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Research Article

Carbon Stock and Soil Properties Analysis along Altitudinal Gradient and Slope in Gra Kahsu National Forest Priority Area: Southern Tigray, Ethiopia

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ABSTRACT

The study was conducted to assess the impacts of altitude and slope on carbon stock and soil properties on the slopes of Gra-kahsu national forest priority area. Data were collected from 35 quadrats, each with 20 m X 20 m with trees of diameter at breast or stump height ≥2.5 cm. Above and below ground carbon (allometric equation), organic carbon (Walkely-Black), PH (1:25water), and total nitrogen (Kjedah) were the mothed used for analyzed. Analysis of one way using R-software was used to analysis the mean of carbon stock pools and soil properties across the altitudinal gradients and slopes. The upper altitudinal class of the study area had better carbon stock than the rest classes due to the presence of high diameter at breast height. The distribution of carbon stocks with each sample quadrate in litter, herb, above ground and below ground carbon pools was found positively correlated and had significant differences with altitude. However, positively correlated and had non-significant differences in litter, dead woody carbon and soil organic carbon pools with slope was found. Except organic carbon percentage, soil organic matter and total nitrogen, all considered soil properties showed non-significant differences among the three-altitudinal class. The differences may be attributed to leaching and differences in organic matter (carbon) contents within the soil profiles due to altitude. The current study shows that carbon stock value, soil properties of study area was highly affected by environmental factors such as altitude, and slope. Nevertheless, altitude was the only factor that showed significance difference in carbon stocks of the study area.

Key words: Altitude, Carbon stock, Slope gradient; Soil organic carbon

INTRODUCTION

Forests and trees absorb carbon dioxide from the atmosphere and store it as carbon. Forests store about 20-40 times carbon per unit area than most crops and most of the carbon is released into the atmosphere through deforestation (Emmanuel, 2013). Forest carbon more significantly, affects bioenergy emissions when biomass is source from standing trees compared to residues and when less GHG-intensive fuels are displaced (Keith, 2014). Forests have a large potential for temporary and long-term carbon storage (Houghton, 2005) and influence by altitudinal variations (Alves *et al.*, 2010). Forest carbon stock could be affects by different environmental factors such as topographical factors like altitude, slope and aspect gradients. Landscape attributes including slope, aspect, elevation, and land use are the dominant factors influencing forest organic carbon in areas with the same climate regime (Clark *et al.*, 2000; Houghton, 2005; Dianwei *et al*., 2006).

Significant differences in soil chemical and physical properties in a small area on uniform geology are known to be related to landscape position (Jenny, 1941; Ruhe, 1956). The relationships between soil physical properties and landscape attributes including slope and Altitude affect plant growth through indirect influences involving soil physical properties (McIntosh *et al.*, 2000; Seyed and Robert, 2004). Altitude is often employed to study the effects of climatic variables on SOM dynamics, which determines the level of decomposition of the organic matter (Lemenih and Itanna, 2004). The change in altitudinal gradients influences SOM by controlling soil erosion, species and biomass production of the native vegetation (Tan *et al.*, 2004).

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Carbon sequestration from atmosphere can be advantageous from both environmental and socioeconomic perspectives (Yohannes *et al.,* 2015). According to Kumar (2012) although changes in species composition and distribution, biodiversity and community structure along topographic gradients have been well documented in but altitudinal and slope patters of carbon storage in forest ecosystems remain poorly studied. This is true in Ethiopia particularly in Tigray, there has been very limited forest carbon stock study by considering slopes and altitudinal gradients that affect carbon stock and soil properties.

Gra Kahsu national forest priority area is one of Tigray's forests, which have tremendous role for stocking carbon within their biomass and soil. This contributes a lot to mitigate climate change but different topographic features could influence carbon-stocking process and soil properties. There is limit scientific study that shows slopes and altitudinal gradients influence and variation on carbon stock amount and soil physical and chemical properties in Tigray, particularly in the study area. Therefore, this study shows and proves scientifically the role of altitudinal gradients and slope on the amount of national forest priority area carbon stock and soil properties in the study area.

MATERIALS AND METHODS

Description of the Study Area

Alamata is located 600 km north of Addis Ababa and about 180 km south of the Tigray Regional capital state (Mekelle) (Figure 1). It is geographically located between 12°19'21"N and 12°24'28.5" North and 39°14'52"E and 39°45'47.8" East longitude, in Southern Tigray. Alamata Wereda is borders with Amhara region from the south and west and Afar region from the East. The altitude of the Wereda ranges from 1,178 to 2,300 meters above sea level (masl).The annual mean precipitation ranges from 615-927 mm, with mean maximum and minimum temperatures of 23 °C and 14 °C, respectively (Girmay *et al.*, 2014).

Gra Kahsu national forest priority area is designated to conserve unique natural features, historical interests and other natural values with legal and administration supports on the upper part of Alamata town. It is endowed with different natural resources such as wildlife and other bio diversities, which contribute great potent source as important pillars for future development. The total area is 3500ha. Monkey, Ethiopian Tiger (Panthera Tigris), Menelik Bushbuck (Tragelapphus scriptus), Python (Snake type), Fox and different species of birds were examples of wild life species that found at Gra Kahsu national forest priority area (WAOARD, 2016).

