Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.7, No.3, 2017

Species Specific Allometric Model for Biomass Estimation of Millettia ferruginea (Hochst) Bak. in Tumata Chirecha Agroforestry Gedeo Zone: Implication for Climatic Change Mitigation

Abiy Mulat and Teshome Soromessa
Center for Environmental Science, Addis Ababa University, Addis Ababa, Ethiopia

Abstract
Species specific allometric equation is important for accurate net aboveground biomass estimation and quantifying carbon stock in living tree biomass of terrestrial ecosystems. This study was undertaken to develop species-specific allometric equation non-destructively of the Millettia ferruginea in Tumata Chirecha KPA agroforestry Gedeo Zone. Currently, like that of most Ethiopian agroforestry such model did not exist for this particular species and study area. The data was taken from 12 individuals with DBH class intervals in between (20-60 cm). Preferential sampling method was used to collect data from four rectangular plots each with a 10m*20m. The allometric equations were developed by relating tree component biomass to DBH or basal diameter. And the post analysis was highly significant ($P > 0.000$) fit for linear models for all the components and displayed minimal bias. It had a mean total biomass of 599.36 kg. It is understood that previously published allometric model in agroforestry reveal errors of over estimation of biomass, and propose the new equations to be used in the future for the selected four indigenous species. And it would create an opportunities for sustainable management of agroforestry and to mitigate climatic change through increasing the household income.
Keywords: Allometric equation, Biomass, DBH, Non-destructive, Tumata Chirecha KPA

INTRODUCTION

Estimation of biomass is an important attribute of vegetation for several reasons and it is directly related to the number of trees present in the area, the tree size and height. The accurate estimation of forest biomass is crucial for many applications, from the commercial use of wood to the global carbon (C) cycle (Bombelli *et al*., 2009). It is an essential aspect of studies of C stocks and the effect of deforestation and C sequestration on the globe C balance. Measuring biomass in local, regional and global scales is critical for estimating global carbon storage and assessing ecosystem response to climate change and anthropogenic disturbances (Ni-Meister *et al*., 2010). Accordingly, forest ecosystem plays very important role in the global carbon cycle. It also offers opportunities to sequester carbon or avoid emissions, and so it helps for the emission reduction benefits. It stores about 80% of all above-ground and 40% of all below-ground terrestrial organic carbon (IPCC, 2001),even more lately it is use as a source for foreign income generation as it absorbs CO_2 from the atmosphere, which is one of the basic elements of greenhouse gases, enhancing the rapid increment of world's temperature. Hence, the world climate is changing alarmingly due to the fact that the average atmospheric temperature is escalating. But it is so important to significantly indicate how much carbon will be sequestered in the forest, especially within a single species, in order to mitigate climatic change and manage it sustainably. Though developing countries are lacking data on carbon stock and forest biomass potentials, the implementation of $REDD^+$ highly requires estimation on the impact of forest degradation and deforestation on carbon (C) stocks, identifying baselines and monitoring forests. Accurate estimations of biomass in tropical forests are lacking in many areas, and this is due to the lack of appropriate allometric models for predicting a biomass in species-rich tropical ecosystems (Chave *et al.,* 2005). The use of the available generalized and species-specific biomass equations across wider ecological zones can lead to a bias in estimating biomass for particular species and sites (Henry *et al*., 2011) because, there are variations among species in wood specific gravity, tree sizes, growth stages, and also since some geographic areas have not been covered by the equations is that it can be applicable for these types of geographic areas which are available for similar species (Navar *et al*., 2002). In addition, the accuracy of biomass estimations can be affected by several factors such as variation of the soil, climate, disturbance regime, succession status, and topographic conditions (Ketterings *et al*., 2001; Litton and Kauffman, 2008). Allometric equation is studying the relative sizes of plant parts usually; the relationships between DBH (diameter at breast height, or 1.3 m up from ground level), tree height, total biomass, leaf weight, etc., and these relationships are calculated by using the allometric equation. It's also the convenient and common method to estimate the biomass of a forest or stand. So, biomass estimation through allometric equation is very vital for mitigation of climate change and sustainable management of forest, even if there is no universally accepted allometric equation for biomass predictions (Chuankuan, 2005).

Ethiopia has variety of agro-climatic zones, which has made the country a botanical treasure house, containing about 6000 different vascular plant species, out of which about 10% are endemic. Ethiopia has an estimated total high forest area of 4.07 million hectares or about 3.56% of the land area of the country. And about 95% of the total high forest is located in three regions of Oromia, SNNPR and Gambella regional states (WBISPP, 2004). Gedeo is one of the zones found in SNNPR which is rich in agroforestry, containing a number of indigenous trees. The general objective of this study was to develop allometric equation for selected indigenous tree in Tumata Chirecha agroforestry and estimating the carbon stock in line with biomass estimation of the indigenous trees for sustainable management and climatic change mitigation.

