Article

Quantifying carbon stock potential of woody plant species in Seyo watershed, South-West Ethiopia

Gebre Gidey Weldeabzgi[1], **Chala Kitila**[2]
[1]Department of Natural Resource Management, Dambi Dollo University, Ethiopia
[2]Department of Plant Science, Dambi Dollo University, Ethiopia
E-mail: gebregidey09@gmail.com

Received 28 March 2023; *Accepted 5 May 2023*; *Published online 20 May 2023*; *Published 1 September 2023*

Abstract
The carbon stock pool is a reservoir, which has the capacity to accumulate carbon through carbon stock pools. Carbon stock pools of the woody plant species encompass maily above ground and below ground biomass. Woody plant species play a crucial role for climate change mitigation by capturing atmospheric carbon through photosynthesis. The goal this study was to quantify carbon stock and climate change potential of woody plant species in Seyo watershed, south-west Ethiopia. The data was collected through systematic random sampling techniques from 20 m × 20 m area of sample plots. The carbon stocks of above ground and below ground carbon pools were quantified using different allometric models and analyzed by SPSS software. A total of 40 woody plant species were identified in the study area. The result showed that, the mean carbon stock of aboveground carbon and belowground carbon accounted about 245.07 and 49.01 t/ha respectively, which gives a total carbon stock of 294.04 t/ha. The carbon stock of woody plant species showed that, *Acacia abyssinica* and *Maytenus arbutifolia* had the largest and the least carbon reserves, which accounted 31.2 and 0.13 t/ha respectively. The study area was mitigated about 1079.13 ton/ha CO_2 equivalent. The ultimate result showed that, Seyo watershed is a reservoir of high carbon stock. To sustain and enhance the carbon stock potential of this watershed, the government should be integrated the watershed clean development mechanism of carbon trading system of the Kyoto protocol.

Keywords quantifying; carbon stock potential; woody plant species; Ethiopia.

Computational Ecology and Software
ISSN 2220-721X
URL: http://www.iaees.org/publications/journals/ces/online-version.asp
RSS: http://www.iaees.org/publications/journals/ces/rss.xml
E-mail: ces@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Global climate change becomes an environmental problem in today's modern world that has become a source of major global threat to human (Freestone and Streck, 2009). This is mainly caused by greenhouse gas emissions of carbon dioxide (Perschel et al., 2007). So, it is important to study carbon stock potential of woody plant species in specific area to aware local communities about the importance of woody plant in climate change mitigation of the area (Genene et al., 2013). It is known that woody plant species (Trees and Shrubs) play a significant role for climate change mitigation by capturing atmospheric carbon through photosynthesis, which transforms the gas into the solid carbon that make up their barks, woods, leaves and roots of carbon pools (FAO, 2014, 2016).

The carbon stock pool is defined as a reservoir, which has the capacity to accumulate or release carbon (FAO, 2014). According to Fentahun et al. (2017), carbon pools of the woody plant species encompass maily above ground and below ground biomass. The aboveground biomasses of woody plant species comprise all woody stems, branches, and leaves of living trees and shrubs (Pearson et al., 2005).And, below ground biomass of the woody plants consists of the biomass contained within live roots of trees and shrubs, which predict root biomass of trees and shrubs based on their above ground biomass (Pearson et al., 2005).

Different woody plant species differ in their ability to capture and store carbon based on the collective functional characteristics of plant communities (Thompson, 2009). Carbon stocks of woody plant species increases with increasing of plant density, that larger diameter of plants have greater carbon stocks than plants having smaller diameter (Nowak and Crane, 2002). Different scholars in different watersheds like Mohammed et al. (2014) at Tera Gedam watershed and Fentahun et al. (2017) at Banja watershed showed that carbon stock had been affected by tree species; however they didn’t incorporate the shrubs spices. So, in the current study this gap was fill full and it incorporates the shrubs with the tree all considers as woody plants.

