Variations in Forest Carbon Stocks along Environmental Gradients in Weiramba Forest of Amhara Region, Ethiopia: Implications of ManagingForests for Climate Change Mitigation

Zelalem Teshager, Mekuria Argaw, Abeje Eshete

Abstract--Climate change, caused by global warming, is the most pressing environmental problem of the world today and it is a phenomenon partly resulting from the abundance of carbon dioxide in the atmosphere. The problem of increasing atmospheric carbon dioxide can be addressed in a number of ways. One of such actions is forestry development and forest management undertakings that can contribute to mitigation. This study was conducted in Weiramba Forest, with the objectives of estimating of the carbon stock and its variation along the environmental gradients in Weiramba Forest. A systematic sampling method was used to conduct the vegetation sampling. In order to collect vegetation data a total of 40 quadrats, each with the size of 10 m x 20 m at an interval of 100 m, were laid along the established transects at 200 m apart. For litter and soil sample collection, five sub-quadrats each with the size of 1 m x 1 m were established at four corners and center of every quadrat. Results revealed that the total mean carbon stock density of Weiramba Forest was 323.85 t/ha, of which 152.33 t/ha, 41.13 t/ha, 1.3 t/ha, 63.39 t/ha, 65.72 t/ha was contained in the above-ground biomass, belowground biomass, litter biomass, soil (0-20 cm depth) and (21-40 cm depth), respectively. Altitudinal gradient, slope, and aspect were the three environmental factors that affect the different carbon pools of the forest. From the point of view of managing forests for climate change mitigation, the result suggested that the forest should be conserved and protected in a sustainable way for further carbon sinks.

Index Terms- Biomass, Weiramba Forest, Environmental variables, Carbon stock.

◆

1 INTRODUCTION

The recent weather abnormalities experienced in the country and around the world are indications of a changing climate. The definition of climate change is "a change in the state of the climate that persists [i]for an extended period, typically decades or longer" [1]. Climate change is affecting rainfall patterns, water availability, sea levels, and droughts, increasingly impacting on human health, agriculture productivity and biodiversity [2]. Global greenhouse gases (GHGs) emissions, especially atmospheric CO_2 from about 280 to more than 380 parts per million (ppm) over the last 250 years, due to human activities are the causes of change in climate and have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 [2].

The 1997 Kyoto Protocol, the first major international agreement on climate change, explained that forest carbon sequestration as one of the key approaches to reduce atmospheric carbon concentrations [3]. Forests are, vital for life on earth, ecologically important in influencing climate and maintaining global balances of carbon and atmospheric pollutants. Forests can be both sources and sinks of carbon, depending upon the specific management regime and activities [4].

In Ethiopia, only small efforts have been made so far to assess the biomass and soil carbon sequestration potential at small scale level (CCB-AR-PDD, 2009; cited in [5]). No study has been conducted in Weiramba forest that aimed at carbon sequestration potential of this forest. Therefore, this study was taken up to estimate the carbon stocks capacity by quantifying the major potential carbon pools of Weiramba Forest.

2 MATERIALS AND METHODS

2.1 Study Area

This study was conducted in Gerado Kebele, Habru district which is Located in the Amhara National regional state North Wollo East Plain in Weiramba forest located at about 15 km from Mersa, 375 km from Bahirdar and 500 km from Addis Ababa. Habru district is located in a geographical zone of 39°30' to 39°45'N and 11°30' to 11°15'E within an altitude range of 1430-2800 m above sea level. Geographically, Weiramba forest is located between 1297343′ - 1297867′E longitude and 562799′- 569978′N latitude.

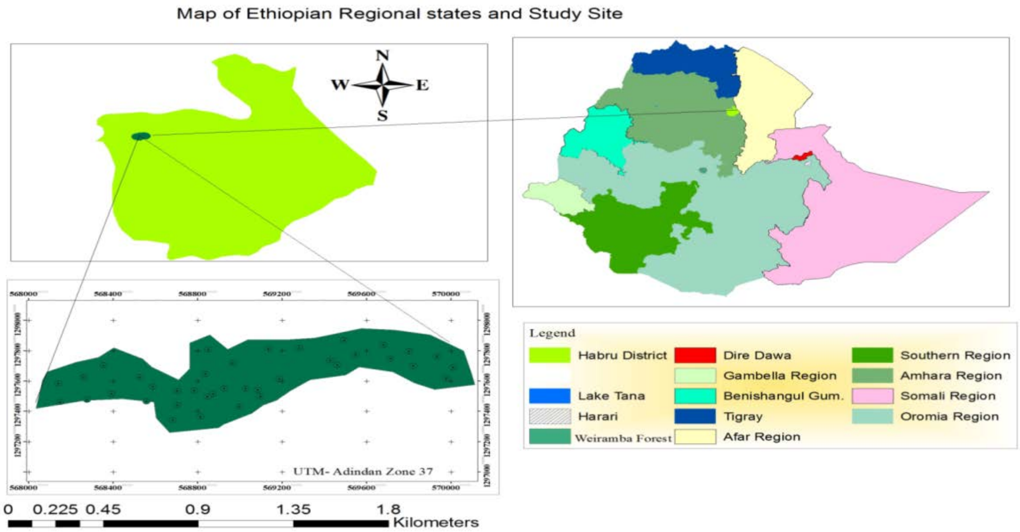

Fig.1 Map of the study area

The mean annual maximum and minimum temperature ranges 28.6 ^{0}c and 15 ^{0}c respectively and the mean annual rainfall ranges from 750 to 1000 mm.

Weiramba Forest is one of the remnants dry evergreen Afromontane forests in northern Ethiopia and the forest has an altitudinal gradient ranging from 1923 to 2225 m above sea level. According to the Habru District Agriculture and Rural Development Office (HDARDO), the forest covers a total area of 153 ha and it is a home for a variety of flora and fauna.

