

Carbon Sequestration Potential of Grazing Lands in Abijata-Shalla Lake National Park, Oromia Regional State, Ethiopia

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To cite this article:

Meseret Tilahun, Tessema Zewdu, Abule Ebro. Carbon Sequestration Potential of Grazing Lands in Abijata-Shalla Lake National Park, Oromia Regional State, Ethiopia. *Science Frontiers*. Vol. 3, No. 2, 2022, pp. 74-87. doi: 10.11648/j.sf.20220302.13

Received: March 8, 2022; Accepted: June 2, 2022; Published: June 9, 2022

Abstract: This study aimed to estimate the carbon sequestration potential and soil properties of the Abijata-Shalla Lake National Park in Ethiopia. The random sampling techniques were used for dead wood, litter, soil, woody trees and herbaceous under the different grazing pressure. The DBH (> 2cm) and height of woody trees were used for biomass estimation with allometric equation and the dead wood volumes by smallian formula. The specific wood density was used for each species to estimate the total biomass. The high proportion of (45.35%) woody species found in (10-20cm) DBH classes in the highly grazed area and (38.78%) in the low grazed area. The densities of woody trees decrease as the height and the DBH increases in the study area. The overall mean of carbon stock of aboveground, belowground, dead wood and litter were 112.3, 22.5, 6.9 and 0.95 t C ha⁻¹, respectively. The soil physical properties (sand and silt) and the electric conductivity (EC) PH, Av.p, CEC shows the significance difference ($P < 0.05$) with grazing pressure and across soil depth. Generally, the overgrazing has negative impacts on the vegetation biomass and the soil quality. Therefore, the sustainable management, such as destocking of livestock, rotational grazing and intervention of community based conservation was suggested to sustain the ecosystem health and enhance the carbon sequestration potentials.

Keywords: Aboveground Biomass, Soil, Carbon Stock, Carbon Equivalent, Bulk Density, Organic Carbon

1. Introduction

Ethiopia is one of the tropical countries that is endowed with rich biological resources [18, 42] and encompasses different agro- ecologies that provides different good and services [73]. However, due to anthropogenic impacts and natural factors, the serious problem of land degradation and deforestation [29] is facing and has been declining [17]. For instance, expansion of crop land, uncontrolled exploitation of fuel, wood charcoal, construction and inadequate standard of forest management [25] are anthropogenic impacts that reduces the biological diversity and negatively affecting vital ecosystem functions and services that regulate the earth system upon which humans ultimately depend on [50]. Overgrazing is also one of the causes of degradation due to

grazing pressure [65] and affects the soil carbon cycling and sequestration potential of the grazing lands [20] and uses as the substantial source of carbon emission. Carbon sequestration is one of the ecosystem services that can be undertaken by vegetation and soil. Carbon can exist in many forms and found in all living things, predominately as plant biomass, soil organic matter and as the gas carbon dioxide (CO₂) in the atmosphere and dissolved in sea water. Aboveground plant biomass contains the largest pool of carbon [29] and comprise all woody stems, branches, and leaves of living trees, creepers, climbers and epiphyte as well as understory plants and herbaceous growth. The below-ground biomass also comprises living and dead roots, soil fauna and the microbial community. There is also a large pool of organic C in various forms of humus and other soil organic carbon pools [73]. The accurate CO₂ sequestered

from the given stand of trees or the amount of carbon released when existing forests are cut [56] uses to measure the payment of ecosystem services [2].

The Abijata Shalla Lake National Park (ASLNP) is one of the ecosystems that were established for the conservation of flora and fauna. It exists with the anthropogenic impact and grazing pressures that influences the ecosystem services and functions, for instance, mining of sand and salt from the lake shoreline for income generation. Until recently, 80 trucks of sand were transported from the park to surrounding cities for construction per day. Currently, there are more than 5,600 households with their family of about 56,000 people are living in the park [19] that depends on its wood resources for fuel and charcoal production, livestock rearing and subsistence agriculture to sustain their life. The household has an averagely about 6 cattle, 7 goats, 2 sheep and 2 equines and totally 95,200 livestock were owned by the households living in the park. The land resources are clearly overgrazed and degraded by these abundant livestock populations with concentrated grazing and trampling, to the extent that shallow topsoil is exposed to wind erosion [69]. In addition, the grasses and soil exhausted due to overgrazing [27]. This left many *Vachellia* trees intentionally uprooted and fallen that might have increased the CO₂ emission. Thus, carbon sequestration is the way for the reduction of the emissions from the ecosystem by vegetation conservation which increases the annual productivity. Increase in annual productivity directly indicates an increase in forest biomass and hence higher carbon sequestration potential [64]. Net primary productivity (NPP) is the rate at which chemical or solar energy is converted to biomass by green plants which can convert solar energy, carbon dioxide and water into glucose, and eventually to plant tissue. The estimation of productivity can be obtained through different methods and the reliability of available data is variable. The data are limited in number and not evenly distributed among the various types of ecosystems [38]. Therefore, to link carbon sequestration potential with the current ecosystem conservation activities, it is very important to assess their contribution to offsetting emissions of greenhouse gases through carbon storage. Such data also provide baseline information to determine if the current ecosystem conservation can be engaged in carbon credit trading, but real and accurate carbon data is scarce in the area. In this respect, measuring the carbon sequestration and storage potential of the protected areas plays a vital role in the carbon trading scheme of the country. The protected area are also useful for carbon sequestration from the atmosphere and minimizes the global warming (particularly in its' specific area to stabilize the ecology) to some extent. Due to this, it is important to estimate the carbon sequestration potential of the protected area because, biomass being harvested or lost to other that exceeds the rate of re-growth adds carbon dioxide to the atmosphere. Furthermore, there is limited knowledge of carbon sequestration potential of the protected area [11] with the different grazing intensities and actual quantities of carbon stored. Therefore, this study was done with the

general objectives of assessing the carbon sequestration potential under low and heavy grazing pressure of Abijata Shalla National Park in Oromia region of Ethiopia.

Specific Objectives

- 1) To determine the carbon sequestration potential of Abijata Shalla Lake National Park under low and heavy grazing pressures, and
- 2) To assess soil qualities of Abijata Shalla Lake National Park under low and heavy grazing pressures.

2. Material and Method

2.1. Description of the Study Area

Abijata Shalla Lake National Park is one of the low and dry land protected habitat and an important wildlife conservation area. It is a critical ecosystem in the Great Rift Valley of the Oromia Regional State, Ethiopia. It was established as a National Park by the Ethiopian Wildlife Conservation Authority in 1970 with the aim of conserving the biodiversity of the magnificent number of aquatic birds [67]. It comprises two types of ecosystems, namely, the aquatic parts (482 km²) and terrestrial (dry land) (405 km²) together covering a total area of 887 km² [16]. It located between 7°15'-7°45'N and 38°30'-38°45'E and found at about 207km south of Addis Ababa. The altitude of the Park ranges from 1,540 to 2,075 meters above sea level (masl), the highest peak being Mount Fike, which is situated between the two lakes (Abijata and Shalla).