MATERIALS AND METHODOLOGY

Study Area

Tumata Chirecha Kebele Peasant Association agroforestry is situated in Gedeo Zone of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS). Geographically, it is located North of Equator from $5^0$53' N to $6^0$27' N latitude and from 38^0 8'to $38^0$30' East, Longitudinal with an altitude ranging from 1500 to 3000m and it covers a total area of 1347.04 km^2.The topographic feature consists of gentle slope and undulating areas to a hilly terrain, some incised valleys and with a small frequently perennial rivers. The land area of the region is estimated at about 1,347.04 km^2.It comprises of 50% flat plain, 35% mountainous and 15% undulated towards its southeastwards. The hilly areas rise up to 2000 m a.s.l. The geology of the study area constitutes volcanic rock of Jima volcanic ignimbrite and pumices of the rift floor as well as subordinate *lacustirine*se *diments* and some swamp deposits. According to FAO classification, the soil type is *farrsole* and *Nithosole*; having greater depth. The traditional soil classification shows that the zone comprises brown soil (90%), red soil (5%) and black soil (5%) (SLUF, 2006). According to EMSAs data, the result of the analysis showed that the Zone has sub-humid tropical climate receiving a mean annual rainfall of 1,567.5 mm with a maximum of 3,408.4mm and with a minimum of 916.8 mm annual rainfall. The rainfall pattern is bimodal with short rain season between March and May accounting for 30% of the total rainfall and with long rainy season between July and October accounting for more than 60% of total rainfall. The mean annual temperature is 20.4^{0}Cand the range of mean minimum and maximum temperature of the study area are30.4^{0}C and 10.3^{0}C respectively. The zone experiences three distinctive agro ecological zone namely "Dega" (30%)"Woyna Dega" (67%) and "Kefil-kolla" (3%).

Millettia ferruginea (Hochst) Bak./Darrato/

Millettia ferruginea belongs to the family Fabacae (Leguminosae) (Thulin, 1989). It is an endemic, N_2-fixing tree species with multiple uses and the seeds are dispersed through self-dispersal mechanisms (Legesse Negash, 1995). It can grow into a big tree, up to 25 m. high. Leaves are compound, each consisting of up to 27 leaflets. *M. ferruginea* is one of the most valuable multipurpose tree species of Ethiopia (Tadesse Hailu *et al.*, 2000). The flowers are violet and eventually result in fairly big, flat pods, with large, red and rounded seeds. The seeds are dispersed through self-dispersal mechanisms (Legesse Negash, 1995). It has the ability to re-orient its leaves and leaflets during midday, so as to avoid direct solar radiation (Jiregna Gindaba *et al.*, 2004).

Sampling and Analysis

This study was examined or studied through 12 individuals, the selected plants were assumed to have covered the variability of selected tree biomass in the study area. The plants were located in the immediate delineated area within the sample plot of 10 m∗20 m quadrat or plot that was established. All individuals were categorized into groups by using DBH interval of 20-30cm, 30.1- 40cm, 40.1-50cm, 50.1-60cm based on their size. All Trees were divided into separate architectural elements as trimmed small branch, untrimmed large branch and trunk for the purposes of measurement and analysis. Generally, four branches per plant were destruct for the small branches. Trunk weight was estimated from serial measurements of height, diameter and section volume using parabolic estimation of trunk shape. These estimations were used to develop the whole tree regressions of trunk and canopy component weight.

Above Ground Biomass Estimations

Based on the general guide line of FAO (2012), it can be semi or non- destructively measure the above ground biomass of specific tree through the following detail processes. Generally, the trunk and the large branches are not trimmed, only the small branches are affected or trimmed. The measurement of fresh biomass (in kg) may be divided into two parts: measuring trimmed fresh biomass and measuring untrimmed fresh biomass.

Trimmed Fresh Biomass

The leaves were separated from the trimmed branches. The fresh biomass of the leaves was determined by weighting from the trimmed branches (Btrimmed fresh leaves) and the fresh biomass of the wood from the trimmed branches (Btrimmed fresh wood). Suitable scales should be used for these weighing operations. Measure its fresh weight (B aliquot fresh leaf in g). An aliquot of the wood was also taken at random from the trimmed branches, without debarking. Measured its fresh mass (B aliquot fresh wood in g) in the field, immediately after cutting. Placed these aliquots in numbered plastic bags and sent to the laboratory. 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 were measured indirectly as non-destructive. The different branches in the trimmed tree were numbered. The small untrimmed branches were processed differently from the large branches and the trunk. For the small branches, only basal diameters were measured. The biomasses of these small untrimmed branches were estimated from the relationship between their basal diameter and their mass. The biomass of the trunk and the large branches were estimated from measurements of volume (Vi in cm^3) and mean wood density (ρin g cm−3). The large branches and trunk were divided virtually into sections that were then materialized by marking the tree. The volume Vi of each section i was obtained by measuring its diameter (or its circumference) and its length. Sections about one meter in length are preferred in order to consider diameter variations along the length of the trunk and branches. The dry biomass of the tree was obtained by the sum of the trimmed dry biomass and the untrimmed dry biomass (FAO, 2012).

Bdry = Btrimmed dry +Buntrimmed dry …………………… (equ.1)

From the fresh biomass B aliquot fresh wood of a wood aliquot and its dry biomass B aliquot dry wood, calculated as above, the moisture content of the wood (including bark) and the moisture content of the leaves were calculated from the fresh biomass B aliquot fresh leaf of the leaf aliquot and its dry biomass B aliquot dry leaf as in FAO (2012).

X wood= $\frac{\text{dry wood}}{\text{frsh wood}}$ ……. (equ.2) and X leaf =$\frac{\text{dry leaf}}{\text{fresh leaf}}$ …… (eqn.3)

Trimmed dry biomass can then be calculated:

Btrimmed dry = Btrimmed fresh wood × Xwood + Btrimmed fresh leaf ×Xleaf... (equ.4)

Two calculations were required to calculate the dry biomass of the untrimmed part (i.e. that still standing): one for the small branches, the other for the large branches and the trunk. The untrimmed biomass is the sum of the two results (FAO, 2012).

