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RESEARCH ARTICLE

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Carbon Stock Potential of Shilabo Shrubs Land among Soil Texture Somali Region, Eastern Ethiopia

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ABSTRACT

Forests, shrubs and grasslands play an imperative role in climate change mitigation and balancing nature by sequestering and retaining carbon above and below the ground in biomass. The study was conducted to determine the total carbon stock potential of shrub lands in Shilabo district, Somalia, Ethiopia, as well as the implications for climate change mitigation. The study was restricted to the carbon stock potential of the shrub land depending on soil texture for three major carbon pools: Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Soil Organic Carbon (SOC). Using generic allometric equations that are readily available, the biomass of each species of tree and shrub was determined. To gather the necessary and pertinent data for the study region at every 390 m between each sample plot and 700 m between each transect line, sample plots of 20 by 20 m were established using systematic random sampling techniques. Using Breast Height (BH) tape, standing trees with branches and twigs measuring 5 cm or less in Diameter at Breast Height (DBH) were measured on 400 m^2 of sample plots. The height of the trees was also assessed using a hypsometer. Each of the five 1 x 1 m shrub land subplots, one in the middle and four at the corners of the main plot, had litter samples carefully taken from it. Litter samples from each of the five subplots of the main plot were combined to create a composite sample that weighed about 100 grams. Each of the five 1 by 1 m subplot regions, one at each of the four corners and the main plot's center, had samples of soil organic carbon and bulk density taken at a depth of 30 cm using an auger. The Statistical Package for Social Science (SPSS) software version 26 was used to estimate and assess the carbon stock of various carbon pools. The findings demonstrated that the below ground and above-ground biomass total mean carbon stocks at the sandy loam and sandy textured soil sites were approximately 507.36 t ha and 297.24 t ha, respectively. An independent sample t-test revealed that the mean difference in carbon pool and carbon dioxide sequestration between sandy loam texture soil (site 1) and sandy texture soil (site 2) was statistically significant. Shrub lands have provided great environmental benefits and services, as well as mitigating climate change impacts. Therefore, any environmental protection agencies, both government and non-government, have to look for and protect this resource.

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Introduction

Background of study

Global warming and its subsequent climate change can have major adverse effects on many life forms on earth [1]. Increasing economic development coupled with accelerated urbanization has led to a rapid increase in anthropogenic carbon dioxide emissions. This has resulted in increased carbon dioxide concentrations in the atmosphere, which have led to rising global temperatures [2]. Land use changes, such as forest clearance for agriculture, settlement, and industrial expansion to the atmosphere over the last 150 years.

Carbon emissions from deforestation and forest degradation are the second largest source of anthropogenic carbon emissions [3]. Historically, the conversion of land use from forests and grasslands to intensive agricultural cropping systems has also contributed to the increase in atmospheric CO_2 [4].

Terrestrial habitats significantly contribute to climate change mitigation by sinking greenhouse gases [5]. Carbon (C) sequestration is considered one of the main cost effective tools (one of the natural climate solutions) to mitigate climate change *via* reducing GHG concentrations in the atmosphere [6].

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Forests store approximately 30% of the global terrestrial Carbon (C) stock, with 60% located below ground [7]. These forests act mostly as a large net sink for atmospheric carbon, but concerns exist for the potential release of carbon under the impact of global warming over the next century [8,9]. Forest ecosystems are the main source of livelihood for many people and play a crucial role in the economic development of many countries [10,11]. They are essential natural resources that furnish a wide range of ecosystem services, such as moderating atmospheric carbon balance and, thus, climate change [12].

In sub-Saharan African countries, the rapid conversion from forest and woodland to agricultural land was driven by both proximate and underlying forces. The interaction of anthropogenic and biophysical drivers initiates change processes [13,14]. Expansion of agricultural land at the expense of forest land, grassland and shrub land and prolonged use for agriculture without conserving natural resources were the most detrimental factors for land use and land cover change [15].

In Ethiopia, population growth and investment are followed by deforestation and land use changes have resulted in a dramatic decrease in forest land over the last few decades [16]. Burning of forests and heavy disturbances in the remaining natural forests, such as cattle grazing or logging, that result in severe soil degradation [17]. Overgrazing is one of the major factors aggravating ecosystem degradation, which causes an increase in unpalatable species by destroying the most palatable species and reducing plant cover and biomass, thereby increasing erosion hazards and reducing the overall productivity of the land [18].