2.1.1. Climate

The agro-ecology of the area is semi-arid with the climate of two distinct rainy seasons, short rains in March to May and long rain during June to September [67] with annual rainfall ranging between 500- 700mm and 16 to 24°C with a mean annual temperature of 21°C [27].

2.1.2. Geology

The rift floor is occupied by a series of large lakes fed by perennial rivers originating from the nearby highlands both to the east and west directions [63]. Moreover, geological records from the area showed that there have been great changes in the sizes of the lakes in the past years and other features of the park such as hot springs, cliffs, and lava cave [3]. The water level has declined due to various factors, mainly by the soda ash factory, and increased irrigation upstream [69].

2.1.3. Flora and Fauna

Abijata-Shalla Lake National Park has immense natural resources, including wetland, aquatic and terrestrial birds. It is dominated by different species of vegetation (woods, shrubs and herbaceous). The vegetation zone of the study site is generally classified as savannah, *Vachellia* trees and *Ficus* savannah [68]. The habitat surrounding the lakes in the park is generally dominated by tree species of *Vachellia* and open scrub rocky slopes. Among the different type of vegetation, the dominants are *Vachellia* woodlands, *Euphorbia* woodland

with small areas of riverine vegetation, bush and open shrub on the rocky slopes with herbaceous species and short grasslands comprising of *Cynodon* and *Sporobolus* that are important for stabilizing the fragile soils [23, 28]. Of the *Vachellia* species, *Vachellia tortilis*, *Vachellia seyal*, *Senegalia Senegal* and *Vachellia gerardi* were the dominant species [19].

The Abijata Shala Lake National park hosts 31 species of mammals such as spotted Hyena, golden and black backed Jackals, Olive Baboon, Grant's gazelle, etc. The countless birds either of endemic or exotic birds that come from Europe and different parts of the world congregate here in at Lake Abijata. Hundreds of thousands of Flamingoes and great white Pelicans, Fish eagles, Kingfishers, the tall marabou stork, Cormorants, and Darters, etc. roam here in Lake Abijata and on the side- by lake Shalla. There are also vast colonies of scared Ibis, Queela, Stilt, Snap Black Heron, Avocet, Egyptian Geese, Eagles, Plovers, etc. Generally, a total of 453 bird species has been recorded in the Park and 6 are endemic to Ethiopia [62]. Flamingos are the most prominent and important consumer in the lakes [67]. Thus, it uses in the eco - tourism region in the rift valley for tourist attraction.

2.2. Site Selection and Sampling Procedures

The study area was selected due to the presence of having diverse plant species and also exists as a protected area with grazing impacts. The two grazing pressure areas, i.e., heavy and the low grazed area were sought. Prior to the field layout and sampling techniques, a reconnaissance survey was made to assess its present situation with the park scouts. In order to establish permanent plots, the area of interest was clearly identified and detail observation was made around the area to be sampled to assure that the sample plots did not all fall in the similar site.

2.2.1. Stratification of the Study Area

The stratification was done based on the grazing intensity by the livestock and wildlife, which affected the vegetation types and productivity of the grazing land in the Abijata Shalla Lake National Park [19]. Thus, the study area was stratified into two (high and the low) grazed areas. The study area encompasses grazing lands, settlement, farmland and other sandy source [19]. The grazing land was preferred for this study if it has a high interaction with livestock production and degrading. Therefore, the heavy and the low grazed area were stratified based on the physical observation and consulting with the employee of the national park. The twelve 30m*30m, sites in each grazing intensities, were identified randomly and the red ribbons were tied to the feasible place during the stratification of the study area as a demarcation to identify the selected area of the main plot.

2.2.2. Sampling Design and Techniques

The simple random nested designs, sampling techniques were used for carbon pool sample collection. The total of (2-grazing pressure x 12-plot site x 5- plot=120) were used. The

five different plot size (10m*10m, 5m*5m and 1m*1m) was nested within 30m*30m and used for measuring and counting of trees, shrubs and (herbaceous, litter foliage and soil) respectively. All vegetation types and layer were sampled and measured [24] that were used for morphometric measurement (height, DBH and tree crown) and quantification.

2.2.3. Vegetation Sampling Procedures

The five (10m x 10m, 5m x 5m and 1m x 1m) plot size were used for trees, shrubs and herbaceous respectively. The different parameters were measured for the tree (diameter at breast height (DBH), canopy cover, and height) and the quadrant of the sample was harvested for herbaceous to estimate the total biomass. The five quadrants four from the corner and one from the center per main plot were sampled. In each quadrant, all the trees and shrubs have been counted, DBH at 1.5m, crown cover and height were measured by caliper and meter tape, respectively. An estimating of the vegetation biomass can provide the information about the nutrients and carbon stored in the vegetation as a whole, or the amount in specific fractions such as extractable wood [23]. Thus, the biomasses of trees were obtained from the measurement of tree parametric and non- destructively using allometric biomass regression equations [32, 10]. In addition, the height and DBH of the shrub at 0.3m heights were measured by meter tape and caliper as stated by [53]. Shrubs with a basal stem circumference less than 2cm were not sampled, but considered under herbs. The herbaceous vegetation biomass were taken at four corners and the center of the main plots. To estimate the biomass of herbaceous species within each sample, it was clipped close to the ground at (0.5cm). The clipped vegetation was weighed, recorded and separated into botanical compositions based on biomass grass and herbs (non-grass species). The botanical composition was weighed separately to determine the contribution of each component in the total dry matter yield of the pasture [34]. The proportions of desirable and undesirable species, richness and diversity with the life form of herbaceous were determined. Then, the fresh weight of clipped biomass was taken by using a weighing balance. For the total weight determination, a sub-sample of grasses and forbs, fresh weight was taken and placed in a paper bag separately. The sub-samples were kept for later dry weight measurements. The dry weights of the sub-samples were used for calculating the whole biomass of the quadrant dry matter of grass and forbs. Then, the samples were oven dried at 105°C for 24hr at Adami Tulu Agriculture Research Center (ATARC) for further dry matter (DM) and organic matter (OM) determinations. Oven-dry weights of sub- samples were used to compute for the total dry weights [29]. After the DM was determined, the organic matter of dried sample was calculated from DM and Ash. The total DM and organic matter computed proportionally from 1m*1m (1m²) sub-plot to hectare and study area to recognize the carbon and sequestration potential of the study area. The %OC was subsequently used to estimate the carbon stock of herbaceous species. The carbon stock in under-canopy herbaceous

species was estimated by multiplying the oven-dried biomass by a factor of 0.5 [60] if it exists. Therefore, the carbon storage in herbaceous vegetation and litter layer was computed to determine the carbon stock/ carbon sequestration potential of the study area.

2.2.4. Basal Cover and Bare Ground Estimation

The basal area is a forest measurement to estimate volumes, understand stand density and competition of the trees. The basal area determined from the radius of trees and shrubs at a DBH height (1.3m) and (0.3m), respectively. Generally, the total basal area was calculated from the sum of the total diameter of emerging stem. The basal area of herbaceous species is an indicator of growing stock and biomass production. It can be measured on the ground level by using calipers. But, due to shortage of time, it was estimated by physical observations visually in percentage before the herbaceous stands were clipped within the quadrants. The bare ground cover also estimated visually [66] from the 1mx1m quadrant coverage of vegetation by categorizing plot into two diagonally.