Buntrimmed dry = Buntrimmed dry branch + B dry section………….. (equ.5)

Each section i of the trunk and the large branches may be considered to be a cylinder of Volume (Newton's formula or truncated cone volume formula) (FAO, 2012).

Vi = $\frac{\pi}{8}$ Li $(D_{1i}^2 + D_{2i}^2)$…………………………………………………… (equ.6)

Where Vi were the volume of the section i, Li its length, and D1i and D2i are the diameters of the two extremities of section i. The truncated cone volume formula can also be used instead of the cylinder formula, but the differences between the results were slight as the tapering over one meter is not very pronounced in trees.

The dry biomass of the large branches and trunk were the products of mean wood density and total volume of the large branches and trunk (FAO, 2012).

B dry section=$\bar{\rho} \times \sum_i Vi$………………………………………………... (equ.7)

According to FAO (2012), where the sum corresponds to all the sections in the large branches and the trunk, and where mean wood density was calculated by

$\rho = \frac{B_{dry\ wood}^{aliquot}}{V_{fresh\ wood}^{aliquot}}$……………………………………………….................. (equ.8)

The dry biomasses of the untrimmed small branches were calculated using a model between dry biomass and basal diameter. This model is established by following the same procedure as for the development of an allometric model (FAO, 2012). Power type equations were used:

$Bdry\ branch\ = a\ +\ bD^c$……………………………………………. (equ.9)

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

$Buntrimmed\ dry\ branch\ = \sum_J (a\ +\ bD_J^C)$……………………….. (equ.10)

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

Estimation of Below Ground Biomass (BGB)

Below ground biomass estimation was much more difficult and time consuming than estimating aboveground biomass (Geider *et al.,* 2001). According to MacDicken (1997), standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass i.e., root-to-shoot ratio value of 1:5 was used. Similarly, Pearson *et al.,* (2005) described this method as it is more efficient and effective to apply a regression model to determine belowground biomass from knowledge of biomass of aboveground. Thus, the equation developed by MacDicken (1997) to estimate below ground biomass was used. The equation is given below:

BGB = AGB × 0.2 ……………………………………………….…………. (equ.11)

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

Data Analysis

The data measured in the forests were accomplished by organizing and recording on the excel data sheet. The data obtained from section volume, fresh biomass of small trimmed branches, large branch and trunk biomass, fresh weight of trimmed leaf and dry weight of trimmed leaf, fresh trimmed wood, and fresh trimmed dry wood were analyzed using Statistical Package R software (version 2.11.1.) which was also used to develop allometric equation.

RESULTS

Biomass Estimation

The result that were measured with a total twelve individuals measured from four plots represent almost all trees size in the study area, by classifying them into DBH class in the preliminary step.

Trimmed Biomass

The trimmed fresh biomass obtained as indicated below (Table 1) from the aliquot that was measured on the field and in the laboratory. Then after getting the fresh and dry biomass values of the aliquots, calculate the X wood and X leaf values according to equation (2&3) and X values will require to calculate the trimmed values as equation (4). The Trimmed fresh wood of *Millettia ferruginea* weighs total of 7, 760 gm, a mean value of 646.67 gm with a range of 350 gm. After oven drying the 12 individual measurements became 3,046.1 gm of total mass, 253.84 gm of mean value, and a range of 145.97gm. Its fresh leaf biomass was 5,150 gm with mean weight of 429 and a range of 350 gm after the leaves were dried out in oven it accounted mean weight and range values of 3.45, 0.29 and 0.16 gm respectively.

Table 1: Trimmed component biomass (in gm) of *Millettia ferruginea*

Tree component	n	Maximum	Minimum	Range	Sum	Mean
Fresh Wood mass	12	850	500	350	7760	646.67
Wood After oven	12	338.04	192.07	145.97	3046.1	253.84
X Wood	12	0.419	0.381	0.038	4.716	0.393
Fresh Leaf mass	12	650	300	350	5150	429
Leaf After oven	12	157.24	93.4	63.84	1462.4	121.86
X Leaf	12	0.346	0.240	0.106	3.452	0.288
Trimmed biomass	12	494.29	292.12	202.17	4508.5	375.71

Untrimmed Biomass

Measurements of each component underwent a series of procedures. Accordingly, for the fulfillment equation (6) was done, i.e. through measuring the trunk and large branches diameters with a one meter interval by assuming that it has a cylindrical shape. The density of the branch was calculated based on equation (8), i.e. by taking the ratio of after oven wood aliquot mass of the branch to its volume before oven. The density of a trimmed branch that was calculated as indicated in equation (8) had determining factor for total biomass estimation and or allometric model development, that in turn determined by the trimmed branch volume. Then, the resulted single branch density was considered the density of the tree as a whole.

Table 2: Trimmed branch density (in g/cm^3) and whole tree volume (in m^3)

Tree	Volume	Density
1	0.281	403.4
2	0.607	385.69
3	0.579	373.09
4	2.251	384.73
5	2.055	373.59
6	1.691	366.29
7	0.546	365.85
8	1.667	360.56
9	0.612	377.06
10	3.223	348.49
11	0.996	364.60
12	1.538	364.73

The results of untrimmed component biomass from 12 individuals indicated on Table 3. The dry section was calculated based on equation (7) and so the dry section of *Millettia ferruginea* has a total mass of 6,905.94 kg, 575.49 kg of mean value and 1,009.65 kg range value.

