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REVIEW ON THE ABOVE AND BELOW GROUND BIOMASS AND CARBON STOCK ESTIMATION OPTIONS FOR TREES AND FOREST RESOURCES: WITHIN AND AROUND MAGO NATIONAL PARK, SOUTHERN REGION OF ETHIOPIA

AKLILU WODEBO WOLA
Wondo Genet College of Forestry and Natural Resources, Hawassa University, P.O. Box 128, Shashemene, Ethiopia
Email: akliluw2008@gmail.com

Abstract

Forests play an essential role as source and sink in global carbon cycle. Development and other human induced activities have led to degradation of forest land, and ultimately, it results in loss of biodiversity and increases concentration of CO_2 in atmospheres. Therefore, there is urgent need to estimate regional and national level carbon stock for making forest-based policies and strategies for mitigation of CO_2. Variable and periodic information is available on biomass and carbon stock of Gambo Natural Forest. This review presents a systematic review on the Biomass Carbon Stock Estimation Options for Trees and Forests Resources: Within and Around Mago National Park, Southern Region of Ethiopia. In order to review and gain information from existing research on types of forest, basal area, biomass/carbon stock, sequestration pool in different forest ecosystems of Mago National Park, a literature search was carried out during January 2022 to October 2022 using Web of Science, Google Scholar Citation, Research Gate,IPCC, United Nations Framework Convention on Climate Change (UNFCCC) and REDD+ report, offline journals, book chapters, , government scientific reports, Forest Survey data, Botanical Survey data, as well as reports published by Ministry of Environment, Forest and Climate Change. The review is limited to in and around Mago National Park forest ecosystem in relation to above and below biomass and carbon stock estimations. Formulating allometric equations for all woody plants in Ethiopia is quite desirable for accurately quantifying the biomass and carbon stock of forests to achieve accurate national and international reporting of carbon dioxide emission inventories. Depending on this in Ethiopia several study undertaken regarding allometric equation for biomass estimation, but it is not as forest resource of the country. Most of the study undertaken was depend on semi-destructive method which is not accurate as destructive measurement.

Key Words: *Allometric equation, Biomass, Mago National Park, Carbon Stock, Forest Resources*

Introduction

Forest ecosystems act as source and sink of atmospheric carbon dioxide (CO_2) and are one of the most faithful options for carbon sequestration and play a crucial role in regulating global carbon cycle. Local, regional, and national carbon inventories of source and sinks of carbon are indispensable to assess the prospective role of various carbon sequestration pools for reducing atmospheric CO_2 accumulation, and therefore it is a pioneer step for preventing global warming. The studies also important for developing of systems/markets for national and international carbon credit/emission trading as well as in reducing emission from deforestation and forest degradation (REDD+) programs in developing countries (Han *et al*., 2007; NEFA 2002; Kale *et al*., 2004).

Growing concerns about climate change resulting from increased concentration of greenhouse gases in the atmosphere have stimulated discussions about the importance and potential of forests and Agroforestry for carbon sequestration. Due to anthropogenic emissions, the concentration of the major greenhouse gas, carbon dioxide (CO_2), has reached 400 parts per million (ppm) for the first time in record history, according to report from the Mauna Loa Observatory in Hawaii in 2015 (MLOH, 2015). The globally averaged combined land and ocean surface temperature data show a warming of 0.85 [0.65 to 1.06] °C over the period 1880 to 2012. The total increase between the middling of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C. Regional temperatures may increase even by 1 to 5 ºC, if the current atmospheric CO2 concentration is doubled (IPCC, 2014).

To reduce the rising levels of greenhouse gases, in particular CO2, afforestation and reforestation systems have been encouraged as means to sequester CO2 in biomass and soil, an idea formally recognized by the Kyoto Protocol. The Kyoto Protocol agrees for the opportunity to offset CO2 emissions through cooperation between developed and developing nations to undertaking into reforestation or afforestation projects (UNFCCC, 1997).

Forest ecosystem is a major constituent of the carbon reserves and it plays an important role in regulating global climate change through process of carbon sequestration (Addi *et al*., 2019; Tadesse *et al*., 2019). Tropical forest is a main constituent of terrestrial carbon cycle and it has a great potential for carbon sequestration, accounting for 26% carbon pool in aboveground biomass and soils (Brassard *et al*., 2009).

Agroforestry is also recognized as one of the greenhouse gas lessening strategies under the Kyoto Protocol, which was adopted in 1997. As a result, the sequestration potential of agroforestry systems has gained the attention of many countries throughout the world, prompting them to concentrate on it. Several authors have suggested that trees in agroforestry practices absorb and store larger quantities of atmospheric carbon dioxide (CO_2) than do the herbaceous seasonal or annual crops and pastures (Nair *et al*., 2009; Sharrow and Ismail, 2004). This is because incorporation of perennial trees and shrubs in croplands and pastures would result in higher Carbon sequestration both in biomass and the soil (Nair *et al*., 200 and Haile *et al*., 2008). Therefore, improving C stock in farmlands by introducing AF practices could be a potential option to mitigate climate change impacts (Gebremeskel *et al*., 2021). Biomass assessment of tropical forests and Agroforestry are crucial for appreciative the role of terrestrial ecosystems to the carbon cycle and climate change mitigation (Ali *et al*., 2015; Ancelm *et al*., 2016).