2.2.5. Aboveground Biomass and Carbon Stock Estimation

The above ground biomass includes (live and dead standing tree, shrubs, herbaceous and litter foliage) samples were collected as per field measurements at specific sites (quadrants) or plot size of each carbon pool. The estimation of the biomass was done by measuring of diameter at breast height (DBH) (1.3m) for the tree and 30cm for shrubs and crown (canopy) diameter in two perpendicular directions, termed here for convenience “length” (L) and “width” (W), and species type were measured and recorded for all vegetation according to their size class in the respective sub-plots. Trees with multiple stems at 1.3m height were treated as a single individual and DBH of the main stem was taken as indicated by [13].

For biomass estimation of woody vegetation, any live plant greater than or equal to 2cm DBH was treated as above ground woody plant [24]. To compute the biomass index per hectare, the D²H was used, where D is the diameter at breast height and H is the height of the tree. Generally, the total biomass were calculated for each tree in the sample quadrant by the addition of the trunk and crown biomass estimates, then summing the results for all trees in the sample quadrant. This value can then be converted to tones per hectare.

The woody vegetation biomasses were estimated by using allometric equation. After taking the sum of all the individual weights (in kg) of a sampling plot and dividing it by the area of a sampling plot (100m²), the biomass stock density is attained in kg m⁻². This value can be converted to t ha⁻¹ by multiplying it by 10. Since the plot areas are part of the tropical and sub-tropical region, the biomass stock density of a sampling plot was converted to carbon stock densities after multiplication with the [35] default carbon fraction of 0.47.

Then, the carbon stock in the AGB was estimated through measurement of five carbon pool materials (live and standing dead trees and continuous and discrete shrub cover and herbaceous) using proper measurement techniques.

Herbaceous biomass was estimated by harvesting five 1m*1m quadrant sample from the main plot. Thus, the calculation of carbon stock as biomass is multiplying the total biomass by a conversion factor that represents the average carbon content in biomass. It is not practically possible to separate the different biomass components in order to account for variations in carbon content as a function of the biomass component. Therefore, the conversion factor 0.5 is used for the conversion biomass in to carbon. Specific wood density (oven- dry mass over total green volume) and a reduction factor of 50% represent the ratio of the total volume that can be attributed to carbon and must also be included in the estimate.

2.2.6. Biomass Estimation by Allometric Equation

The tree biomass are related to the CO₂ absorbed and can be estimated based on the DBH and height of woody vegetation and the carbon sequestration potential was computed by the allometric equation. All biomass values were converted to carbon using a factor 0.5Mg DM/MgC while multiplication factor 3.67 (44/12) molar mass was used to estimate CO₂ equivalent [36]. After the tree carbon weight was summed for each plot, the amount of carbon per plot was calculated and extrapolated to a per hectare figure basis and expressed as tons per hectare. That means the total carbon contents of live and dead trees were converted from kg/ha to t/ha and summing individual tree values within each plot to be applied to a study area. Most of the time, the allometric equation might be based on the agro- ecology of the ecosystem to predict the amount of biomass and carbon sequestered. Thus, to estimate carbon stock, allometric relationships between the aboveground biomass (AGB) of a tree and its trunk diameter [9] was used. The allometric equations stated by [10] was used because, it was confirmed for Ethiopian forest biomass estimation in tropical countries.

2.2.7. Estimation of Dead Wood and Carbon Sequestration Potential

(i). Deadwood

The total dead, fallen and stand woody tree were counted and identified from the (10m*10m) plot and were assigned for dead wood and estimated by measurements of large diameter at the bottom and small diameters at the head (top) of dead trees. Deadwood carbon was estimated by applying techniques using smalian formula [43], and converting estimated volume to biomass by multiplying with the wood specific density. The volume of wood contained in the stem of a tree is one of the most important measurements made in forestry, because: wood is the principal commercial product of forests and the stem contains a very large proportion of the biomass of a tree [73].

(ii). Litter

Fallen leaf and fine branches are considered as litter. Therefore, the five 1m*1m (1m²) of plot size were used to estimate the biomass and carbon contents of litter from the four corners and center of the main plots. The litter's samples

collected were weighed on the site to estimate fresh weight, mixed and the composite was taken for further analysis. Then the sub-samples were taken to ATARC and oven dried to 105°C for 24hr. The oven dried sample was burnt to determine the ash of dry matter in Carbolite oven by 600°C for 3hr to extrapolate the organic matter. Then, the dry weight was extrapolated to sub-plot and hectares to estimate the potential of the site.

2.3. Below-Ground Biomass and Carbon Estimation

2.3.1. Roots of Vegetation and Carbon Sequestration Estimation

The estimation of root biomass is very difficult and time consuming [5]. Thus, the below ground vegetation biomass and carbon were directly derived from aboveground vegetation biomass and carbon using known conversion factors and estimated using root to shoot ratio (1:5) [24]. Therefore, the standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass. In the same way, [50] described this method as it is more efficient and effective to apply a regression model to determine below-ground biomass from knowledge of biomass of AGB [5]. Furthermore, for tropical rainforest or humid forest, below ground biomass is estimated to be about 20% of the above ground biomass (woody and non -woody) estimates [24].

2.3.2. Soil Sampling and Laboratory Analysis

The vegetation and litter was removed from the soil surface prior to sampling [40]. The soil samples were taken by augur in 7.962cm diameter and 10cm height inserting at four corners and the center of the main plot at the depth of 30cm, by categorizing into 0-10, 10-20, 20-30cm depths because 60% of carbon contents found at 30cm depth as stated by [57, 59]. Hence the carbon loss and accumulation on the ground is intense in the top layer [54]. The collected samples were bulked together by mixing each soil sample properly to make a composite in order to make homogeneity and take sub- sample. A total of 72 composite samples (2-highly grazed and low grazed x 12 sample-site per strata x 3 soil depth =72) were collected. The composite samples were taken to Batu soil research center for laboratory analysis. The composite samples were air dried ground to pass through a 2mm mesh sieve for physical and chemical analysis. The soil texture and textural class were analyzed by hydrometer methods. The bulk density was determined from the oven dried mass at (105°C for 24hr) to the volume of core sampler.

The chemical properties, such as PH and EC were determined by using PH meter method and electro conductivity meter in the water suspension with the soil to water ratio w/v of 1:2.5, and CEC by using ammonia acetate (NH₄OAC) method at pH 7, total nitrogen by using Kjeldahl method [52], phosphorus [48], potassium status (Soil and plant analysis Council Incorporated, 1992) and C: N ratio was determined. The soil organic carbon was determined by Walker's and Black's titration method [35] by reducing potassium dichromate (K₂Cr₂O₇) by OC compounds (Walkley, 1947; [14]. The percent of soil organic matter was

calculated by multiplying the percent organic carbon by a factor of 1.724 [10]. In the analysis of exchangeable bases, Mg and Ca were determined by reading Atomic Absorption Spectrophotometer while Flame Photometer was ready for the K and Na [36].