The goal this study was to quantify carbon stock and climate change potential of woody plant species in Seyo watershed, south-west Ethiopia. Seyo watershed is one of the woody plants dominated watershed in south-west Ethiopia, which is under pressure of human being with extensive clearing of existing woody pants for fuel wood, fodder and construction materials. So it is helpful, local communities to have good understanding on the importance of woody plants in carbon stock potential of their watershed by collecting sufficient scientific quantitative data on carbon stock potential and disseminating the analyzed findings on the climate change mitigation potential by researcher for sound management of woody plants in the watershed. Therefore, the study was conducted through quantifying above and below ground carbon stocks potential of woody plant species in Seyo watershed.

A next section of this paper includes methodology (study site description, research design, and data type and sources, sampling and identification of woody plant species, estimation of biomasses, and estimation of carbon stocks and data analysis), results and discussion, and conclusion.

2 Methodology

2.1 Description the study area

Seyo watershed is found in Kellem Wollega zone of Oromia region, South-West Ethiopia. It is located at a distance of 7 km East of Dambi Dollo town, and 545 Km far from Addis Ababa (KWZAO, 2018) (Fig. 1). The woody plants of Seyo watershed are composed of both natural and human plantation.

2.2 Research design

This study was relied on an experimental research design. The researcher was took the diameter above breast height (DBH) and height data of live trees and shrubs from field measurement. The experiment laid on about 400 m^2 area (20 m $\times$ 20 m) of square sample plot was employed for sampling of the study watershed, which has a better probability to incorporate more of within plot heterogeneity (Pearson et al., 2005).

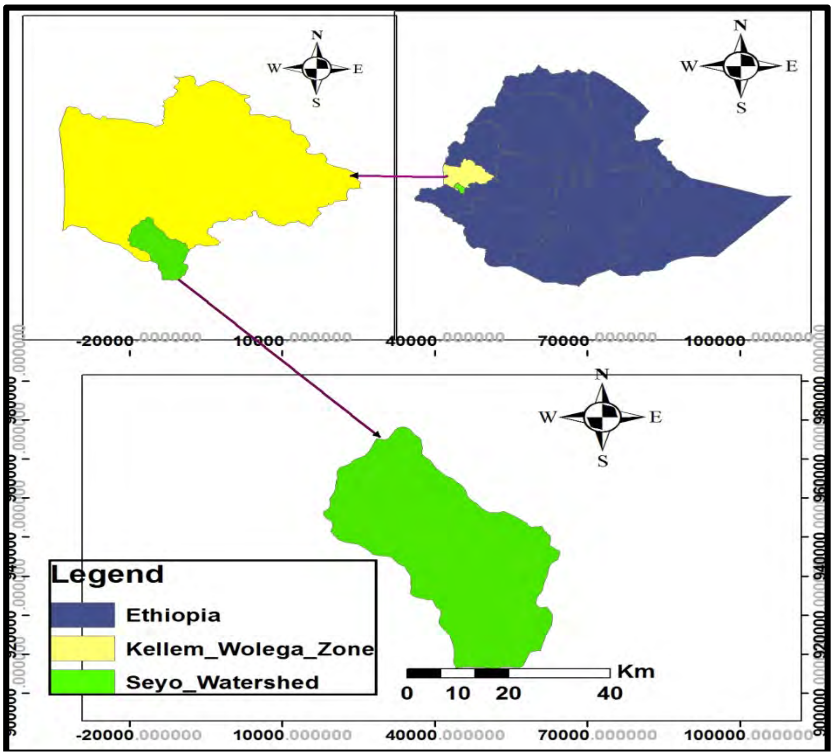

Fig. 1 Map of the study area.

2.3 Data type and sources

Primary data was used to achieve the objectives of this study. The data were collected through field measurements from two carbon storage pools i.e. above ground biomass and below ground biomass.

2.4 Sampling and identification of woody plant species

All woody plants (tree and shrub species) having ≥ 5 cm DBH were measured from 400 m^2 area of sample plots using diameter tape, and the height of those trees was also measured by using hypsometer. Woody plants having multiple stems at 1.3 m (DBH) were considered as a single tree and the largest stem was taken, while woody plants forked below 1.3 m was treated as a single individual as indicated by Pearson et al. (2005). The trees that were tagged, the numbered tag and the nail was placed at 10 cm below the DBH to avoid errors arising from bumps or other imperfections as it recommended by Houghton (2005). Plant identification was using published volumes of Flora of Ethiopia and Eritrea (Azene, 1993).

