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Modeling dry weight and carbon dioxide sequestered by A.nilotica

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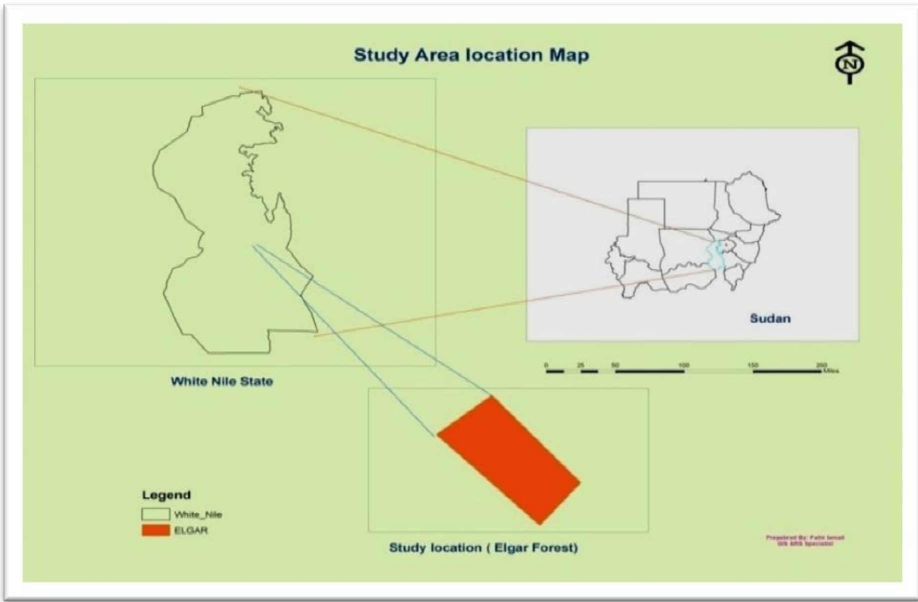
Abstract
This study was conducted in Al Gar forest reserve at the Eastern bank of the White Nile. It aims at investigating and modeling the allometric equation for dry weight of *Acacia nilotica* using different models of step-wise regression procedure. The results revealed that DBH was the best fitted parameter in the models used to predict tree dry weight and DBH^2 for crown dry weight, while DBH*H for bole dry weight with R^2 values of 0.907, 0.966, 0.61 respectively. The Multi-variable models tested showed lower value of regression coefficient (R^2). The selection of one independent variable (DBH) for estimation of total dry weight of *A.nilotica* makes the process of forest inventory easy, accurate, and time saving. Other models using different independent variables, revealed varied degrees of regression coefficients.
Key words: Allometric, dry weight, Co2 sequestration, Acacia nilotica, DBH.

Introduction
Forest biomass, expressed in terms of dry weight, is an important indicator of ecosystem energy potential and productivity. Biomass, in general, includes the above ground and below ground living mass, such as main stem, large branches, small branches, leaves, and roots. Due to the difficulty in collecting field data of below ground biomass, most previous research on biomass estimation focused on above ground biomass (AGB) (Lu, 2006). Estimating carbon through allometric equation may contribute positively in quantifying forest carbon stock. The accurate estimation of forest biomass is crucial for many applications, from the commercial use of wood (Morgan and Moss 1985) to the global carbon (C) cycle (Bombelli *et al*., 2009). Because of interest in the global carbon cycle, estimating aboveground biomass with sufficient accuracy to establish the increments or decrements of carbon stored in forests is increasingly important. Forest inventory data are valuable in forest carbon research because they provide tree ground-based estimate of carbon stock and fluxes across heterogeneous regions, furthermore there is no or very limited studies addressing these issues in the Sudan especially when considering carbon sequestration estimates. The tree biomass is generally determined based on forest inventory data and allometric equations. The allometric method uses estimate of the whole or partial biomass of a tree from measurable variables including main stem diameter, total height, and crown diameters. Estimates of carbon storage are obtained from allometric equations that use several parameters to calculate tree biomass: diameter at breast height (dbh), tree height, wood density, moisture content, site index and tree condition (Jamal, 2015). Parameters like wood density and moisture content vary not only among species but also among trees of the same species. Even within a single tree there can be significant differences in density and moisture content (DOE. 2001; Leys A, 2011). Therefore, some error is associated with the use of average densities and moisture contents in allometric formulas. There are two types of allometric biomass equations: volumetric and direct. Volumetric equations calculate the above ground volume of a tree using dbh and tree height for the species. Direct equations yield above ground dry weight of a tree using dbh and tree height (Jamal, 2015).