Ethiopia's total GHG emissions have reached 141 million metric tons of carbon dioxide equivalent (Mt CO_2 eq), according to (world resources institute climate analysis indicators tool [19].

Even Addis Abeba's greenhouse gas inventory has reached 4.89 mt CO_2 eq. Since 2012, Ethiopia's government has been working on the Climate Resilient Green Economy (CRGE), which aims to stabilize greenhouse gas levels and achieve carbon neutrality by 2025 by implementing reduction measures in a variety of national industries, including forestry, agriculture and manufacturing Karki, et al. ministry of environment, forest and climate change [20,21].

Somali region, Eastern part of Ethiopia, forest and shrub land resources account for a small proportion of the total land area. It suffered badly from recurrent droughts and serious tree cutting practices recently [22]. Irrespective of charcoal exports, it can hardly meet the local demands for wood, fuel, charcoal, building materials, feed, furniture, etc. The absence of law and order for nearly two decades has worsened the situation. Since then, no forest inventory has been produced to allow for close monitoring of those resources.

A few studies related to the carbon stock potential of forests, grasslands, and shrub lands were conducted in different parts of Ethiopia; such as Atsbha, et al. on the carbon sequestration potential of natural vegetation under grazing influence in southern Tigray, Ethiopia; Abebe, et al. on the biomass, carbon stock and sequestration potential of *oxytenanthera* abyssinica forests in the lower beles river basin, Northwestern Ethiopia; Belay, et al. on the carbon sequestration potential of degraded agricultural land in the Amhara region of Ethiopia [23,24]. However, their study only focused on highland regions affected by frost and ignored the potential carbon stock of shrub carbon pools on dry land. The majority of researchers didn't discover offsets in shrub land carbon stock potential dependent on soil texture. The carbon stock potential of the Shilabo shrub lands was also not researched by any of the aforementioned experts, so there is a lack of quantitative scientific data on it. In order to absorb a significant amount of atmospheric CO_2 and achieve the goals of REDD+, it is crucial to integrate the current management techniques of Shilabo shrub land with climate change mitigation through carbon sequestration. So, there is a need to study the carbon stock potential of Shilabo shrub land to examine its relevance to climate change.

Materials and Methods

Description of the study area

Geographical location: The study area is located in Shilabo district, Korahe zone, Somali National Regional State, Ethiopia, bordered on the south-east by Shebelle zone, on the west by Debeweyin, on the northwest by Kebridehar, on the northeast by the Warder zone, and on the southeast by Somalia. It is approximately 1,130 kilometers southeast of Ethiopia's capital city, Addis Ababa, and approximately 530 kilometers from the town of Jigjiga. It has an average elevation of 395 m above mean sea level and is located between latitudes 5° 25' and 6° 55' N and 43° 30' and 46° 30' E (Figure 1). According to the data obtained from Sheng, et al., the range of mean maximum temperature and mean minimum temperature is 30 °C to 35 °C and 19 °C to 23 °C, respectively and the range of precipitation is 0 mm to 150 mm [25].