Reliable estimation of forest biomass with a sufficient accuracy is crucial to measure the variations of Carbon Stored in the forest (Ketterings *et al*., 2001; Chave *et al*., 2004). It is a fundamental aspect of studies of Carbon stocks and the effect of deforestation and Carbon sequestration on the globe Carbon 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).

Accurate estimations of biomass in tropical forests are deficient in many areas, and this is due to the lack of appropriate allometric models for predicting a biomass in species-rich tropical ecosystems and such paucity of information makes estimation of the value of these species as carbon sinks difficult (Chave *et al*., 2005). There is a lot of uncertainty in the amount and spatial variations of above-ground biomass in Africa, partly because very few allometric equations are available (Fayolle *et al*., 2013).

The use of existing generalized biomass equations across wider ecological zones can lead to a bias and error in estimating biomass for particular species and sites (Henry *et al*., 2011) because, there are differences among species in wood specific gravity, tree sizes, growth stages, and also since some geographic areas have not been covered by the existing general allometric equations is that it cannot 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 climate, topography, soil fertility, water supply, wood density, distribution of tree species, tree functional types and forest disturbances have impact on forest variability (Fearnside, 1997; Slik *et al*., 2008). For a determined tree species, tree mass is influenced by the size of the tree, its architecture, (form), and health (e.g. hollow trees), (Fearnside, 1997).

Allometric equations are a basic tool for non-destructive estimation of biomass in woody vegetation. These equations express tree biomass as a function of easy-to-measure parameters such as diameter, height, volume or wood density, or a combination of thereof (FAO, 2012; Brown, 2002 and Chave *et al*., 2014). Equations generated from a small sample of trees are then used to estimate biomass at plot level and landscape scales. It's also the convenient and common method to estimate the biomass of a forest or stand. Biomass estimation through allometric equation for forest and Agroforestry are very vital for mitigation of climate change and sustainable management of the two systems (Wang, 2006). Thus, the overall objective of this review is to identify what is known and what is not known (research gap) on the following specific objectives.(i) To develop allometric equation for biomass carbon stock estimation carbon for selected important tree species of Mago National Park forest ecosystem.(ii)To determine uncertainties associated with using species specific, site specific and generic biomass models for forest biomass estimation.(iii) To estimate the biomass carbon stock in harvested wood products for selected tree species of the Forest.

Study Area

Mago National Park is one of the parks in Ethiopia located in SNNPR of Ethiopia. It is about 782 km south of Addis Ababa and north of a large 90° bend in the Omo River. The Mago national park was established in 1979. The Mago Park covers area about 1869.95 km^2. Geographically, the park lies between latitude 05°20'-05°50'N and longitude 36°00'-36°30'E. The elevation ranges from 400m.a.s.l on the plains in south, to 1,776 m on top of Mt Mago. The interior section of the park mainly consists of flat plains. However, periphery and boundaries, except to the south, are formed by the Mago and Mursi Mountains, associated ridges and chains of hills.

