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The Effect of Age of Exclosures and Aspect on Aboveground Carbon of *Boswellia papyrifera* Dominated Woodland of Kafta Humera, Western Tigray, Northern Ethiopia

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Abstract

This study was conducted in Boswellia dominated woodland at Kafta Humera to estimate the amount of carbon stored in different age of exclosures and along different aspects. Ages of exclosures (eight, four, two and zero year) were used, and the aspects were classified in to east, west, north and south aspects. One hundred twenty eight (128) sampling quadrants having an area of 20 m × 20 m, were systematically laid using four transect lines at different distance. The aboveground carbon was analyzed using two-way analysis of variance. A total of twenty one (21) woody spices belongs to thirteen (13) families were identified and documented. There were significantly different (P<0.05) among age of exclosures. Eight-year exclosure was significantly higher in aboveground biomass (88.57 Mg/ha) and aboveground carbon (41.63 Mg/ha) followed by four, two and zero years of exclosure. Despite no significant differences (P<0.05) was seen between aspect for aboveground biomass and carbon. It had the order of west>east>south>north aspects. The results confirmed that exclosures plays a major role in the conservation of native woody species. However, more afforestation and reforestation are needed for better carbon storage in all exclosures.

Keywords: Age; Aspect; Aboveground; Biomass; Carbon; Exclosures

Introduction

Ethiopia's rich floral diversity provides diverse Non-Timber Forest Products (NTFPs) that have economic and cultural values. These biological resources are not only to be conserved but they must also be used sustainably and the benefit from this use must be shared equitably. NTFPs are collection of biological resources other than timber derived from both natural and managed forests and other wooded areas [1]. Examples include variety of fruits, nuts, seeds, oils, spices, resins, gums, honey and beeswax, medicinal products, firewood and many more products and services specific to the particular areas from which they originate [2].

Boswellia papyrifera (Del.) Hochst in Ethiopia is widely known commercially as bitter frankincense and belongs to the family Burseraceae. It is known by different local names in Ethiopia as Kererrie and Ye- etan zaf (Amharigna), Galgalem and Kftal (Oromigna), Meqer and Walwa (Tigrigna), Fatuka (Agewigna) and Libeant (Hadigna) [3]. Mainly the *Boswellia* species are found in the drier low lying arid to semi-arid lands in Ethiopia at altitudes varying from 200-1800 m.a.s.l, temperature range of 21-25°C and with rainfall of less than 900 mm per annum [3,4]. The gum belt runs in a narrow semi-circle around the western, southern and eastern parts of the country close to the borders as well as in Blue Nile gorges on steep rocky slopes or ridges, lava flows or sandy river valleys, and often associated with gypsum out-crops in the southeastern and eastern part of the country [3]. They are dominantly found in the Tigray, Afar, Amhara, Beneshangul-Gumuz, Gambella, Oromiya, and ESNRS regional states.

Among the NTFPs, natural gums and gum resins such as frankincense, gum Arabic, myrrh and opopanax which are tapped from the vast dry land vegetation of the country have indispensable socio-economic significance. Natural gums and gum resins are among dry land resources of Ethiopia that represent a significant part of the forest economy both at local and national levels [5]. They contribute to improved livelihoods of dry land local communities in terms of food security and income generation, while also contributing to the national economy being among the few export articles. One of these species is *Boswellia papyrifera,* known to produce a commercially important and widely traded aromatic product called frankincense. Production of frankincense by private and government organizations for commerce has a long history in Ethiopia [6].

Gebrehiwot [2] has indicated the rehabilitation of *B. papyrifera* forest through natural regeneration depends on the condition after germination. He indicated that any factor that interferes in any of the development phases after germination such fire, grazing, trampling, or clearing can hamper or eliminate the chance of natural regeneration. According to Ogbazghi, et al. [4] and Gebrehiwot [2], the number of established seedlings has been increased in closed areas where grazing is completely stopped or avoided. Still the growth of seedling was not encouraging and the study species does not accumulate long-living seed bank in the soil, but it germinates easily and produce sufficient juveniles or young seedlings in the natural environment [7].