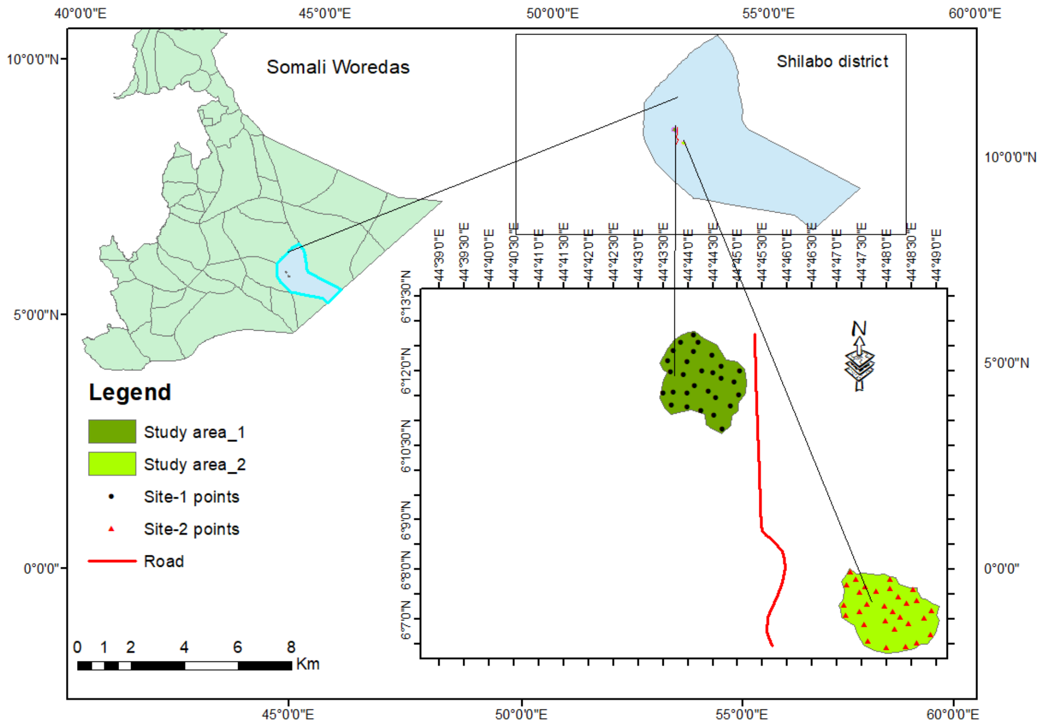

Figure 1. Study area map

The soil texture of the study area ranges from sandy to sandy loam, and the soil type of the study area is vertisol, according to (Shlabio Woreda Agricultural Office (ShWAO). Shilabo shrub land and grass land are part of the dry Afro-Montane natural resources in Ethiopia, which are only natural forests and shrubs. Most of the Shilabo Worda coverage is dominated by shrub land. To some extent, shrubs also comprise different understory vegetation, shrubs and trees from the lower to higher strata in this study area [26].

Data type and sources: Combinations of primary and secondary data were used to achieve the objectives of this study. The primary data was collected through field measurements from three carbon storage pools, such as above ground biomass, below-ground biomass, and soil organic carbon, whereas the secondary data was collected from different journals, books, and an unpublished document of the Korahe zone agricultural office.

Procedure of data collection: The spatial boundaries of the study area were clearly defined to facilitate the accurate measuring, monitoring, and accounting of the field data as recommended by Brown, et al. [27]. The boundaries of the study area were delineated by taking geographic coordinates through the Geographical Positioning System (GPS) at each turning point of the study area.

Stratification of the study area: A relatively homogeneous unit of elevation, a stable rainfall regime, a high level of disturbance and a steep slope are all potential criteria for stratification in Ethiopian forests [28]. Accordingly, Shilabo shrub land independently did not get divided into strata based on the relative homogenous unit of topography because each land use of the area almost has the same elevation, and the efficiency and accuracy of the shrub land carbon counting are not influenced by topography. Rather, the area was classified based on soil texture in order to conduct this study because there was a definite difference in soil texture between the two study sites in Shilabo district.

Sample size determination: Small sample plots are efficient for relatively homogenous tree sizes, but if the trees are widely different sizes, local variability becomes high, and therefore larger sample plots are more efficient. The typical sizes of sample plots used in the forest carbon inventory are 200 m^2, 400 m^2, and 500 m^2, as indicated by Blaxekjaer [29]. As a result, approximately 400 m^2 of a square sample plot were used to sample the study shrub land, which has a higher likelihood of incorporating more within plot heterogeneity and thus being more representative than other shapes of sample plots in the same area, as indicated by Hairiah, et al. [30].

Sample plots of 20 m by 20 m were laid using systematic random sampling techniques at every 390 m difference between each sample plot and every 700 m difference between each transect line to collect the required and relevant data for the study of shrub land. Finally, using GPS instruments and four (4) transect lines, 30 sample plots for sandy loam soil texture and 30 for sandy soil texture on shrub land were laid out. The distance between transect lines and sample plots is determined by the principles of Lampadariou, et al., which allow for a maximum difference of one km (1 km) between each sample plot and each transect line for relatively homogeneous sized shrub land [31].

Field measurements

Sampling and identification of trees and shrubs (≥ 5 cm DBH): All shrubs and trees with a Diameter at Breast Height (DBH) of greater than 5 cm were measured in each plot of a 400 meter square area. Trees measuring greater than 2.5 cm in Diameter at Breast Height (DBH), approximately 1.30 cm above the ground, and shrubs measuring greater than 2.5 cm in Diameter at Stump Height (DSH), about 30 cm from the ground, were measured from each quadrant of the corresponding size. In cases where the stem of a tree was branched at breast height or below, the diameter of separate branches was measured to be considered as an individual tree [32]. Similarly, this was applied to multistemmed shrubs. According to Pearson, et al., the height of trees and shrubs was measured with a hypsometer.