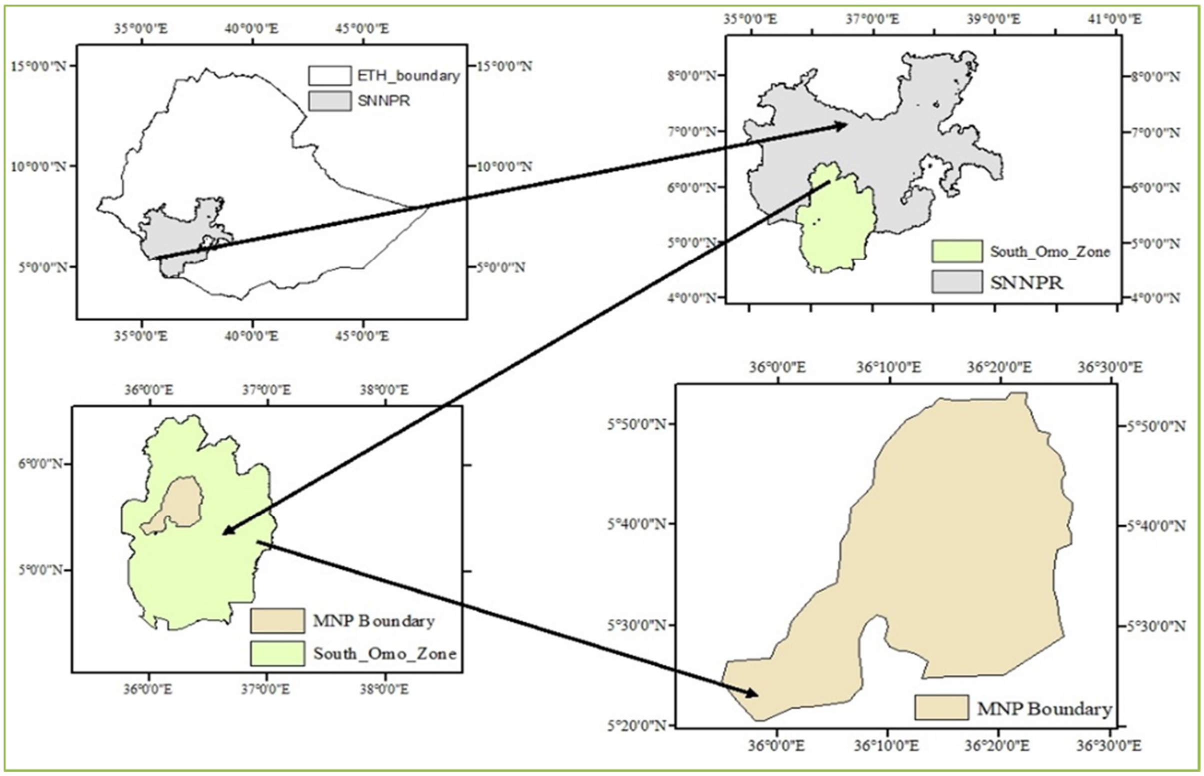

Fig. 1: Map of the study area

Key findings and Discussion

An Overview of the Reviewed Articles related to Allometric Equation

Allometric equations have been developed for different types of vegetation in Ethiopia. This review tries to concentrate mostly on recent articles (Figure 2). Most developed equations were undertaken since 2016.

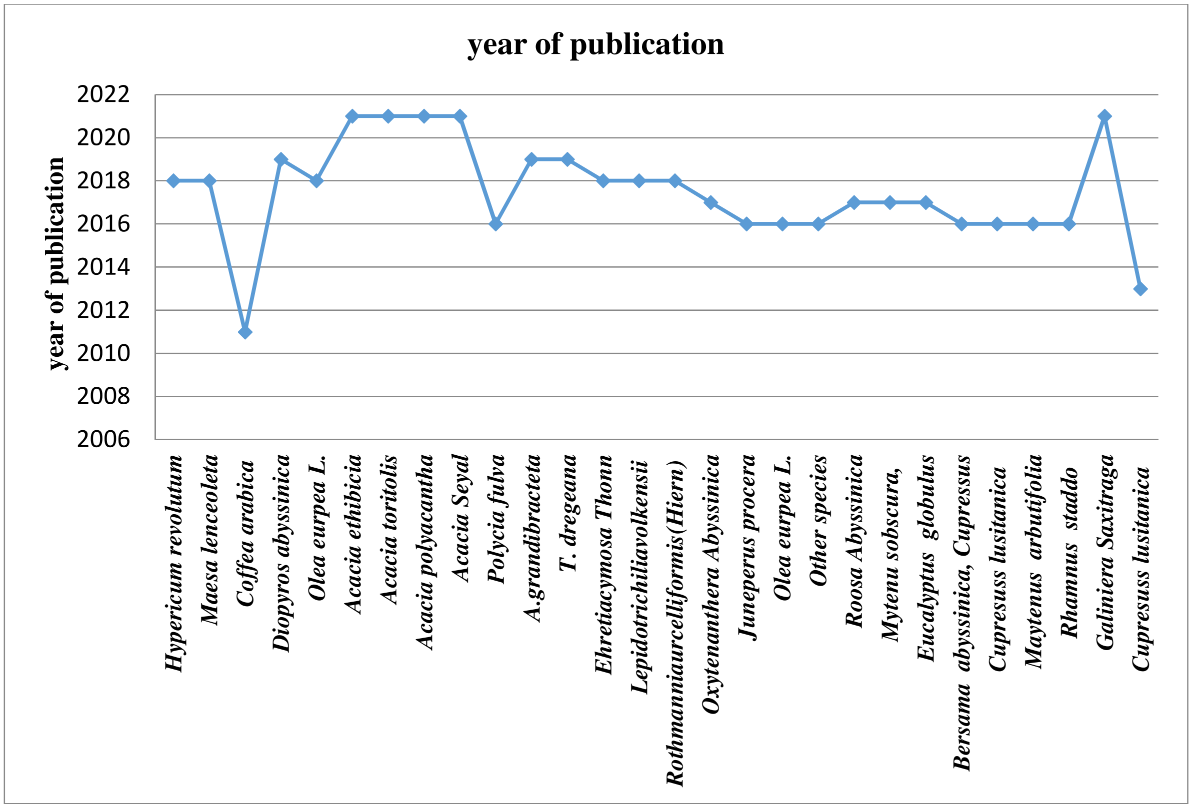

Fig 2: Year of publication for articles reviewed

IPCC Recommend that for Allometric equation development a minimum of thirty plant species should be selected (IPCC, 2006). 57% of the reviewed articles selected 12 plant species which is below half of the recommended. Only 29% reviewed articles selected appropriate sample (Fig. 3). The one which selected 45 plant species was aimed to develop Allometric equation for mult-species or the Allometric equation developed was site specific but not species specific. From the reviewed articles 14% on Acacia Species and this make largest share from selected plant Species.