2.2 Methodology

The reconnaissance survey was made across the forest in order to obtain an impression in site conditions and physiognomy of the vegetation, collect information on accessibility, identify sampling sites and calculate sample size. Then, the elevation range and transect direction of the forest were determined and transects were laid from the lowest altitudinal elevation to the highest [6]. The boundaries of the study forest area were delineated by taking geographic coordinates with GPS at each turning point to facilitate accurate measurement and accounting of the forest carbon stock. Stratification was done in the study forest in order to take accurate data from the field as well as to maintain the homogeneity of the area. Altitude, Slope, and Aspect were the major parameters to classify the study area. Therefore, based on altitudinal variation, the study site was stratified into three zones namely: lower (1923-2023 m), middle (2024-2124 m) and higher (2125-2225 m). Slope classes were classified into lower (10-35%), middle (35.1-60%) and higher >60%. Aspect was classified into six classes: North (N), East (E), West (W), North East (NE), North West (NW) and South West (SW). Quadrats were not found on South and South West aspects. Quadrat slope and aspect were recorded using Clinometer and compass, respectively. Altitude and geographical locations (latitude and longitude) of each sample quadrat were measured using GPS. In this study area, there is high variability in topography and vegetation types. Hence, a rectangular nested quadrat design which is appropriate to incorporate the variable tree sizes [7], [8] was used. Accordingly, a total of seven transects lines and 40 quadrats of 10 m x 20 m (200 m^2 each) in size were systematically established for vegetation sampling. The alignment of transects was done using Compass and GPS. It was set up purposively across areas where there are rapid changes in vegetation and marked environmental gradients [9]. Quadrats were laid systematically at every 100 m along transect lines, which were 200 m apart from each other. For the purpose of litter and soil sampling, a total of five sub-quadrats with the area of 1 m X 1 m were laid within each main quadrat in a way those four sub-quadrats at the corner and one at the center. In order to eliminate any influence of the road effects on the forest biomass, all the quadrats were laid at least 100 m away from nearest roads. Primary data was obtained through field measurements in the study areas and the secondary data was collected from different resources like published and unpublished materials, books, journals, articles, reports, and electronic websites. To reveal below and above ground biomass, all tree/shrub species with DBH ≥ 5 cm were measured in each quadrat using Caliper and Diameter Tape. In addition, the total tree heights (to the top of the crown) were measured using Hypsometer [10], [11]. Each tree was recorded individually, together with its species name and ID. Trees/Shrubs with multiple stems at 1.3 m height were treated as a single individual and the diameter was measured separately for the branches and averaged as one DBH and the tree/shrub boles buttressed, DBH measurement was undertaken from the point just above the buttresses. Trees with multiple stems or fork below 1.3 m height were also treated as a single individual [9]. Local names of trees were recorded and later scientific names were identified from all published volumes of Flora of Ethiopia and Eritrea and Useful trees and shrubs for Ethiopia [12]. For species that proved difficult to identify in the field, herbarium specimens were collected, dried properly and transported to the National Herbarium at Addis Ababa University for identification. In this study, allometric equation given by [13] was used to estimate AGB. Since the general criteria described by the author are similar to the study area. The inclusion of country-specific wood density in the equation significantly improves biomass estimation [13]. For this reason, the following parameters are needed to express aboveground biomass in carbon stock: diameter at breast height (DBH), tree height, a wood density factor. While DBH and height parameters are directly measured in the field, a wood density of species was obtained from other studies and databases.

$$AGB = 0.0673 * (\rho * (DBH)^2 * H)^{\wedge}0.976 \qquad (1)$$

Where: AGB = above ground biomass (in kg dry matter), ρ = wood density (g/cm^3)
DBH = diameter at breast height (in cm), H = total height of the tree (in m).

Above ground carbon stock of each tree biomass conversion to carbon, the stock based on [14], [15], [16], [10], [17]

$$AGCS = AGB * 0.5 \qquad (2)$$

Where, AGCS = Above Ground Carbon Stock, AGB = Above Ground Biomass (kg/tree)

For Ethiopia dry forest, below ground biomass is estimated to be about 27% of the above-ground biomass [18]. Hence, for the estimation of below ground biomass for every tree, the recommended root-to-shoot ratio value of 1: 0.27 was used.

$$BGB = AGB * 0.27 \qquad (3)$$

Where, **AGB** = Above Ground Biomass (kg/tree), **BGB** = belowground biomass, 0.27 is conversion factor (or 27% of AGB). To estimate the carbon content and amount of CO_2 in BGB, the same procedure was applied like that of AGB.

$$BGC = BGB * 0.5 \qquad (4)$$

Where, BGC = carbon content of below-ground biomass, BGB = belowground biomass
The carbon in above and below ground has to be multiplied by 3.67 to get CO_2. Deadwood was not considered in this study because of the unavailability of it in the study site.

Litter samples were collected in a 1 x 1 m square sub-quadrat within each quadrat. A total of five sub-quadrats (four at corners and one in the center) were used for litter collection. The 100 g subsample fresh weights were sampled from the five sub-samples collected from each quadrat which were mixed homogeneously and placed in a plastic bag to take it to the laboratory. The collected litter samples were oven dried at 105^{0}C for 48 h using dry ashing method [19]. Oven-dried samples were taken in pre-weighed crucibles. Then the samples were ignited at 550^{0}C for one hour in the muffle furnace. After cooling, the crucibles with ash were weighed and percentage of organic carbon was calculated. Finally, carbon in litter t/ha for each sample was determined. The amount of biomass estimation in the leaf litter was calculated as recommended by [15]

$$LB = \frac{Wfield}{A} * \frac{Wsampler - sample\ (dry)}{Wsub - sample\ (fres)} * \frac{1}{10{,}000} \qquad (5)$$

Where, LB = Litter (biomass of litter t/ha), W field = Weight of wet field sample of litter sampled within an area of size 1

m^2 (g), A= size of the area in which litter were collected (ha), W sub-sample, dry = weight of the oven-dry sub-sample of litter taken to the laboratory to determine moisture content (g), and W sub-sample, fresh = weight of the fresh sub-sample of litter taken to the laboratory to determine moisture content (g).

The percentage of organic carbon storage from the dry ashing in the litter carbon pool was calculated as follows [19]:

$$\% Ash = Wc - \frac{Wa}{Wb} - Wa * 100 \tag{6}$$

$$\% C = (100 - Ash\%) * 0.58 \tag{7}$$

Where, C = organic carbon (%), Wa = the weight of the crucible (g), Wb = the weight of oven dried grind samples and crucibles (g), Wc = the weight of ash and crucibles (g).

$$CL = LB * \% C \tag{8}$$

Where, CL is total carbon stocks in the dead litter in t/ha, % C is carbon fraction determined in the laboratory [15].

Soil samples for the determination of soil carbon were collected from sample quadrats laid for litter sampling mean that from four corners and at the center of each quadrat to a depth of 40 cm within each quadrat by pressing an auger to a depth of 0-20 cm and 21- 40 cm, and the five soil samples of each layer were composited [20], [21]. Five equal weights of each layer soil samples were taken and mixed homogeneously while a 100 g composite sample was taken from each sample quadrat for the determination of organic carbon in the laboratory using [22] method. The soil samples were air-dried, well mixed and sieved through a 2 mm mesh size sieve for soil carbon analysis following the right technique [22]. In addition, from the same quadrats, soil samples for soil bulk density determination were collected from the surface soil (from 0-20 cm and 21-40 cm depths) using 10 cm length and 3.4 cm diameter core sampler carefully driven into the soil to avoid compaction [20].