Table 3: Untrimmed components biomass (in kg) of *Millettia ferruginea*

Tree component	N	Maximum	Minimum	Range	Sum	Mean
Dry section	12	1123.16	113.50	1009.65	6905.94	575.49
Dry branch	12	11.94	4.41	7.53	100.36	8.36
Untrimmed biomass	12	1135.09	117.91	1017.18	5989.12	499.09

According to equation (9), the dry biomass of the untrimmed small dry branches was calculated by using a model which was developed following the same procedure as for the development of an allometric model

(FAO, 2012). The linear regression was developed by taking the dry (after oven) biomass and the basal diameter of the branch wood aliquot (trimmed branch) as dependent and independent variable respectively. The model is highly significant (P> 0.000) and had R^2value 0.98 with an intercept value of 2.21 and 35. 98 slope value of *Millettia ferruginea*. Based on equation (9) B dry branch= a+bD^c in which we use the basal diameter of the trimmed small branch as (D). *Millettia ferruginea* had range of 7.53 kg, which is the difference between 11.94 kg and 4.41 kg, with sum mass of100.36 kg and 8.36 kg of mean value for the dry branch. Thus, based on FAO (2012), as indicated in equation (5),by simply adding the dry branch and dry section biomass values of a tree were obtained the untrimmed biomass(untrimmed large branch and trunk). This result was obtained from a total of 12 individuals' measurements as indicated on Table 3. *Millettia ferruginea'* untrimmed dry biomass was calculated and had a sum of 5,989.12 kg, with a mean of 1017.18 kg, and with a range of 499.09 kg. All the required components were fulfilled either by measurement and /or by calculation as indicated on the previous series of tables which we needed to come up with the objective of this particular study. Finally, the total above ground biomass which helped to estimate the below ground biomass and the resulting total biomass were obtained. The above ground biomass (AGB) was obtained by using equation (1). Below ground biomass was also calculated (20% of AGB) based on equation (11). Then after AGB and BGB were calculated, those values were also important for calculating total biomass (Table 4). 5,993.63 kg of total, 499.47 kg mean and 1,017.37 kg range value for the above ground biomass was noted for *Millettia ferruginea*. Its below ground biomass became 1,198.73 kg sum, with a 99.89 kg mean and 203.47 kg range. Then the sum total biomass will be 7,192.36 kg, with a 599.36 kg mean value and with a range of 1,220.84 kg.

Table 4: AGB, BGB and Total biomass (in kg) of *Millettia ferruginea*

Tree components	n	Maximum	Minimum	Range	Sum	Mean
AGB	12	1135.59	118.22	1017.37	5993.63	499.47
BGB	12	227.12	23.64	203.47	1198.73	99.89
Total biomass	12	1362.70	141.86	1220.84	7192.36	599.36

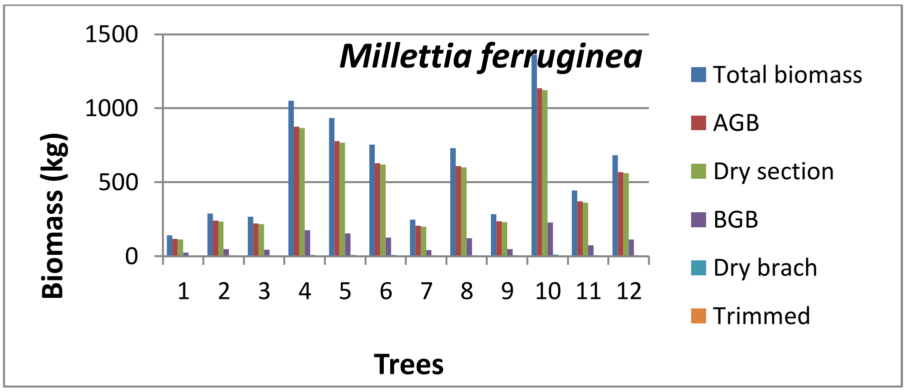

Figure 1: All the 12 trees biomass components of *Millettia ferruginea*

Allometric Equations

After predicting the whole biomass components of the tree, we developed the allometric model for each component. The allometric model in a linear regression considered the DBH as an independent variable and other components (dry branch, dry section, AGB and total biomass) as dependent variables. But for the trimmed biomass as a dependent variable, has basal diameter as independent variable exceptionally. With no exception the results were significant at the (P >0.000) level. The goodness of fit (R^2) of regressions was higher as indicated bole in table 5. The trimmed allometric in linear regression model of *Millettia ferruginea* is -0.024 with a slope value of 0.050 and had a high significant value (R^2=0.96). For its dry section compartment it has-621.957 coefficient of intercept, a27.859 of slope value and a significant value of (R^2=0.96).For the dry branch it has 0.792, 0.174 of coefficient of intercept and slope values respectively and with a high significant value of (R^2=0.94). It's AGB and total biomass components have an intercept of -621.010 and -745.212 in their order, where as its AGB slope is 28.038, with a slope value total biomass of 33.646. It has also a high significant value of (R^2=0.96) for both the AGB and the total biomass.

Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.7, No.3, 2017

Table 5: Models estimation for trimmed, dry section, AGB and Total biomass (biomass in kg) and (diameter in cm) of *Millettia ferruginea*

Tree component	Equation	Coefficients		Performance statistics	
		Intercept (a)	slope (b)	R^2	P
Trimmed	trimmed=a+b(basal diameter)	0.0234	0.050	0.96	0.000
	ln(trimmede)=ln(a)+bln(basal diameter)	-2.778	0.925	0.96	0.000
Dry section	drysection=a+b(DBH)	-621.957	27.859	0.96	0.000
	ln(drysection)=ln(a)+bln(DBH)	-2.915	2.437	0.99	0.000
Dry branch	Dry branch=a+b(DBH)	0.792	0.174	0.94	0.000
	ln(dry branch)=ln(a)+bln(DBH)	-1.185	0.877	0.95	0.000
Above ground biomass (AGB)	above ground biomass=a+b(DBH)	-621.010	28.038	0.96	0.000
	ln(above ground biomas)=ln(a)+bln(DBH)	-2.769	2.404	0.99	0.000
Total biomass	Total biomass=a+b(DBH)	-745.212	33.646	0.96	0.000
	ln(total biomas)=ln(a)+bln(DBH)	-2.588	2.404	0.99	0.000

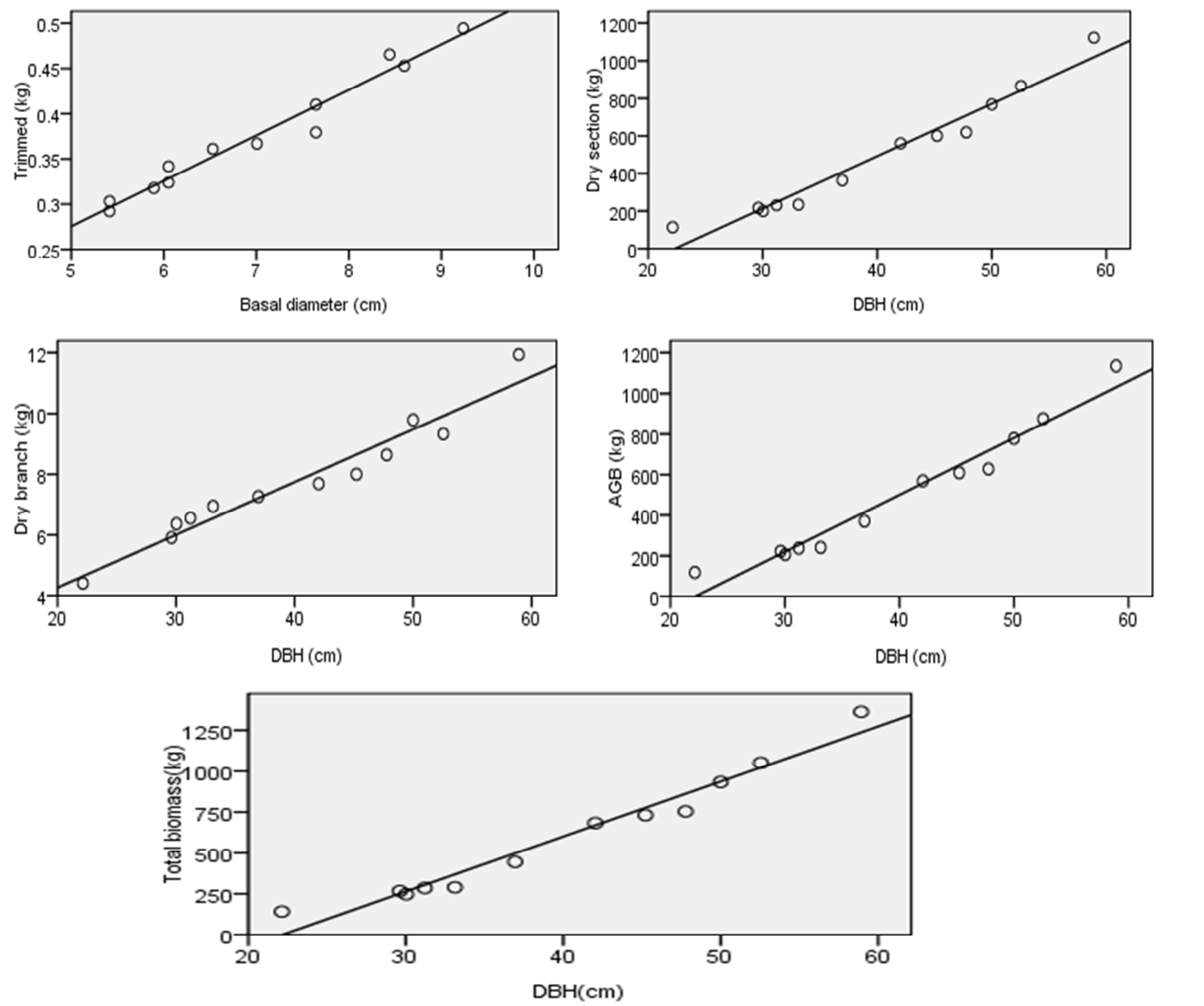

Figure 2: Linear relationship between DBH (basal diameter) with biomass components of *Millettia ferruginea*