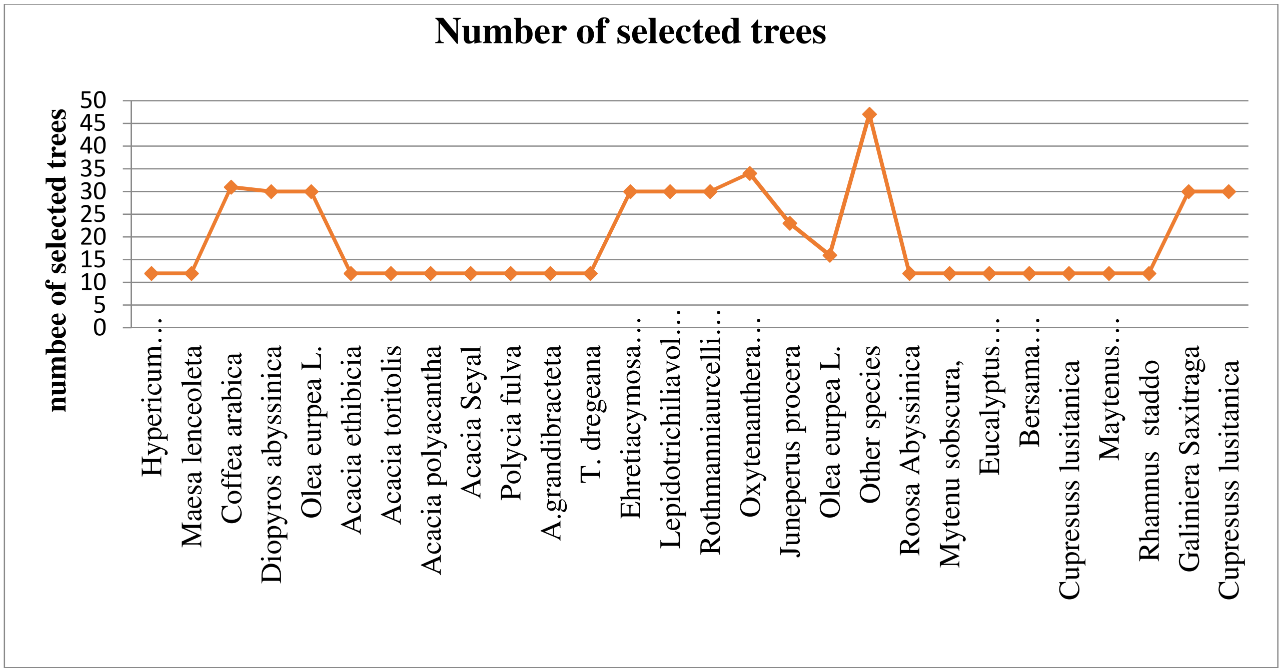

Fig. 3: Number of selected trees for Allometric equation development for each plant species

Destructive method is the most accurate method to develop regression equations from destructively sampled trees that are in the size range of interest (Abola *et al*., 2005). According to IPCC, (2006) the increasing order of accuracy to develop regression equation are Destructive, semi-destructive and using default value. Despite this fact most of the article reviewed (75%) use semi-destructive method for Allometric equation development. Only the rest percentage use destructive method.