2.5 Estimation of biomasses

2.5.1 Estimation of Aboveground Biomass (AGB)

The aboveground biomass (AGB) of woody plants (trees and shrubs species) existed in the study area was calculated using the general allometric model of Chava et al. (2014) as follows:

$$\text{AGB best} = 0.0673 \times (\rho \, \text{DBH}^2 \, \text{H})^{0.976} \qquad (1)$$

where,

AGB – Aboveground biomass (kg);

DBH – Diameter of woody plant at breast height (cm);

H – Height of tree (m);

ρ – Wood density = 0.6 ton/m^3, which is the average value of wood density of trees in Africa (Henry et al., 2010).

2.5.2 Estimation of Belowground Biomass (BGB)

Belowground biomass (BGB) of trees and shrubs found in the study area was estimated by using root-shoot ratio factors (MacDicken, 1997). According to Mac Dicken (1997) and Pearson et al. (2005) standard methods of estimating BGB can be obtained as 20% of aboveground woody plant biomass:

$$BGB = AGB \times 0.2 \qquad (2)$$

2.6 Estimation of Carbon Stocks

2.6.1 Estimation of Aboveground Carbon Stock (AGC)

The aboveground carbon (AGC) and CO_2 equivalent sequestrated in aboveground biomass of trees and shrubs found in the study area was calculated by the principles of Pearson et al. (2005) and Pearson et al. (2007) respectively as follows:

$$AGC = \text{aboveground biomass} \times 0.5 \qquad (3)$$

The CO_2 equivalent sequestered in the aboveground biomass = AGC × 3.67 (4)

2.6.2 Estimation of Belowground Carbon Stock (BGC)

Standard methods of estimating belowground carbon (BGC) can be obtained as 50% of belowground biomass:

$$BGC = BGB \times 0.5 \qquad (5)$$

where, BGB = belowground biomass, BGC = carbon content of belowground biomass.

The amount of CO_2 equivalent sequestrated in belowground biomass of the study area was calculated by multiplying BGC by the molecular mass ratio of carbon dioxide to carbon (44/12) which is 3.67 as indicated by Pearson et al. (2007).

2.6.3 Estimation of Total Carbon Stock (TC)

The total carbon stock is calculated by summing the carbon stock densities of the individual carbon pools of the stratum using the Pearson et al. (2005) formula. Carbon stock density of a study area is:

$$TC = AGC + BGC \qquad (6)$$

where, CT = Total Carbon stock (t/ha), AGC = aboveground carbon stock (t/ha), BGC = belowground carbon stock (t/ha).

2.7 Data analysis

The collected data of DBH of live woody plant species were recorded on the Microsoft excel data sheet and it was analyzed by using Statistical Package for social science (SPSS) software version 21. Descriptive statistics were used to summarize the data, including the mean, maximum, minimum and standard deviations of carbon stock of each carbon pool of the study area.

3 Results and Discussion

3.1 Identified woody plant species of the study area

A total number of 40 woody plant species (25 tree species and 15 shrub species) having 2,500 individuals, belonging to 25 families were identified in the sample plots of the Gudina watershed. The total number of woody plant species found in study area was greater than the total number of woody plant species in Chilimo watershed (24), Danaba watershed (27) and Banja watershed (30) that studied by Mehari (2015), Muluken et al. (2015) and Fentahun et al. (2017) respectively. It was also lower than the total number of woody plant species found by Alefu et al. (2013) in Humbo watershed (48), and Meskel Gedam watershed (33) found by Kidanemariam (2014). This variation might be due to the presence of different disturbance regime and the degree of management practice of the watersheds.

Table 1 Woody plant species of Seyo watershed.

