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# Modeling Dry Weight and Carbon Dioxide Sequestration for *Acacia tortilis* Alhumara Reserved Forest, White Nile State, Sudan

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## Abstract

The study was conducted in Alhumara reserved forest at the west-northern part of White Nile State. It aims for investigating and modeling the allometric equation for dry weight of *Acacia tortilis* using different models of step-wise regression procedure. The results revealed that $DBH^2*H$ was the best fitted parameter in the models used. The Multi-variable model selected makes the process of forest inventory time consuming and could be replaced by $DBH^2$ as independent variable in forest with expanded or large area, and when *A.tortilis* was concerned. The study recommended that for *Acacia nilotica*, DBH could be used to estimate the biomass dry weight. While for *Acacia tortilis*, $DBH^2*H$ could be used only when DBH was equal to or greater than 8cm. For diameters less than 8 cm. the summation of crown and pole dry weight should be applied.

**Key words: Allometric, *Acacia tortilis*, $Co^2$ sequestration, dry weight and DBH.**

## Introduction

Forests play a double role in climate regulation. Deforestation and forest degradation release the carbon that is stored in the trees into the atmosphere as carbon dioxide and other gases. Scientists estimate that deforestation and forest degradation accounts for 12 to 20 per cent of the annual green house gases (GHG) emissions. But, in addition, healthy forests absorb carbon dioxide from the atmosphere. Studies suggest that 5 billion of the 32 billion tons of carbon dioxide emitted annually by human activities (that is over 15 percent) are absorbed by forests. But if deforestation and forest degradation are a double loss in the fight against climate change, EPA (2012).

Improved knowledge of carbon stocks and fluxes is needed in order to understand the current state of the carbon cycle and how it might evolve with changing land use and climate conditions (Hollinger, 2008). This had led to an increased interest in estimating forest biomass. Tree biomass is an important component of the carbon pool in forest, and can be estimated by using biomass or by relating biomass functions to tree-level data obtained in forest inventory (Hall *et al* 2001). Sustainable forest management can increase total carbon sequestration because much of the carbon in wood products removed during forest harvest is not returned immediately to the atmosphere, but is stored in durable products and more trees can be grown to sequester more carbon (Liu and Zhao(2013).

Carbon is stored in forest ecosystems in the form of living tree biomass and dead organic matter. In most forests, the largest carbon pools are above ground live biomass and mineral soil organic matter, with smaller amounts in roots and surface detritus.(Holinger , 2008).

The conventional allometric biomass model is the most commonly fitted and reported equation (Návar, 2010).

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. 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 (Domec, 2002) . 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).

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$^2$.

Elhumara forest is located in Eldueim locality between longitudes 13.95.377 N and 13.94.872 N and latitudes 32.04.135 E and 32.04.242 E with total area of about 258.064 feddans( Fig.(1)).

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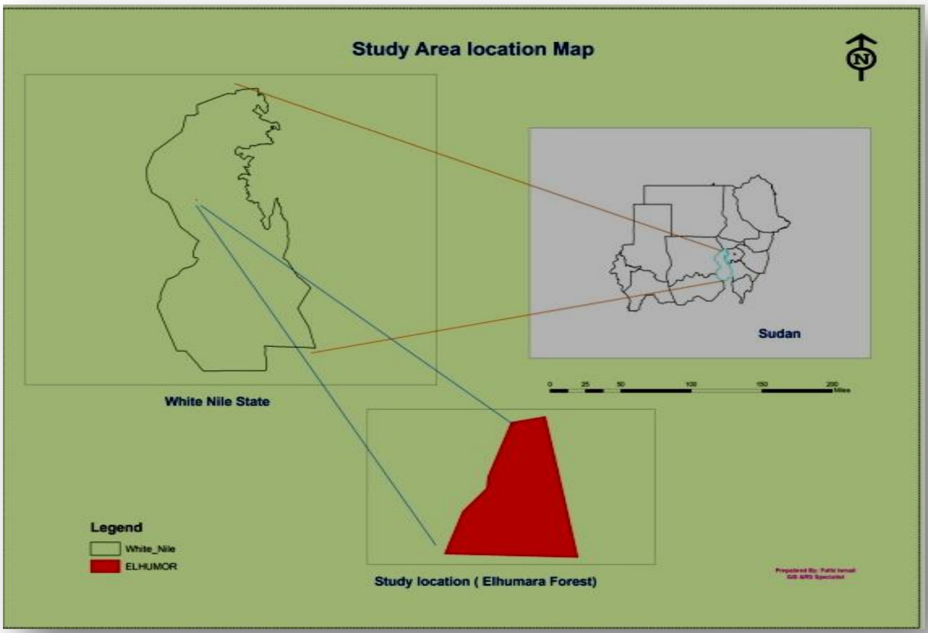
**Fig.(1):Location map of the study area**




**Source: Forest National Corporation. White Nile State. 2017.**

## Materials and Methods

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 heigh (DBH), and crown diameter 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 balance. Subsamples were prepared from each part, measured and weighted. Subsamples were dried using an oven, and then dry weighted using sensitive balance. The total dry weight for each part was estimated from subsample weight.