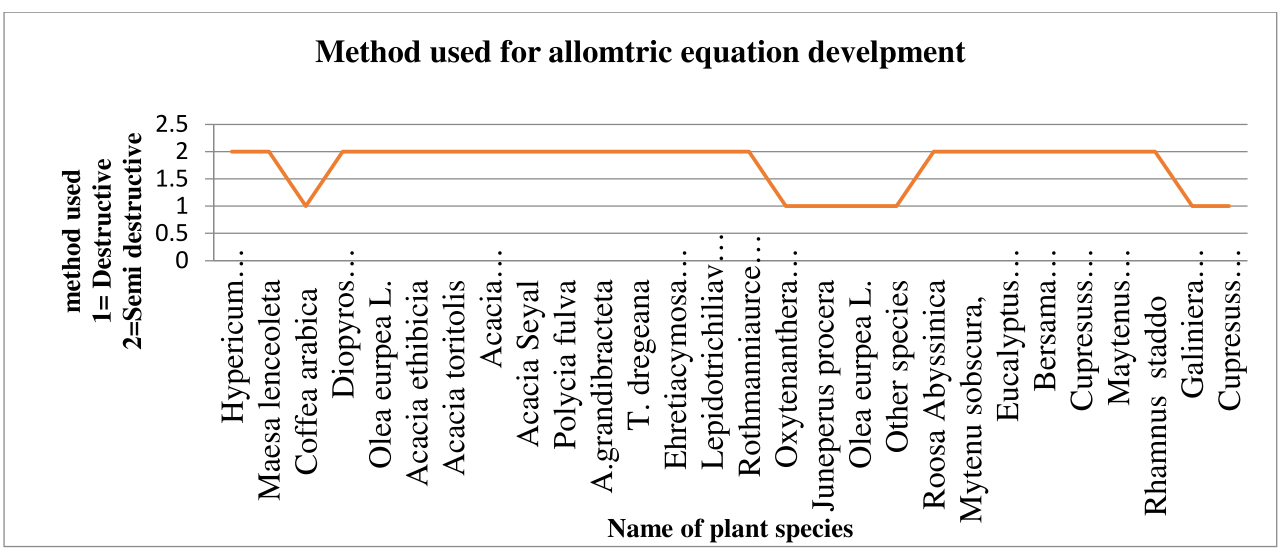

Fig. 4: Method used for Allometric equation development by reviewed articles

Major Findings (What is known) on Allometric Equation

Several study have been conducted on the development of allometric equation in Ethiopia. Most of them were conducted by using semi destructive method. The following are some of the conducted research in Ethiopia with the relationship between biomass and dendrometric variables. Mecheal Hordofa *et al*. (2018) conducted a research in Chuqala natural forest and develop allometric models for biomass estimation with independent observable predictor, such as Diameter at Breast Height (DBH) of a tree, height of a tree, and volume of tree components. According to their result, among the independent variables that are DBH, H, and V the most appropriate independent variable to fit the models for the two selected tree were the DBH. Birhanu and Teshome (2018) Pointed out that, the AGB was strongly correlated with DBH and was not significantly correlated with wood density and height individually in *O. europaea* L. subsp. *cuspidata* allometric equation development. In combination, AGB was strongly correlated with DBH and height; DBH and wood density; and the combination of DBH, height, and wood density. They also indicate that the Species-specific equations are better carbon assessment than general equations. Another study on Allometric equation development was the study undertaken by Mulugeta *et al*. (2018). They harvested and weighed 84 trees from eleven dominant species from six grazing enclosures and adjacent communal grazing land. They observed that AGB correlates significantly with diameter at stump height DSH, and tree height H.

Abiy and Teshome (2016) also indicate that, DBH alone is a good predictor of biomass especially, in terms of multiple tradeoffs between accuracy, cost and practicability of the measurement. And also they 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.

Another study which was done in the Banja district of Awi zone estimate AGB against combination dendrometric variables such as DBH, H and D in the species specific allometric model showed the best model performance. The developed models related AGB against predictors in the log–log forms and these model relationships between AGB and predictors was the best in terms of goodness of fits. Their result revealed that the inclusion of diameter, height and wood density in the development of species-specific allometric equations predicted aboveground biomass with small bias than using a single or two predictors (Getaneh *et al*., 2020)

The allometric equations are used to predict tree and stand biomass, based on easily measured tree variables such as DBH and height. Tesfaye *et al*. (2017) pointed out that DBH was 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. Their revealed also as DBH is a strong indicator of above ground biomass. So, DBH alone is a good predictor of biomass especially, in terms of multiple tradeoffs between accuracy, cost and practicability of the measurement. The study by Yehualashet *et al*. (2016) Egdu Forest indicates that diameter at breast height, wood specific gravity, and tree height were important estimator to consider for the estimation of aboveground biomass at tree scale. Comparison of these results with those obtained using generalized allometric model revealed differences with biomass estimation. The application of the newly proposed allometric models from this study shall be based on the availability of forest inventory data for incorporation of the various estimator variables.

Mesele *et al*. (2013) *Coffea arabica* L.grown in the Rift Valley escarpment of Ethiopia. The harvests 31 plants and develop power equations using stem diameter measured at either 40 cm (d40) or at breast height (d, 1.3 m) with and without stem height (h) were evaluated. The square power equation, $Y = b_1d^240$, was found to be the best (highest ranked using goodness-of-fit statistics) for predicting total and component biomass. The study conducted in the Omo-Gibe woodland of south-western Ethiopia to develop an allometric equation to estimate the Above-ground Biomass (AGB) of the four Acacia species (*Acacia polyacantha, Acacia seyal, Acacia etbaica* and *Acacia tortilis*). Fifty- four (54) acacia trees were sampled According to their result the model containing DBH alone was more accurate to estimate AGB compared to the use of multiple predictor variables (Abreham *et al*., 2021). Fekadu *et al*., (2017) conduct a research in Dicho forest to develop Allometric Equations to Estimate the Biomass of *Oxytenanthera Abyssinica* (A. Rich.) They develop linear allometric equations to estimate TAGB and TBGB of individual bamboo trees. In order to develop the regression equation they used destructive method. Accordingly, the linear model in the form of $Y = a + b*X$ (where: Y is biomass, a and b are constant parameters, and X is independent variable such as DBH, Height, Basal diameter and/or basal area or a combination of these variables) They were tried many possibilities using DBH, height, basal diameter (D10), basal area (BA), wood density (ϱ) and their combinations and logarithmic transformations as predictor variable. They also found that DBH was the best predictor variable for the total above ground biomass (TAGB). Another study conducted by Buruh Abebe *et al*. (2016) in Desa'a dry Afromontane forest was by using destructive methods. They tried to develop Allometric equation for two plant species namely *Juneperus procera* and *Olea eurpea* L and another equation for the rest plant species. They identify relationships between the response variable (AGB) and the potential predictor variables (DBH, DSH, H, CA, ρ). Among all the tested AGB models for two dominant species and for other species under Model System II, only those with DBH and DSH as sole predictor variables had significant parameter estimates. This article was the only article that I reviewed that use DSH for large trees. Tura and Admassu (2021) conducted study in Gesha-Sayilem forest, on allometric equation for aboveground biomass estimation of *Galiniera saxifraga* (Hochst.) Their results indicated that DBH and crown area were found to be the best fit variables for *G. saxifrage.* This was the only study that I came across thatuse crown area for developing Allometric equation.

