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Allometric Equation for Biomass Determination in Chuqala Natural Forest, Ethiopia: Implication for Climate Change Mitigation

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Abstract

Biomass determination of species-specific in forest ecosystem by semi-destructive measures requires the development of allometric equations; predict aboveground biomass observable independent variables such as, Diameter at Breast Height, Height, and Volume are crucial role. There has not been equation of this type in mountain Chuqala natural forest. In this study two species namely, *Hypericum revolutum* Vahl. & *Maesa lanceoleta* Forssk. with tree diameter classes (15-20, 20.5-25, and 25.5-35 cm), with the purpose of conducting allometric equations were characterized. Each species assumed considered individually. For the linear model fit the two observed variable DBH, H and V were preferred for the prediction of above ground biomass. The best fitted model choose among the two formed model were identified using Akaike Information Criterion (AIC), and R^2 and adjacent R^2. Based on this the best fit model for *Hypericum revolutum* Vahl. was AGB=-681.015+4,494.06 (DBH), and for *Maesa lanceoleta* Forrsk. was. AGB=-936.96+5,268.92 (DBH).

Key Words: above ground biomass, Chuqala mountain, semi-destructive, total biomass, *Hypericum revolutum*, *Maesa lanceoleta*

Introduction

Reliable estimation of total biomass for standing trees and forest or their components such as stem, branches, foliage and stump are very crucial parts of forest carbon. Destructive harvesting of forest tree is not always possible because it is time-consuming and there is high risk of uncertainty when the obtained results are extrapolated to larger area (Mcwilliam et al. 1993). Moreover, the most common approach is to obtain biomass estimates at standing level. Biomass is the result of Diameter at Breast Height (DBH), Height (H) and wood density (ρ) in a given location. However, the contribution of these variables to the above ground biomass (AGB) differs from area to area. Succession stage of the forest, disturbance levels, species composition, etc. (Brunig 1983; Whitemore 1984). Several attempts have been made to estimate biomass involving all the parameters such as, DBH, tree height and wood density with different regression equation (Cannell 1984). It was the fact that there is strong relation of biomass with these parameters (Rai 1981; Rai and Proctor 1986).

Because of interest in global carbon cycle, estimating above ground biomass with sufficient accuracy to establish the increment and decrement of carbon stock in forest is increasing important on earth ecosystem forest forms a great component of the carbon reserves, and life on the earth eco-

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system influenced by this carbon reserves (Whittaker and Likens 1975). Specific- species in a given forest ecosystem also has a great important in the global carbon cycle.

Managing forests through forestry, agroforestry, and community forestry unity is as a critical opportunity for a climate change mitigation and adaptation (Canadell and Kaupach 2008). Afforestation and reforestation (A/R) project activities are eligible under the Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nation Convention on Climate Change (UNFCCC 1998), likewise allometric equations are useful to estimate the carbon storage of the tree species the result from tree plantation activities with aim to implement Afforestation or Reforestation (A/R) Clean Development Mechanism (CDM) projects worldwide. Thus, the negotiation on Reducing Emissions from Deforestation and forest Degradation (REDD) and important role of conservation, sustainable forest management and enhancement of forest carbon stocks in developing countries under the next commitment periods of the Kyoto Protocol have aimed even more attention on methods for estimating biomass and carbon stocks (UNFCCC 2009).

Reducing emission from deforestation and forest degradation instead conservation of forest + sustainable forest management + enhancement forest carbon stock in forest (restoration, afforestation, agro forestry, forest rehabilitation etc.) (REDD^+) (Navar et al. 2002). the emerging mechanism of the Kyoto protocol, high resolution temporal and spatial assessments of carbon stocks are required with the exception of few reasons where a whole tree population can be harvested to determine its biomass. Though tree biomass is over all predicted based on forest inventory data and allometric equations.

The allometry methods use allometric equations to estimate the whole or particular (by compartment) mass of a tree from measureable tree dimensions, such as stem diameter and height (Kangas and Maltano 2006). Therefore, the dendrometric parameters of all trees are measured and the allometric equations are then used to estimate the stand biomass by assuming the biomass of the individual species. Therefore two methods to build allometric equations for individual specific-species. A sprout or stand, these methods directly measure the biomass by harvesting the tree and measuring the actual mass of each of its compartments, (e.g. roots, stems, branches and foliage) (Kangas and Maltano 2006).

Semi-destructive methods are attempt to estimate tree biomass by measuring variables that are more accessible and less time consuming to assess, e.g. wood volume and density (Peltier et al. 2007). Weighing trees in the field is undoubtedly the most precise or accurate methods of estimating above ground tree biomass, but it is time consuming and is generally based on small sample sizes. Species- specific allometric equations are preferred because tree species may differ greatly in tree architecture and wood gravity (Kettering et al. 2001).