The carbon stock density of soil organic was calculated as recommended by [15] from the volume and bulk density of the soil.

$$V = h \, X \, \pi \, r2 \tag{9}$$

Where V is a volume of the soil in the core sampler augur in cm^3, h is the height of core sampler augur in cm, and r is the radius of core sampler augur in cm [15]. Moreover, the bulk density of a soil sample can be calculated as follows:

$$BD = \frac{Wav,\ dry}{V} \tag{10}$$

Where, BD is the bulk density of the soil sample, Wav, dry is an average air-dry weight of soil sample per quadrat, V is a volume of the soil sample in the core sampler auger in cm^3 [15]. Then, the soil organic carbon stock pool was calculated using the formula [15]:

$$SOC = BD * d * \% C \tag{11}$$

Where, SOC= soil organic carbon stock per unit area (t/ha), BD = soil bulk density (g/cm^3), D = the total depth at which the sample was taken (0-20 cm and 21-40 cm), and % C = Carbon concentration (%) determined in the laboratory. Finally, the total carbon stock density was calculated by summing the carbon stock densities of the individual carbon pools of the stratum using the [15] formula.

$$C\ density = CAGB + CBGB + C\ Lit + SOC \tag{12}$$

Where: $C_{density}$ = Carbon stock density for all pools [t/ha], C_{AGTB} = Carbon in above -ground tree biomass [t C/ha], C_{BGB} = Carbon in below-ground biomass [t C/ha], C_{Lit} = Carbon in dead litter [t C/ha], SOC = Soil organic carbon, the total carbon stock is then converted to tons of CO_2 equivalent by multiplying it by 44/12, or 3.67 [11]. The analysis of data collected from DBH, height, weights of litter and soil was made using Microsoft excel of 2010 and Statistical Package for Social Science (SPSS) software version 20. The relationship between different parameters was tested by linear regression and One-Way ANOVA.

3 RESULTS

3.1 Carbon Stock in the Different Carbon Pools

The carbon stock value of the study site in different carbon pools showed different storage of carbon. The mean aboveground carbon stock in the study site was 152.33 t/ha, while the mean below ground carbon stock of the study site was 41.13 t/ha. The mean total carbon stock in litter biomass of the study site was 1.30 t/ha, whereas the mean soil carbon stock of the study site was 63.39 t/ha in the 0-20 cm depth and 65.72 t/ha in the 21-40 cm depth. In other words, about 78.73% of the biomass was contained in above ground, while below ground biomass comprised 21.26% of the total biomass. It was found that about 0.01% of the biomass was contained in the litter. The carbon stock that was stored in the aboveground biomass was 47.04 %, whereas 19.57 and 20.29 % were contained in the soil at the depth of 0-20 and 21-40 cm, respectively. The mean carbon density in all carbon pools of the study site was 323.87 t/ha.

3.2 Carbon Stocks of Different Pools along Altitudinal Variation

The presence of variation in altitudinal gradient affects the carbon stock of different pools in the forest. The middle part of altitude is high in aboveground carbon stocks while the upper and lower parts of altitude have low to moderate carbon stocks in aboveground biomass. 162.04, 163.27 and 111.35 t/ha carbon stocks were recorded at the lower, middle and upper altitude, respectively.

Similar trend was shown in below ground biomass in which 43.77, 44.08 and 30.06 t/ha carbon stocks were recorded in the lower, middle and upper altitude, respectively with the highest value found at the middle part of altitudinal classes followed by the lower and upper parts since it was obtained from the above ground carbon pool. But this was not very much significant at 95% confidence interval (F = 0.965, P = 0.390) in AGC and (F = 0.965, P = 0.390) in BGC stocks (Table 1).

In contrast to the aboveground and belowground biomass, the litter carbon density showed clear patterns along the altitudinal gradient and reached higher in the upper altitude, lower in the lower altitude and moderate in middle altitude with the mean carbon value of 1.46, 1.05 and 1.36 t/ha, respectively; but, they were not statistically significant at $\alpha = 0.05$ (F = 0.708, P = 0.499).

Similarly, soil pool carbon stock showed a similar pattern to that observed carbon stock in the litter. The carbon stock in the soil pool was higher in upper altitude and lower in the lower altitude with moderate carbon stocks in the middle altitudinal classes. 38.07, 79.77 and 87.06 t/ha stocks of carbon were recorded in the lower, middle and upper altitude, respectively in the soil pool (0-20 cm depth) and 38.23, 82.65 and 90.12 t/ha stocks of carbon were recorded in the lower, middle and upper altitude, respectively in the soil pool (21-40 cm depth) of Wieramba Forest. In contrast to litter, above and below ground carbon, they were statistically significant at $\alpha = 0.05$ (F = 16.024, P = 0.000) in SOC (0-20 cm depth) stocks and SOC (21-40 cm depth) which has a value of F=8.669 and P = 0.001 (Table 4).

The total carbon stocks density of each carbon pools (above and below ground, litter and soil carbon) in different altitude classes of the study area were varied with the altitude classes. As it is indicated by table 1, the middle part of the altitude contains more carbon stock (371.14 t/ha), followed by the upper (320.05 t/ha) and the lower altitudinal gradient (283.21 t/ha).

TABLE 1

MEAN CARBON STOCK (t/ha) IN ABOVE GROUND, BELOW GROUND, LITTER BIOMASS AND SOIL ALONG AN ALTITUDINAL GRADIENT

Altitude class	Altitude range (m)	AGB	AGC	BGB	BGC	LB	LC	SOC (0-20 cm)	SOC (21-40 cm)	TCD (t/ha)
Lower	1923-2023	324.19	162.09	87.53	43.77	0.04	1.05	38.07	38.23	283.21
Middle	2024-2124	326.54	163.27	88.17	44.08	0.05	1.36	79.77	82.65	371.14
Higher	2125-2225	222.70	111.35	60.13	30.06	0.06	1.46	87.06	90.12	320.05

AGB denotes above-ground biomass; AGC-above-ground carbon stock; BGB- below-ground biomass; BGC-below-ground carbon stock; LB- Litter biomass; LC-Litter carbon stock; SOC-Soil organic carbon; TCD-Total carbon density

3.3 Carbon Stocks of Different Pools and Aspect

Aspect was another parameter that affects the carbon stocks above ground biomass, belowground biomass, litter and soil through which the direction of the quadrats was found to determine in which direction the highest and lowest carbon stocks is found in the study forest. Based on the result that obtained, the mean AGC stock was lowest in W (9.58 t/ha) and highest in N (183.00 t/ha). The similar trend was observed for carbon stocks in belowground carbon pool with the highest value 49.41 t/ha in North (N) direction and the lowest value 2.59 t/ha in West (W) direction.