Botanical Name	Local Name	Amharic Name	Family Name
Acacia abyssinica (Hochst. ex Benth)	laaftoo	Girar	Fabaceae
Albizia gumifera (J.F.Gmel.) C.A.Sm.	Ambabbeessa	Sessa d	Fabaceae
Albizia grandibracteata (Taub.)	Shaawoo	6-30 m	Fabaceae
Allophylus abyssinicus (Hochest).(Radlkofer)	Xaaxessaa	Embs	Sapindaceae
Azadirachta indica (A.indica)A.	Rigarraabaa	25 m Mahogany	Meliaceae
Bersama abyssinica (Fresen)	Lolchssaa	Azamira	Melianthaceae
Buddleja polystachya (Fresen)	Anfaarree	Anfar	Loganiaceae
Calpurnia aurea (Aiton) Benth	Ceekaa		Fabaceae
Combretum molle (R.Br. ex G. Don)	Dhandhansa	Ykolaabalo	Combretaceae
Cordia africana (Lam.)	Waddeessa	Wanza d	Boraginaceae
Croton macrostachyus (Del.)	Makkanniisa	Bisana d	Euphorbiaceae
Cupressus lusitanica (Mill.)	Xidiifaranjii	Yefernjtidra	Cuppressaceae
Dichrostachys cinerea (L.) Wight & Arn	Hadheessa	Erget demo T	Fabaceae
Dombeya torrida (G.F.Gmel.) & (P.Bamps)	Daannisaa	Wulikifa	Sterculiaceae
Ekebergia capensis (Sparrm.)	Shorooroo	-20 m lol	Meliaceae
Embelia schimperi (Burm.f)	Dhanquu	Enkoko	Myrisnaceae
Erythrina brucei (Lam.ex.DC)	Waleensuu	Korchrar	Fabaceae
Eucalyptus camaldunlensis (Dehnh)	Baargamoo	K. bahirzaf r	Myrtaceae
Euphorbia ampliphylla (pax)	Adaamii	Kulkualrar	Euphorbiaceae
Ficus sur (Forsk)	Hrbuu	Shola some	Moraceae
Ficus sycomorus (Linn.)	Akuukkuu	Bamba some	Moraceae
Ficus thonningii (Blume)	Odaa	Warka d	Moracea
Grevillea robusta (A. cunn. ex R.Br)	Giraaviilaa	Giraviliarar	Proteaceae
Grewia bicolar (Juss)	Arooressaa	2-10m-teye	Tiliaceae
Hypericum revolutum (Vahl)	Garamba	Amja	Hypericaceae
Juniperusprocera (Hochst. ex Endel.)	Omii	Yehabeshatid r	Cuppressaceae
Lepidotruchilia volkensii (Gurke) Ler'y	Mixoo		Meliaceae
Leucasstachy diformis (L.)	Ulmaa	Limich	Lamiaceae
Markhamia lutea (Benth.) K.	Botoroo	Tree do	Bignoniaceae
Maytenus arbutifolia (A. Rich.),(Wilcze)	Kombolchaa	Atat	Celasteraceae

Milletia ferruginea (Hochst.)	Sootalloo	Biribiramedi	Fabaceae
Mimusops kummel (Bruce ex A.DC.)	Qollaatii	TREE	Sapotaceae
Myrsine melanophloeos (L) R. Br.	Tulu	Kechemo med	Myrsinaceae
Olea africana (L.)	Ejersa	Woirarar	Oleaceae
Osyris quadripartite (Salzm. ex Decne.)	Waatoo	Keretrar	Santalceae
Premna schimperi Engl.	Urgeessaa	Checho	Verbenaceae
Prunus africana (Hook.f.)	Gurayu	Tikurinchetrar	Rosaceae
Pavetta abyssinica (Hochst. ex A. Rich)	Dambii	Dingayseber r	Rubiaceae
Pteroloblum stellautm (Forssk) Brenan.	Ambaltaa	Kentafarar	Fabaceae
Rosa abyss inica (Lindley)	Gooraa	Kegarar	Rosaceae

3.2 Aboveground and belowground biomass (AGB & BGB)

The result showed that, the mean aboveground biomass of the woody plant species of the study area were estimated to be 458.07±30.5 t/ha. And, the mean belowground biomass of woody plant species of the study area were estimated to be 91.6±12.3 t/ha, with the mean total biomass of 535.8 t/ha (Table 2).

Table 2 Biomass of each woody plant species found in Seyo watershed.