Moreover, in tropical forest stand, more than 7,000 tree species may be found (Gibbs et al. 2007), and allometric equations should represent the variability of biomass for those species. As mentioned (Mcwalliam et al. 1993), destructive harvesting to made allometric equation seldom conducted in the tropics and sample plot sizes have been small compared to the scale or species diversity patterns. Therefore results may not be representative. Grouping all species all together and using generalized allometric relationship that are stratified by broad forest type or ecological zone has been highly effective in the tropics (Brown et al. 1989). It is evident that, there are very limited allometric equations in Sub-Saharan Africa including Ethiopia, none of the used by (Chave et al. 2005), to made general allometric equations was from African forests.

Ethiopia signed the United Nation Framework Convention on Climate Change that international community adopted in 1992 to combat Climate Change in the world. Later Ethiopia ratified this on 5 April 1994. Since then, Ethiopia has paid great attention to the issue of Climate Change and various activities have been under taken including conducting Climate Change country study and participating in Climate Change negotiation (UNFCCC 2009). Protecting and plantation forests as ecological benefits as well, economic and ecosystem services, including as carbon storage is one of the four pillars of Climate-Resilience Green Economy (CRGE) initiative, which Ethiopia aim to achieve its development goals while limiting 2030 Green House Gases (GHG) emissions to around todays 150 Mt CO_2e and around 250 Mt CO_2e less than estimated under convectional development path.

Ethiopia is lacking inventory data of forest carbon stock, and this makes the country to fail to develop sustainable forest management planning that attracts climate finances carbon stock evaluation of specific- species in mountain forest like mount Chuqala natural forest. Therefore the objective of this study is to develop Allometric Equation for estimating above ground and below ground biomass of *Hypericum revolutum* and *Maesa lanceoleta* indigenous tree species in mount Chuqala natural forest and its implication for sustainable forest for climate change mitigation.

Materials and Methods

Study site location

The study site is located in Mount Chuqala natural forest of East Shoa- Zone, Adulala district of the central rift valley boarder of Ethiopia and at an altitude of 3,000 m .a.s.l. It is located between 38° 42′-38° 55′ E longitude and 8° 28′-8° 35′ N latitude. It covers the area of 9,400 hectares and the forest has a crater that is estimated at 200 hectares. The mean annual temperature ranges between 11°C , and 22°C , and average annual precipitation is 895 mm for the last 10 years based on Ethiopia Metrological Agency data from 2004-2014 , with bimodal rain fall distribution of lower precipitation from February to April, and high rain fall distribution from June to September. The main rock type in the area is sediments form in low altitude gradient up to tip of mountain, while at the tip of the mountain areas are covered with volcanic rocks; As a result there was a Crater Lake formation at the middle of the tip in circular forms. The main tree species in the study site were Myrsine *melanophloeos, Erica arborea, Juniperus procera, Galiniera saxiferaga, Hygenia abyssinica, Hypericum revolutum, Olea europea ssp. cuspidatea, Acacia decurrens, Arundinaria alpinea, Maesa lanceolata, Podocurpus falcutus*, and *Inulia confertifora* are some of the species.

Methodology

Primary field and laboratory data were used in order to collect the relevant data to achieve the objective of the study. The sources of primary data were obtained through field and laboratory measurements to estimate dendrometric quantities on the selected species of the study area. The methodological procedures using standard allometric equation development techniques and carbon inventory principles as indicated in (Picard et al. 2012), the manual for building tree biomass and volume allomertic equation.

Data collection

The two tree species in the natural forest were selected for developing above ground biomass equation. *Hypericum revolutum* and *Maesa lanceoleta* tree of each species were randomly selected along forest transect based on diameter class from 15-20 cm, 20.5-25 cm, and 25.5-35 cm for tree selected species-specific that had been obtained from the plot inventory data. The tree was dendrometrically representative of the population for each species- specific studies.

Data analysis

A total of 24 *Hypericum revolutum*, and *Maesa lanceoleta* individual plants from three plots (four trees per plot for each species) were selected. According to (Picard et al. 2012), guide line there were a lot task work had been done by selecting few trees for estimation of biomass in order to minimize the error of sampling plants were classified into three groups based on Diameter at Breast Height (DBH) class ranging from 15-20 cm, 20.5- 25 cm, and 25.5-35 cm. The individual plants were located in the immediate delineated area with in the sample plot of 20×20 m quadrant and all individual of DBH (15-20 cm, 20.5-25 cm, and 25.5-35 cm) were identified for *Hypericum revolutum*, and *Maesa lanceoleta* from three diameter classes two individuals plants were then randomly selected for each plot.