Methodology

White Nile state is located in south west part of the Sudan. The northern part of the state is semi-desert and the low rain savannah is in southern part of the state. It is bordered by Khartoum state from the north, North Kordofan state from the west, Republic of Southern Sudan from the south and Sennar state from the east. It lies between latitude 13˚17 ¯N and longitude 32 ˚20 ¯E, with a total area of 30411Km^2. Fig. (1).

Fig.(1): Location map of the study area



The vegetation coverage is gradually changing according to the amount of rainfall from northern to the southern part of the state. The state's vegetation ranges from a semi-desert in the north of the state to a poor Savannah in the south. The state is also rich in natural forests with mostly Savannah trees and shrubs. Elgar forest is located in Rabak locality between longitudes 13.30.776 N and 13.31.555 N and latitudes 32.59.927 E and 32.59.403 E with total area of about 51 fedans. The forest is covered by *A.nilotica* spp. On the flood basin of the White Nile eastern bank.

Data collection

10 healthy trees with different range of diameters and heights were selected carefully from the forest to represent the stand community. Total height, diameter at breast height, and crown diameters were measured for each tree and recorded. Trees were then felled and sectioned into logs according to the four classified parts, main stem, large branches, small branches, and leaves. The total green weight was obtained for each part using a balance. Subsamples were prepared from each part, measured and green weighted. Subsamples were dried using an oven, and then dry weighted using a sensitive balance. The total dry weight for each part was estimated from subsamples weight. The total above ground biomass (weight) was obtained for each tree, the amount of carbon(C) and CO_2 sequestered were determined. SPSS statistical package was used to analyze the collected data. Stepwise procedure for linear regression was selected to obtain the best fitted model for dry weight as a dependent variable, while DBH, total height, crown diameter and their interaction were used as independent variables. Different models of allometric equations were found with different degrees of coefficient of regression.

Results and Discussion

According to the step wise procedure used to select the best fitted parameters to estimate the wood biomass for *A.nilotica*. Table (1,2) shows the ANOVA and coefficients of the model which indicate high significance of the regression, constant, and the variable DBH. The equations used in the models represent estimation of oven dry weight of the dependent variables which could be used to estimate co_2 sequestered by these variables according to the following:

Carbon content (C) = 50% of the oven dry weight

Co2 sequestered = Carbon content * 3.6663

Table 1. ANOVA of the regression for A.nilotica

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	571210.960	1	571210.960	77.976	.000[a]
	Residual	58603.745	8	7325.468		
	Total	629814.705	9			

Table2. Coefficients of the model for *A.nilotica*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-517.243	113.838		-4.544	.002
	DBH	42.361	4.797	.952	8.830	.000

The best fitted equation for estimation of oven dry weight of *A.nilotica* tree species was shown in table (3)

Table 3. The fitted equation using dependent and independent variables for *A.nilotica*

Dependent Variable	Independent Variable	R^2	Equation
Dry Weight (D.W)	DBH	0.907	-517.243+42.361DBH

The results of model performance for estimation of above ground oven dry weight using different dependent variable(s) are shown in table (4,5,6). Plotted data was shown in fig.(2).