Exclosures in Tigray region are in the positive progress of achieving their objectives as they have been played a significant contribution since their establishment up to now in regulating environmental services through the improvement of below and aboveground carbon sequestration [8,9], controlling soil erosion [10], improvement of soil fertility [9,11], restoration of native woody plants [12,13] and

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improvement of biomass production [14]; and other socioeconomic benefits through production of animal feed [15].

The present study attempts to assess the effects of age of exclosure and aspect as favorable factors influencing the aboveground carbon and biomass on *Boswellia papyrifera* dominated woodlands of Kafta Humera, Western Tigray, northern Ethiopia

Materials and Methods

Study area description

The study was conducted in the dry forests of western zones of Tigray Regional State, where *Boswellia papyrifera* naturally exist. Kafta Humera district is located in the north-western Ethiopia and in the western part of Tigray Regional State with a total land area of 632,877.75 hectare which is about 23.6 percent of the western zone of Tigray is located between 36°27'5" to 37°33'7"E and from 13°39'46" to 14° 26'35"N. It is located 991 km away from Addis Ababa (Figure 1).

Kafta Humera has dominated by early tertiary volcanic and Precambrian rocks and also the dominant soil types in the study area are Chromic Eutric and Calcic Combisols; Chromic and Orthic Luvisols; Chromic and Pellic Vertisols with in an altitude range of 560-1849 meter above sea level. The mean total rainfall ranges from 400-650 mm. The mean maximum temperature varied between 33°C in April and 41.7°C in May, while the mean minimum temperature is between 17.5°C in August and 22.2°C in July. The rainy season of the study area is from June to September. The remaining 8-9 months between October and May/June is dry and hot.

Sampling and data collection methods

Vegetation sampling: Vegetation sampling for *Boswellia papyrifera* dominated exclosure was done on transect lines perpendicular to the contours [16]. The first sample plot was placed randomly, following systematic sampling procedure with 100 m interval between plots of the same transect [14,17]. All tree diameters in the larger plot were measured at breast height (DBH) (1.3 m aboveground level) and at stump height (DSH) (30 cm aboveground level) [18]. In addition, the total tree heights (to the top of the crown) were measured using Hypsometer. In the plot, local names of trees were recorded and later scientific names were identified from "Useful trees and shrubs for Ethiopia" [3].

Data analysis

Aboveground biomass and carbon estimation: The usual methods for determining of the aboveground biomass (AGB) of forests are the combination of forest inventories with allometric tree biomass regression models [19]. Therefore, the model of Chave, Réjou-Méchain [20] was used by many studies and has been the best model for carbon stock assessment in Africa [21] on the basis of climatic condition, DBH of trees and forest type of the study area to determine biomass of tree species having ≥ 5 cm DBH.

The model: $Y=0.0673 \times (\rho D^2 H)^{0.976}$

Where, Y=aboveground biomass (kg), H=height of tree (m), D=diameter (cm) at breast height (1.3 m), and ρ=wood density (g/cm^3).

The DBH and tree height were directly measured, wood density of species was obtained from other studies and databases [22,23]. Average