Above ground biomass estimation

Forest regulation meant that trees could not be felt, and then Above Ground Biomass was estimated by semi-destructive methods. For the sake of measurements and analysis, the trees were divided into separately architectural elements as trimmed small branches, untrimmed large branches and trunks. As a whole one small branch or two small branches per individual trees were destructed. Trunks and large branches weights were estimated serial measurements of height, diameter, and section volume using parabolic estimation of the shape. These estimates were used to develop whole tree regressions of trunk and large branches and canopy component weight.

Trimmed fresh biomass

Wood, and leaves of small branches were trimmed from the individual large branches, and determine (by weighing separately, fresh biomass of the leaves from the trimmed one) B trimmed fresh leaf, then through randomly sampling of leaves from the untrimmed large branches at least few sample of leaves from one trimmed or two trimmed small branches, were generally required to constitute the aliquot, and measured its fresh weight B aliquot fresh wood in g, and aliquot of the wood was also taken at random from the trimmed branches, without debarking. The fresh volume of the wood aliquot were measured later in the lab, and the value used to determine mean wood density.

Untrimmed fresh biomass

Untrimmed biomass was indirectly as non- destructively, the different branches in the trimmed trees were processed differently from the large branches and trunk. For the small branches only the basal diameter was measured. The biomass of these small untrimmed branches was estimated from the relationship between their basal diameter and their mass. The biomass of the trunk, and large branches were estimated from measurement of volumes (Vi in cm^3), mean wood density ($\dot{\rho}$ in cm^3). The large branches and trunk should be divided virtually in to sections that were, then materialized by making the tree. The volume Vi of each section i was obtained by measuring its diameter (or its circumferences), and its length. Section about one meter in length was preferably chosen in order to consider diameter variation along the length of the trunk and the branches. The dry biomass of the tree was obtained by the sum of the trimmed dry biomass and the untrimmed dry biomass (Picard et al. 2012).

$$\text{B dry} = \text{B trimmed} + \text{B untrimmed it} \qquad \text{(equ. 1)}$$

From the fresh biomass B aliquot fresh wood of a wood aliquot, B aliquot fresh leaves aliquot and its dry biomass, B aliquot dry wood and dry leaves, the moisture content of the wood were measured by the following equations respectively as given in (Picard et al. 2012).

$$\text{X wood} = \frac{B\ aliquot\ dry\ wood}{B\ aliquot\ fresh\ wood}, \text{ and}$$

$$\text{X leaf} = \frac{B\ aliquot\ dry\ leaf}{B\ aliquot\ fresh\ leaf} \qquad \text{(equ. 2, 3)}$$

Trimmed dry biomass can then being calculated:

$$\text{B trimmed} = \text{B trimmed fresh wood} \times \text{X wood} + \text{B fresh leaf} \times \text{X leaf} \qquad \text{(equ. 4)}$$

Where B trimmed fresh leaf was the fresh biomass of the leaves stripped from the trimmed branches and B trimmed fresh wood was the fresh biomass of the wood in the trimmed branches. After determining the trimmed components of the tree then it is possible to calculate the untrimmed components of the tree. Two calculation was required to calculate the dry biomass of the untrimmed parts (i.e. that still standing); one for the small branches, and the other for the large branches and trunks. The untrimmed biomass was the sum of the two results (Picard et al. 2012).

$$\text{B untrimmed dry} = \text{B untrimmed dry branch} + \text{B dry section} \qquad \text{(equ. 5)}$$

According to (Picard et al. 2012), each section i of the trunk and large branches may be considered to be a cylinder of volume (Newton's Formula or trenched cone volume formula.

$$\text{Vi} = \frac{\pi}{8} 8Li\ (Di1 + \text{Di2}) \qquad \text{(equ. 6)}$$

Where Vi was the volume of the section i, Li its length, and D1i1 and Dli2 where the diameter of the two extremities of the section i.