Stratification and Sampling Techniques

A reconnaissance survey was conducted, to collect base line information, observe vegetation distribution and determine number of transect lines to be laid. Accordingly, stratified in to three units based on Altitude, namely lower (1655-1869 masl), middle (1870-2084 masl) and higher ($\geq$2085 masl). Slope gradient was the second parameter to classify the area. Slope classified into lower (0-25%), middle (26-45%) and higher ($\geq$ 46%). A parallel line transects were laid at 500m interval that lie with parallel to the slope of the stand was established. The quadrates were distributed along transects that ranges from 1 km to 1.5 km which were laid parallel to the slope. Sample quadrate size 20mx20m was used to collect the data (identity, DBH/DSH for both live and dead woody plants) and 35 numbers of quadrats (1.4ha) were taken.

Data Collection Methods

Trees and other woody vegetation biomass measurement

All trees/shrubs (live and dead) within the quadrate were recorded and their diameter at breast height (1.30m above the ground) for trees and diameter at stamp height (30cm above the ground) for shrubs was measured using caliper. Whereas, in cases where there are multi-stemmed small trees and shrubs (>1 stem on a sample shrub or small tree) prone to multi-stem below 1.3 m diameter the measurement of the diameter was calculated by the diameter equivalent (de) as follows:

$$\mathrm{de} = \sqrt{\sum_{i=1}^{n} \mathbf{di2}}$$ (Snowdon, 2002)………..…….. (Eq. 1)

Where: di = diameter of the ith stem at 30 cm (d30) height.

Herb and litter layer

A quadrate with a size of 1 m × 1 m was established to sample litters and herb. In each sample quadrates, five small quadrates were laid four at the corner and one in the center to minimize heterogeneity. All the herbaceous vegetation emerging within the quadrate areas (1m x 1m) were cut at the ground level, weighed, and a composite sample was obtained from each sub-quadrate for oven-dry mass determination in the laboratory (Dossa *et al.*, 2008; Jina *et al.*, 2008). Oven drying was set at 70 ^{0}C and observed for 24 hours or until the samples reached their stable weight (Labata *et al.,* 2012).

Sampling of soil

Soil sampling was done from five points per quadrate (400m^2) using soil auger at depth of 30 cm and then the soil samples from the five points were composited to represent a quadrat. Soil texture, PH, organic carbon, electrical conductivity, Cation exchange capacity, total nitrogen, Available phosphorus and organic matter were analyzed for each sample at Mekelle soil laboratory research center. In 20x20m^2, an undisturbed soil was taken through core sampling to determine bulk density (MacDicken, 1997). Soil sample was oven dried at 105°C for 24 hours at Mekelle soil laboratory research center.

Estimation of aboveground trees and shrubs carbon stock

The AGB of trees ≥2.5 cm in DBH and ≥1.5 m in height estimated using the allometric model of Kuyah *et al*, (2012). The equation is as follows:

$$\mathrm{AGB} = 0.1428 * \mathrm{DBH}^{2.2471}$$ ……………………... (eq. 2)

AGB diameter measures at DSH of multi-stem trees and shrubs were estimated from DSH using a regression model WBISPP, (2000). The equation is as follows:

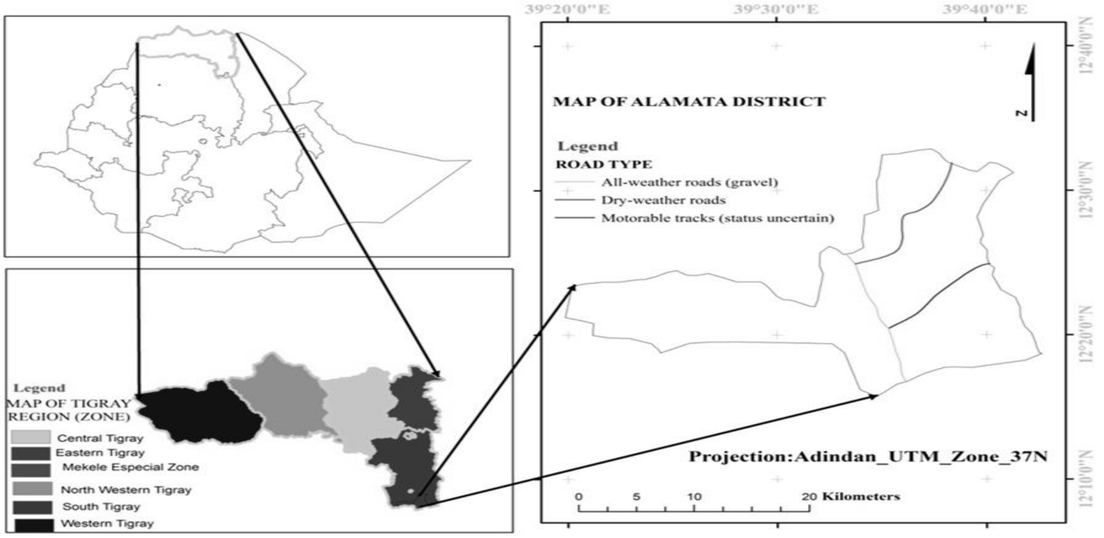

Fig. 1: Location map of the study area.

$$AGB = (0.4861 * DSH) + (0.1659 * (DSH^{2.2}))\text{.... (eq.3)}$$

To convert the above ground dry biomass to carbon, 50% of all trees and shrubs biomass were assumed to be the carbon stock. So based on the aboveground trees and shrubs biomass carbon stock calculated as follows:

$$AG\ TSCS = AG\ TSDBM\ *\ 0.5\ (Brown, 2002)\text{...... (eq.4)}$$

where; AGTSCS: Above ground trees and shrubs carbon stocks AG TSDBM: Above ground trees and shrubs dry biomass.