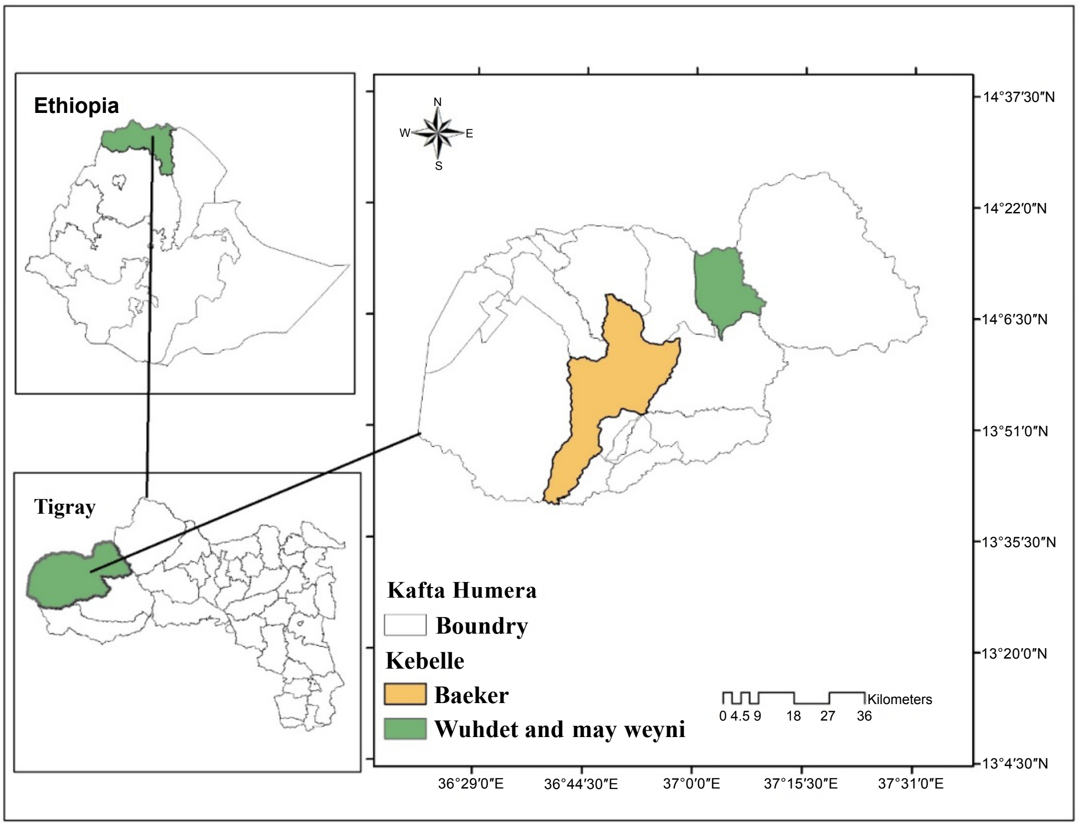

Figure 1: Map of Kafta Humera, western Tigray and northern Ethiopia.

wood density value of the known species was used for species which wood density was not found which was 0.6 g/cm³ that was equivalent to average value reported for wood density of trees in Africa ranges between 0.58 and 0.67 g/cm³ [24]. According to IPCC [25], the biomass stock density of a sampling plot is converted to carbon stock densities by default carbon fraction of 0.47, as the dry biomass contains 47% organic carbon in the tropical and sub-tropical region. Aboveground carbon was analyzed using two-way analysis of variance (ANOVA) at $P<0.05$ with the help of statistical package for the social science (SPSS) version 23. Least significance difference (LSD) test was used to separate the means.

Results

Woody species composition

The floristic composition of woody and shrub species associated with *Boswellia papyrifera* along the entire area exclosure was described in terms of presence (+) or absence (-) (Table 1). During the field survey, a total of 21 (19 woody trees and 2 shrubs) species belongs to thirteen (13) families were recorded in all study areas. Of these, *Boswellia papyrifera* had the highest density and frequency of any other species in all study areas.

Aboveground woody biomass carbon stocks

Carbon stock and area exclosures: From the different age of exclosure practices, area closed for eight years was significantly highest in aboveground tree carbon (41.63 Mg/ha) and aboveground biomass (88.57 Mg/ha); followed by four, two and zero-year area closures (Table 2). However, there was significant difference in above ground biomass and aboveground carbon among different age of area exclosures and as the age of exclosures increases there is also increase aboveground carbon.