The dry biomass of the large branches and trunk was the product of mean wood density and total volume of the large branches and trunk (Picard et al. 2012).

$$\text{B dry section} = \dot{\rho}\ \text{X}\ \epsilon ivi \qquad \text{(equ. 7)}$$

Where as mean wood density was calculated by

$$\rho = \frac{B\ aliquot\ dry\ wood}{V\ aliquot\ fresh\ wood} \qquad \text{(equ. 8)}$$

The dry biomass of the untrimmed small branches was calculated using models between dry biomass and basal diameter. This model was established by following the same procedures as for the development of the allometric model (Picard et al. 2012) power type equations were used:

$$\text{B dry biomass} = a + bD^{c} \qquad \text{(equ. 9)}$$

Where a, b and c model parameters, and D branch basal diameter, using a model of this the dry biomass of the untrimmed branches was:

$$\text{B untrimmed dry branch} = \text{€J}\ (a + b\ D^{c}J) \qquad \text{(equ. 10)}$$

Where the sum was all the untrimmed small branches and D_J was the basal diameter of the branch.

Estimation of below ground biomass (BGB)

Below ground biomass estimation was much more difficult, and time consuming than estimation of above ground biomass. According to (Macdicken 1997). Standard method for estimation of below ground biomass can be obtained as 20% of above ground biomass i,e, root to shoot ration value of 1:5 was used; similarly (Pearson et al. 2007), described this method as it is more efficient and effective to apply a regressions model to determine below ground biomass from knowledge of biomass as above ground. Thus the equation developed by (Macdicken 1997), to estimate below ground biomass was used. The equation is given as:

$$\text{BGB} = \text{AGB} \times 0.2 \qquad \text{(equ. 11)}$$

Where, BGB was below ground biomass, AGB above ground biomass, 0.2 is conversion factor (20% of AGB).

Results

Biomass estimation based on the (Picards et al. 2012), guide line was followed the series procedures. Then begun start to classify the trees in to three Diameter at Breast Height (DBH) classes which help to measures the variability of most of the tree size in specific study area. Hence, 24 individuals per specific- species were selected at three plots based on the Diameter at Brest Height (DBH) classes.

Trimmed biomass

Fresh wood biomass from 12 aliquot for *Hypericum revolutum* had a total mass, mean, and range value of 6,120 g,

Table 1. Trimmed components of *Hypericum revolutum* and *Maesa lanceolata*

Tree components	No.	Max	Min.	Range	Sum	Mean
Before oven dry (wood) *H. revolutum*	12	640	410	230	6,120	510
After oven dry (wood) *H. revolutum*	12	311.3	204.3	113.01	2,958.9	246.6
X wood	12	0.54	0.44	0.06	5.8	0.48
Beforeovendry (leaf) *H. revolutum*	12	349	200	140	2,970	254.6
After oven dry (leaf) *H. revolutum*	12	245.3	123.3	121.9	1,955.9	162.99
X leaf	12	0.76	0.57	0.19	6.74	0.63
Before oven dry (wood) *M. lanceoleta*	12	800	500	300	7,570	630.83
After oven dry (wood) *M. lanceoleta*	12	415.2	256.5	158.5	3,938.5	328.24
X wood	12	0.55	0.46	0.09	6.22	0.52
Before oven dry (leaf) *M. laceoleta*	12	500	270	230	4,150	345.4
After oven dry (leaf) *M. laceoleta*	12	243.01	98.5	144.5	1,840.3	153.4
X leaf.	12	0.48	0.38	0.13	5.23	0.43

Before oven dry (wood) Hypericum, fresh weight of branches wood & before oven (wood) Maesa fresh weight of branches wood; After oven dried (wood) Hypericum, the dried weight of branches wood & after oven (wood) Maesa the dried weight of branches wood; Before oven (leaf) of Hypericum, fresh weight of branches leaf, & before oven (leaf) Maesa fresh weight of branches leaf; X wood Hypericum, the moisture content of wood aliquot, and X wood of Maesa the moisture content wood aliquot.

510 g, and 230 g value respectively. The total mass, mean and range after oven dry trimmed aliquot became 2,958.9 g, 246.61 g and 113.03 g value respectively. The total mass of fresh leaves was 2,970 g, 254.6 g mean, and 140 g range value, after oven dried this became total mass, mean and range of 1,955.95 g, 162.99 g, and 121.89 g value respectively. Then this result gave the X wood and X leaf according to (equ. 2, 3). The total×wood 5.8 g, mean value 0.48 g, and range value became 0.06 g; while X leaf total mass was 6.06 g, mean value 0.63 g and range value 0.19 g. Similarly the fresh wood biomass of *Maesa lanceoleta* had a total mass 7,570 g, mean value of 630.83 g, and range 300 g. After oven dried the 12 individuals had a total mass, mean, and range value of 3,938.5 g, 328.24 g, and 158.5 g respectively. Likewise the fresh leaves total mass were 4,150 g with 345.4 g mean and the range value of 230 g. After they were dried out in oven the total mass, mean and range value became 1840.3 g, 153.35 g, and 144.51 g respectively. The total mass, mean, and range of X wood and X leaf of *Maesa lanceoleta* could be estimated and had a sum total mass, mean, and range value of 6.22 g, 0.52 g, and 0.09 g for X wood respectively, and 5.23 g total mass, 0.43 g mean value, 0.13 g range value for X leaf (Table 1).