Below ground trees and shrubs dry biomass and carbon stock

Below ground dry biomass for trees and shrubs were measured by taking 20% of above ground dry biomass of trees and shrubs and accordingly 50% was adopted for its carbon estimation. Below ground trees and shrubs dry biomass was computed using the formula (MacDicken, 1997):

$$BG\ TSDBM = AG\ TSDBM *\ 0.20\text{ .... (eq.5)}$$

Where; BG TSDBM: Below ground trees and shrubs dry biomass AG TSDBM: Above ground trees and shrubs dry biomass

Similarly, the carbon stock for below ground component of trees and shrubs had measured as follows:

$$BG\ TSCS = BG\ TSDBM\ *\ 0.5\ (Brown, 2002)\text{...... (eq.6)}$$

Where; BG TSCS: Below ground trees and shrubs carbon stocks BG TSDBM: Below ground trees and shrubs dry biomass.

Estimation of carbon stocks in the herb and litter layer biomass

Oven-dry weights of herb and litter subsamples were determined to compute for the total dry weights using the formula (Hairiah *et al.*, 2001):

$$\text{Total dry weight (kg m}^{-2}) = \frac{\textbf{Total fresh weight (kg)*subsample dry weight (g)}}{\textbf{Subsample fresh weight (g)* sample area (m}^2)}\text{ .... (eq.7)}$$

Carbon storage in herb and litter layer was computed using the formula (Lasco *et al.*, 2006):

$$\text{C stored (ton/ha)} = \text{Total dry weight} * \text{C content (eq.8)}$$

The carbon stock (carbon content) for the dry biomass of herbs and litters is 47% of the total dry biomass of the quadrate (IPCC, 2007).

Estimation of dry biomass and carbon stock in the dead wood

Dead wood biomass was computed using the formula (Pearson *et al.*, 2005):

$$BSDW = 0.139DBH^{2.32}\text{ -5.5\% .... (eq.9)}$$

Where, BSDW = Biomass of standing dead wood in ton/ha, DBH = Diameter at breast height of standing dead wood (cm)

The total carbon stock in dead wood was computed by multiplying the total biomass of the dead wood by 0.5 (Persson *et al.*, 2005).

Estimation of soil organic carbon stock

Bulk density (ρ_b)

Soil bulk density was determined after oven drying the soil samples that are taken with core sampler as follows formula as recommended by Pearson *et al.* (2005).

$$V = h * \pi r^2\text{.. (eq.10)}$$

Where: - V = volume of the soil in the core sampler in cm^3, h = the height of core sampler in cm, π =3.14 cm, r = the radius of core sampler in cm. Moreover, the bulk density (ρ_b) of a soil sample was calculated as follows:

$$\rho b = \frac{Wav,dry}{v}\text{ .... (eq.11)}$$

Where, ρ_b is bulk density of the soil sample per quadrate (g cm^{-3}), Wav, dry is average air dry weight of soil sample per the quadrate, V is volume of the soil sample in the core sampler auger in cm^3 (Pearson *et al.*, 2005).

Soil organic carbon (SOC)

Collected composite soil samples were examined for SOC estimation using the Walkely-Black methods (Gupta, 2000). SOC per quadrate and then per hectare in tons calculated as follows:

$$SOC = \left(\rho b \left(\frac{g}{cm3}\right) * D\ (cm) * \%C \right) \ldots\ldots\ldots\ldots\ldots\ldots \text{(eq.12)}$$

Where, SOC = Soil organic carbon (t /ha), % OC = Organic carbon concentration of the quadrate (%) expressed in decimal, ρ_b = Bulk density of the quadrate (g cm^{-3}), D = Depth of the soil sample (cm)

Soil textures were determined by hydrometer after dispersion in a mixer with hex metaphosphate. Exchangeable base cations were extracted with 1N ammonium acetate at pH 7. Available phosphorus (Olson) was analyzed according to the standard methods of analyses (Olsen *et al.*, 1954). Soil pH was measured with combined electrodes in a 1:2.5 soil to water suspension. Cation exchange capacity was estimated titrimetric ally by distillation ammonium displaced by sodium (Chapman, 1965). Organic carbon was determined by the wet acid dichromate digestion method and SOM was calculated by multi- plying percent OC by a factor of 1.724 (Walkley and Black. 1934) whereas total nitrogen was analyzed by the semi-micro Kjeldahl digestion followed by ammonium distillation and titrimetric determinations (Bremner M., 1965).

Statistical analyses

Analysis of one way ANOVA using R-software Version 3.3.3 was used to analysis the mean of carbon stock pools and soil restoration across the altitudinal gradients. The least significant difference was used to separate the means. The correlation between carbon stock pools, soil properties with altitudinal gradients and slope was tested using the Pearson correlation matrix. Differences were considered significant at P<0·05.