Carbon stock and aspect

Across aspect, the aboveground tree carbon and aboveground biomass have shown the order of west>east>south>north aspect. However, there was no significant difference ($F=2.631$, $P=0.053$) seen between these aspects for aboveground Biomass and aboveground carbon (Table 3).

The interaction effect of aspect and age of exclosure on AGC

There was a significant interaction effect between age of exclosure and aspect on the aboveground carbon stock ($F=34.09$, $P=0.001$). Figure 2 and Table 4 show that west aspects, age of area exclosure have little effect, the aboveground carbon stock is quite stable across the four ages of exclosures. However, east, north and south aspects the aboveground carbon stock increases when the age of exclosure increases.

Discussion

Aboveground carbon stock and age of area exclosures

Kafta Humera *Boswellia papyrifera* dominated woodlands, like

No	Local name	Scientific name	Family	8 Years				4 Years				2 Years				0 Years				Status
				E	W	S	N	E	W	S	N	E	W	S	N	E	W	S	N	
1	Chea	*Acacia nilotica*	Mimosoideae	+	+	+	+	+	+	+	+	+	+		+	+	+		+	T
2	Gumero	*Acacia polycantha*	Mimosoideae		+	+		+	+		+	+				+				T
3	Dimma	*Adansonia digitata*	Bombacaceae									+				+				T
4	Hanse	*Anogeissus leiocarpus*	Combretaceae	+	+	+	+	+	+	+	+	+		+				+		T
5	Mekie	*Balanites aegyptiaca*	Balanitaceae			+	+		+				+	+			+	+		T
6	Meqer	*Boswellia papyrifera*	Burseraceae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	T
7	Sessewe	*Combretum molle*	Combretaceae	+	+	+	+	+		+	+	+	+	+	+	+		+	+	T
8	Tenquelibay	*Combretum fragrans*	Combretaceae				+									+				S
9	Akumma	*Comparatum sp*	Combretaceae	+	+	+	+	+	+	+	+	+	+		+	+	+	+		T
10	Zibbe	*Dalbergia melanoxylon*	Papilionoideae		+	+					+		+				+			T
11	Ziwaw'e	*Erythrina abyssinica*	Papilionoideae			+			+	+		+				+	+			T
12	Afekemo	*Ficus hochstetteri*	Moraceae		+	+			+		+		+	+		+	+			T
13	Hatsinay	*Gardenia lutea*	Rubiaceae		+			+									+			T
14	Dugdugunga	*Lannea fruticosa*	Anacardiaceae				+	+						+			+	+		T
15	Dengerifa	*Lonchocarpus bussei (L. laxiflorus)*	Papilionoideae		+	+			+		+	+		+		+		+		T
16	Alendia	*Ormocarpum pubescens*	Papilionoideae	+			+		+	+			+		+		+		+	T
17	Tsara	*Pterocarpus leucens*	Fabaceae		+	+			+	+	+				+	+			+	T
18	Harmazo /Ayehaday/	*Flueggia virosa (Securinega virosa)*	Euphorbiaceae	+			+	+		+		+	+		+	+	+		+	S
19	Adgi-Zana	*Stereospermum kunthianum*	Bignoniaceae		+	+								+						T
20	Humer	*Tamarindus indica*	Caesalpinioideae		+	+			+		+	+	+	+	+		+	+		T
21	Weiyba	*Terminalia brownii*	Combretaceae	+	+	+				+			+		+				+	T

E: East; W: West; S: South; N: North; T: Tree; S: Shrub

Table 1: List, scientific name and family name of all woody and shrub species found in association with *Boswellia papyrifera* along its entire study area located at Kafta Humera, Northern Ethiopia.

Age of exclosures	AGB (Mg ha^{-1})	AGC (Mg ha^{-1})
8 Year	88.57 ± 3.64^{a}	41.63 ± 3.56^{a}
4 Year	72.79 ± 3.58^{ab}	34.21 ± 1.68^{ab}
2 Year	63.22 ± 5.29^{b}	29.71 ± 2.48^{b}
0 Year	60.28 ± 7.58^{b}	28.33 ± 3.56^{b}

Table 2: AGB and AGC in different area of exclosures of Kafta Humera. Similar letters (a, b or ab) show no significant difference ($F=5.824$, $P=0.001$).