The highest carbon stock in litter biomass was recorded in the North East (NE) 26.95 t/ha and the minimum carbon stock (0.67 t/ha) was recorded in South West (SW) aspect. The carbon stocks in soil (0-20 cm depth) was recorded the minimum value in East (E) 22.16 t/ha and the maximum value 95.56 t/ha in South West (SW) direction. On the other hand, the minimum (28.59 t/ha) and maximum (85.60 t/ha) values of SOC in the 21-40 cm depth were recorded the in the East (E) and in the South West (SW) direction, respectively (Table 2). Statistically, it was not recorded a significant difference in all carbon pools of the forest carbon stocks at 95% confidence interval (α = 0.05) among aspects (F = 1.768, p = 0.146) in above and below ground carbon, (F = 0.935, P = 0.471) in litter carbon, (F = 0.446, P = 0.813) in soil organic carbon at depth 0-20 cm and (F = 0.371, P = 0.865) in soil organic carbon at depth 21-40 cm (Table 4). In general, the mean minimum and maximum total carbon stock were recorded on West (W) 113.61 t/ha and North (N) 398.52 t/ha aspect, respectively (Table 2). All the aspects of study site showed a trend of SOC (0-20 cm) as SW> N > NW > NE > W > E and a trend of SOC (21-40 cm) as SW >N >NW >NE >W >E.

TABLE 2

MEAN CARBON STOCK (t/ha) IN ABOVE GROUND, BELOW GROUND, LITTER BIOMASS AND SOIL WITH DIFFERENT ASPECTS

Aspects (facing)	AGC (t/ha)	BGC (t/ha)	LC (t/ha)	SOC (0-20 cm)	SOC (21-40 cm)	Total carbon (t/ha)
N	183.00	49.41	25.71	68.68	71.71	398.52
NE	127.47	34.42	26.95	51.71	57.70	298.24
NW	128.11	34.59	24.50	65.99	60.10	313.30
SW	68.01	18.36	0.67	95.56	85.60	268.21
E	154.49	41.71	22.27	22.16	28.59	269.22
W	9.58	2.59	15.29	49.30	36.85	113.61

3.4 Carbon Stocks of Different Pools and Slope

Likewise, the slope gradient was also another factor that influences the carbon stock of the study area. The mean aboveground carbon stock was high in middle slope class which is 171.05 t/ha, whereas the lower and the higher slope classes range from 149.91 and 138.75 t/ha, respectively. Similarly, the below ground carbon pool showed an increasing trend in carbon stock in middle slope 46.18 t/ha, and the lower and higher slope class showed a decreasing trend which recorded 40.48 and 37.46 t/ha, respectively (Table 3). But this was not statistically significant at α = 0.05 (F = 0.441, P = 0.647) in aboveground carbon, (F = 0.441, P = 0.647) in belowground carbon, (F = 0.231, P = 0.795) in litter carbon stock and (F = 1.772, P = 0.184) in soil organic carbon (0-20 cm depth) but the difference was significant (F = 4.743, P = 0.015) for soil organic carbon (21-40 cm depth) along the slope gradient (Table 4).

Similar to the above and below ground carbon, the litter carbon stock of the study site had the highest carbon stock at the middle slope gradient (27.43 t/ha) followed by the lower slope gradient (26.31 t/ha) and the higher slope gradient (22.82 t/ha) (Table 3). In the case of soil organic carbon (0-20 cm), the middle slope class recorded high amount of organic carbon (71.92 t/ha) followed by the higher slope class (69.13 t/ha) and the lower class of slope (49.86 t/ha). Unlike that of the SOC (0-20 cm depth), the SOC (21-40 cm depth) of the study site had shown relatively increasing trend with an increase in slope gradient. Accordingly, the maximum mean carbon stock was recorded in higher slope and the minimum was in the lower slope class. 42.07, 69.54 and 80.27 t/ha carbon stocks were recorded in the lower, middle and higher slope classes, respectively in the soil pool (21-40 cm).

Overall, the total carbon stock density of all carbon pools (above and below ground, litter and soil carbon) along slope gradient of the study area was varied. Accordingly, the maximum and minimum total carbon stock were recorded in middle (386.12 t/ha) and lower slope gradient (308.62 t/ha). The higher slope class has a total carbon stock value of 348.43 t/ha. In all carbon pools except SOC (21-40 cm), there was no any significant difference in carbon stocks of the forest at 95% confidence interval ($\alpha = 0.05$) with slope factor (Table 4).

TABLE 3

MEAN CARBON STOCKS (t/ha) IN DIFFERENT POOLS WITH RESPECT TO SLOPE GRADIENT

Slope class	**Slope range (%)**	**AGC (t/ha)**	**BGC (t/ha)**	**LC (t/ha)**	**SOC**		**Total carbon (t/ha)**
					(0-20 cm)	**(21-40 cm)**	
Lower	10-35	149.91	40.48	26.31	49.86	42.07	308.62
Middle	35.1-60	171.05	46.18	27.43	71.92	69.54	386.12
Higher	>60	138.75	37.46	22.82	69.13	80.27	348.43

AGC denotes Above-ground Carbon; BGC- Below-ground carbon; LC- Litter carbon; SOC- soil organic carbon.