Table 2. Trimmed branches density (g/cm^3) and whole tree volume (m^3)

Tree	Density of a tree (g/cm^3)		Volume of a tree (m^3)	
	Hypericum	*Maesa*	*Hypericum*	*Maesa*
1	512.45	492.33	1.205	1.642
2	517.55	424.45	1.276	1.631
3	777.81	475.44	0.872	1.099
4	469.41	466.75	1.383	1.23
5	589.46	395.35	1.214	0.267
6	662.81	410.81	1.276	0.292
7	915.26	501.45	0.987	1.516
8	944.78	397.85	0.215	0.234
9	1,465.02	427.32	0.145	0.285
10	1,017.71	464.82	0.214	0.226
11	430.01	427.66	0.278	1.303
12	470.55	466.86	0.277	1.862

Untrimmed biomass

The estimated biomass of each specific tree individual was considered through semi-destructive method using the guide line indicated in (Picard et al. 2012) by indirect weight of trees. Weighing of tree was carried out by measuring the circumference by one meter interval up to tip of the trees including the large branches. The fresh biomass of trunk and large branches were calculated from volume and density measurements and it was hypothesized that each section cut was considered to cylinder. The section cut part had a length of one meter and diameter of the initial and after one meter end. The volume of each cut section was determined based on equation (6), and the total volume of each tree was also known. The density was considered by displacement theory (Table 2).

For the 12 individuals of *Hypericum revolutum*, and *Maesa lanceoleta*. Volume of trimmed aliquot had been a vital role for prediction of density that was critical for the estimation of the total biomass of a sampled tree. Hypothetically assumed that density of a semi-destructive wood aliquot considered being the same in all compartments of a tree and the whole biomass of a tree then took the small branch's density of the whole tree.

Calculation of tree density and volume of trunk and large branches of a tree then had been ability to estimate the dry section which was existed at the trunk and large branches by one meter interval (Table 3).

Table 3. Untrimmed components of *Hypericum revolutum* and *Maesa lanceoleta*

section/s	No.	Max.	Min.	Range	Sum	Mean
Dry section *Hypericum*	12	712.7	36.35	676.33	5,062.4	421.86
Drybranch *Hypericum*	12	3.904	2.95	0.95	44.39	3.69
Dry section of *Maesa*	12	982.59	76.92	905.87	5,841.55	486.79
Dry branch of *Maesa*	12	7.33	2.97	4.36	5.43	4.36
Buntrimmed *Hypericum*	12	716.62	39.34	677.28	5,108.79	425.55
B untrimmed *Maesa*	12	989.92	79.69	910.23	5,846.98	491.15

According to (Picard et al. 2012) guide line equation (7) the sum total dry section, range and mean value of *Hypericum revolutum* became 5,062.40 kg, 676.33 kg, and 421.86 kg respectively. Similarly the sum total dry section of *Maesa lanceoleta* was 5,841.55 kg, while the range, and mean value became 905.87 kg, and 486.79 kg. Followed this estimated calculation the dry section was the determination of dry branch based on equation (10) that estimating of untrimmed small branches uses allometric equation. The allometric model was developed for untrimmed branch using all trimmed wood aliquot from 12 individual of trees. In order to fit the equation there were two variables that is the dependent and independent one. Based on this the independent was represented by D which is the basal diameter while the dependent variable was represented by dry branch that represented the biomass of trimmed small branch and its basal diameter was the "D". Based on this the equation formulated was; Bdry branch= 10.034+75.98D for *Hypericum revolutum*, and 12.215+47.081D for *Maesa lanceoleta*. The model significant ($p<0.021$) for *Hypericum revolutum*, and $p<0.000$ for *Maesa lanceoleta* and the $R^2=0.98$ for *Hypericum revolutum*, and $R^2=0.99$ for *Maesa lanceoleta*.

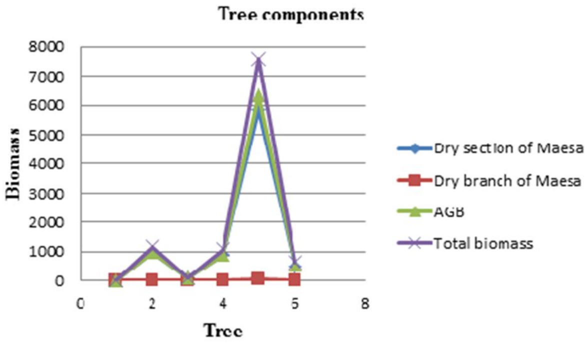

Fig. 1. *Hypericum revolutum* components.