Aspect	AGB (Mg ha^{-1})	AGC (Mg ha^{-1})
East	67.66 ± 5.28	31.80 ± 2.48
West	84.48 ± 5.16	39.70 ± 2.43
North	65.97 ± 5.87	31.00 ± 2.76
South	66.75 ± 5.54	31.37 ± 2.60

Table 3: AGB and AGC in four different aspects.

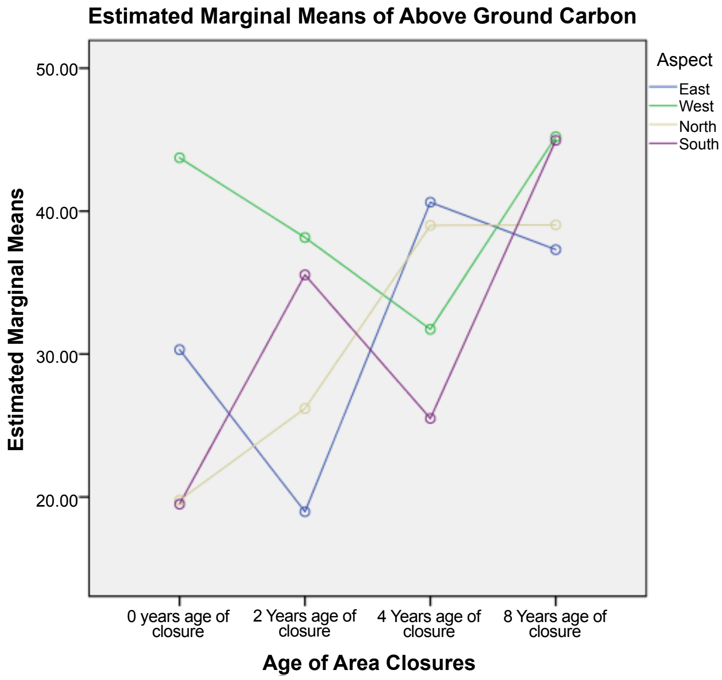

Figure 2: The Interaction effect of age of exclosure and aspect.

		Age of exclosure			
		0 Year	2 Year	4 Year	8 Year
Aspect	East	30.31	18.97	40.62	37.31
	West	43.72	38.16	31.73	45.20
	North	19.77	26.19	38.99	39.04
	South	19.50	35.54	25.50	44.96

Table 4: The interaction effect of age of exclosure and aspects.

other vegetation types, have spatial carbon storage variability because of variations in growth conditions and possibly species composition. The mean aboveground carbon stock of the vegetation biomasses in the selected study areas was significantly different among the four ages of exclosures (P<0.05). Aboveground tree biomass and carbon which was higher on the eight year of exclosure could be linked with high total number of individuals and most of the structural parameters were highest [26]. Also, described that the stand structural parameters such as DBH and height has significant positive relationship with above ground carbon stocks.

The difference in vegetation carbon stock between the ages of exclosures range from 28.33-41.63 Mg C ha^{-1}. The above result was higher than the result in aboveground biomass carbon stock in the exclosures of highlands of Tigray by Mekuria et al. [9] that was between 6.9-23.9 Mg C ha^{-1}. The overall range of the aboveground carbon stock was within the range of 14-123 Mg C ha^{-1} [27]. These differences could be attributed to variation in structure, composition and age of exclosure as compared to the study area.