TABLE 4

SUMMARY OF VALUES OF SIGNIFICANCE FOR ONE-WAY ANOVA BETWEEN THE THREE ENVIRONMENTAL VARIABLES (ALTITUDE, ASPECT AND SLOPE GRADIENT) FOR DIFFERENT POOLS CARBON STOCK

Environmental Variables	Carbon pools	F-value	P-value
ALTITUDE	AGC	.965	.390
	BGC	.965	.390
	LC	.708	.499
	SOC (0-20 cm)	16.024	**.000**
	SOC (21-40 cm)	8.669	**.001**
ASPECT	AGC	1.768	.146
	BGC	1.768	.146
	LC	.935	.471
	SOC (0-20 cm)	.446	.813
	SOC (21-40 cm)	.371	.865
SLOPE	AGC	.441	.647
	BGC	.441	.647
	LC	.231	.795
	SOC (0-20 cm)	1.772	.184
	SOC (21-40 cm)	4.743	**.015**

****Bold values are significant at the p < 0.05 level**

4 DISCUSSION

The present carbon stock study is the first of its kind for Wieramba Forest and covered an estimate of the biomass and carbon density in forest ecosystem components (vegetation, litter, and soil) and the variation of carbon stock along environmental gradients in each carbon pool was done. This is helpful for providing relevant information and understanding the patterns of carbon stock along environmental gradients of a representative tropical dry Afromontane forests. While comparing with other studies, the mean carbon stock in above and belowground biomass of Weiramba forest was lower than Arba Minch Ground Water Forest [23] and Tara Gedam Forest [24]. This is due to the reason that other studies were conducted in trees with larger DBH and height than that of Weiramba forest. The study results in a different forest and different tree species in Ethiopia showed as an age of tree increase, DBH, basal area, and biomass also increase [25], [26]. The DBH and height of trees/shrubs in Weiramba Forest were small. However, its mean carbon stock was higher than those reported from Menagasha Suba State Forest [5] and selected church forests in Addis Ababa [27] (Table 5). Generally, the mean aboveground carbon values recorded in the study sites were above two-fold the values recommended by IPCC for tropical dry forest 65.00 t/ha [28]. According to different literature, Global Aboveground carbon in tropical dry and wet forests ranged between 13.5-122.85 t/ha and 95-527.85 t/ha, respectively [29]. Above ground carbon in Amazonian Brazil forests ranged between 145- 247.5 t/ha (Alves *et al*., 1997: cited in [27]). Thus, the above ground carbon reported in the present study was found within the range recommended for various tropical dry and wet forests, Amazonian Brazil forests life zone. Moreover, the average aboveground carbon in the studied forest sites with the value of 152.33 t/ha were three-fold higher than the previous estimates with the value of 50.5 t/ha of plant biomass carbon stock for forests of Ethiopia [7]. On the other hand, above ground carbon in tropical and subtropical forests in Puerto Rico ranged between 40-95 t/ha [30] and due to this, the result of the study site had almost a positive carbon stock potential and this indicates the forest status was well managed and protected even if some human interference could be there.

Soil organic carbon of the forest depends on not only soil bulk density but also again highly depends on the moisture, decomposition of litter carbon, climatic zone, temperature, slope, altitude, aspect and the nature of soil “un-published” [31]. Accordingly, the higher mean SOC stock is may be due to the presence of high SOM and fast decomposition of litter which results in maximum storage of carbon stock [32]. Overall, the present result revealed that the study forest had high carbon stock and thus sequestered the high amount of CO_2 contributing to the mitigation of global climate change.

TABLE 5

COMPARISON OF CARBON STOCK (t/ha) OF THE PRESENT RESULT WITH OTHER STUDIES

Study place	**AGC**	**BGC**	**LC**	**SOC**
Wieramba Forest (present study)	152.33	41.13	1.30	129.11
Menagasha Suba State Forest [5]	133.00	26.99	5.26	121.28
Church Forest [27]	122.85	25.97	4.95	135.94
Arba Minch Ground Water Forest [23]	414.70	83.48	1.28	83.80
Tara Gedam Forest [24]	306.36	61.52	0.90	274.32

4.1 Influence of Environmental Variables on Carbon Stock

4.1.1 Variation of Carbon Stock along Altitudinal Gradient

Altitude is recognized to have a major effect on the biomass and carbon stock in the forest ecosystems [6]. In the present study area, the middle altitude showed an increasing carbon stock potential and followed by the bottom (lower) altitude and decreased when we go to up or top of the mountain though there was no significant variation in carbon stock in above and below ground carbon pools along an altitudinal gradient. This condition suggests that the lower and the upper parts of the forest have scattered type of plant arrangement and displayed lack of large trees as compared with the middle altitude and due to suitable environmental condition, most species of plants habit in the middle part and result in high biomass and carbon stock values.

The presence of species characterized by large individuals occurring on middle altitude could have an effect on AGB and carbon stock because few large individuals can account for a large proportion of the quadrats above and below ground carbon [33]. This could perhaps be the case in the present study area, whereas bigger trees with maximum DBH were more common in middle altitude and somehow in lower altitude areas. It might be also due to the topographical nature where the middle altitude is almost steep slope made itself away from human disturbance. On the other hand, upper altitude is more prone to arable land due to gentle slope nature made to store less carbon. Similar to the present result, there were similar results reported on other studies in Ethiopia of Banja Forest [34], Ades Forest “un-published”[31], Tara Gedam Forest [24] and Adaba Dodola Community Forest [35] while it showed dissimilarity with the study of Egdu Forest [36] and Arba Minch Ground Water Forest [23].

Unlike the other carbon pools, the mean carbon density in litter pool of the present study showed the clear pattern with altitude. It had shown relatively an increasing trend with increasing altitude though there was no significant variation carbon stock in litter pool along altitudinal gradient, and this condition suggested that at the hilly area of the mountain, the distribution and the number of trees reduced, and hence abundant litter-fall could be available and this situation may be the cause for having exceeded litter carbon than the rest of other altitudinal gradients. In densely populated trees, few litters were found due to the nearness of plants each other make their litter not fall down [37].

The reasons might be due to the decline in litter-fall amount and decomposition with increasing altitude (Zhang *et al*., 2008; cited in [34] and According to Chi *et al*. (1981) as cited in [35], the mean annual temperature decreased linearly with increasing altitude and mean annual precipitation showed an overall increasing trend. Although the rate of decomposition of litter altered by temperature and moisture, factors like stand age, forest types and disturbance play a more important role in the regulation of litter pool size [38]. The similar result was reported in Woody Plants of Arba Minch Ground Water Forest [23], Ades Forest "un-published" [31] and Banja Forest [34].

SOC density increased with precipitation and decreased with temperature [39]. In this study, relatively, an overall increasing trend in mean SOC density with increasing altitude (decreasing temperature increasing precipitation) was observed, due to the higher turnover of organic material (plants) which is agreed with result found by [23], [40] and [34]. Generally, this present study result pointed out that above ground, below ground and litter carbon pools density showed insignificant variation, whereas SOC showed significant difference, similar with [23], and the litter carbon and SOC density show a clear pattern, whereas the other carbon pools (AGC and BGC) did not show a clear pattern along altitudinal gradient. This further revealed that the carbon pool components of forest ecosystem may respond to altitude differently and plays an important role in knowing the possible change in carbon stock and thus carbon sequestration capacity in response to future climate change [40].