Table 1: Summary of literature Reviewed which include Species name, Equation and Area in which the study undertaken

s/n	Species	Equation	Area of study
1	*Hypericum revolutum*	AGB=–681.015＋4,494.094 (DBH)	Chuqala Natural Forest
2	*Maesa lanceoleta*	AGB=–936.96＋5,268.92 (DBH)	Chuqala Natural Forest
3	*Coffeaarabica* L.	$Y= 0.147D_{40}^2$	Rift Valley escarpment of Ethiopia
4	*Olea europaea* L.	$AGB_{est} = 0.623 \times (D)^{1.352} \times (H)^{0.703}$ and $AGB_{est} = 0.866 \times (DBH)^{1.432} \times (H)^{0.608} \times (\rho)^{1.067}$	ManaAngetu Forest
5	*Albizia grandibracteata*	$TAGB = 0.3274 \times (\rho D2H)^{0.759}$	
6	*Trichilia dregeana*	TAGB = 0.0832 × (ρD2H)0.899	Yayu Coffee-Forest Biosphere
7	multi-species allometric equation	$Y= 0.2655*(D_{30})^{1.7737}$	'Gomit watershed', located in South Gondar zone,
8	*Polysciasfulva* (indigenous tree).	AGB =-301.621 + 14.056 (DBH) and ln(AGB)=ln(-2.439)+ 2.129 ln(DBH) Total biomass=-361.945 +16.868 (DBH)	In Agroforestry Gedeo Zone of Ethiopia
9	*Diospyrosabyssinica* (Hiern) F. White tree Species	$AGB_{est} =$ 0:457 $xD^2H^{0.721}$ x $(\rho)^{0.446}$	Yayu Coffee-Forest Biosphere
10	*Acacia seyal*	$\ln (AGB) =2.20636+0.53167\ln (DBH^2)$	Selected Indigenous
11	*Acacia polyacantha*	$\ln(AGB)=2.95854+0.21750\ln((DBH)^2H\rho)$	Acacia
12	*Acacia ethibicia*	$AGB= 29.01898*((DBH)^2H\rho)^{0.21518}$	Species in Omo-Gibe
13	*Acacia toritolis*	$AGB = 3.82427*((DBH)^2H\rho)^{0.26748}$	Woodland Ecosystem
14	*Eucalyptus globules*	$AGB= ((0.08283 \times (DBH^{1.873})) \times (H^{0.8242}) + 10^{(-3)}$	Gambo forest
15	*Ehretiacymosa* Thonn	AGB = exp [-1.137 + 2.129 ln (DBH) – 0.035 ln (H) + 0.460 ln (WD)]	Banja district Awi zone
16	*Lepidotrichilia volkensii (Giirke) Leroy*	AGB = exp [-0.040 + 1.758 ln (DBH) – 0.094 ln (H) + 0.519 ln (WD)].	
17	*Rothmannia urcelliformis*(Hiern)	AGB = exp [-2.309 + 2.289 ln (DBH) + 0.019 (H) – 0.937 ln (WD)].	Banja district Awi zone
18	*Tecleanobilis*Del.	AGB = exp [-1.290 + 1.667 ln (DBH) + 0.397 ln (H) – 0.639 ln (WD)].	
19	*Allophyllusabyssinicus*	$W_{above} = \beta*(d*h)$	
20	*Oleaeuropaeassp.cuspidata*	$W_{above} =\Sigma\ \beta*(d^2*h)+ (\beta*d2)+(\lambda*h) + \beta*(d2*h)$	Chilimo-Gaji dry afro-montane forest
21	*Oliniarochetiana*	$W_{above} =\Sigma\ \beta*(d*h)+ (\beta*d^2)+\lambda*(d^2*h)$	
22	*Rhus glutinosa*	$W_{above} =\Sigma\ \beta*(d*h)+ (\beta*d^2)+(\lambda*h)$	
23	*Scolopi atheifolia.*	$W_{above} =\Sigma\ \beta*(d^2*h)+\beta*(d*h)$	
24	*Oxytenanthera abyssinica* (A. Rich.)(Ethiopian Lowland Bamboo)	$TAGB$=–1.073+0.067×BA+ –0.064×$D\mathbf{10}$ +0.206×H+0.653×DBH	Dicho Forest
25	*Crotonmacrostachys* Hochst. Del.	y = 22.601DBH - 242.74	Munessa-Shashemene Forest Degaga District

26	*Cupressus lusitanica Miller, Cupressaceae*	y = 27.293DBH - 380.14	
27	*Eucalyptus globulus Labill., Myrtaceae*	y = 29.517DBH - 294.8	
28	*Eucalyptus globules*	AGB best =0.295* $(DBH)^{2.088}$	Egdu Forest, in Welmera District
29	*Maytenus obscura*	AGB best =0.255* $(DBH)^{2.103}$	
30	*Rosa abyssinica*	AGB best =0.371* $(DBH)^{2.0251}$	
31	*Juniperus procera*	ln(AGB)=ln(2.48)+2.321ln(DBH)	Wof-washa forest in Ethiopia
32	*Bersama abyssinica*	AGB=9.996+0.518(DBH)-0.044(H)-17.37(ρ)	Egdu Forest, in Welmera District
33	*Cupressus lusitanica,*	AGB=-193.359+25.869(DBH)-15.727(H)+90.952(ρ)	
34	*Maytenus arbutifolia,*	AGB=5.538+1.9545(DBH)+0.316(H) + 8.01(ρ)	
35	*Rhamnus staddo*	AGB=-2.25+3.220(DBH)-1.356(H)	
36	*Cupressus lusitanica Miller, Cupressaceae*	$Y=-2.8157D^2H +e$	Wondo Genet Plantation
37	multi-species allometric equation	AGB = 0.298 + $DBH^{2.034}$	Dry Afromontane Forests of Northern Ethiopia