DISCUSSION

Allometric Equations

This study developed allometric equation in linear regression model and all the analysis of the gathered information indicates that the model's linearity were (P>0.000) with all correlation coefficients of high significant which was fit for all biomass components. The DBH range of the model validation is in between 20-60 cm. Extrapolating beyond the data range used in forest study may cause bias or error in estimating biomass. Our model had incorporated crucial tree compartments and the allometric equations are used to predict tree and stand biomass, based on the easily measured tree variables such as, DBH. DBH as the only explanatory variable provides a satisfactory estimation of biomass since the total variation explained by the relationship is high and the associated bias was small. Our results also indicate that, DBH is a strong indicator of aboveground biomass which agrees with the previous reports (Brown *et al*., 1989; Zianis and Mencuccini, 2004; Basuki *et al*., 2009) so DBH alone is a good predictor of biomass especially, in terms of multiple tradeoffs between accuracy, cost and practicability of the measurement. And also recommended that the use of model where tree biomass is determined from DBH only, which had a practical advantage because most of the inventories include DBH measurements. Moreover, DBH is easy to measure accurately in the field. The models in this study were developed based on FAO (2012) methodology through non-destructive or indirect method with slight modification (semi destructive), which attempts to estimate tree biomass by measuring variables that are more accessible and less time-consuming to assess (e.g., wood volume) (Peltier *et al*., 2007). Both destructive and non-destructive biomass measurements have their own advantages and disadvantages. The destructive measurement has a potential disruption of ecosystem due to the fact that it harvests the whole tree for gathering the data in order to produce higher accurate measurements over the non-destructive one. Even if the destructive measurement has the advantage of higher accuracy, it has a number of disadvantages and impracticality in forest studies, especially if the species of interest are rare or protected. Due to the above mention reasons, this study was done by the application of the non-destructive measurement with slight modification without harvesting the trees. Furthermore it minimizes the labor and time cost of the study with minimum ecological disruption. Allometric equations are used to predict tree stand biomass, based on easily measured tree variables such as height and DBH. It is also very important to quantify carbon in the living tissue which would and help us for the sustainably management of forests and climatic change mitigations. There are wide variety and different forms of allometric equation in biomass estimation. So there is no universally accepted allometric equation for biomass prediction. Most biomass equations in scientific literature adopt power function of Y = aDb (Ter-Mikaelian and Korzukhin, 1997; Ketterings *et al*., 2001) and linear model (Dudlly, 1992; Kettering *et al*., 2001).The most common form of allometric equation that is found in the science of biomass estimation is linear model (Kettering *et al*., 2001).Likewise, our allometric equations are developed by using a linear regression model and its high significant value.

Tree Biomass and Carbon stock

We develop highly significant (P>0.000) species specific allometric model which directly determined on the biomass measurements. The accurate biomass estimations of trees are very crucial for various reasons from commercial use of wood to global carbon trade and also from sustainable forest management to climatic change mitigation. In order to measure biomass accurately, there must be species specific allometric. As reported on the above table the biomass of a single tree is obtained from the commutative measurements' of the tree compartments. According to Abola *et al*. (2005), allometric equations are being strongly different for different tree species within the same climatic zones. It has been reported previously and mainly attributed to differences in specific wood density (weight per volume) of the species, the floristic composition and growth strategies of the species. Similarly, this study reveals that trees in the same DBH class of different species exhibit different AGB values. Wood density is also very important as it differs a lot among tree genus and species (Chave *et al*., 2006). In general, there is variability of basic wood density among species, individual of the same species, among geographical location and with age (Abola *et al*., 2005; Nygard and Elfying, 2000). This study shows that wood density was affected by tree size. Smaller trees had a low mean of value while a high mean was observed in larger trees. Actual model performance, expressed as a goodness of fit (R^2) depended on both species involved and the biomass component to be estimated. Consequently, the model of this particular study is developed from biomass estimation. The main factor which determines the estimation of biomass is density. The below ground biomass of a trees are estimated based on the previous studies which is acceptable. According to MacDicken (1997), standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass i.e., root-to-shoot ratio value of 1:5 was used. Similarly Pearson *et al.* (2005) described this method as it is more efficient and effective to apply a regression model to determine belowground biomass from knowledge of biomass aboveground. So our study is applying this equation for getting the BGB to obtain the total biomass of each species.

After predicting the total biomass of each tree species, the carbon stock of each species was determined. According to Brown (1997) report, carbon quantities are about 50% of the aboveground woody biomass weight. Carbon was assumed to comprise 50% of the oven-dry mass); the dry biomass can be converted to carbon content by taking half of the biomass weight (carbon content ≈50% of biomass) (Westlake, 1966). In similar way to the previous reports of Rowell, R (1984) the carbon stock was calculated. And half of each individual biomass is equals to its carbon stock.

Allometric Equation Comparison

General allometric equations that ignored tree species should provide reasonable estimates of the most biomass components. It also mostly indicates that higher over estimation. However, more precise estimation of component biomass requires species-specific equations. This has been noted in many species under divergent biomes and site conditions (Crow and Schlaegel, 1988; Gower *et al*., 1999).Accordingly, species specific allometric equation was developed with a high significance ($P > 0.000$)fit linear regression. Non-destructive or semi destructive estimation of the above ground biomass (AGB) of trees is generally carried out by means of two dimensional analytical techniques (Whittaker and Maks, 1975), which are based on the relationships between biomass and readily measured biometric variables such as diameter at breast height (DBH).The most important advantage of two-dimensional analytical techniques for estimating the above ground biomass of trees is that the same equation is often valid for all tree species within the ecosystem under consideration (Whittaker and Wood well, 1968). Most generalized allometric equations for biomass estimation mainly depend on the ecological zones of the forest. Our study area Tumata Chirecha agroforestry is described under moist evergreen montane forest. According to Talemos and Sebsebe (2014), tree allometric equations developed by (Brown 1997, Chave *et al*., 2005 and Kuyah *et al*., 2012) were evaluated to estimate the aboveground biomass of the agroforestry trees and no significant difference has been found among the equations. However, the allometric equation of Kuyah *et al*.(2012) which is shown below, typically relates the tree's diameter to its biomass for this study. So, the evaluation of $AGB = 0.091 \times DBH^{2.472}$;