4.1.2 Variation of Carbon Stock along Slope Gradient

The slope is also one of the environmental factors that influence the distribution of carbon density [41]. As indicated in [40], the carbon partitioning among forest carbon pools along slope gradients is important in knowing a possible change in carbon stock and thus carbon sequestration potential in response to the future climate change in mountain regions. The present result revealed that the forest carbon stock in different carbon pools did not show clear patterns along slope gradient and the variation was not significant in all carbon pools except SOC (21-40 cm depth). This situation indicates that the four dependent factors (AGC, BGC, LC and SOC (0-20 cm depth)), except SOC (21-40 cm depth), were not affected by slope.

The middle slope showed an increasing carbon stock potential of all pools (AGC, BGC, LC and SOC in the 0-20 cm depth) and followed by the lower slope and decreased when we go to higher slope of the study site (with exception of soil pool in the 21-40 cm depth, where soil in the 21-20 cm depth carbon density increased with an increase in slope gradient). The vegetation cover varied as a function of slope gradient. Very high slope areas (> 45^0) contain little vegetation cover compared to low slope angle ($0\text{-}10^0$) [42]. This might be the cause of the decrease in above and below ground biomass carbon in higher slope gradient. In a steeply slope the above ground and below ground biomass of the carbon pool reduced due to less vegetation coverage as a result of soil erosion, on another hand the above and below ground biomass and carbon density showed higher values in middle slope because of having high vegetation coverage due to favorable conditions.

Similarly, litter biomass and its carbon density of the forest area showed an increasing pattern at middle slope followed by the lower and higher slope gradient. It might be due to the topographical nature where the middle slope is found between lower and higher slope that made itself away from human disturbance or interference. Slope gradient affects the availability of water and nutrients, which allows more in lower slope or less in higher slope plant growth and litter accumulation (Casado *et al.,* 1985 cited in [42]). This might be the cause for the decreasing of litter biomass carbon in higher slope gradient and increasing in middle and lower slope.

The soil carbon stock in the 0-20 cm depth of the study forest was highest at the middle slope followed by the upper one and decreased at the bottom part of the mountain. This may be due to the absence of dense and

tallest trees having broad leaves, causes more litter fall, at both ends of the forest site and possibly also due to the favorable conditions for tree growth in the middle part.
SOC, on the other hand, depends upon the above ground input received from leaf litter and on the decomposition of fine roots below ground [43]. Thus, the reason might be high decomposition rate of fine roots and litter in the middle slope and the reverse is true for lower and higher slope. As an exploration of [44], higher elevations are usually associated with steeper slopes. Especially, elevation variation has an impact on soil organic carbon stock because of its influence on soil water regime [45].

4.1.3 Variation of Carbon Stock in the Aspects (Slope Facings)

Aspect is one of the environmental factors that can affect the carbon stock of forests in different carbon pools [46] and thus, it can be used as a useful variable to forecast the forest carbon stock in different carbon pools. According to [47], aspect has a significant relationship with biomass carbon in forest areas due to the interaction between solar radiation and soil properties. The result of the present study revealed that higher mean values of above and below ground biomass and carbon stock on North aspect compared to the other aspects, whereas the lowest mean value was recorded on the West aspect. Similarly, in the carbon stock study of Egdu Forest by [36], higher mean values of above and below ground biomass carbon stocks were found on Northern aspect.

In general, the Northern aspects of the study area had higher values of above and below ground biomass and carbon stocks as compared to Southern aspects. This can be attributed to the occurrence of moister and favorable environment such as the type and fertility of the soil on the Northern aspects of Weiramba Forest as pointed out by [47] that soil properties are influenced by aspect. This is because the North and south facing slopes receive an unequal amount of solar radiation. The South facing slopes receive high solar radiation compared to the North facing which receive less sunlight [46]. Thus, the South facing slopes are warmer and drier, whereas the North facing slopes are relatively cooler and form better-growing conditions on the Northern aspects than the Southern aspects. On the other hand, the least above and below carbon stock was found in the Western aspect which was in agreement with result found by “un-published” [31]. The reason might be the availability of less fertile soil and moisture in the western part.

In addition, the higher and lower values of soil organic carbon in the South West and East aspects respectively have been reported in the present study. The reason might be due to the presence of moist climate and high decomposition rate on the South West aspect which had maximum SOC value and the reverse is true for East aspect. As indicated by [46], aspect has the significant relationship with biomass in forest areas due to the interaction between soil radiation and soil properties such as soil moisture and soil nutrients.

Moreover, litter pool enhanced the maximum and minimum carbon stock on North East and South West aspects, respectively. This difference might be due to the difference in litter-fall amount and its decomposition rate. The absence of high decomposition rate of a litter on North East aspect of the forest growing on the North-East aspect are generally exposed to various natural disturbances such as, windfall cause the litter pool enhances the highest biomass and carbon stock in North East aspect than other aspects of the study area, whereas the reverse is true to the South West direction of the site. Overall, the present study pointed out that carbon stock density of all carbon pools did not show significant difference along aspects.

5 CONCLUSION

The average carbon stocks in the forest area were large and the result is comparable to some study results of forests in Ethiopia and other tropical countries. This indicates the contribution of the forest for carbon sequestration and hence mitigation of climate changes.

Analysis of variation of carbon stock in different carbon pools of the forest area showed differences along different environmental gradients. The middle parts of altitude were high in above ground and below ground carbon stocks while the upper and lower parts of altitude had low to moderate carbon stock in both carbon pools due to the fact that there was dense vegetation cover in the middle altitudinal range. However, litter carbon and SOC showed a clear pattern along an altitudinal gradient, an increasing trend with increasing altitudes. On the other hand, above ground, below ground and litter carbon pools density showed insignificant variation, whereas Soil carbon pool was significantly different along altitudinal gradients.

The forest carbon stock in different carbon pools did not show clear patterns along slope gradient and the variation was not significant in all carbon pools except SOC in the 21-40 cm depth. The middle slope showed an increasing carbon stock potential of all pools (AGC, BGC, LC and SOC in the 0-20 cm depth) and followed by the lower and upper slope except SOC (21-40 cm) whose carbon density increased with an increase of slope gradient. Similarly, litter biomass and its carbon density of the forest area showed an increasing pattern at middle slope followed by the lower and higher slope gradient.

The total carbon stock was found to be higher on the Northern side of the forest. There was no significant difference in all carbon pools of the forest carbon stocks among aspects. In general, the total carbon stocks in the different pools were arranged in this order North > North West > North East > East > South West > West.