The total SOC can be predicted by different ways. It can be calculated from bulk density and chemical analysis of organic carbon. The generic coefficient can be assumed in order to transform SOM to SOC. Multiplying the values of SOM of the coefficient and then transforming them from percentage values to tons per hectare can be done through computing a weighted average of SOM over the layers of the analyzed soil profiles. The weights correspond to the thickness of each horizon multiplied by its soil bulk density.

2.4. Estimation of Total Carbon Stock Density

Deliberate land management actions that enhance the uptake of carbon dioxide (CO₂) or reduce its emissions have the potential to remove a significant amount of CO₂ from the atmosphere. The total carbon stock can be estimated by applying a factor of 44/12 (the molar ratio between CO₂ and C) that was obtained from the total amount of carbon dioxide that the tree has sequestered from the atmosphere. Then, the carbon stock density was calculated by summing the carbon stock densities of the individual carbon pools of the high and low grazed area using the [49] according to (22) formula.

2.5. Mathematical Procedures and Statistical Analysis

2.5.1. Mathematical Procedures

The different mathematical procedures were computed to estimate the different parameters. Therefore, the total dry weights of herbaceous biomass were computed as the following formula.

$$\text{Total dry weight } \left(\frac{\text{kg}}{\text{m}^2} \right) = \frac{\text{Total fresh weight (Kg)} \times \text{Subsample dry weight}}{\text{Subsample fresh weight (Kg)} \times \text{sample area (m}^2\text{)}} \quad (1)$$

Then the organic matter and organic carbon were computed from the dry matter to determine the carbon stock of herbaceous species as the following formula.

$$\%OM = \frac{DW - AW \times 100}{DW} \quad (2)$$

$$OC = \frac{OM}{1.724} \quad (3)$$

Where, OM = organic matter, OC = organic carbon, the AW = ash weight of the sample, DW = dry weight of the sample, 1.724 = van Bemmelen factor (i.e. Organic matter contains 58% of OC) [6].

Furthermore, to estimate the carbon sequestration of the study area, the biomass of the woody tree and shrubs were computed from the DBH and the height of the plant species. Therefore, the biomass of woody trees and shrubs were computed by the allometric equation and multiplied by a conversion factor as the following formula.

$$ABG = 0.0673 * (WD * DBH * H) \quad (4)$$

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

This formula was used and selected for carbon stock estimation. Therefore, Ethiopia did an extensive study to determine the most appropriate wood density estimate for the country and basic wood density of 421 indigenous and exotic tree species growing in [10, 21].

$$C = 0.5 \times \text{Total biomass} \quad (5)$$

The dead wood biomass and carbon stock was estimated by smallian formula as the following:

$$\text{Deadwood volume (V)} = f(D_s^2 + D_l^2) * L/2 \quad (6)$$

Where V, is the volume of the wood (m^3), D_s is small diameter (cm), D_l is large diameter (cm), L is length (m), f is adjustment factor = 0.00007854.

In addition, the litter foliage of leaf were calculated with the following formula.

$$C = DM * 0.47 \quad (7)$$

Generally, the total AGB carbon is estimated as the sum of the carbon pool with the following formula,

$$AGC = WC + HC + DC + LC \quad (8)$$

AGC=above ground carbon, WC=woody vegetation carbon, HC=herbaceous carbon, DC= dead material carbon and LC=litter carbon.

The below ground carbon pool were the root of plants and soil organic matter. The below ground carbon stock were estimated with the following formula.

$$\text{Belowground biomass} = \text{aboveground forest biomass} \times 0.2 \quad (9)$$

$$\% \text{Carbon} = \text{below ground biomass} \times 0.5 \quad (10)$$

The total soil organic carbon of below ground was estimated from the bulk density, soil depth and percentage of carbon. To estimate the bulk density and compactness of the soil, the volume of soil sample was predicted from height and radius of core sampler as the following:

$$V = h \times \pi r^2 \quad (11)$$

Where V is the volume of the soil in the core sampler in cm^3 , h is the height of core sampler in cm, and r is the radius of core sampler in cm.

Moreover, the bulk density of a soil sample might be calculated as follows:

$$BD = W_v, \text{ dry} / V \quad (12)$$

Whereas, BD is the bulk density of the soil sample per, $W_v, \text{ dry}$ is the average air dry weight of soil sample per the quadrant, V is the volume of the soil sample in the core sampler in cm^3 .

The soil organic carbon stock pool was calculated using the formula [49]:

$$SOC = BD * D * \% C \quad (13)$$

Where, SOC= soil organic carbon stock per unit area (t ha^{-1}) BD = soil bulk density (g cm^{-3}), D = the total depth at which the sample was taken (30 cm), and %C = Carbon concentration (%).

$$CT = AGC + BGC + CL + SOC. \quad (14)$$

Where, CT = Carbon stock density for all pools (ton ha^{-1}), AGC = Carbon in above -ground tree biomass [t C ha^{-1}], BGC = Carbon in below-ground biomass (t C ha^{-1}), CL = Carbon in dead litter (t C ha^{-1}) and SOC = Soil organic carbon.

2.5.2. Statistical Data Analysis

All the data collected from the field were arranged and incorporated into the Microsoft Excel for further statistical analysis. The SAS, software, version 9.1 and One-way ANOVA was computed for the mean comparisons of all carbon pool. Furthermore, Factorial ANOVA was used for the effects of grazing and soil depth on the soil physical and chemical properties by using with Tukey's Studentized Range (HSD) test at $P < 0.05$.

3. Results and Discussion

3.1. Trees Height Distribution

The height is the basic character to vegetation structure measurement, biomass estimation and determination of woody vegetation's productivity. The height classes of trees and shrubs ranged from 2 to 25 meters. As indicated in the following figures, it was classified into five and the highest percentage of individual species abundance found in 5.1-10m height classes followed by 10.1-15m in both the low and heavy grazed area.

The heavy grazed area showed high percentage of species abundance in 2-5m height class than the low grazed area. This refers that, the bush encroachment of heavy grazed area than the low grazed. However, most of the woody vegetation species (49.45%) and (39.39%) in the heavy grazed and low grazed were found in the height class of 5.1-10m, respectively. When the height increased from one class to the other, the density of individual species fell dramatically. Fekadu (2010) also stated that, the decrease in density with increasing height could be attributed to a high rate of regeneration but irregular recruitment potential. This clearly reveals the dominance of medium sized individual classes and the presence of high bush encroachment in the grazing lands. It might be due to the presence of competition among the species and the area was disturbed by anthropogenic factors such as deforestation, expansion of agricultural land, overgrazing and unsustainable utilization of species some decades ago [69, 41]. Furthermore, [15] revealed that the dominance of small trees and shrubs in the forest suggests that the bigger tree species are selectively removed or exploited. The woody species, particularly, in the low grazed area have longer periods of protection from cutting or

logging [72]. This indicates that the contribution of the highest height class in the low grazed area.