$R^2 = 0.98$, $n = 72$, where AGB (kg) = aboveground biomass, DBH (cm) = diameter at breast height. This equation was selected because it had the highest R^2 and the lowest error of prediction values, which is used only for a breast height diameter. Here, the equation is applied for trees grown in agroforestry systems in western Kenya, having similar environmental conditions (climate and soils) to our current study site. For this particular study, a species specific allometric model were developed and there mean total biomass from 12 individual measurements reported as 599.36 kg based on our proposed allometric model. While these species resulted biomass through general allometric model $AGB = 0.091 \times DBH^{2.472}$ (Kuyah *et al*., 2012) becomes 936.36. Based on the differences of the result, we can say that it has a huge difference between the general and species specific model in similar with that of many scientists previous report species specific allometric equation is accurate than any other. On the other hand previous reports said that general allometric equations cause bias due to overestimation. Similarely Eyosias and Teshome (2015), when the results are compared, these collected through non- destructive, species specific estimation of biomass with generalized equations they had significance difference at the total amount of biomass. Moreover, we need to compare our resulted total biomass with other similar species specific biomass prediction on similar species. Unfortunately, equation for our species are not available, hence no comparisons were possible. In most allometric science AGB and height are a predictor in both case above ground biomass was subjected to natural logarithm to normalize its distribution. The model selected as a double logarithm model, it is linearized by taking the logarithm of both the left and right hand side of the equation, giving the linear function. Other models gave a worse fit, and were rejected. So this study developed allometric model for all main compartment of trees.

Linear regression model of *Millettia ferruginea* except for dry branch which is (R^2=0.94) for all trimmed, dry section, AGB and total biomass (R^2=0.96). However, for double logarithmic model, the R^2 value for AGB, total and dry section component was 0.99.It had 0.95 for dry branch and0.96 for trimmed. The European Union and other states put legally binding obligations on their biggest industries to reduce their emissions. Firms with high emissions need to pay a price for each tons of CO_2 which they are emitting called the 'carbon price'. Attaching a price to carbon emissions and creating markets to trade them is thought to provide financial incentives to encourage emitters to undertake emission reduction efforts. If a company wants to emit more than it is allowed to, it can buy credits from those who have reduced their emissions below the target level, or from a project in a developing country which has certified emission reduction credit to sell. This trading forms the basis of the carbon market.

Table 5: Expected carbon price for the 4 tree species (average tree biomass per ton)

Species name	**Average total biomass (a tree)**	**Co_2(tone)**	**Expected price (\$/ton)**		
			\$5 to \$35	**\$20**	**\$25**
Millettia ferruginea	599.36	0.276	1.38	5.51	6.89

CONCLUSION AND RECOMMENDATIONS

Conclusion

The result in this study shows that species specific allometric equation is very crucial model to an accurate estimation of biomass as well as for a quantification of carbon stock in the living biomass. Once the model is developed, it can be applied to the same species within similar geographic area. The species specific allometric equations that we have developed are for tree which is indigenous and dominant species in the study area. And these allometric models will significantly improve our capacity to accurately estimate biomass and consequent carbon stocks. Accordingly, it would create an opportunities for sustainable management of agroforestry and to mitigate climatic change through increasing the household income. The tree and tree component data described in this thesis would enable us for developing species specific allometric model, and also for predicting the above ground biomass in Tumata Chirecha agroforestry. Moreover, this study developed models not only for AGB but also for other tree components too i.e. trimmed, dry branch, dry section and total biomass. We propose the models as appropriate equations for the trees in a DBH range of 20-60cm.

Recommendations

On the basis of results of the study and conclusion made, the following recommendations are forwarded.

- Formulating allometric equation through species specific methods for all the indigenous tree species that are found in Tumata Chirecha KPA agroforestry.
- Incorporate all the diameter class of tree species.
- Calculating tree density is one of the most determinant aspects of accurate biomass estimation in order to develop allometric model. So, some detail research should be done on it.

REFERENCE

Aboal, J.R., Arevalo, J.R. and Fernandez, A. (2005). Allometric relationships of different tree species and stand above ground biomass in the Gomeralaurel forest (Canary Islands). Flora - Morphology, Distribution, Functional Ecology of Plants, 200(3): 264-274.

Basuki, T. M., van Laake, P.E., Skidmore, A.K., Hussin, Y.A. (2009). Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. Forest Ecology and Management 257: 1684–1694.

Bombelli, A., Avitabile, V., Belelli Marchesini, L., Balzter, H., Bernoux, M., Hall, R., Henry, M., Law, B.E., Manlay, R., Marklund, L.G. &Shimabukuro, Y.E (2009). Assessment of the status of the development of the standards for the Terrestrial Essential Climate Variables: Biomass. Food and Agriculture Organization – Global Terrestrial Observation System. 18 p.

Brown, S (1997). Estimating Biomass and Biomass Change of Tropical Forests: A Primer. UN FAO Forestry Paper, Rome 134: 55.

Brown,S.A. Gillespie, J.R. and Lugo, A. E.(1989). Biomass estimation methods for tropical forests with application to forest inventory data. Forest Science 35(4), 881-902.