Aboveground carbon stock and aspect

Aspect has significant relationship with biomass carbon in forest areas due to the interaction between solar radiation and soil properties [28]. Hence, aspect could be used as a useful variable to predict the forest carbon stock in different carbon pools. But other studies pointed out that aspect had insignificant relation with biomass carbon [29]. The result of this study showed that highest mean value of aboveground biomass carbon stocks on west aspect and lowest mean value on the north aspect were recorded. Similarly, in the carbon stock study of Apennine Beech forest by Bayat [29] higher mean values of aboveground biomass carbon stocks on western aspect was found. In addition, the highest carbon stock was found in the western aspect in Tara Gedam forest of Ethiopia [30] and the lowest carbon stock found on north eastern aspect in woody plants of Arba Minch ground water forest of Ethiopia [31] were in excellent agreement to the present study. This is possibly due to the availability of moisture and fertile soil in the western part and less moisture and fertility in north-eastern part of Banja forest as noted by Hicks and Frank [28] that soil properties are influenced by aspect.

Conclusions and Recommendations

The study has shown that the age of exclosure in *Boswellia papyrifera* dominated woodland of Kafta Humera are differently important in storing carbon in the system. Consequently, the aboveground tree carbon and aboveground biomass was significantly found higher (eight years) age exclosure than four, two and zero years of exclosure. However, for better carbon stock the exclosure should have be support by afforestation and reforestation activities. The aboveground carbon and aboveground biomass was highest in west aspect suggesting that more tree plantations are needed in east, south and north aspects for better carbon storage of the area. Therefore, promotion of area exclosure practices and technologies in *Boswellia papyrifera* dominated woodlands of Kafta Humera prove to be potential activity in carbon storing. However, *Boswellia paprifera* is much more important for household economy due to its resin than any other lowland species, and it is not easy for farmers to close all Boswellia dominated woodland. Therefore, extensive agents and other stake holders need to give different training sessions to the people of study area in order to create awareness among them.