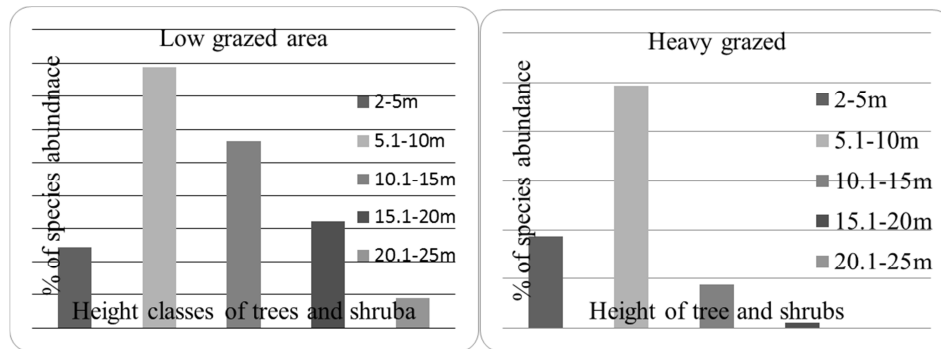


Figure 1. The of height classes of trees and shrubs percentage in the heavy and low grazed area.

3.2. Diameter at Breast Height

The diameter at breast height (DBH) is one of the characters of vegetation structure determination. The DBH of woody vegetation was classified into six classes. The highest abundance of woody species percentage found in 10-20cm DBH in both heavy and the low grazed area.

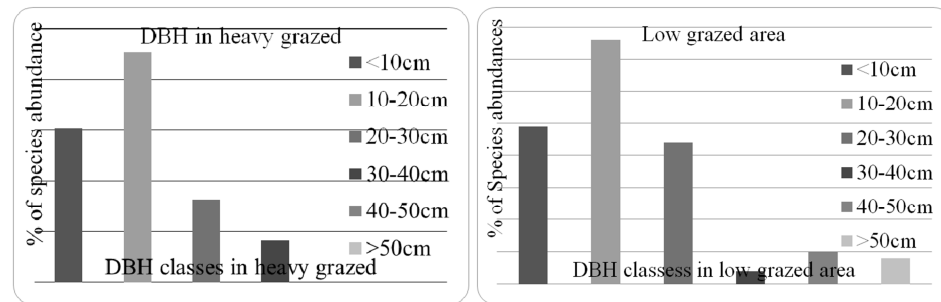


Figure 2. Trees and shrubs DBH classes in the heavy and low grazed area of ASLNP.

The result in the table shows that the DBH classes of woody trees has the higher proportion (heavy grazed =45.35%; low grazed=38.78%) of woody species in the DBH class of 10-20cm and the lowest in the DBH classes of 40-50cm and >50cm (heavy grazed) and >50cm (low grazed). These results indicate that as DBH increase, the number of individual decrease and a similar result was reported by [64] at Jibat natural forest west Shewa zone. This reflects that the status of grazing land was under serious degradation due to overgrazing, browsing and human activities [22] such as charcoal and firewood production. According to [22] there are six different sizes of DBH classes that can be define as follows: <10 cm, 10-20cm, 20- 30cm, 30-40cm, 40-50cm and >50cm and a similar report was indicated as (<20cm) DBH were dominating the grazing land/Ecosystem. In

general, similar to the DBH, the result indicated that the proportion of trees in each successive class decreased as the height class increase.

3.3. Aboveground Biomass Estimation and Carbon Sequestration Potential

3.3.1. Woody Vegetation Biomass and Carbon Sequestration

The aboveground biomass of trees constitutes the major portion of the carbon pool [5] and might be influenced by diameter at breast height, crown diameter and wood density [32]. However, this study was focused on the DBH and woody specific density to estimate the woody vegetation biomasses and carbon stock. Thus, the following table 1 result indicated that, there is not have significant variation with grazing pressures.

Table 1. The overall biomass of the carbon pools in the Abijata Shalla Lake national park.

AGBT	AGBT	AGBh	BGBT	BGBH	TAGB	TBGB	LB	DWB
Heavy grazed	199.9 ± 35.0a	2.25 ± 0.17b	39.9 ± 7.01a	0.31 ± 0.01a	203.03±35.07a	40.24±7.01a	1.72±0.13b	0.0±0.0b
Low grazed	244.0 ± 43.6a	3.14 ± 0.19a	48.79 ± 8.7a	0.23 ± 0.02b	246.21±43.61a	49.02±8.7a	2.28±0.15a	27.4±5.2a
Mean	221.9 ±27.7	2.7 ± 0.15	44.4±5.6	0.27 ± 0.02	224.6±27.7	44.6±5.6	2.00±0.28	13.7±3.8
CV	61.70	22.96	61.76	22.96	61.02	61.42	24.79	93.5
P-value	0.44	0.0020	0.44	0.002	0.45	0.44	<.0001	<.0001

ABGT=above ground biomass of tree and shrubs, AGBh=above ground biomass of herbaceous, BGBH=belowground biomass of herbaceous, BGBT=belowground tree biomass, TBG= total below ground biomass, TAGB=total above ground biomass.

Table 2. The overall biomass of the carbon pools in the Abijata Shalla Lake national park.

AGCT	TC _h	DWC	TLC-h	BGC	SOC	TAGC	TBGC	TC	Co ₂ e tha ⁻¹	
HG	99.9±17.5a	1.1±0.08b	0.0±0.0b	0.8±0.06b	19.9±3.5a	119.2±12.1a	101.5±17.5a	20.3±3.5a	242.1±20.9a	888.5±76.5a
LG	121.9±21.8a	1.6±0.09a	13.7±2.6a	1.1±0.07a	24.4±4.4a	142.1±15.1a	123.1±21.8a	24.6±4.4a	304.4±21.6a	1117.0±79.4a
Mean	110.9±13.9	1.4±0.07	6.9±1.9	0.95±0.05	22.2±2.8	130.7±9.8	112.3±13.8	22.5±2.8	273.2±16.1	1002.7±58.9
CV	61.70	22.96	93.50	24.79	61.67	36.35	61.03	61.03	26.93	26.93
P-value	0.44	0.0020	<.0001	0.014	0.44	0.25	0.45	0.45	0.0502	0.0502

AGCT=above ground carbon of tree and shrubs, TC_h= Total carbon of herbaceous, DWC=deadwood carbon, VGC=below ground carbon, TLC-h =total litter carbon per hectare, SOC=soil organic carbon, TAGC =total above ground carbon, TBGC=total belowground carbon, HG=highly grazed, LG=Low grazed, CV= coefficient of variation, Co₂e=Carbon dioxide equivalent

a* Means with the same letter in the same column are not significantly different at P<0.05.

The carbon stocks of woody vegetation also considered as to be 110.97tC ha⁻¹ and computed from the trees biomass. Due to this using generalized allometric model was limited to by climate zone in different literatures the tree height and specific wood density was considered [32], but using generalized allometric equations could result in an error of 3% [33].