Chave, J.,Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J.-P., Nelson, B. W., Ogawa, H., Puig, H., Riéra, B., and Yamakura, T (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests, Oecologia, 145, 87–99, doi:10.1007/s00442-005-0100-x.

Chuankuan ,W (2005).Biomass allometric equations for 10 co-occurring tree species in Chinese temperate forests. Forest Ecology and Management 222: 9–16.

Crow, T.R., Schlaegel, B.E (1988). A guide to using regression equations for estimating tree biomass. North. J. Appl. For. 5, 5–22.

Dudley, N.S., Fownes, J.H (1992). Preliminary biomass equations for eight species offast-growing tropical trees. J. Trop. Forest Sci. 5 (1), 68–73.

Eyosias Worku and Teshome Soromessa (2015). Allometric Equation for Biomass Determination in *Juniperus procera* Endl. and *Podocarpus falcatus* Mirb of Wof-Washa Forest: Implication for Climate Change Mitigation. American Journal of Life Sciences. Vol. 3, No. 3, 2015, pp. 190-202.doi: 10.11648/j.ajls.20150303.20

FAO (2012).Manual for building tree volume and biomass allometric equations: from field measurement to prediction 00153 Rome, Italy. pp 51-78 August.

Geider, R. J., Delucia, E. H., FalkowskI, P. G., Finzi, A. C., Grime, J. P., Grace, J., Kana, T. M., LA Roche, J., Long, S. P. & Osborne, B. A. (2001). Primary productivity of planet earth: biological determinants and physical constraints in terrestrial and aquatic habitats. Global Change Biology, 7, 849-882.

Gower, S.T., Kucharik, C.J., Norman, J.M., (1999). Direct and indirect estimation of leaf area index, F(APAR), and net primary production of terrestrial ecosystems. Remote Sens. Environ. 70, 29–51.

IPCC (2001). Climate Change. (2001). Working Group I: The Scientific Basis. Cambridge University Press, New York.

Jiregna Gindaba, Rozanov, A. and Legesse Negash (2004). Response of seedlings of two Eucalyptus and three deciduous tree species from Ethiopia to severe water stress. Forest Ecology and Management 201: 119-129.

Ketterings, Q.M., Coe, R., Noordwijk, M., Ambagau, Y., Palm, C.A (2001).Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. For. Ecol. Manage 146:199–209.

Kuyah, S., Dietz, J., Muthuri, C., JamnadasS, R., Mwangi, P., Coe, R. & Neufeldt, H. (2012). Allometric equations for estimating biomass in agricultural landscapes: I. Aboveground biomass. Agriculture, Ecosystems & Environment, 158, 216-224.

Legesse Negash (1995). Indigenous trees of Ethiopia: Biology, Uses and Propagation techniques. Printed by the SLU Reprocentralen, Umea, Sweden, 285 pp.

Litton, C.M., Kauffman, J.B (2008). Allometric models for predicting above-ground biomass in two widespread woody plants in Hawaii. Biotropica 40, 313-320.

Macdicken, K. G. (1997). A guide to monitoring carbon storage in forestry and agroforestry projects, Winrock International Institute for Agricultural Development USA.

Ni-Meister, W., Lee, S., Strahler, A.H., Woodcock, C.E., Schaaf, C., Ranson,J., Sun, G., Blair, J.B (2010).Assessing general relationships between above-ground biomass and vegetation structure parameters for improved carbon estimate from vegetation lidar. J. Geophys. Res. 115, G00E11

Peltier, R., Forkong, C.N., Ntoupka, M., Manlay, R., Henry, M., Morillon, V. (2007). Évaluation du stock de carbone et de la productivité en bois d'un parc à karités du Nord-Cameroun. Bois et Forêts des Tropiques 294 (4), 39–50.

Rowell, R (1984). The Chemistry of Solid Wood; Advances in Chemistry Series, 207; American Chemical Society: Washington, DC, USA, p. 614.

SLUF (2006). Indigenous Agroforestry Practices and Their Implications on Sustainable Land Use and Natural Resources Management. The Case of WonagoWoreda. Research Report No 1. Addis Ababa, Ethiopia.

Tadesse Hailu, LegesseNegash and Olsson, M (2000). Millettia ferruginea from Southern Ethiopia: Impacts on soil fertility and growth of maize. Agrofoestry Systems 48: 9-24.

Talemos Seta and Sebsebe Demissew (2014). Diversity and Standing Carbon Stocks of Native Agroforestry Trees in Wenago District, Ethiopia Addis Ababa University.

Ter-Mikaelian, M.T., Korzukhin, M.D (1997). Biomass equations for sixty-five North American tree species. For. Ecol. Manage. 97, 1–24.

Thulin, M. (1989). Fabaceae (Leguminasae). In: Flora of Ethiopia, Volume 3, Pittosporaceae to Aralliaceae, pp.49-25, (Hedberg, I. and Edwards S., eds.) Addis Ababa (Ethiopia) and Uppsala (Sweden).

WBISPP (2004). A strategic plan for the sustainable development and conservation and management of the woody biomass resources. Final Report. MoA.

Westlake D F (1966) .The biomass and productivity of glyceria maxima: I. Seasonal changes in biomass J. Ecol. 54 745–53.

Whittaker, R.H., Maks, P.L (1975). Methods of assessing terrestrial productivity. In: Lieth, R.J., Whittaker, R.H. (Eds.), Primary productivity of the biosphere. Springer, New York, pp. 101–131.