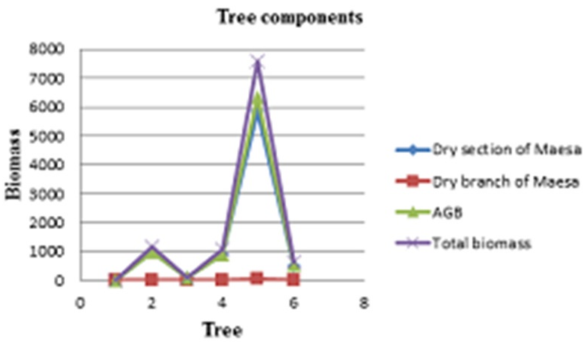

Fig. 2. Biomass of *masea lanceoleta* components.

Based on this to predict the biomass of untrimmed small branches or dry branches of the non-destructive compartment dry branches through the model substitute "D" by measuring the circumstances or basal diameter of small untrimmed tree component of dry branches based on equation (10). Using this equation, the small untrimmed dry branch of *Hypericum revolutum* had a sum total of 5,106.79 kg, range, and mean value became 677.28 kg, and 425.55 kg respectively. Likewise the sum total, range and mean value of *Maesa lanceoleta* became 5,846.98 kg, 910.23 kg and 491.15 respectively. Finally the biomass of the 12 selected species individuals in different value in Fig. 1, 2 that gives various amount of biomass were the predicted factor among other independent variables like H, and V, though DBH of this specific-species was a vital role to estimate the biomass of the selected trees which was, as the DBH increases the biomass of both selected species also increases too.

Based on the result, all selected species were filling up to measure the above ground biomass of a tree. All the finding of this study mentioned above had been used to determine the overall objective of semi-destructive that was measuring the biomass of a tree species (Fig. 3).

It can be conclude that the 12 individual measurements the total AGB of *H.revolutum* had 5,107.78 kg, with 425.64 kg mean value and 675.92 kg, range value. And also had a total mass of 1,021.55 kg, with mean of 85.73 kg, value, and range of 135.12 kg BGB of this species. By adding up the AGB and BGB the above value that obtained a sum total of 7,587.63 kg, 627.82 kg and 1,087.63 kg mean and

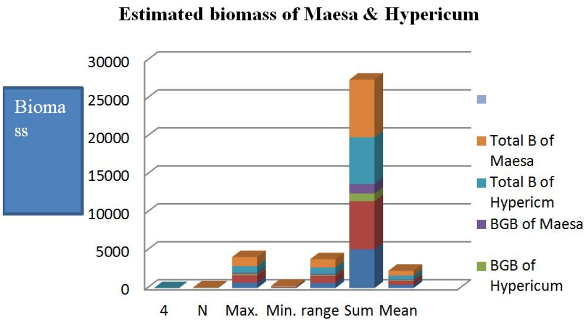

Fig. 3. AGB, BGB and total biomass for *Hypericum revolutum* & *masea laceoleta*.

Table 4. AGB, BGB, and total biomass of *Hypericum revolute* and *Maesa lanceoleta*

Para meter	N	Max.	Min.	range	Sum	Mean
AGB of *Hypericum*	12	716.09	40.15	675.92	5,107.78	425.64
AGB of *Maesa*	12	986.65	80.66	905.99	6,323.03	522.19
BGB of *Hypericum*	12	143.22	8.03	135.12	1,021.55	85.13
BGB of *Maesa*	12	197.33	16.56	181.18	1,264.61	104.638
Total B of *Hypericum*	12	859.31	48.18	811.04	6,129.33	510.77
Total B of *Maesa*	12	1183.9	96.79	1,097.1	7,587.64	627.828

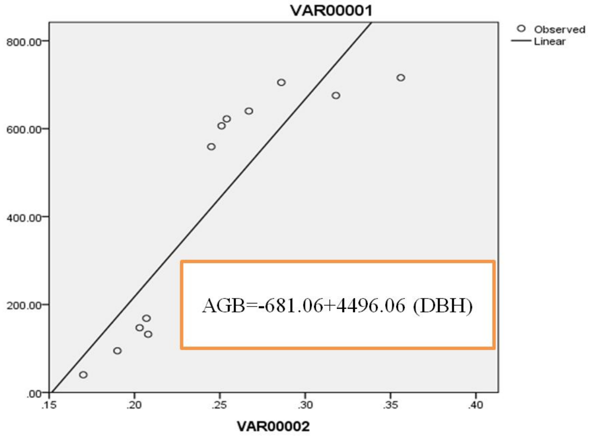

Fig. 4. Allometric model the line best fit for *Hypericum revolutum*.