RESULTS

Altitudinal variation of carbon stock pools

Due to the altitudinal gradient, the values of litter and herb carbon stock varied (Table 1). The upper altitudinal class had the highest herb carbon stock of 0.79 ton/ha, whereas the lower altitudinal class had the lowest herb carbon stock with the recorded value of 0.44 ton/ha. In addition, the litter carbon stock was significantly lower in the lower altitudinal class compared to the other altitudinal class (P<0.001) (Table 1).

The AGC stock was significantly larger in the upper altitudinal class compared to the others altitudinal class (P<0.001) (Table 1).The AGC stock of the lower altitudinal class was between 11.59 and 25.76 ton/ha with the average value of 16.44 ton/ha (Table 1). Similarly, the mean total SOC stock density was varied in classes of lower, middle and higher altitude with carbon stock density of 13.77±3.44, 18.49±4.60 , and 16.13±3.53 ton/ha, respectively. Therefore, the mean total maximum soil carbon stock was stored in the middle altitudinal class, followed by higher and lower altitudinal classes with statistical significant differences along altitudinal gradient (p<0.05) (Table 1). Generally, the present study revealed distinct pattern of variation of carbon stock in each pools although the variation has significant difference. The carbon stocks in AGC, BGC, herb, litter carbon and SOC exhibited distinct patterns along altitudinal gradients.

Altitudinal variation of soil physical and chemical properties

SOM showed a significant variation across the altitude (P<0.05) ranged from 2.85% for the lower (1655-1869 m.a.s.l) to 3.24% for the higher (>2085 m.a.s.l). Organic carbon percentage showed a decreasing trend across the altitudinal class which varied from 1.66% for lower altitudinal class to 1.94% for middle class (Table 2). Total nitrogen varied highly significantly (P<0.001) from as low as 0.22% for the lower altitudinal class to as high as 0.27% for the middle altitudinal class. According to the current study, non-significant differences (P>0.05) was noticed for available phosphorus, PH, soil bulk density, CEC, EC, and soil texture across the three altitudinal class (Table 2).

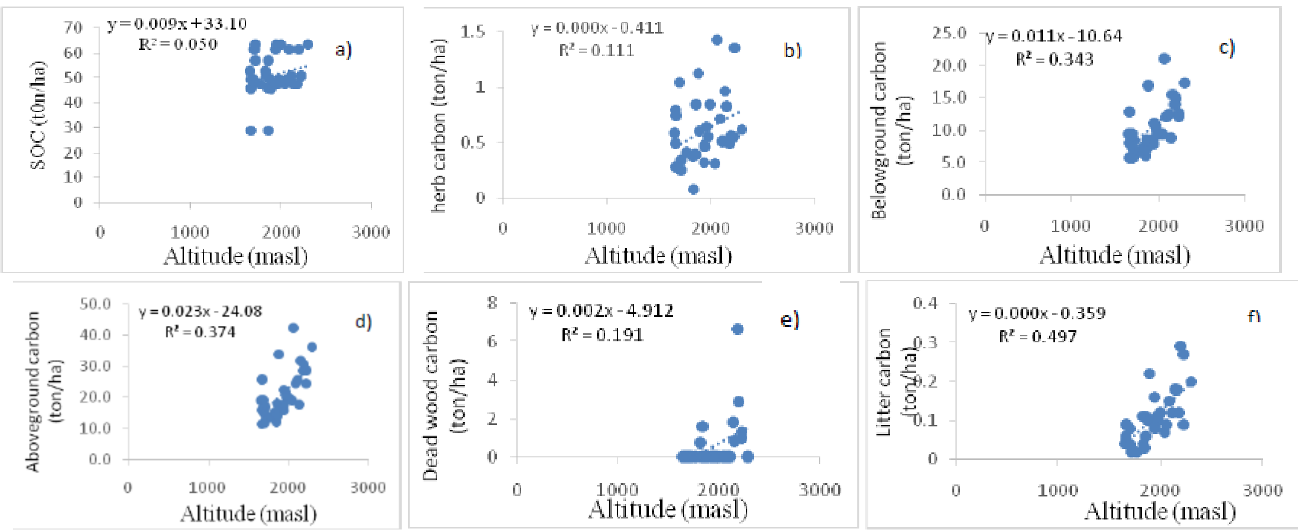

Fig. 2: Linear regression model for carbon stock pools versus altitudinal gradient.

Table 1: Altitudinal variations of carbon stock pools in Gra-kahsu national forest priority area

Altitude class		Higher	Middle	Lower	p-value
Values (ton/ha)	Herb carbon stock	0.79[a]	0.62[ab]	0.44[b]	0.02
	Litter carbon stock	0.16[a]	0.12[b]	0.05[c]	<0.001
	AGC	29.00[a]	20.02[b]	16.44[b]	<0.001
	BCG	14.15[a]	9.96[b]	8.18[b]	<0.001
	WC	1.44[a]	0.16[b]	0[c]	<0.001
	SOC	16.13[ab]	18.49[a]	13.76[b]	0.03

Different letters in the same row are significantly different (P<0.05), AGC-above ground carbon, BGC-below ground carbon, WC-dead woody carbon, SOC-soil organic carbon.