3.3.2. Litter Biomass and Carbon Stock

The One-way ANOVA result showed that there was significant variation (P<0.05) of biomass and the carbon stock of litter foliage with grazing pressures. The lower grazed area has higher, (2.28tDM ha⁻¹) dry matter yield and organic carbon (1.1tC ha⁻¹) of litter foliage due to high vegetation biomass than the heavy grazed area (1.72tDM ha⁻¹) and (0.8tC ha⁻¹) respectively. This result revealed that the impacts of grazing pressures degrade the vegetation biomass and the litter foliage in the heavy grazed area. Thus, the carbon stocks of litter foliage also lower in heavy grazed area than the low grazed area due to overgrazing and trampling. The part of the soil fauna are also able to incorporate dead leaves into the soil and the soil becomes tightly linked with the litter layer on top that is formed by dead leaves and other parts of plants such as twigs, flowers or fruits. The decomposed litter foliage uses the micro-organism in different ecosystems and for soil fertility. On grazing lands, grassroots were fibrous near the soil surface and easily decompose, and adding organic matter [4].

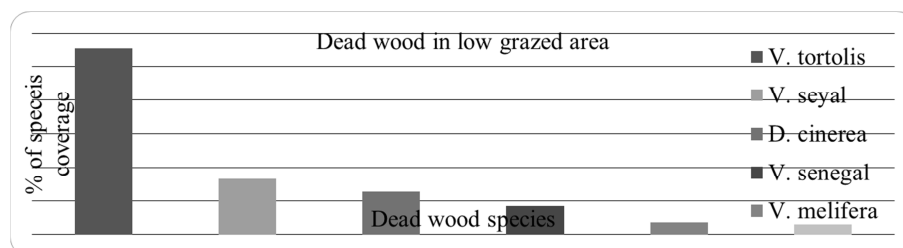
3.3.3. Herbaceous Biomass and Carbon Stock

The above table 1 indicated that herbaceous biomass has

high significance difference (P<0.05) with grazing pressures. The lower grazed area has higher 3.14tDM ha⁻¹ biomass than the heavy grazed 2.28 tDM ha⁻¹ whereas, carbon stock of the low grazed area was higher 1.6 tC ha⁻¹ than the heavy grazed area (1.1tC ha⁻¹) respectively. This response revealed that the grazing intensity has negative influences on the vegetation biomass and carbon stock of the ecosystem. As [30] reported overgrazing has major causes of land degradation under continuous grazing system and there is strong evidence that overgrazing leads to erosion and subsequent loss of nutrients and carbon as well as soil compaction and reducing the productivity of grazing lands. In addition, heavy grazing leads to excessive defoliation of herbaceous vegetation, reducing standing biomass, basal cover and plant species diversity, often triggered by a decline in net primary productivity (NPP) [66]. It might be due climate change, overgrazing and anthropogenic impacts (farm land expansion, sand and salt mining for income generation [4].

3.3.4. Stand and Fallen Dead Wood Biomass and Carbon Stock

The carbon stock from the stand and fallen trees are used as the carbon sink. Hence, based on the assessment the following result was stated. The study area was dominated by the fabaceae family and the five *Vachellia* species and one *Dichrostachys cinerea* were encountered in the low grazed area with different proportion as indicated in the following figures 3.

**Figure 3.** The percentage of dead wood sampled in the Low grazed area.

The above figure indicates that, different dead wood species and proportion in the lower grazed strata. The *Vachellia tortolis* was dominated 4.37 (55.46%) the study area and encompasses more than half of the total dead wood found following *Vachellia seyal* 1.32 (16.75%) and the *Dychrostus cinera* 1 (12.69%). The volume of dead wood biomass was estimated in metric cube per hectare from the

diameter and height of fallen and stand trees in the lower grazed area whereas, the heavy grazed area does not have dead wood due to the community consumption for firewood and charcoal. The mass of dead wood and carbon stock was predicted from specific wood density and mean value of 6.86tC ha⁻¹ was found with 0.0tC ha⁻¹ heavy grazed and 13.72tC ha⁻¹ in the low grazed area.

3.4. Belowground Biomass and Carbon Sequestration Potential

Grazing has a direct impact on plant production and thereby of soil C inputs. It also influences the amount and composition of soil organic matter through its effects on litter accumulation and decomposition. Grasslands store considerably more carbon in the soil organic matter than in the vegetation. Carbon sequestration brings additional carbon in the soil.

3.4.1. Root Biomass and Carbon Sequestration

The One way ANOVA result showed that grazing pressure does not have significance change ($P < 0.05$) on the belowground biomass and carbon stock. The heavy grazed mean value of biomass and carbon stored were 40.24 t ha^{-1} and 20.30 tC ha^{-1} whereas 49.02 t ha^{-1} with 24.62 tC ha^{-1} in the low grazed area. The captured carbon from the procedures of photosynthesis activities move downward from vegetation into the soil. This can be occurred during the growth of roots, which form the basis of a belowground food web through fungi, bacteria and all the animals that feed on them. Hence, the total biomass of large trees tend to have large roots, which are an important part of the C cycle because they transfer large amounts of C directly into the soil where it may be stored for a long time.

3.4.2. Soil Carbon Sequestration Potential

The larger amounts of carbons are present in the soil, primarily as soil organic matter. Soil organic matter plays a key role in determining soil quality and its potential to produce food, fiber, and fuel. The following table 3 showed that total soil carbon of the heavy grazed was $119.21 \text{ tC ha}^{-1}$ compared to the low grazed area $142.08 \text{ tC ha}^{-1}$ with the mean value of $130.65 \text{ tC ha}^{-1}$. This result refers that there was the wildlife impact on the low grazed area as livestock in the heavy grazed. As heavy grazing and trampling by large

herbivores reduces the vegetation cover and standing biomass bare soil patches develop, increasing the chances for soil surface erosion, and this leads to physical and chemical changes in soil properties. Through trampling, consumption, and excreta deposition, large herbivores alter soil nutrient availability for plants, changing the soil nutrient cycling rates and redistribution of soil nutrients. Hence, the soil organic carbon varies based upon the soil depth, type, physical and chemical properties. The overgrazing is often associated with reductions in soil carbon concentrations in the grazing land.

3.5. Total Biomass and Carbon Stock of the Abijata Shalla Lake National Park

The total biomass and carbon stock of ASLNP was predicted from all the carbon pool and this study showed a significant difference between the different levels of grazing. The total above ground biomass of woody vegetation does not have significant differences with the carbon stock but, the herbaceous biomass and carbon stock showed significant variation ($P < 0.05$) with the grazing pressure. The total aboveground biomass and carbon stock of the heavy grazed area were 203.03 t ha^{-1} and $101.51 \text{ tC ha}^{-1}$ while the low grazed area was 246.21 t ha^{-1} with $123.12 \text{ tC ha}^{-1}$ respectively. The total belowground biomass and carbon stock in the heavy grazed area were 40.24 t ha^{-1} and 20.30 tC ha^{-1} while the low grazed area has 49.02 t ha^{-1} and 24.02 tC ha^{-1} . Furthermore, the soil organic matter was $119.21 \text{ tC ha}^{-1}$ in the heavy grazed and $142.08 \text{ tC ha}^{-1}$ in the low grazed area.

3.6. Soil Characteristics in Grazing Land of Abijata Shalla Lake National Park

3.6.1. Effects of Grazing and Soil Depth on Soil Physical Properties

The soil texture and bulk density have showed significance difference as on the following table 3.

Table 3. Effects of grazing intensities, soil depth and their interaction on soil nutrient contents with statistical results of the factorial ANOVA (F, P, and R2).