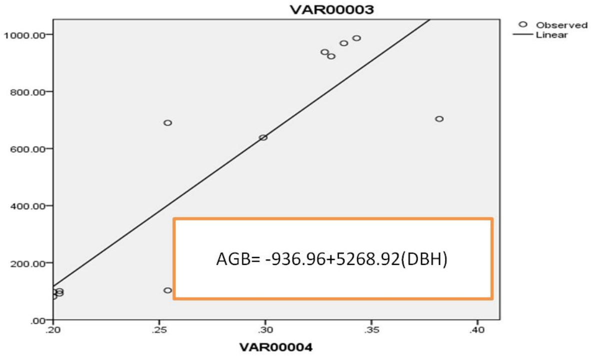

Fig. 5. Allometric model the line best fit for *Masea lanceoleta*.

range value respectively. Similarly 6,323.03 kg, sum total, 523.19 kg mean value and 905.99 kg range value of AGB had been recorded for *M. lanceoleta* respectively. The below ground biomass of 12 individuals for *M.lanceoleta* 1,264.606 kg, sum total, 104.63 kg, of mean value, and 181.19 kg, for range value of this tree species. By simply adding up the AGB, and BGB of the 12 individual's for this specific tree species the sum total had been 6,129.21 kg, 510.77 kg, and 811.04 kg, mean, and range value respectively (Table 4).

Allometric models

Different allometric models were developed using R-statistical software analysis for biomass estimation with one or more independent observable predictor, such as Diameter at Breast Height (DBH) of a tree, height of a tree, and volume of a tree components. Among the independent variables that are DBH, H, and V the most appropriate independent variable to fit the models for this two selected tree were the DBH of this species is the most preferable by comparing using Akaike Information Criterion (AIC). AIC is a measure of relativeness fit of the statistical models comparison between the fitted models, the one which is smaller algebra is preferred.

The linear regression model with DBH, as independent variable result in allometric model for *Hypericum revolutum* in the form of:

AGB=-681.05+4,494.064 (DBH), with p-value 0.004 and with a scatter plot a line best fit as shown in Fig. 3 with R^2=0.79 and adjacent R^2=0.88 of the value significant in statistical software.

The linear regression model analysis for *Maesa lanceoleta* above ground biomass using DBH independent predictor variable of the allometric model in the form of:

AGB=-936.963+5,268.92 (DBH) with p-value 0.000 which is very much below 0.05 value marks for a significant and a scatter plot with a line best fit as shown in figure with R^2=0.78 and adjacent R^2=0.88 of the value significant in statistical software (Fig. 4, 5).

Discussion

In order to know how much carbon is stored in particular forest or in specific species it is important that estimation of biomass is made. Biomass is then estimated through allometric equation of this type generally correlated on easily measured observable variable like Diameter at Breast Height, Height, and Volume to other components like biomass and relative accurate estimation. There are different forms of allometric equation that is found in this field of study which is biomass study in linear regression model (Dudley and Fowner 1992). This research also fit with the Allometric model reported by (Picard et al. 2012) guide line for specific-species, namely *Hypericum revolutum* and *Maesa lanceoleta*. By the data collected from Chuqala Natural Forest, and the model best fit at p-value between 0.000 and 0.003 in linear regression. Regression model should not be used beyond their range of validity. The model proposed here are valid in the Diameter at Breast Height (DBH) class 15-35 cm for the two species of *Hypericum revolutum* and *Maesa lanceoleta*.

Equation of species- specific is more suitable than the generalized equation (Singh et al. 2011). Though this research fit with the allometric model through species-specific equations. There are many type of biomass estimation method among these, destructive and non-destructive are the one to be mentioned. Both have their own demerit and merit (Aboal et al. 2005). Among the two methods mentioned above and in views of forest sustainability and species protection in forest ecology, it is better to use non- destructive mechanism and it also allows to measure biodiversity hotspot species (Ketterings et al. 2001).