Table 2: Altitudinal variations of physical and chemical soil properties in Gra-kahsu national forest priority area

Altitude class		Higher	Middle	Lower	p-value
Soil physical and chemical properties	PH (1:2.5)	6.79	6.78	6.79	0.96
	EC (ds/m)	0.11	0.13	0.14	0.17
	OC (%)	1.90[ab]	1.94[a]	1.66[b]	0.03
	SBD (g cm^{-3})	0.99	1.02	1.03	0.31
	OM (%)	3.24[ab]	3.31[a]	2.85[b]	0.04
	TN (%)	0.25[ab]	0.27[a]	0.22[b]	<0.001
	Av.P (ppm)	0.99	1.16	1.24	0.15
	CEC (meq/100gm)	43.86	43.12	41.33	0.14
	Sand%	67.78	65.67	66.87	0.73
	Silt %	20.37	22.63	21.31	0.69
	Clay %	11.85	11.7	11.82	0.96

Different letters in the same row are significantly different (P<0.05).

Table 3: Pearson correlations of carbon stock with altitude

Parameter	Carbon pool	Correlation coefficient value	P-value
Altitudinal gradients	AGC	0.68**	<0.001
	BGC	0.67**	<0.001
	WC	0.39*	0.022
	HC	0.47**	0.004
	LC	0.71**	<0.001
	SOC	0.24	0.19

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level.

Table 4: Slope variations of carbon stock pools in Gra-kahsu national forest priority area

Slope class		Higher	Middle	Lower	p-value
Values (ton/ha)	Herb carbon stock	0.43	0.69	0.57	0.18
	Litter carbon stock	0.09	0.12	0.09	0.41
	AGC	19.88	20.97	21.79	0.86
	BCG	9.89	10.24	10.85	0.84
	WC	0.34	0.91	0.06	0.22
	SOC	16.13[ab]	18.49[a]	13.77[b]	0.04

Table 5: Pearson correlations of carbon stock with slope

Parameter	Carbon pool	Correlation coefficient value	P-value
Slope gradient	AGC	-0.09	0.59
	BGC	-0.10	0.56
	WC	0.06	0.72
	HC	-0.10	0.56
	LC	0.04	0.83
	SOC	0.24	0.19

AGC-Above ground carbon, BGC-below ground carbon, WC-dead woody carbon, HC-herb carbon, LC-litter carbon, SOC-soil organic carbon

Correlation of carbon stock pools and physical and chemical soil properties with altitude

AGC and BGC shows strong positive relation with altitude (r= 0.68 and 0.67; P<0.001) at 0.05 respectively. In the presence study area the mean AGC and BGC, herb carbon and litter carbons of all quadrates with corresponding altitude were more regressed linearly than SOC and dead wood carbon (Figure 2 a– f). On the other hand, Litter carbon and herb carbon shows strong positive relation with altitude (r= 0.71, P=0.004 and 0.47; P<0.001) at 0.05 respectively (Table 3). The distribution of carbon stocks with each sample quadrate in litter, herb, AGC and BGC pools was found to be positively correlated and had significant differences with altitude. The result showed that weak correlation (r= 0.24; P=0.19) (Table 3). EC, SBD and available of phosphorus shows strong negative relation with altitude (r= -0.9, P>0.05) at 0.05. In addition, organic carbon percentage, organic matter, total nitrogen and CEC shows strong positive relation with altitude (r= 0.8, 0.8, 0.6 and 0.9; P>0.05) at 0.05, respectively (Table 3).

Slope variation of carbon stock pools and soil properties

Litter biomass carbon, herb biomass carbon, AGC and BGC was no significant differences (p>0.05) along slope gradient. It was observed that the higher numerically AGC and BGC was estimated in the lower slope class with mean total of 21.79± 9.03 ton/ha and 10.84 ± 4.52 ton/ha, respectively. On the other hand, the higher carbon in herb and litter biomass was estimated in the middle slope class with the mean total of 0.69 ± 0.33 and 0.12 ±0.06 ton/ha and the lower litter biomass carbon was computed in higher and lower slope class with no significant differences (p>0.05) along slope gradient. The mean total soil carbon stock density was varied in classes of lower, middle and higher slope with carbon stock density of 13.77±3.44, 18.49±4.60, and 16.13±3.53 ton/ha, respectively. Therefore, the mean total maximum soil carbon stock was stored in the higher slope class, followed by middle and lower slope class with statistical significant differences along slope gradient (Table 4). The effects of slope on the study area carbon stocks were very small; the relations were insignificant for all carbon pools except SOC.

Correlation of carbon stock pools with slope

In the present study, the relationship between litter biomass carbon and dead woody carbon related to slope class was positive (r=0.06 and 0.04 respectively). However, herb biomass carbon, AGC and BGC was negatively (r=-0.10, -0.09 and -0.10 correspondingly) correlated with slope at the study area (Table 5). AGC, BGC and herb carbon trend shows decrease as slope class increases. As the result revealed that the correlation between herb carbon and SOC distribution and slope gradient did not show clear pattern in linear regression. Therefore, slope gradient did not influence the carbon pools considerably.