Types of woody plant species	AGB t/ha	BGB t/ha	TB t/ha
Acacia abyssinica	52.00	10.40	62.40
Albizia gumifera	49.00	9.80	58.80
Ficus thonningii	47.00	9.40	56.40
Azadirachta indica	37.00	7.40	44.40
Albizia grandibracteata	36.20	7.24	43.44
Schefflera abyssinica	34.40	6.88	41.28
Ficus sycomorus	33.50	6.70	40.20
Ekebergia capensis	28.00	5.60	33.60
Cordia africana	17.50	3.50	21.00
Ficus sur	15.60	3.12	18.72
Prunus africana	14.00	2.80	16.80
Syzygium guineense	12.30	2.46	14.76
Dichrostachys cinerea	12.10	2.42	14.52
Mimusops kummel	11.00	2.20	13.20
Lepidotruchilia volkensii	7.50	1.50	9.00
Buddleja polystachya	6.30	1.26	7.56
Sapium ellipticum	6.00	1.20	7.20
Maesa lanceolata	4.50	0.90	5.40
Erythrina brucei	4.40	0.88	5.28
Combretum molle	3.00	0.60	3.60
Cupressus lusitanica	4.20	0.84	5.04
Eucalyptus camaldunlensis	3.50	0.70	4.20
Euphorbia ampliphylla	2.70	0.54	3.24

Grevillea robusta	2.50	0.50	3.00
Juniperus procera	2.30	0.46	2.76
Olea africana	2.00	0.40	2.40
Terminalia laxiflora	1.50	0.30	1.80
Dombeya torrida	1.20	0.24	1.44
Myrsine melanophloeos	0.95	0.19	1.14
Bersama abyssinica	0.92	0.18	1.10
Vernonia amygdalina	0.91	0.18	1.09
Ehretia cymosa	0.75	0.15	0.90
Grewia bicolar	0.72	0.14	0.86
Calpurnia aurea	0.59	0.12	0.71
Allophylus abyssinicus	0.46	0.09	0.55
Osyris quadripartite	0.44	0.09	0.53
Rosa abyssinica	0.32	0.06	0.38
Leucasstachy diformis	0.31	0.06	0.37
Embelia schimperi	0.29	0.06	0.35
Maytenus arbutifolia	0.21	0.04	0.25
Mean	**458.07**	**91.6**	**535.8**

3.3 Aboveground and belowground carbon stocks (AGC &BGC)

The result showed that, the mean aboveground carbon stock in woody plant species of the study area was estimated to be 245.07±35.05 t/ha. And, the mean below ground carbon stock in woody plants species of the study area was 49.01±6.2 t/ha. Accordingly, a mean of 1079.13±25.01 t/ha CO_2 eq. was sequestered in both above ground and below ground biomass of woody plants of the study area (Table 3).

When compared to other dry studies, the mean above ground carbon stock of Seyo watershed was greater than the mean above ground carbon stock of Menagesha Suba watershed and Meskel Gedam watershed. It was also lower than the mean above ground carbon stock of Edgu watershed and Banja watershed. This variation was due to the presence of different DBH and height class of woody plants existed in the study watersheds (Larionova et al., 2002). And, the mean BGC stock of the study area compared to the mean BGC stock of other studies, it was greater than the mean BGC stock of Menagesha Suba watershed and Meskel Gedam watershed. And less than the mean BGC stock of Edgu watershed and Banja watershed. Likewise the variation of the AGC stock of the above watersheds, the variation of their below ground carbon stock was due to the presence of different DBH, height and density of woody plants existed in the study watersheds.

Table 2 Carbon stocks and CO_2 eq of each woody plant species found in Seyo watershed.