The total above ground biomass (weight) was obtained for each tree. SPSS statistical package was used to analyze the collected data. Stepwise linear regression was selected to obtain the best fitted model for dry weight as a dependent variable, while DBH, total height and crown diameter were used as independent variables.

Different models of allometric equations were found with different degrees of coefficient of regression.

## Results and Discussion

Five models using different parameters as independent variables were used to estimate the total dry weight of the three tree parts. These models include DBH, $DBH^2$, DBH*H, $DBH^2$*H, DBH*$H^2$. The allometric equations derived were selected according to the step wise procedure of linear regression. The entered independent variables in table (1), showed variation in the value of $R^2$.

**Table (1): The models of independent variables used in regression for tree dry weight of *A.tortilis.***

| Dependent variable | I.Variables | $R^2$ | S.E | F | Equation |
|---|---|---|---|---|---|
| Total Dry Weight | DBH | 0.585 | 97.011 | 11.29 | -304.469+23.535DBH |
| Total Dry Weight | $DBH^2$ | 0.672 | 86.244 | 16.41 | -100.82+0.64$DBH^2$ |
| Total Dry Weight | DBH*H | 0.593 | 96.064 | 11.67 | -252.385+2.668DBH*H |
| Total Dry Weight | $DBH^2$*H | 0.752 | 75.08 | 24.21 | -108.291+0.084$DBH^2$*H |
| Total Dry Weight | DBH*$H^2$ | 0.5 | 108.09 | 7.542 | -149.484+0.251DBH*$H^2$ |

The selected models used in the process of equation fitting were, a+bx, a+b$x^2$ , a+bx*y, a+b$x^2$*y, and a+b*$x^2$. Where "a" represent unstandardized coefficient of the constant, "b" represent the unstandardized coefficient of The dependent variables used, while x and y were the variables selected to estimate total dry weight, crown dry weight, and bole dry weight.

From table (1), the best fitted equation for estimating total dry weight for *A.tortilis* is that using independent variable $DBH^2$H with $R^2$ equal to 0.752. Introducing $DBH^2$ increase the value of $R^2$, while introducing the height (H) into the model reduce the value. This result is consistent with Li and Zhao (2013) whom found that the use of height implied a decrease in the sum of squares of residual by 72%for stem wood.

**Table ( 2 ): The models of independent variables used in regression for crown dry weight of *A.tortilis***

| Dependent variable | I.Variables | $R^2$ | S.E | F | Equation |
|---|---|---|---|---|---|
| Crown Dry Weight | DBH | 0.642 | 50.30 | 14.32 | -164.343+13.745DBH |
| Crown Dry Weight | $DBH^2$ | 0.723 | 44.2 | 20.923 | -44.069+0.37$DBH^2$ |
| Crown Dry Weight | DBH*H | 0.612 | 52.336 | 12.629 | -126.94+1.511DBH*H |
| Crown Dry Weight | $DBH^2$*H | 0.8 | 39.479 | 28.252 | -45.671+0.48$DBH^2$H |
| Crown Dry Weight | DBH*$H^2$ | 0.477 | 60.78 | 7.295 | -64.617+0.139DBH*$H^2$ |

Table(2) showed the best fitted equation to estimate dry weight of the crown of *A.tortilis* spp. The best fitted independent variable was the $DBH^2$*H with $R^2$ value of 0.8. Introduction of height into the model reduced the value of R2 by 0.03, while it gives high value of $R^2$ when introduced with $DBH^2$.

**Table ( 3 ): The models of independent variables used in regression for pole dry weight of *A. tortilis*.**

| Dependent variable | I.Variables | $R^2$ | S.E | F | Equation |
|---|---|---|---|---|---|
| Pole Dry Weight(PDW) | DBH | 0.724 | 10.87 | 21.02 | -35.883+3.599DBH |
| Pole Dry Weight(PDW) | $DBH^2$ | 0.763 | 10.08 | 25.766 | $-3.136+0.094DBH^2$ |
| Pole Dry Weight(PDW) | DBH*H | 0.752 | 10.31 | 24.267 | -28.653+0.413DBH*H |
| Pole Dry Weight(PDW) | $DBH^2*H$ | 0.9 | 7.944 | 46.383 | $-4.225+0.012DBH^2H$ |
| Pole Dry Weight(PDW) | $DBH*H^2$ | 0.622 | 12.73 | 13.157 | $-12.986+0.039DBH*H^2$ |

Table (3) indicated that $DBH^2*H$ as independent variable gives the highest value of $R^2$that reach 0.9. This revealed that the DBH2*H was the compatible independent variable for the estimation of biomass production for the three tree parts.

**Conclusion and recommendations**

The study concluded that estimation of dry biomass of *A. tortilis* could be predicted by using $DBH^2*H$ as independent variable. This model gives high value of $R^2$, low value of standard error (S.E.),and high F value. Other species such *A.nilotica*, shows DBH variable alone as the best fitted independent variable for estimation of dry biomass. This may be due to form of the tree, main stem, and branching of the tree species.

The study recommend that $DBH^2*H$ could be used in estimation of dry weight in forests of relatively small areas, while in large areas, $DBH^2$could used for time consumption. Allometric equations for estimating dry weight of other species could be derived to estimate the total carbon dioxide sequestration in the whole forest land of the country.

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