Overall, the present study result revealed that because of different factors affecting forest carbon stocks, these carbon stocks of different forest ecosystem components showed different patterns along environmental gradients and thus these variables can play different roles in carbon sequestration. We recommend that the carbon sequestration of the study forest should be integrated with Reduced Emission from Deforestation and Degradation (REDD+) and Clean Development Mechanism (CDM) carbon trading system of the Kyoto Protocol to get the monetary benefit of carbon dioxide mitigation which can help in conservation and further enhancement of the forests.

ACKNOWLEDGEMENT

Ethiopian Environment and Forest Research Institute, Non-Timber Forest Products research case team, in particular, are highly acknowledged for the financial support. Mersa Bureau of Agriculture and Rural Development, and Sirinka Agricultural Research Center are acknowledged for the provision of secondary data.

REFERENCES

[1] IPCC (2007b) “Facts on climatic change,” A summary of the 2007 assessment report of IPCC, Cambridge University Press, Cambridge, UK.

[2] IPCC (2007a) “The Physical Science Basis,” Highlights from Climate Change 2007, Summary for Policy Makers, The contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. eds), Cambridge University Press, Institute of Terrestrial Ecology, Edinburgh, Pp. 545-552.

[3] Broadmeadow, M. and Robert, M. (2003) “Forests, Carbon and Climate Change”, the UK Contribution, Forestry Commission Bulletin 125, Forestry Commission, Edinburgh.

[4] IPCC (2000a) “Land Use, Land-Use Change, and Forestry,” Special Report, IPCC, Geneva, Switzerland.

[5] Mesfin Sahile, Dagnachew Legesse, Zewedu Eshetu (2011) “Estimating and Mapping of Carbon Stocks based on Remote Sensing, GIS and Ground Survey in the Menagesha Suba State Forest, Ethiopia,” Addis Ababa University, Addis Ababa.

[6] Alves, L.F., Vieira, S.A., Scaranello, M.A., Camargo, P.B., Santos, F.A.M., Joly, C.A., and Martinelli, L.A. (2010) “Forest structure and live aboveground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil),” *Forest Ecology and Management* 260: 679-691.

[7] Brown, S. (1997) “Estimating Biomass and Biomass Change of Tropical Forests,”A primer, UN FAO Forestry paper, Rome **134**: 20-55.

[8] Hairiah, K., Sitompul, S.M., van Noordwijk, M., and Palm, C. (2001) “Carbon Stocks of Tropical Land Use Systems as Part of the Global Carbon Balance: Effects of Forest Conversion and Options for ‘Clean Development' Activities,” ICRAF, Indonesia. 49 Pp.

[9] Kent, M. and Coker, P. (1992) “Vegetation Description and Analysis,” Belhaven Press, London 363 Pp.

[10] Brown, S. (2002) “Measuring carbon in forests: current status and future challenges,” *Environmental Pollution* 116: 363-372.

[11] Pearson, T. R., Brown, S. L., and Birdsey, R. A. (2007) “Measurement guidelines for the sequestration of forest carbon,” Northern Research Station, Department of Agriculture, Washington, D.C, Pp. 6-15.

[12] Azene Bekele (2007) “Useful Trees and Shrubs for Ethiopia, Identification, Propagation, and Management for 17 Agroclimatic zones,” Technical manual, Pp. 550, (Tengnas, B., Ensermu Kelbessa, Sebsebe Demissew and Maundu, P. eds), World Agroforestry Center, English Press, Nairobi, Kenya.

[13] Chave, J., Rejou, M., Burquez, A., and Chidumayo, E., S. Colgan, M., B.C. Delitti, W., Duque, A., Eid, T., M.Fearnside, P., Goodman, R., Henry, M., Martinez, A., A. Mugasha, W., C. Mullerlandu,. H., Mencuccini, M., W.Nelson, B., Ngomanda, A., M. Nogueira, E. Ortiz Malavassi, E., Pelissier, R., Quadraton, P., M. Ryan, C., G. SaldArriaga, J., and Vieilledent, G. (2014) “Improved allometric models to estimate the aboveground biomass of tropical trees”.

[14] MacDicken, K. G. (1997) "A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects," In: *Forest Carbon Monitoring Program*, Winrock International Institute for Agricultural Development, Arlington, Virginia, Pp. 87.

[15] Pearson, T., Brown, S., and Walker, S. 2005 "Sourcebook for Land Use, Land-Use Change, and Forestry Projects," With input from Bernhard Schlamadinger, Igino Emmer, Wolfram Kägi, Ian Noble, Benoit Bosquet and Lasse Ringius.

[16] Cairns, M. A., Brown, S., Helmer, E. H. and Baumgardner, G. A. (1997) "Root biomass allocation in the world's upland forests," *Oecologia* 111:1-11.

[17] IPCC (2006) "IPCC Guidelines for National Greenhouse Gas Inventories Volume 4," Prepared by National Greenhouse Gas Inventories Program, (Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe, K. eds), Institute for Global Environmental Strategies (IGES) Publishing, Hayama, Japan.

[18] FAO (Food and Agricultural Organization of United Nations) (2010) "Global Forest Resources Assessment," Country Report, Ethiopia, FRA 065.

[19] Allen S. E., Grimshaw H. M., and Rowland, A. P. (1986) "Chemical analysis," In: Methods in plant ecology (Moore, P. D., Chapman, S. B. eds), Blackwell Scientific Publications, London, UK, Pp. 285-344.

[20] Roshetko, J.M., Delaney, M., Hairiah, K. and Purnomosidhi, P. (2002) "Carbon stocks in Indonesian home-garden systems: Can smallholder systems be targeted for increased carbon storage?," *American Journal of Alternative Agriculture* 17: 138–148.

[21] Takimoto, A., Ramachandran Nair, P.K., and D. Nair, V. (2008) "Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel," *Agriculture, Ecosystems and Environment* 125: 159-166.

[22] Walkley, A. and Black, I.A. (1934) "An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method," *Soil Sci.* 37: 29-38.

[23] Belay Melese, Ensermu Kelbessa and Teshome Soromessa (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(2): 141-147.

[24] Mohammed Gedefaw, Teshome Soromessa and Satishkumar Belliethathan (2014) "Forest carbon stocks in woody plants of Tara Gedam forest: Implication for climate change mitigation," *Sci. Technol. Arts Res. J.* 3(1): 101-107.

[25] Nagash Mamo, Berhane Habte and Dawit Beyan (1995) "Growth and form factor of some indigenous and exotic tree species in Ethiopia," Forestry research center ministry of natural resources development and environmental protection, Ethiopia.