Parameter	Grazing intensity		Soil depth			GI		Soil depth		GI x SD		R2
	Heavy grazed	Low grazed	0-10cm	10-20cm	20-30cm	F (df=1,66)	P	F (df=2,66)	P	F (df=2,66)	P	
EC	0.44±0.04	0.29±0.02	0.31±0.03	0.35±0.04	0.43±0.05	14.41	0.0003	2.83	0.0663	0.44	0.6435	0.24
PH	7.63±0.08	7.81±0.06	7.50±0.09	7.78±0.07	7.88±0.09	3.61	0.0619	5.43	0.0066	0.44	0.6479	0.19
CEC	20.87±0.93	25.42±1.13	24.47±1.49	22.74±1.10	22.24±1.39	9.43	0.0031	0.82	0.4428	0.07	0.9313	0.15
Av-P	13.06±0.7	10.36±1.58	7.77±1.08	11.79±1.03	15.56±1.90	3.21	0.0776	8.94	0.0004	5.12	0.0086	0.32
Ca+	10.11±0.49	15.38±0.59	12.03±0.79	12.39±0.87	13.81±0.88	47.60	<.0001	2.02	0.1411	0.24	0.7880	0.44
Mg+	2.55±0.13	2.03±0.14	2.59±0.19	2.11±0.14	2.15±0.15	8.79	0.0042	3.07	0.0531	1.14	0.3266	0.21
Na+	2.05±0.28	1.18±0.19	1.23±0.28	1.61±0.33	2.00±0.29	6.54	0.0129	1.70	0.1914	0.04	0.9638	0.13
K+	6.09±0.19	6.62±0.28	6.55±0.32	6.36±0.29	6.15±0.28	2.37	0.1283	0.46	0.6363	0.11	0.8931	0.05
OM	2.05±0.15	2.64±0.19	2.21±0.24	2.28±0.23	2.55±0.19	5.97	0.0172	0.72	0.4901	1.37	0.2604	0.13
OC	0.99±0.09	1.18±0.08	1.39±0.10	0.97±0.06	0.90±0.13	2.34	0.1312	6.57	0.0025	0.62	0.5392	0.20
N	0.37±0.02	0.16±0.02	0.30±0.03	0.25±0.03	0.23±0.03	58.99	<.0001	1.94	0.1519	0.18	0.8321	0.49
Clay	5.67±0.27	6.11±0.42	6.00±0.39	6.58±0.39	5.08±0.46	1.04	0.3119	4.01	0.0228	9.07	0.0003	0.29
Silt	18.94±0.93	22.56±1.42	23.6±2.07	21.08±1.09	17.50±0.81	5.78	0.0190	5.67	0.0053	5.89	0.0044	0.31
Sand	75.39±0.95	71.28±1.54	70.33±2.1	72.25±1.00	77.42±1.08	7.14	0.0095	7.56	0.0011	7.75	0.0009	0.36
BD	1.44±0.03	1.43±0.03	1.3±0.02	1.39±0.02	1.58±0.03	0.15	0.6952	25.19	<.0001	0.34	0.7121	0.44

HG=highly y grazed, LG=low grazed, GI grazing intensity, BD=bulk density, EC= Electric conductivity, df=degree of freedom, OC=organic carbon, Av-P=Available phosphorus, Ca+=Calcium ion, Mg+=Magnesium ion, Na+=sodium ion k+=Potassium ion, N=nitrogen, Av-P= Available phosphorus, Ca+=calcium ion, Mg+= magnesium ion, Na+= sodium ion, K+=potassium ion, OM organic matter, OC=organic carbon

a* Means with the same letter in the same column are not significantly different at $P < 0.05$.

(i). Soil Texture

Table 3 shows that there is a significance difference ($P<0.05$) in sand and silt percentage between the heavy and the low grazed area of ASLNP grazing lands. The heavy grazed strata has high sandy soil (75.39%) and lower silt (18.94%) than the low grazed area (Sand=71.28%), (Silt=22.56%) because of the grazing impacts and exposures of the upper soil for wind erosion [55]. Overgrazing has significant effect on soil texture and similar result of higher proportion of sand was reported by [66] in heavy grazed areas than in the low grazed area. The overall sandy percentage of ASLNP ranges from (71.28-75.33%) and similar result was reported by [1]. In addition the percentage of sandy soil showed high significance variation ($P<0.05$) across the soil depth and increasing with the soil depths. The upper surface (0-10cm) has low mean value (70.33%) of a sand percentage than two bottom layers 72.25% (10-20cm and 77.42% (20-30cm). In addition, the low grazed area (22.56%) has higher proportion of silt than the heavy grazed area (18.94%). Furthermore, the silt soil percentage has significance difference ($P<0.05$) across the soil depths with high mean value (23.67%) at the upper layer and low values (17.50) at bottom depth (20- 30cm) layer. The clay also has significance difference ($P<0.05$) across the soil depth. The upper surface was slightly significant change from the two bottom surfaces and the middle layer (10-20cm) has highly significant variation from the bottom (20-30cm) depth layer. In general, this result indicates that the sandy soil proportion increases with increasing of grazing intensity while the silt soil decreasing with grazing pressures. The ASLNP was endowed by sandy soil and the community uses for income generating activity. Therefore, more than 80 cars of sand were transported daily for construction to nearby town [23].

The clay soil has significance difference ($P<0.05$) across the soil depths of the soil layer but, not with grazing intensity. It was the highest for the depth 10 to 20 cm than the other depths which significantly differed from the 20-30cm depth in terms of its clay content. However, no significant difference ($P<0.05$) was observed between the 10 to 20 and 20-30 cm depths in terms of clay content.

The proportion of the soil texture can influence the soil properties and water relationships, gas exchange, and plant nutrition (growth, and activity of soil organisms, including plants) [48] and can be influenced with the grazing impacts and soil depth layer. Hence, most of the soil in the study area has a weak top soil structure, fragile and with fine sandy structure renders them vulnerable to wind erosion [7]. The higher content of sand and lower content of the clay fraction in grazing lands may be attributed to the low rate of weathering processes and continual leaching of the clay fraction from the upper surface.

Actually, sandy soils are heavier; they have higher mass in dry condition because they have a smaller total volume of the pores, that is, higher volume of solids. The largest fraction of the soil was sandy and the heavy grazing sites had a higher sand content than the lightly grazed sites [66]. Thus, the

highest proportions of soil texture were sandy loam following loamy sand in the study area.

(ii). Bulk Density

There is a significance difference ($P<0.05$) in bulk density with grazing intensity in the ASLNP grazing land and across the soil depths. The highly grazed strata have a high soil bulk density (1.42) compared to the low grazed area (1.34) due to the presence of compactness and trample by livestock and similar result was reported by [23]. In addition, this study states that the soil bulk density increase across the soil depth as indicated in (table 3) and the similar report was stated by [42] due to overgrazing and compaction by livestock [19]. Compaction increases bulk density and reduces yield production and vegetative cover of the habitats that uses to protect soil from erosion and the more compacted soil surface has low organic matter. The mechanical impact of animal hooves on the soil surface can be a severe disturbance of topsoil structure and lower organic matter content in the subsoil, compaction, less aggregation and less root [55]. The bulk density is primarily an inverse function of organic matter content of the soil [47] and depends on the soil texture and an organic matter.