DISCUSSION

Environmental factors disturbing different carbon pools and soil properties

Altitude is a major effect on the biomass and carbon stock in the forest ecosystems (Luo *et al.*, 2005). The current study indicates that, the upper altitudinal class showed an increasing herb and litter carbon stock and followed by the middle altitudinal class and decreased when we go to bottom of the mountain. The reason greater litter and herb biomass carbon stock in the upper altitudinal class could be due to the presence of higher species density, less human and livestock interference than in the others. This result was agree with many studies it was reported that as altitude increase litter biomass carbon increases (Tsui and Hsieh, 2004; Zhang *et al.,* 2008;Chang *et al.*, 2010; Belay *et al.,* 2014;Yohannes *et al.,* 2015).

The reason of high carbon stock in the upper altitude might be its climatic conditions that allow many species to coexist and due to the topographical nature where upper altitude is almost steep slope made itself away from human disturbance. On the other hand, lower altitude is more prone to arable land due to gentle slope nature made to store less carbon. Results of the study indicated that, the highest SOC content (18.49ton/ha) was found in the middle altitude whereas lowest SOC (13.76 ton/ha) was observed in the lower altitude due to might be some human interference, the presence of different tree species, decomposition rate, disturbance regime and presence of relatively high litter biomass. Yohannes *et al.* (2015) conclude that, mountain forest mostly affects by environmental variables due to change in species structure and composition.

The carbon stocks in AGC, BGC, herb, litter carbon and SOC exhibited distinct patterns along altitudinal gradients. This finding supports the reports of Feyissa *et al.* (2013) concluded that, the carbon storage in different carbon pools of the Egdu forest area varies with altitudinal gradient. On the other hand, it has been reported by many studies as an increase in carbon stocks with increasing altitude (Zhu *et al.,* 2010; Gairola *et al.,* 2011; Mwakisunga and Majule, 2012; Feyissa *et al.,* 2013). The anthropogenic disturbances in the study area are higher at the lower altitude (for example, logging and wood collection) and lower at the higher altitude. This is could be the main reason for the increasing trend of AGC and BGC stock along altitudinal gradient. However, Moser *et al* (2011) showed that the litter biomass carbon and total AGC decreased by 50 to 70% between 1050 and 3060 m. Alefu *et al* (2015) also reported that, there was no significant variation of carbon pools between altitudinal ranges. On the contrary, in this study the carbon in herb, litter, AGC ,BGC and SOC increased by 18.92%, 33.33%, 19.18%, 18.49% and 10.93% respectively between 1655 and 2298 meter above sea level.

In the present study, the distribution of carbon stocks with each sample quadrate in litter, herb, AGC and BGC pools was found to be positively correlated and had significant differences with altitude. AGC and BGC shows strong positive relation with altitude ($r= 0.68$ and 0.67; $P<0.001$) at 0.05 respectively. Similarly, Moser and Leuschner (2007); Mwakisunga and Majule (2012) finding that, total AGC and BGC stock were significantly and positively correlated with altitude ($P<0.05$). Controversy, Luo *et al.* (2005) finding that, total AGC and BGC stock were significantly and negatively correlated with altitude ($P<0.05$).Yohannes *et al. (*2015) also finding that altitude has significant difference and inverse correlation with all carbon pools except litter biomass carbon. However, Muluken (2014); Alefu *et al.* (2015) studies done in Ethiopia and Bayat (2011) in Apennine Beech Italy forest, the distribution of carbon stocks in all carbon pools was found to be positively correlated and had insignificant differences with altitude. According to Feyissa *et al* (2013) the AGC and BGC stock showed an increasing trend with increasing altitude while the litter carbon stock showed irregular patterns along altitude though statistically there was no strong relationship between each of these carbon pools and altitudinal gradients.

Percentage of SOC was observed statically significant in the three altitudinal class ($p<0.05$). Dianwei *et al.* (2006) finding that, altitude is the dominant factors influencing forest organic carbon in areas with the same climate regime. In line with this, a positive correlation between SOM and altitude has been reported by Abreha *et al.* (2012). The variability in SOM content among the three altitudinal classes was might be due to the difference in species composition, herb and litter biomass which affects the SOM decomposition. The negative relationships of pH with altitude according to Rezaei and Gilkes (2005) could be due to the fact that increasing altitude increases rainfall and thus causing increased leaching and a reduction in soluble base cations leading to higher H^+ activity and registered as decreased pH levels.

Similarly, Slope gradient is also another environmental factor that affects and limits the spreading of carbon stock in the study site. Slope is one of the environmental factors that influence the distribution of carbon density (Clark *et al.,* 2000). In a higher human and animal interference site (lower slope) the above ground and below ground biomass of the carbon pool reduced due to less vegetation coverage as a result of high human and livestock interference. on other hand, the above and below ground biomass and carbon density showed higher values in higher slope because of having high vegetation coverage due to the case of low human and livestock interference.

In the present study, relatively, an overall increasing trend in mean SOC density with increasing slope was observed concurred with result found by Belay *et al.* (2014) and Alcántara, *et al* (2015). The mean SOC of the study area was more or less comparable with studies of slope variation effect on SOC (Feyissa *et al.*, 2013) and (Mohammed *et al.,* 2014) .On the contrary, the effects of slope on the study area, carbon stocks were very small and the relations were insignificant for all carbon pools except SOC, which is similar with other studies of Bayat, 2011 and Muluken, 2014 with a slightly small variation among slope classes. In general, the carbon stock of the current study has been highly correlated with environmental factors, which were knowingly the altitude and slope.