Major Findings (What is known) on Carbon Sequestration on Agroforestry

The capacity of Agroforestry systems to store Carbon varies among different agro-ecological landscapes and the types of Agroforestry system (Montagnini and Nair, 2004). As a result, the storage potential for semiarid, sub-humid, humid, and temperate regions is estimated at 9, 21, 50, and 63 t C ha^{-1}, respectively (Montagnini, F. and Nair, P.K.R., 2004). Extensive reviews by (Luedeling and Neufeldt, 2012) for West African Sahel countries (extending from arid Sahara Desert to humid region Guinea) reported biomass Carbon stocks ranging from 22.2 to 70.8 t C ha^{-1}. As reports showed, globally, the total biomass Carbon stock for AF systems ranges between 12 and 228 t C ha^{-1}(Albrecht, A. and Kandji, S.T., 2003). Another study by (Nair and Nair, 2003) reported that Agroforestry practices stored Carbon ranging from 0.29 to 15.21 t C ha^{-1} yr^{-1} in their aboveground biomass and can have from 30 to 300 t C ha^{-1} in their soil down to one-meter depth. Soil Carbon stock for the 0–60 cm soil layer differs among different land uses and regions. For instance, the Carbon stock in the above mentioned soil layer is 121–123 t ha^{-1} for tropical forests and 110–117 t ha^{-1} for tropical savanna (Lal, 2004).). As reported by Takimoto *et al*. (2008) in the study of an agroforestry systems (traditional parkland systems with Faidherbia albida and Vitellaria paradoxa as the dominant tree species, live fence, fodder banks and an abandoned previously cultivated land) in the West African Sahel, biomass Carbon stock ranged from 0.7 to 54.0 Mg C ha^{-1} and total Carbon stock (biomass Carbon + soil Carbon, into 1m depth) from 28.7 to 87.3 Mg C ha-1, in which a major portion of the total amount of C in the system is stored in the soil. The studies conducted in Ethiopia also showed that the Agroforestry systems have a great potential in sequestering a significant quantity of Carbon. For instance: Reta *et al*. (2015) Undertaken a research on Parkland Agroforestry Practice in Minjar

Shenkora. Their result revealed that, the average, carbon stock of parklands practice in Minjar shenkora was 59.65 Mg C ha^{-1}. Another study by Mihert in (2019) on Biomass and Soil Carbon Stocks Assessment of Agroforestry Systems and Adjacent Cultivated Land, in Cheha Wereda, reported that the total ecosystem carbon stocks in home garden and woodlot AFS were 100.4 and 72.9Mg C ha-1 respectively. This study also showed that the highest SOC stock was recorded in home garden agroforestry system. The study undertaken on Assessing carbon pools of three indigenous Agroforestry systems in the Southeastern Rift-Valley Landscapes, Ethiopia, indicated that the mean AGB ranged from 81.1 to 255.9 t ha^{-1} and for BGB from 26.9 to 72.2 t ha^{-1}. The highest C stock was found in Coffee–Fruit tree–Enset based (233.3 $\pm$ 81.0 t ha^{-1}), and the lowest was in Coffee–Enset based AF system (190.1 $\pm$ 29.8 t ha^{-1}). The carbon stock in Enset based AF system was (197.8 $\pm$ 58.7 t ha^{-1}) (Tesfay *et al*., 2022). Negash and Starr (2015), undertaken the study on biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment. Their result indicated that the smallholding total biomass C stocks averaged 67 Mg ha^{-1} and SOC stocks (0–60 cm) were 109–253 Mg ha−1 (52–91% of total C stocks). As reported by Ashenafi *et al*. (2021) the four smallholdings AF practices (parkland, home garden, boundary planting and woodlot) Carbon stocks ranged from 77 to 135 Mg ha^{-1}. 2.4 Major Findings (What is known) on application of general ***Allometric Equation***

Allometric equations are important for their application to local and national forest carbon assessments, as well as for global carbon balance assessments (Basuki *et al*., 2009). Primarily, the current issue of global carbon cycles is the prominent factor for the formulation of biomass regression models (Henry *et al*., 2011; Jara *et al*., 2014 and Wang, 2006). As a result, generalized pantropical allometric equations were developed by many researchers (Henry *et al*., 2011; Chave *et al*., 2005 and Brown, 1997). The development of a generalized allometric equation was approached by measuring multiple tree species and it was intended to be applied to a broad range of tropical forests (Chave *et al*., 2005). However, a great error is generated related to adopting generic pantropical allometric equations for many forests (Alvarez *et al*., 2012, Ngomanda *et al*., 2014). Biomass error that can be generated at individual tree level is also regularly propagated bias at forest stand and country level during the assessment of biomass and carbon stock change the appropriate allometric equation is not used.