Weighting trees in the field through harvesting is undoubtedly the most accurate methods of estimation of biomass and limit the use of conversion coefficients that decrease the accuracy. However, it is time consuming, limited by technical, financial and in some cases legal consideration which will make it difficult to do it. Considering this demerit of destructive measurements of biomass this study used non-destructive as the mechanisms to estimate biomass. One of the merits of considering such methods is consumes less time and could have the capacity to deal with threatened species and enable to study the evolutions of individual trees without disturbing the forest ecosystem. Followed this most authors have developed Allometric equations through wood density as the representative factors of a specific group with similar wood density (Chave et al. 2004; IPCC 2006; Henry et al. 2011). This is a significant role for estimation of tree biomass and representative for species groups with the same biomass contained in the volume unit. This study assumed that density of a wood to be uniforms in all compartments of the trees according to (Picard et al. 2012). And analyzed the aliquot branch mean wood density for the two species to be 0.41 g/cm^3 and 0.44 g/cm^3 *Hypericum revolutum* and *Maesa lanceoleta* respectively. Comparisons between fitted models of each two species using Akaike Information Criterion.

Comparison of the study fitted models for its accuracy and precision with AIC and R^2 and adjacent R^2 between the fitted models of a single species by statistical indicators for selecting is very crucial. The overall finding of the result for the study using more than one independent variable to predict the AGB and models that fit among the independent variable for this study was Diameter at Breast height (DBH), Height, and Volume. These statistical indicators should be to ensure the models closest with actual data as indicators suggested by (Chave et al. 2005; Basuki et al. 2009) are:

Table 5. Summary of the models using R^2, adjacent R^2 p-value and AIC

Model equation	Allometric equation	R^2	Adjacent R^2	p-value	AIC
Model-A	AGB=-681.015+4,494.06 (DBH)	79%	88.9%	0.003	126.67
Model-E	AGB=161.93+1,185.11 (DBH)+36.46 (H)	79%	79.8%	0.000	138.7
Model-K	branch=10.03+75.986 (BD)	75%	98%	0.00	101.3
model- B	AGB=-936.96+5268.92 (DBH)	78%	88%	0.000	164.4
Model -I	AGB=149.13+104.97 (DBH)+3.8 (H)+0.94 V	99%	99.5%	0.001	111.27
Model-L	branchB=12.215+47.081 (DB)	98%	73%	0.000	87.43

Table 6. Expected total biomass pre-tree carbon stock, and carbon price for the two species

Species name	Total biomass per-tree	Carbon stock	Expected prices
H. revolutum	425.648 KG	0.851	\$3.405
M. lanceoleta	519.335 GK	1.038	\$4.15

Akaike Information Criterion (AIC) is to measure the relative fit of statistical models. The models with smaller AIC algebra are preferred.

$\mathrm{AIC} = nXln\frac{n(Rss+2K)}{n}$; where n: number of sample, the Rss; the residual sum of square K; parameters of models including the parameters of errors estimated (for examples) the models Y=a+bx, then K=3 (equ. 12) (Table 5).

Based on the AIC statistical indicators the best model using the least Akaike Information Criterion algebra the best fit model for *Hypericum revolutum* is AIC=126.67 with Adjacent R^2=88.9% and p-value 0.003 is Model-A and also the best fit model using the least AIC algebra=164.4 with R^2=88% and p-value=0.000 is model-B preferred. However the overall preferred models best fit for the two specific-species was

AGB=−681.015+4,494.094 (DBH) for *Hypericum revolutum*

AGB=−936.96+5,268.92 (DBH) for *Maesa lanceoleta*

Moreover this study shows that forests have the potential in the mitigation of global climate change combat. Hence by considering Clean Development Mechanism (CDM) market prices, measuring carbon stock of a tree species begin through measuring of tree biomass, then analyzing through its carbon contents. Estimating single tree carbon content (stocks) takes places by multiplying the carbon content conversion factor (using a default value of 0.64) a tree biomass (Hairian et al. 2001). The above ground carbon stocks for the tree sample are obtained as 46% of their biomass. Based on the AGB estimation carbon stock and CO_2 can be calculated C (AGB)=0.46, and for CO_2= 3.6*C total biomass (Table 6).

Conclusion

In Ethiopia there has been inadequate research finding concerning carbon stock and biomass estimations by species- specific Allometric equation was developed by the present study to calculate above ground, below ground and total biomass for two tree species, namely *Hypericum revolutum*, and *Maesa lanceoleta* in Ethiopia. In this finding, it was found out that the following equation was developed as appropriate equation from 15-35 cm Diameter classes for the two species by taking 24 total selected individuals, 12 for *Hypericum revolutum* and 12 for *Maesa lanceoleta* in mount Chuqala Natural Forest.

The result to this study showed that species- specific Allometric equation is very important for accurate estimation to predict biomass and as well as for quantification of carbon stocks in living tissue of trees. The model developed for such species can be applied for the same species in similar geographical areas.

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