Fig.(2):plotting dry weight against DBH

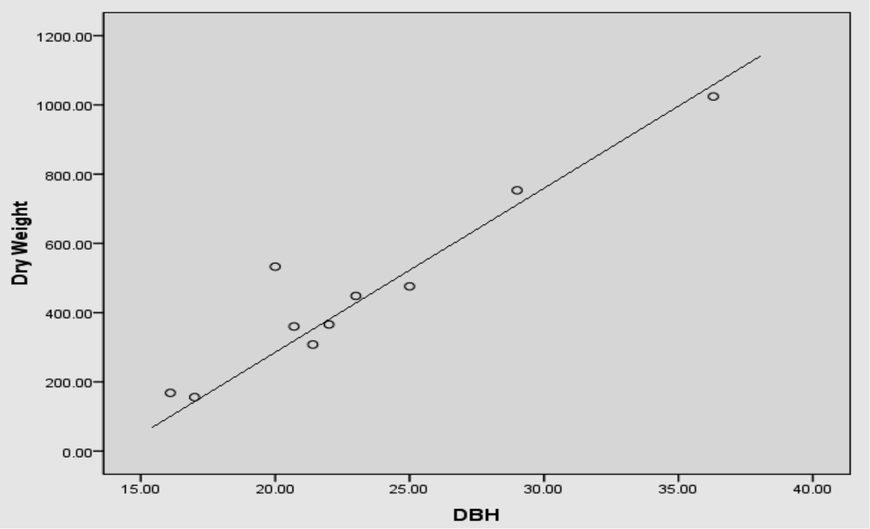


Table 4. Model performance and regression parameters for *A.nilotica* using above ground dry weight as dependent variable.

Dependent variable	I.Variables	R^2	S.E	F	Equation
T.Dry Weight	DBH	0.907	85.5	77.97	-517.243+42.361DBH
T.Dry Weight	DBH^2	0.898	89.80	70.085	$8.12+0.801DBH^2$
T.Dry Weight	DBH*H	0.902	87.9	73.4	-211.53+1.72DBH*H
T.Dry Weight	DBH^2*H	0.903	87.5	74.12	$89.09+0.038DBH^2*H$
T.Dry Weight	$DBH*H^2$	0.846	110.09	43.99	$-15.245+DBH*H^2$

Table 5. Model performance and regression parameters for *A.nilotica* using crown dry weight as dependent variable.

Dependent variable	I.Variables	R^2	S.E	F	Equation
Crown D.W.	DBH	0.94	35.45	125.36	-338.3+22.25DBH
Crown D.W.	DBH^2	0.966	26.88	223.91	$-66.815+0.429DBH^2$
Crown D.W.	DBH*H	0.85	55.97	45.5	-161.51+0.865DBH*H
Crown D.W.	DBH^2*H	0.919	41.16	90.9	$-18.133+0.02DBH^2*H$
Crown D.W.	$DBH*H^2$	0.752	72.14	24.2	$-56.15+0.035DBH*H^2$

Table 6. Model performance and regression parameters for *A.nilotica* using bole dry weight as dependent variable.

Dependent variable	I.Variables	R^2	S.E	F	Equation
Bole Dry Weight(BDW)	DBH	0.55	98.69	9.77	-167.119+17.291DBH
Bole Dry Weight(BDW)	DBH^2	0.535	100.32	9.199	$48.90+0.324DBH^2$
Bole Dry Weight(BDW)	DBH*H	0.611	91.8	12.546	-57.903+0.745DBH*H
Bole Dry Weight(BDW)	DBH^2*H	0.575	95.92	10.81	$76.629+0.016DBH^2*H$
Bole Dry Weight(BDW)	$DBH*H^2$	0.61	91.85	12.516	$20.247+0.032DBH*H^2$

From above tables, DBH was found to be the best fitted independent variable for estimating the oven dry weight of the total tree species of *A.nilotica* in Alshawa forest. This could be measured according to the value of R^2. The value decreased when height (H) was introduced in the model. The introduction of one variable with high value of R^2, gives the model an advantage by measuring one parameter to estimate the dry weight and/or carbon dioxide sequestered. For the crown dry weight, the best fitted variable was DBH^2 with R^2 of 0.966, while introducing DBH resulted in R^2 equal to 0.94. Introducing height in the model reduced the value of R^2. This may indicate that DBH was the most suitable and compatible variable for estimating dry weight and/or carbon dioxide sequestered for the tree or the crown. For bole dry weight, Height (H) and DBH together gave the best fitted equations for the model by using DBH*H and $DBH*H^2$ with R^2 of 0.61for both.

Conclusion and recommendations

The study concluded that DBH was the best independent variable introduced to estimate the above ground dry weight and/or carbon dioxide sequestered by different tree parts. The study also concluded that measuring only the DBH will leads to the best estimation of dry weight and/or Co2 sequestered by *A.nilotica* in Alshawa forest which further help in the process of forest inventories. The study recommends using DBH as an independent variable for estimating biomass productivity of *A.nilotica*. The results obtained could be compared and replicated with other tree species to produce a biomass production tables and equations for different tree species.

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