The silt loam, clay, and clay loam have a lower bulk density compared to sandy soil and the health of soil can be detected from soil compactness that undermine infiltration, rooting depth/ restriction available water holding capacity, plant nutrient availability and soil microorganism activity. The pore spaces between soil particles are largely responsible for the amount of water holding capacity. Finer soil textures have greater surface area, smaller soil pores, and slower water infiltration into the soil profile [12]. The large percentage of sandy soil and low clay enhance the infiltration to expose of leaching the soil nutrient and the soil erosion.

Most of time the soil bulk density range from 1.0 to 1.8 g/cm^3 and average density of soils is 1.4 g/cm^3 [39, 2]. The bulk density increases with soil profile depth, due to changes in organic matter content, porosity and compaction. The soils of the study area are often fragile, alluvial and very fine in nature, and is very susceptible to both wind and water erosion [69]. It is maintained by the *Vachellia* and *Euphorbia* woodland around. The soils generally have low fertility and low organic matter with moderate nutrient retention capacity [61]. Therefore, the soil of the areas is not fertile for agriculture [19].

3.6.2. Effects of Grazing and Soil Depths on Soil Chemical Properties

The factorial ANOVA result showed that some of soil chemical properties has significance variation ($p<0.05$) with the grazing intensity and the soil depth profile as indicated on the table 3. For instance, the electric conductivity (EC) showed a significance difference ($P<0.05$) due to grazing pressure and have higher mean value in heavy grazed (0.44) than low grazed area (0.29). The PH of soil also has significance variation ($P<0.05$) with grazing intensity with lower mean value (7.63) in the heavy grazed area than in low

grazed (7.81) area. The total laboratory results and the statistical analysis showed that the study area was a very alkaline soil. A similar report was documented by [61] as it was highly alkaline (PH of 7.6–8.2) especially where high ionic strength has caused a precipitation of calcium carbonate [1]. There is no significance difference ($P>0.05$) in cation exchange capacity (CEC) with grazing intensity. The Phosphorus and Nitrogen are lower in the lower grazed area than the heavy grazed area and have significance variation ($P<0.05$) with grazing pressure. These indicates that the disturbance of grazing land due to overgrazing and trampling. The higher PH and Electrical- conductivity (EC) are indicating improved soil nutrient status compared to the heavy grazed area [66] mainly attributed to the higher basal cover and standing biomass at low grazed sites, and the export of nutrients through grazing and the dung collection, from the heavily grazed sites. The higher soil nutrient indicates that high species composition, aboveground biomass and basal cover and [66] reported similar result at Habernosa ranch and Awash National park. The Nitrogen and organic carbon variation have observed across the grazing intensity. The organic carbon is higher in the low grazed than the heavy grazed site in case of overgrazing by livestock and high bulk density due to trampling.

Furthermore, the exchangeable base has significance difference ($P<0.05$) except potassium (K^+) with grazing intensity. The exchangeable calcium has lower mean value (10.11) in the heavy grazed area than in the low grazed area (15.38). The magnesium exchangeable ion indicates high mean value in the heavy grazed area (2.55) than in the low grazed area. A high Magnesium value was found in the heavy grazed area and this is a similar to that reported by [4] as the grazing land has high Mg^+ . In addition, the sodium exchangeable base has a high mean value in heavy grazed areas (3.08) than in the lower grazed areas (1.76). The overall amount of exchangeable base are $Ca^{++}>K^{+}>Mg^{++}>Na$ in the study area.

Furthermore, there is a significance difference ($P<0.05$) in electric conductivity among the soil depths and increasing with soil depth profile. The upper layer (0-10cm) has slightly significant difference from (10-20cm) and high significance difference from 20-30cm depth and vice versa. The PH also has a statistical variation ($P<0.05$) with depth profile and higher at the bottom surface (20-30cm) than in the other two depth layer. Dynamics in soil properties such as (pH, CEC and exchangeable cations) are important indicators of soil qualities of different land uses [58].

There is significant difference ($P<0.05$) of organic matter, organic carbon and total nitrogen and phosphorus with grazing intensity and soil depth profile of the study area. The organic matter was slightly higher in low grazed areas than the heavy grazed that indicate the loss of soil fertility as a result of overgrazing. The organic matter, organic carbon and total nitrogen were decreasing with the soil depth which concurred with the finding of [43, 46]. In general, overgrazing has great impact and influence on the soil chemical and physical properties.

The OM content of the soil affects the soil bulk density and the bulk density increases as the organic matter decreases and vice versa. The organic matter and granular structure of the soil is lower in sandy soil than clay and silt and it is one of the indicators of soil fertility. Plant residue, animal manure and sewage are the source of nitrogen. The heavy grazed area has higher mean value of total nitrogen than the low grazed area. The organic and total nitrogen of the soils tend to decrease with increasing aridity. In all land use systems, organic carbon and total N decreased with soil depth [72]. Under heavy grazing, the organic carbon and nitrogen declines in the soil [31]. This can be due to the removal of vegetation by livestock and the deduction of plant cover; and consequently, the decrease of the soil organic carbon [45]. Soil organic matter is lesser in extremely degraded areas where overgrazing manifested [4]. Therefore, the microorganisms take ammonium and nitrate out of the soil to fuel decomposition.

4. Conclusion and Recommendations

4.1. Conclusion

From the results of the study, it was possible to conclude that overgrazing and lack of sustainable managements have negatives influence on biomass and carbon sequestration potential of the study area. In addition, all carbon pool (litter, soil, dead wood, woody and herbaceous vegetation) were influenced with the increments of grazing intensities. The heavy grazed area was bush encroached and deteriorated than the low grazed area. Furthermore, the soil chemical and physical properties have significant variation with grazing pressure and soil depth. Generally, the different carbon pool of carbon stock in the ecosystem currently is in danger of becoming seriously degraded owing to natural and human-induced factors. Thus, the goods and service that the ecosystems provides for the community influenced by the over grazing and the grazing land exposed for greenhouse gas emission that enhance the climate change mitigation by carbon sequestering from the atmosphere and storing as biomass in above ground and organic carbon in the soil.. Hence, the values of ecosystem service were under estimated that expected for benefit of community that uses as carbon trading.

4.2. Recommendations

The total dry matter production and carbon sequestration potential of the ecosystem were undermined by grazing intensity based upon the above conclusion. Therefore,

- 1) The community based forest management should be implemented to reduce the carbon emission from the deforestation and degradation.
- 2) The natural resource conservation should be done in the sustainable way by stakeholder and responsible organization to enhance the ecosystem services.
- 3) Furthermore, the destocking of livestock and rotational grazing was suggested to reduce the overgrazing impacts

on biomass and carbon sequestration potential to.

- 4) The total carbon stock of the ecosystem (terrestrial and aquatic carbon stock) and species based study should be done in to recognize the ecosystem service in term of carbon trade.
- 5) Appropriate and integrated land management options for different land use systems are required to enhance soil fertilities by sustaining physicochemical properties.

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