Acacia seyal	15	507.2	188.09	14	Highly Sig. $P < 0.0001$

* Statistical analysis: t-test by SPSS

A t-test was carried out to indicate any significant differences between the estimated and the calculated available shrub biomass (weight). The results show that there are highly significant differences at $P < 0.0001$ (Table 3).

Because of these statistical differences, both estimated and calculated available shrub biomass was used separately to obtain relationships between these weights and the width and height of the selected shrubs.

The relationships between available shrub biomass and the width and height of the shrub.

Three persons were involved in estimation of available shrub biomass of the selected shrubs.

Prior to the derivation of the relationships between the available browse and the width and height of the shrubs, statistical test to show any significant differences between operators was carried out using MINTAB program. ANOVA for the three operators were carried out and the results show that there are no significant differences between the three operators (Appendix 1). Therefore, all operators estimated and calculated available browse were used to derive the aforesaid relationships "all operators available browse equals to the sum of operators' available browse divided by 3".

Step-wise linear regressions for each separate shrubs using both estimated and calculated available browse as a dependent variable and the width (x_1) and height (x_2) as independent variables. The regressions were in the form of:

$Y = a + b\, x_1 + cx_2$,

where Y is available shrub biomass, x_1 the width of shrub, x_2 the height of shrub, and a, b and c are constants.

Step-wise regression using estimated available shrub biomass

The results (Table 4a) show that the coefficient of determination (R^2) is 0.625, 0.838, 0.604 and 0.861 for *Leptadenia pyrotechnica, Acacia nilotica, Acacia raddiana* and *Acacia seyal*, respectively. The R^2 values are found to be significant at $P < 0.0002$.

The amount of available shrub biomass, using estimated weights, is presented in Table 4a. These values are 146, 282, 200 and 508 gm for *Leptadenia pyrotechnica, Acacia nilotica, Acacia raddiana* and *Acacia seyal*, respectively.

Step-wise regression using calculated available browse

The results (Table 4b) show that the coefficient of determination (R^2) is 0.605, 0.866, 0.72 and 0.95 for *Leptadenia pyrotechnica, Acacia nilotica, Acacia raddiana* and *Acacia seyal*, respectively. The R^2 values are found to be significant at $P < 0.0002$.

TABLE 4. Available shrub biomass regressions determined by Adelaide technique a. regressions for estimated available shrub biomass against the width (x_1) and height (x_2) of shrubs.

Shrub spp.	No. of samples	Equation	R^2	Av. sh. biomass (gm/shrub)
Leptadenia pyrotechnica	20	$Y = -217.715 + 1.447\, x_1 + 1.454\, x_2$	0.625*	145.741
Acacia nilotica	20	$Y = -104.419 + 1.99\, x_1 + 1.123\, x_2$	0.838*	282.399
Acacia raddiana	20	$Y = -80.484 + 1.372\, x_1 + 1.51\, x_2$	0.604*	200.491
Acacia seyal	20	$Y = -388.56 + 4.317\, x_1 + 3.902\, x_2$	0.861*	508.44

* S, P<0.0002.

b. Regressions for calculated available shrub biomass against the width (x_1) and height (x_2) of shrubs.

Shrub spp.	No. of samples	Equation	R^2	Av. sh. biomass (gm/ shrub)
Leptadenia pyrotechnica	20	$Y = -103.356 + 0.794\, x_1 + 0.591\, x_2$	0.60*	54.346
Acacia nilotica	20	$Y = -84.179 + 2.058\, x_1 + 0.458\, x_2$	0.86*	123.403
Acacia raddiana	20	$Y = -91.106 + 1.911\, x_1 + 1.132\, x_2$	0.72*	176.853
Acacia seyal	20	$Y = -164.802 + 2.01\, x_1 + 1.23\, x_2$	0.95*	187.993

*S, P<0.0001

The amount of available shrub biomass, using calculated weights, is presented in Table 4 b. These values are 54, 123, 177 and 188 gm for *Leptadenia pyrotechnica, Acacia nilotica, Acacia raddiana* and *Acacia seyal,* respectively.