Types of woody plant species	AGC	BGC	TC	TCO_2 eq.
Acacia abyssinica	26.00	5.20	31.20	114.50
Albizia gumifera	24.50	4.90	29.40	107.90
Ficus thonningii	23.50	4.70	28.20	103.49
Milletia ferruginea	21.50	4.30	25.80	94.69
Azadirachta indica	18.50	3.70	22.20	81.47

Albizia grandibracteata	18.10	3.62	21.72	79.71
Schefflera abyssinica	17.20	3.44	20.64	75.75
Ficus sycomorus	16.75	3.35	20.10	73.77
Ekebergia capensis	14.00	2.80	16.80	61.66
Cordia africana	8.75	1.75	10.50	38.54
Ficus sur	7.80	1.56	9.36	34.35
Prunus africana	7.00	1.40	8.40	30.83
Syzygium guineense	6.15	1.23	7.38	27.08
Dichrostachys cinerea	6.05	1.21	7.26	26.64
Lepidotruchilia volkensii	3.75	0.75	4.50	16.52
Buddleja polystachya	3.15	0.63	3.78	13.87
Sapium ellipticum	3.00	0.60	3.60	13.21
Maesa lanceolata	2.25	0.45	2.70	9.91
Erythrina brucei	2.20	0.44	2.64	9.69
Combretum molle	1.50	0.30	1.80	6.61
Cupressus lusitanica	2.10	0.42	2.52	9.25
Eucalyptus camaldunlensis	1.75	0.35	2.10	7.71
Euphorbia ampliphylla	1.35	0.27	1.62	5.95
Grevillea robusta	1.25	0.25	1.50	5.51
Juniperus procera	1.15	0.23	1.38	5.06
Olea africana	1.00	0.20	1.20	4.40
Terminalia laxiflora	0.75	0.15	0.90	3.30
Dombeya torrida	0.60	0.12	0.72	2.64
Myrsine melanophloeos	0.48	0.10	0.57	2.09
Bersama abyssinica	0.46	0.09	0.55	2.03
Vernonia amygdalina	0.46	0.09	0.55	2.00
Ehretia cymosa	0.38	0.08	0.45	1.65
Grewia bicolar	0.36	0.07	0.43	1.59
Calpurnia aurea	0.30	0.06	0.35	1.30
Allophylus abyssinicus	0.23	0.05	0.28	1.01
Osyris quadripartite	0.22	0.04	0.26	0.97
Rosa abyssinica	0.16	0.03	0.19	0.70
Leucasstachy diformis	0.16	0.03	0.19	0.68
Embelia schimperi	0.15	0.03	0.17	0.64
Maytenus arbutifolia	0.11	0.02	0.13	0.46
Mean	**245.07**	**49.01**	**294.04**	**1079.13**

3.4 Carbon stock variation among different woody plant species

The finding of the study showed that, the total amount of AGC and BGC stock of each woody plant species of Seyo watershed was varied from one species to another species. Out of the total number of 40 woody plant species found in the sample plots of the study area, *Acacia abyssinica*, *Albizia gumifera*, and *Ficus thonningii* were the leading species having the largest carbon stock reserves with 31.2, 29.4, and 28.2 carbon t/ha respectively. On the other hand, species of Maytenus arbutifolia and Embeliaschimperi had the least carbon stock potential with 0.13 and 0.17 carbon t/ha respectively. This variation was existed due to the differences of DBH, height and density of trees and shrub species existed in the sample plot of the study area. Large number of *Acacia abyssinica*, *Albizia gumifera*, and *Ficus thonningii* had large DBH and height class, while Maytenus arbutifolia and Embeliaschimperi had the smallest DBH and height record in the sample plots of the study area.

4 Conclusion

The carbon stock pool is a reservoir, which has the capacity to accumulate carbon. Carbon pools of the woody plant species encompass maily above ground and below ground biomass. The carbon stock potential of woody plants in the study area was determined by the carbon stock capacity of above and below ground carbon pools. Seyo watershed has played an important role for carbon sequestration and climate change mitigation. The carbon pools of AGB and BGB had a potential of total climate change mitigation 1079.13 t/ha CO_2 equivalents. The largest climate change mitigation capacity of the watershed was covered by the above ground biomass of woody plants. This was the reason that, Seyo watershed had a large number of trees having large DBH and height class distribution. To sustain and enhance the carbon stock potential of this watershed, the government should be integrated the watershed clean development mechanism of carbon trading system of the Kyoto protocol.