References

1. Neumann RP, Hirsch E (2000) Commercialisation of non-timber forest products: review and analysis of research. Cifor.
2. Gebrehiwot K (2003) Ecology and management of *Boswellia papyrifera* (Del.) Hochst. dry forests in Tigray, Northern Ethiopia. Cuvillier.
3. Bekele-Tesemma A, Tengnäs B (2007) Useful trees and shrubs of Ethiopia: identification, propagation, and management for 17 agroclimatic zones. RELMA in ICRAF Project, World Agroforestry Centre, Eastern Africa Region.
4. Ogbazghi W, Wessel M, Bongers F, Poorter L (2001) The distribution and regeneration of *Boswellia papyrifera* (Del.) Hochst. in Eritrea, Tropical Resource Management Papers.
5. Lemenih M (2005) Non-Timber Forest Products (NTFPs) and their socio-economic significances in Ethiopia. Implication for policy dialogue.
6. Lemenih M, Teketay D (2003) Frankincense and myrrh resources of Ethiopia: I distribution, production, opportunities for dryland development and research needs. SINET: Ethiopian Journal of Science 26: 63-72.
7. Eshete A, Teketay D, Hulten H (2005) The socio-economic importance and status of populations of *Boswellia papyrifera* (Del.) Hochst. in northern Ethiopia: the case of North Gonder Zone. Forests, Trees and Livelihoods 15: 55-74.
8. Mekuria W, Veldkamp E, Corre MD, Haile M (2011) Restoration of ecosystem carbon stocks following exclosure establishment in communal grazing lands in Tigray, Ethiopia. Soil Science Society of America Journal 75: 246-256.
9. Mekuria W (2013) Changes in regulating ecosystem services following establishing exclosures on communal grazing lands in Ethiopia: a synthesis. Journal of Ecosystems 2013.
10. Mekuria W, Veldkamp E, Haile M (2009) Carbon stock changes with relation to land use conversion in the lowlands of Tigray, Ethiopia. InConference on International Research on Food Security, Natural Resource Management and Rural Development.
11. Abiy T (2007) Area closure as a strategy for land management: a case study at Kelala Dalacha. AAU.
12. Birhan E (2002) Actual and potential contributions of enclosure to enhance biodiversity in drylands of Eastern Tigray with particular emphasis on woody plants.
13. Meron T (2010) The role of area exclosures for biodiversity conservation and its contribution to local livelihoods the case of Biyo-Kelala area exclosures in Adaa Wereda. AAU.
14. Giday K, Eshete G, Barklund P, Aertsen W, Muys B (2013) Wood biomass functions for *Acacia abyssinica* trees and shrubs and implications for provision of ecosystem services in a community managed exclosure in Tigray, Ethiopia. Journal of Arid Environments 94: 80-86.
15. Asres HG (2012) Effect of exclosure on environment and its socio economic contributions to local people: in the case study of halla exclosure, Tigray, Ethiopia. Norwegian University of Life Sciences, Ås.
16. Abiyu A, Lemenih M, Gratzer G, Aerts R, Teketay D, et al. (2011) Status of native woody species diversity and soil characteristics in an exclosure and in plantations of *Eucalyptus globulus* and *Cupressus lusitanica* in Northern Ethiopia. Mountain Research and Development 31: 144-152.
17. Aynekulu E, Wubneh W, Birhane E, Begashaw N (2006) Monitoring and evaluating land use/land cover change using Participatory Geographic Information System (PGIS) tools: A case study of Begasheka watershed, Tigray, Ethiopia. The Electronic Journal of Information Systems in Developing Countries 25.
18. Macdicken KG (1997) A guide to monitoring carbon storage in forestry and agroforestry projects.
19. Houghton RA (2005) Tropical deforestation as a source of greenhouse gas emissions. Tropical Deforestation and Climate Change 13.
20. Chave J, Réjou-Méchain M, Búrquez A, Chidumayo E, Colgan MS, et al. (2014) Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology 20: 3177-3190.
21. MEFCC (Ministry of Environment Forest and Climate Change) (2016) Ethiopia's forest reference level submission to the United Nations Framework Convention for Climate Change. Addis Ababa, Ethiopia.
22. Reyes G, Brown S, Chapman J, Lugo AE (1992) Wood densities of tropical tree species. Gen Tech Rep SO-88. New Orleans LA: US Dept of Agriculture, Forest Service, Southern Forest Experiment Station 15: 88.
23. Tanabe K, Wagner F (2003) Good practice guidance for land use, land-use change and forestry. Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.
24. Henry M, Besnard A, Asante W, Eshun J, Adu-Bredu S, et al. (2010) Wood density, phytomass variations within and among trees, and allometric equations in a tropical rainforest of Africa. Forest Ecology and Management 260: 1375-1388.
25. 2006 IPCC guidelines for National greenhouse gas inventories (2006). Intergovernmental Panel on Climate Change (IPPC).
26. Wang W, Lei X, Ma Z, Kneeshaw DD, Peng C (2011) Positive relationship between aboveground carbon stocks and structural diversity in spruce-dominated forest stands in New Brunswick, Canada. Forest Science 57: 506-515.
27. Murphy PG, Lugo AE (1986) Structure and biomass of a subtropical dry forest in Puerto Rico. Biotropica 89-96.
28. Hicks RR, Frank PS (1984) Relationship of aspect to soil nutrients, species importance and biomass in a forested watershed in West Virginia. Forest Ecology and Management 8: 281-291.
29. Bayat AT (2011) Carbon Stock in an Apennine Beech Forest. Enschede, TheNetherlands: University of Twente.
30. Gedefaw M, Soromessa T, Belliethathan S (2014) Forest carbon stocks in woody plants of Tara Gedam forest: Implication for climate change mitigation. Science, Technology and Arts Research Journal 3: 101-107.
31. Wolde BM, Kelbessa E, Soromessa T (2014) Forest Carbon Stocks in Woody Plants of Arba Minch Ground Water Forest and its Variations along Environmental Gradients. Science, Technology and Arts Research Journal 3: 141-147.