Conclusion

This study indicated that different environmental variables has great role for the variation of carbon stock amount and soil properties in the forest. Altitudinal gradients play a key role in both aboveground and belowground carbon pool account. This is because with altitude tree species and composition tends vary and they affects carbon stock contents. Each carbon pool shows variation along these altitudinal gradients. This study concludes that environmental variables has great role for the variation of carbon stock amount and soil properties in the national forest priority area. Further studies are required to fully understand the interactive relationships among topographic attributes such as aspect and landscape positions for different agro ecology soil resource management practices.

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REFERENCES

Abreha K, G Heluf, M Tekalign and K Kibebew, 2012.Impact of altitude and land use type on some physical and chemical properties of acidic soils in Tsegede Highlands, Northern Ethiopia. Open Journal of Soil Science, 2: 223-233.

Alcántara L, B García, and A Espejo, 2015. Soil organic carbon along an altitudinal gradient in the Despeñaperros Natural Park, southern Spain. Solid Earth, 6: 125–134.

Alefu C, S Teshome and B Eyale, 2015. Carbon stock in woody plants of Humbo Forest and its variation along altitudinal gradients: The Case of Humbo District, Wolaita Zone, Southern Ethiopia. International Journal of Environmental Protection and Policy, 3 (4):97-103.

Alves LF, SA Vieira, MA Scaranello, PB Camargo, FAM Santos, CA Joly and LA Martinelli, 2010. Forest structure and live aboveground biomass variation along elevation gradient of tropical Atlantic moist forest of Brazil. Forest Ecology Manage, 260: 679-691.

Bayat TA, 2011. Carbon stock in an Apennine beech forest. MSc. Thesis, University of Twente, Enschede, the Netherlands.

Belay M, K Ensermu and S Teshome, 2014. Forest carbon stocks in woody plants of Arba Minch ground water forest and its variations along environmental gradients. Science and Technology Arts Research Journal, 3(2): 141-147.

Blake GR, 1965. Bulk density. Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Methods of soilana, 374-390.

Bremner M, 1965.Total Nitrogen, In: C. A. Black, et al., Eds., Methods of Soil Analysis, Part 2, American Society of Agronomy, Madison, 1149-1178.

Brown SL, P Schroeder and JS Kern, 2002. Spatial distribution of biomass in forests of the eastern USA. Forest Ecology and Management, 123: 81–90.

Chang C, C Wang, C Chou, C Duh, 2010. The importance of litter biomass in estimating soil organic carbon pools in natural forests of Taiwan. Taiwan Journal of Science, 25(2): 171-80.

Chapman HD, 1965. Cation exchange capacity. In: Black, C.A., et al. (Eds.), Methods of Soil Analysis. Agronomy 9. Am. Soc. Agro. Inc., Madison, Wisconsin.891–901.

Clark DB and DA Clark, 2000. Landscape-scale variation in forest structure and biomass in tropical rain forest. Forest Ecology Manage, 137(3): 185-198.

Dianwei L, Zongming Z Bai, S Kaishan, L Xiaoyan, L Jianping, L Fang and D Hongtao, 2006. Spatial distribution of soil organic carbon and analysis of related factors in croplands of the black soil region, Northeast China. Agriculture, Ecosystems and Environment, 113: 73-81

Dossa E, E Fernandes, W Reid and K Ezui, 2008. Above and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. Agroforestry System, 72:103-115.

Emmanuel A, 2013. Environmental Impact Assessment (EIA); A Useful tool to address climate change in ghana. International Journal of Environmental Protection and Policy, 1(4): 94-100.

Feyissa A, S Teshome, A Mekuria, 2013. Forest carbon stocks and variations along altitudinal gradients in Egdu Forest: Implications of managing forests for climate change mitigation. Journal of STAR, 2(4): 40-46.

Gairola S, CM Sharma, SK Ghildiyal and S Suyal, 2011. Live tree biomass and carbon variation along an altitudinal gradient in moist temperate valley slopes of the Garhwal Himalaya (India). Journal of Current science, 100(12): 1862-1870

Girmay T, G Girmay, G Alem and T Hailemariam, 2014. Participatory rural appraisal report: Raya-Alamata Wereda, Tigray region. CASCAPE working paper, 2.6.4.

Gupta PK, 2000. Methods in Environmental Analysis: Water Soil and Air. Agrobios,

Hairiah K, SM Sitompul, M Noordwijk, and C Palm, 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. International Centre for Research in Agroforesty *(ICRAF)*, Indonesia. pp 49.

Houghton R A, 2005. Aboveground forest biomass and the global carbon balance. Global Change Biology, 11: 945-958.

Inter-governmental panel on climate change (IPCC), 2007. Climate change, Synthesis report: Contribution of working groups II, III, and I to the fourth assessment report of the intergovernmental panel on climate change (Core Writing Team, Pachauri RK and Reisinger A. (eds.). IPCC, Geneva, Switzerland, 104 pp.

Jenny H, 1941. Factors of Soil Formation: A System of Quantitative Pedology/by Hans Jenny. McGraw-Hill, New York

Jina BS, P Sah, MD Bhatt, and YS Rawat, 2008. Estimating carbon sequestration rates and total carbon stockpile in degraded and non-degraded sites of Oak and Pine forest of Kumaun central Himalaya. Eco print, 15: 75-81.