Environmental variations among different forests are the ultimate factors for the variation of their biomass. Climatic regimes are the prominent factors that affect the growth of woody plants and biomass accumulation of different forest stands (Xu *et al*., 2018, Pfeifer *et al*., 2018). Also, environmental variability in the context of physiographic and edaphic conditions plays a significant role in the variation of species composition and biomass difference among different forest sites. (Alves *et al*., 2010, Laumonier *et al*., 2010). Within-stand variation of biomass for different tree species is related to tree architecture, growth strategies and its dynamic interplay with the biophysical environments (Ketterings *et al*., 2001, Muller-Landau, 2004, Clark and Clark, 2000]. The difference of TAGB across a forest landscape is mostly related to the variation in slope, elevation, and aspect (Alves *et al*., 2010, SalinaS-Melgoza *et al*., 2018). Generally, tropical forests are known for their high diversity of woody plants. The application of multispecies pan-tropical equations to individual tree species generates uncertainty of TAGB (Basuki *et al*., 2009, Djomo and Chimi, 2017). Therefore, formulating a species- and site-specific biomass regression model was found the best approach to accurately quantify biomass and carbon storage of forests (Goussanou *et al*., 2016).

What is Not Known/ New

Species specific models provide less bias than general models and site specific because, local climatic, soil properties, altitude, and land-use history are affected by tree growth characteristics (Yuen *et al*., 2016). According to Mokria *et al*. (2018), the lack of a species -specific allometric model for estimation of AGB is the key reason for persistent inaccuracy and low uncertainty in biomass estimation in sub-Saharan Africa. Solomon *et al*. (2012) stated that the precise estimation of biomass and carbon stock in a forest can be achieved using species specific and site-specific allometric equations for the species and forest types. According to Henry *et al*. (2019), reviews of biomass models in sub-Saharan Africa, 63 models have been established in Ethiopia, which focused only on six allometric equations, of which 70% of the models were developed for eucalyptus species (Tetemke *et al*., 2019). However, following the review of Henry *et al*. (2011), there have been attempts to develop local species-specific and site specific allometric equations for estimating AGB of trees in different parts of Ethiopia in recent studies such as Tetemke *et al*. (2019), Feyisa *et al*., (2018), Kebede and Soromessa (2018), Daba and Soromessa (2019) but still, they are not sufficient in respective of vegetation types and agro-ecology of Ethiopia. In addition to this fact most the species specific Allometric equations developed depend on semi-destructive which was less accurate than destructive method. The development of a new allometric equation requires that at least 30 trees covering the full range of diameter classes. If the regression based on the 30 trees does not result in a statistically significant relationship (high r-squared value), then additional trees will need to be harvested (Walker *et al*., 2015). According to the reviewed literature, most of the study took sampled trees which were less than the minimum required for the investigation.

Many of adopted generalized equations generate great uncertainty of biomass. The study of (Alvarez *et al*., 2012) reports that higher bias was observed related to the Chave's model II largely overestimating by approximately 300% to 400% for two tropical forest sites. This confirms the significance of formulating species-and site-specific allometric equations for tropical forests. Ethiopia is known for its diverse vegetation ecosystems and associated high diversity of woody plants. However, the assessment of biomass and carbon stock of forests has been practiced by adopting the generic pan-tropical allometric equations that cause great uncertainty. This uncertainty can be recognized by comparing measured value with species specific and general allometric equation.

The different studies have been conducted by different researchers in Ethiopia regarding carbon sequestration potential of Agroforestry such as, Reta *et al*. (2015), Ashenafi *et al*. (2021), Tesfay *et al*. (2022), Seta and Demissew (2014), Negash and Starr, (2015), Mihert, (2019), Birhane *et al*. (2020), and Siyum and Tassew (2019) but this study cover only small portion if our country so, further study is important.

In the case of my review area, no allometric equation has been developed for selected tree species. Regarding Agroforestry there was a study which was conducted by (Wele, D. Ambachewet al., 2009) on carbon stocks in traditional Agroforestry systems adjacent to Mago Forest.

Conclusion

United Nations Framework Convention on Climate Change recently agreed to study and consider new initiatives, in favor of forest-rich developing countries. It provides financial or economic incentives to help developing countries voluntarily to reduce national deforestation rates and associated carbon emissions below a baseline (REDD). Countries that demonstrate emissions reductions may be able to sell those carbon credits to the international carbon market or elsewhere. Under the UNFCCC, countries have to regularly report the state of their forest resources**.** Forest ecosystem and Agroforestry system are the major constituent of the carbon reserves and it plays an important role in regulating global climate change through process of carbon sequestration. Measuring biomass in local, regional and global scales is critical for estimating global carbon storage and assessing ecosystem response to climate change. Formulating allometric equations for all woody plants in Ethiopia is quite desirable for accurately quantifying the biomass and carbon stock of forests to achieve accurate national and international reporting of carbon dioxide emission inventories. Depending on this in Ethiopia several study undertaken regarding allometric equation for biomass estimation, but it is not as forest resource of the country. Most of the study undertaken was depend on semi-destructive method which is not accurate as destructive measurement. The number of plant selected for biomass estimation by allometric equation was much more less than the standard put by IPCC. Generally, in response to global climate change mitigation, the monitoring and assessment of carbon dioxide from forests and Agroforestry is essential.

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