The cost of sampling

Field observations indicated that it took about 2 to 3 man-minutes to select a hand-held unit for each shrub; it took 3 – 4 man-minutes to estimate the standard shrubs and about 10 – 15 seconds to estimate the unit-equivalents for the specific shrub (excluding time to locate them). Harvesting of twigs of the standard shrub took about 5 man-minutes per shrub. Thus the method is rapid in the field; the most time-consuming aspect is harvesting the standard shrubs.

The adequacy and usefulness of the method

Irrespective of the fact that, this method was adopted for the Australian rangeland shrubs but it could be applied for Sudanese rangeland shrubs. As the method was found non-destructive, and less time – consuming compare to the harvesting of all the shrubs.

The stepwise regressions in this study had given fairly good results but, other methodologies can be used such as multiple and curvilinear regressions.

Apparently, no alternative techniques applicable to the Sudanese rangeland shrubs have been yet published. For that reason the "Adelaide" technique offers a reliable and standard method for shrub available browse measurements.

General conclusions about methods of vegetation measurements

The Adelaide technique is a further development of visual estimation methods of Pechanec & Pickford (1937) and was originally described by Andrew *et al.* (1979). In this method, Available Browse is estimated directly in terms of a small, hand-held branch called the production unit, and the total of these unit equivalents are later converted to weight by a linear calibration.

In the present study, the Adelaide technique was used in a very simple and straightforward way. However, in addition to the unit equivalents other parameters such as the width and height of a shrub were used in developing step-wise linear regressions.

Nevertheless, the results obtained were satisfactory but application of other multiple or curvilinear regression may improve the results.

In its simple application the method was found reliable, non-destructive and not time-consuming.

More studies using Adelaide Technique in shrubland ranges of the Sudan may help in assessing the condition and trend of these rangelands.

Appendix 1. Persons differences determined by Adelaide technique

(a): ANOVA for operators differences as determined by Adelaide technique (*Leptadenia pyrotechnica*).

Source	DF	SS	MS	F	P
Factor	2	1849	925	0.10	0.908
Error	57	543565	9536		
Total	59	545414			

(b): ANOVA for persons differences as determined by Adelaide technique (*Acacia nilotica*)

Source	DF	SS	MS	F	P
Factor	2	5877519	2938760	56.39	0.000
Error	57	2970631	52116		
Total	59	8848150			

(c): ANOVA for persons differences as determined by Adelaide technique (*Acacia raddiana*)

Source	DF	SS	MS	F	P
Factor	2	9910	4955	0.33	0.723
Error	57	867443	15218		
Total	59	877353			

(d): ANOVA for persons differences as determined by Adelaide technique (*Acacia seyal*)

Source	DF	SS	MS	F	P
Factor	2	29395	14698	0.27	0.764
Error	57	3098851	54366		
Total	59	3128246			

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استعمال طريقة أدليد لتحديد العلف الشجري المتاح من الشجيرات

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أثبتت النتائج في هذه الدراسة أن كمية العلف الشجري المتاح قد تم حسابه بالمعادلة الخطية التالية:

$$Y=a + bx_1 + cx_2$$

هذا وقد أوضحت النتائج ان معدل الانحدار (R^2) كان ٠,٦٢ ، ٠,٨٣، ٠,٧٢ ، ٠,٨ عند أستنباط المعادلات الخطية لشجيرات المرخ والسنط والسيال والطلح (*Leptadenia pyrotechnica, Acacia nilotica, Acacia raddiana* and *Acacia seyal*) على التوالى وذلك عند استعمال الوزن التقديري (بالعين). بينما كان المعدل ٠,٦ ، ٠,٨٧، ٠,٧٢ و ٠,٩٥ عند استعمال معامل التصحيح (C.F.). هذا وقد كانت كمية العلف الشجري المتاح عند استعمال الوزن التقديري على النحو التالي ١٤٥,٧، ٢٨٢,٤، ٢٠٠,٤و ٥٠٨,٤ جم لشجيرات المرخ والسنط والسيال والطلح على التوالي. بينما كانت الكمية ٥٤,٣، ١٢٣,٤، ١٧٨,٨و ١٨٨ جرام لنفس الشجيرات عند استعمال معامل التصحيح. فى هذه الدراسة تم استعمال طريقة ادليد بطريقة سهلة وبسيطة. ولقد أعطت هذه الطريقة نتائج معقولة نسبيا حيث وجدت غير مدمرة ولا تأخذ وقتا كبيرا.