Keith O, 2014. Forest Bioenergy or Forest Carbon: A Review. International Journal of Sustainable and Green Energy, 3(6): 132-142.

Kumar S, M Kumar, AM Sheikh, 2012. Carbon stock variation of Pinus roxburghii Sarg. Forest along altitudes of Garhwal Himalaya, India. Russian. Journal of Ecology, 44: 131-136.

Kuyah S, J Dietz, M Catherine, R Jamnadassa, P Mwangi, R Coe, H Neufeldt, 2012. Allometric equations for estimating biomass in agricultural landscapes: I. Aboveground biomass. Agricultural Ecosystem and Environment, 158:216–224.

Labata MM, EC Aranico, ACE Tabaranza, JHP Patricio and RF Amparado, 2012. Carbon stock assessment of three selected agroforestry systems in Bukidnon, Philippines. Advances in Environmental Sciences, 4:1.

Lasco RD, KG Macdicken, FB Pulhin, IQ Guillermo, RF Sales, RVO Cruz, 2006. Carbon stocks assessment of a selectively logged dipterocarp forest and wood processing mill in the Philippines. Journal of Tropical Forest Science, 18(4): 166-172.

Lemenih M and F Itanna, 2004. Soil Carbon Stocks and Turnovers in various vegetation type and Arable Lands along an elevation gradient in Southern Ethiopia. Ge-oderma, 123 (1-2): 177-188.

Luo TX, S Brown, YD Pan, PL Shi, H Ouyang, ZL Yu, HZ Zhu, 2005. Root biomass along subtropical to alpine gradients: global implication from Tibetan transects studies. For Ecology Manage, 206:349–363

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.

McIntosh PD, IH Lynn, PD Johnstone, 2000. Creating and testing a geometric soil-landscape model in dry steep lands using a very low sampling density. Australian Journal of Soil Research, 38: 101– 112.

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

Moser G, D Hertel and C Leuschner, 2007. Altitudinal change in LAI and stand leaf biomass in tropical montane forests: a transect study in Ecuador and a pan-tropical meta-analysis. Journal of Ecosystems, 10: 924–935.

Moser G, C Leuschner, D Hertel, S Graefe, N Soethe, and S Iost, 2011. Elevation effects on the carbon budget of tropical mountain forests (S Ecuador): the role of the belowground compartment. Global Change Biology, 17(6): 2211-2226.

Muluken N, 2014. Carbon stock in Adaba-Dodola community forest of Danaba District, West-Arsi Zone of Oromia Region, Ethiopia: An implication for climate change mitigation. MSc Thesis. Addis Ababa University. Addis Ababa, Ethiopia.

Mwakisunga B and AE Majule, 2012. The influence of altitude and management on carbon stock quantities in Rungwe forest, southern highland of Tanzania. Open Journal of Ecology, 2(4): 214-221

Olsen SR, CV Cole, FS Watanabe, LA Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonet. US Department of Agriculture. Cir. 939, USDA.

Pearson T, S Walker and S Brown, 2005. Source book for land use, land use change and forestry projects. Winrock International and the Biocarbon fund of the Worldbank. 57 pp.

Ruhe RV, 1956. Geomorphic surface and the nature of soils. Soil Science, 82: 441– 455.

Seyed A, and J Robert, 2004. The effects of landscape attributes and plant community on soil physical properties in rangelands. Geoderma, 125: 145–154.

Snowdon P, J Raison, H Keith, P Ritson, P Grierson, M Adams, K Montagu, BiH, W Burrows and D Eamus, 2002. Protocol for sampling tree and stand biomass. National carbon accounting system technical report No. 31.

Tan X, R Lal, E Smeck and G Calhoun, 2004. Relationships between surface soil organic carbon pool and site variables, Geoderma, 121 (3-4): 185-187.

The R Core Team, 2012. A language and environment for statistical computing, Version 3.3.3. R foundation for statistical computing.

Tsui C, Z Chena, and C Hsieh, 2004. Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan. Journal of Geoderma, 123: 131–142.

Walkley A and A Black, 1934. An Examination of Degtja-reff method for determining soil organic matter and proposed modification of the proposed modification of the chromic acid titration method. Soil Science, 37 (1): 29-38.

WBISPP (Woody Biomass Inventory and Strategic Planning Project), 2000. Manual for woody biomass inventory. Woody biomass inventory and strategic planning project, Ministry of Agriculture, Addiss Ababa, Ethiopia.

Wereda Alamata Office of Agricultural and Rural Development (WAOARD), 2016. Natural resources core process, annual report. Alamata wereda office of agriculture and rural development, unpublished, Tigrigna version.

Yohannes H, S Teshome and A Mekuria, 2015. Carbon stock analysis along altitudinal gradient in gedo forest: Implications for forest management and climate change mitigation. American journal of environmental protection, 4 (5):237-244.

Zhang D, D Hui, Y Luo and G Zhou, 2008. Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. Journal of Plant Ecology, 1(2): 85-93.

Zhu B, X Wang, J Fang, S Piao, H Shen, S Zhao and C Peng, 2010. Altitudinal changes in carbon storage of temperate forests on Mt. Changbai, Northeast china, journal of plant resource, 123(4): 439-450.