[26] Nagash Mamo (2007) "Growth and yield estimation of the stand of *Cupressus Lusitania*," Technical manual 17, Ethiopian Institute of Agricultural research.

[27] Tura T.T., Argaw M., Eshetu Z. (2013) "Estimation of Carbon Stock in Church Forests: Implications for Managing Church Forest to Help with Carbon Emission Reduction," In: Leal Filho W., Mannke F., Mohee R., Schulte V., Surroop D. (eds) Climate-Smart Technologies. Climate Change Management. Springer, Berlin, Heidelberg

[28] IPCC (1997) "Technical Paper on Implications of Proposed CO2 Emissions Limitation," Tom M. L. Wigley, Atul K. Jain, Fortunat Joos, Buruhani S. Nyenzi, P.R. Shukla, Cambridge University Press, Cambridge, UK.

[29] Murphy, P. G., and Lugo, A. E. (1986) "Ecology of a tropical dry forest," *Ann. Rev. Ecol. Syst.* 17: 67-88.

[30] Weaver, P. and Murphy, P. (1990) "Forest structure and productivity in Puerto Rico´s Luquillo Mountains," *Biotropica* 22: 69-82.

[31] Kidanemariam Kassahun (2014) "Forest Carbon Stock in Woody Plants of Ades Forest and its Variation along Environmental Factors: Implication for Climate Change Mitigation, at Western Hararghe, Ethiopia," M.Sc. Thesis (Unpublished), Addis Ababa University, Addis Ababa.

[32] Sheikh, M. A., Kumar, M., Rainer, W., and Bussmann, R. W. (2009) "Altitudinal variation in soil organic carbon stock in coniferous subtropical and broadleaf temperate forests in Garhwal Himalaya," Department of Forestry, HNB Garhwal University, Srinagar Garhwal, Uttarakhand, India, *Carbon Balance management* 4: 1-6.

[33] Brown, S. and Lugo A. E. (1992) "Above-ground biomass estimates for tropical moist forests of the Brazilian Amazon," *Interciencia* 17: 8-18.

[34] Fentahun Abere, Yehualashet Belete, Alemayehu Kefalew and Teshome Sormessa (2017) "Carbon Stock of Banja Forest in Banja District, Amhara Region, Ethiopia: An Implication for Climate Change

Mitigation," Journal of sustainable Forestry Volume 36, Issue 6, 2017.

[35] Muluken Nega Bazezew, Teshome Soromessa and Eyale Bayable (2014) "Carbon Stock in Adaba-Dodola Community Forest of Oromia Region, Ethiopia: Implications for Climate Change Mitigation," Academic Journal of Ecology and the Natural Environmental, Vol. 7, No.1, 2015, Pp.14-22. doi: 10.5897/JENE2014.0493.

[36] Adugna Feyissa, Teshome Soromessa and Mekuria Argaw (2013) "Forest Carbon Stocks and Variations Along Altitudinal Gradients in Egdu Forest: Implications of Managing Forests for Climate Change Mitigation," *Science, Technology, and Arts Research Journal* 2(4): 40-46.

[37] Demel Teketay (1996) "Germination ecology of 12 indigenous and 8 exotic multipurpose leguminous species from Ethiopia," *Forest Ecology and Management* 80: 209-223.

[38] Harmon, M.E., and Sexton, J. (1996) "Guidelines for Measurements of Woody Detritus in Forest Ecosystems (US LTER Publication No. 20)," US LTER Network Office, University of Washington, Seattle, WA, USA.

[39] Jackson, R.B., Schenk, H.J., Jobbágy, E.G., Canadell, J., Colello, G.D., Dickinson, R.E., Field, C.B., Friedlingstein, P., Heimann, M., Hibbard, K., Kicklighter, D.W., Kleidon, A., Neilson, R.P., Parton, W.J., Sala, O.E. and Sykes, M.T. (2000) "Belowground Consequences of Vegetation Change and their Treatment in Models," In: *Ecological Applications* 10 (2): 470-483.

[40] Zhu, B., Xiangping Wang, Jingyun Fang, Shilong Piao, Haihua Shen, Shuqing Zhao, Changhui Peng (2011) "Altitudinal changes in carbon storage of temperate forests on Mt Changbai, Northeast China. Carbon cycle process in East Asia, The Botanical Society of Japan and Springer 2010," *Journal of Plant Resource* 10:1-14.

[41] Clark, D.B., and Clark, D.A. (2000) "Landscape-scale variation in forest structure and biomass in the tropical rainforest," *Forest Ecol. Manage.* 137(3): 185-198.

[42] Maggi, O., Persiani, M. A., Casado, M. A. and Pineda, F. D. (2005) "Effects of elevation, slope position and livestock exclusion on microfungi isolated from soils of Mediterranean grasslands," The Mycological Society of America, Lawrence, *Mycologia* 97(5): 984–995.

[43] Rasse, D.P., Mulder, J., Moni, C. and Chenu, C. (2006) "Carbon turnover kinetics with depth in a French loamy soil," *Soil Sci Soc Am J* 70(6): 2097-2105.

[44] Regard, V., Lagnous, R., Espurt, N., Darrozes, J., Baby, P., Roddaz, M., Calderon, Y. and Hermoza, W. (2009) "Geomorphic evidence for a recent uplift of the Fitzcarrald Arch, Peru: A response to the Nazca Ridge subduction," *Geomorphology* 107: 107-117.

[45] Schimel and Gulledge (2000) "A contribution of increasing CO_2 and climate to carbon storage by ecosystems in the United States," *Science* 287: 2004-2006.

[46] Bayat, T.A. (2011) "Carbon Stock in an Apennine Beech Forest," M.Sc. Thesis, University of Twente, Enschede, the Netherlands.

[47] Hicks, R.R., and Frank, P.S. (1984) "Relationship of aspect to soil nutrients, species importance, and biomass in a forested watershed in West Virginia," Forest Ecol. *Manage.* 8(4): 281-291.

First and Corresponding Author

Teshager Z., *Researcher in Ethiopian Environment and Forest Research Institute, P.O. Box 24536, Addis Ababa, Ethiopia.*

Email: zelalemteshager1@gmail.com

Guide

Argaw M., *Lecturer and Senior Researcher in Center for Environmental Science, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia.*

Email: mekuriaa69@gmail.com

Eshete A., *Senior Researcher in Ethiopian Environment and Forest Research Institute, P.O. Box 24536, Addis Ababa, Ethiopia.*

Email: abejeeshete@yahoo.com