References

Alefu C, Teshome S, Eyale B. 2013. Carbon stock in woody plants of humbo forest and its variation along altitudinal gradients: The case of Humbo District, Wolaita Zone, Southern Ethiopia. Journal of Environmental Protection and Policy, 3(4): 97-103

Azene B. 1993. Useful Trees and Shrubs for Ethiopia: Identification, Propagation and Management for Agricultural and Pastoral Communities. RSCU/SIDA, Ethiopia

Chave J, RéjouMéchain M, Búrquez A, Chidumayo E, Colgan MS, Delitti WB, Henry M. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Journal of Global Change Biology, 20(10): 3177-3190

FAO (Food and Agricultural Organization of the United Nations). 2014. Climate Change and Forests. Research Paper. FAO, Rome, Italy

FAO (Food and Agricultural Organization of the United Nations). 2016. Forestry for A Low Carbon Future: Integrating Forests and Wood Products In Climate Change Strategies. FAO For. Pp177. FAO, Rome, Italy

Fentahun A, Yehualashet B, Alemayehu K, Teshome S. 2017. Carbon stock of Banja forest in Banja district, Amhara region, Ethiopia: An implication for climate change mitigation. Journal of Sustainable Forestry, 36(6): 604-622

Freestone and Streck. 2009. Legal Aspects of Carbon Trading: Kyoto, Copenhagen, and beyond. Oxford University Press, London, UK

Genene A, Tefera M, Zerihun G, Solomon Z. 2013. Training on Forest carbon pools and forest carbon stock assessment context of SFM and REDD+. Hawassa University, Ethiopia

Henry M, Besnard A, Asante WA, Eshun J, Adu-Bredu S, Valentini R, Saint André L. 2010. Wood density, phytomass variations within and among trees, and allometric equations in a tropical rainforest of Africa. Journal of Forest Ecology and Management, 260(8): 1375-1388

Houghton RA. 2005. Aboveground forest biomass and the global carbon balance. Global Change Biology, 11(6): 945-958

Kauffman JB, Arifanti VB, Basuki I, Kurnianto S, Novita N, Murdiyarso D, Warren MW. 2016. Protocols for the measurement, monitoring, and reporting of structure, biomass, carbon stocks and greenhouse gas emissions in tropical peat swamp forests. Center for International Forestry Research (CIFOR), Indonesia

KWZAO (Kellem Wollega Zone Agricultural office). 2018. Annual Report (unpublished)

Larionova AA, Rozanova LN, Evdokimov IV, Ermolaev AM. 2002. Carbon budget in natural and anthropogenic forest-steppe ecosystems. Eurasian Soil Science, 35(2): 156-164

MacDicken KG. 1997. A Guide To Monitoring Carbon Storage In Forestry And Agro Forestry Projects In Forest Carbon Monitoring Program. Winrock International Institute for Agricultural Development, Arlington, Virginia, USA

Mehari A. 2015. Forest management options and carbon stock and soil rehabilitation in Chilimo Dry Afro-Montane forest, Ethiopia. Environmental Science, Corpus ID: 128312419

Mohammed G, Teshome S, Satishkumar B. 2014. Forest carbon stocks in woody plants of Tara Gedam forest: Implication for climate change mitigation. Science, Technology and Arts Research Journal, 3(1): 101-107

Muluken N, Teshome S, Eyale B. 2015. Carbon stock in Adaba-Dodola community forest of Danaba District, West-Arsi zone of Oromia Region, Ethiopia: An implication for climate change mitigation. Journal of Ecology and the Natural Environment, 7(1): 14-22

Nowak DJ, Crane DE. 2002. Carbon storage and sequestration by urban trees in the USA. Environmental Pollution, 116(3): 381-389

Pearson TR, Walker S, Brown S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the Bio Carbon Fund of the World Bank, Arlington, USA

Pearson TR, Brown SL, Birdsey RA. 2007. Measurement guidelines For The Sequestration 0f Forest Carbon: Northern Research Station. 6-15, Department of Agriculture, Washington DC,USA

Perschel RT, Alexander ME, Marcia JS. 2007. Climate Change, Carbon, and the Forests of the Northeast. Forest Guild, Santa Fe, USA

Thompson I, Mackey B, McNulty S, Mosseler A. 2009. Forest resilience, biodiversity, and climate change. In a synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Technical Series. Secretariat of the Convention on Biological Diversity, Montreal, Canada