Litter sampling: Litter samples (leaves, twinges, fruits or flowers, and bark) were collected from both sites of shrub land's 1 meter square subplot within the main sample plot. This was done at each sample plot's four corners and one in the center. A composite sample of 100 g from 60 leveled and evenly mixed subsamples was transported to the laboratory of the Haremia agricultural research center for analysis. The samples were placed in a plastic bag and oven dried at 105°C for 24 hours and weighed for analysis of total carbon concentrations to determine the oven dry mass, from which the total dry mass and carbon fraction were calculated [33].

Sampling of soil organic carbon, texture and bulk density: The soil samples were collected by using the auger at a depth of 30 cm from each of the 1 meter square areas of subplots, which were located at the four corners and one in the center of the main plot. Five samples taken from one main plot were mixed to yield a 100 gram composted soil sample. To separate root and gravel, a 100 gram air dried composted soil sample was blown through a 2 mm sieve. Then it was placed in a plastic bag and labeled with the sample plot to which it belongs. The Bulk Densities (BD) and texture of the soil sample were collected using a core sampler at a depth of 30 cm from each of the subplots of the main plot in the same way that a soil sample was taken with an auger. A total of 150 soil samples were taken at bulk density (5 x 30) from each site of sandy loam and sandy texture soil. The haremia agricultural research center laboratory received both composite and BD soil samples collected with augur and core sampler, and the moist field soil samples were dried in an oven at 105°C for 12 hours to determine the oven dry weight and the percentage of organic carbon was determined in the laboratory using the black method. Soil texture was identified through laboratory measurements in terms of percentage based on the soil class triangle, which were taken from both study sites.

Estimation of above ground tree biomass and carbon stock: The above ground biomass of trees and shrubs existing in the study area was calculated using the general allometric model of Chave, et al. as follows [34].

$AGB=0.0673 \times (\rho DBHH^2)\ 0.976$ (Equation 1)

AGB: Aboveground Biomass (kg; DBH: Diameter of trees at Breast Height (cm); H: Height of the tree (m) and ρ: Wood density: (0.6 t/m^3); which is the average value of wood density of trees in Africa [35].

The above ground carbon and CO_2 equivalents sequestered in the above ground biomass of trees and shrubs found in the study area were calculated by the principles of Lampadariou, et al. and Pearson, et al., respectively, as follows [36].

Above Ground Carbon (AGC)=above ground biomass × 0.5 (Equation 2)

The CO_2 equivalent sequestered in the aboveground biomass=AGC × 3.67 (Equation 3)

Estimation of below ground tree biomass and carbon stocks: The root shoot ratio factor of MacDonald was used to estimate the below ground biomass of trees and shrubs found in the study area. According to MacDicken and Pearson et al., standard methods of estimating BGB and BGC can be obtained as 20% and 10% of above ground tree biomass, respectively [37].

$BGB=AGB \times 0.2$ (Equation 4)

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

BGB: Below Ground Biomass; BGC: Carbon Content of Below Ground biomass; 0.2 is the conversion factor (or root to shoot ratio), which is 20% of the above ground biomass.

The amount of CO_2 equivalent sequestered in the below ground biomass of the study area was calculated by multiplying BGC by the molecular mass ratio of carbon dioxide to carbon (44/12), which are 3.67 as indicated by Pearson, et al.

Estimation of litter biomass and carbon stock: The litter biomass found in the study area was calculated using the formula of Pearson, et al. as follows:

Total litter biomass ((t/ha))=(Total fresh weight (g) x subsample dry weight (g) x sample area (m^2)/subsample fresh weight (g)) *1/10,000 (Equation 6)

CL=LBM × %C (Equation 7)

CL: Total Carbon stock in the litter biomass (t/ha)

LBM: Oven-dry biomass of litter

%C: Carbon fraction of litter samples determined in the laboratory.

Estimation of soil organic carbon: The carbon stock density of soil organic carbon found in the study area was calculated using the volume and bulk density of soil as recommended by Pearson, et al.

$V=h\times\pi r^2$ (Equation 8)

V is the volume of the soil in the core sampler (in cm^3), h is the height of the core sampler (in cm), and r is the radius of the core sampler (in cm). Moreover, the bulk density of the soil sample was calculated as follows:

BD= (Wav)/V (Equation 9)

BD: soil Bulk Density (g/cm3), Wav: Average Dry Weight of soil sample per sample plot and V: Volume of soil sample in the core sampler (cm^3).

SOC=BD*d*%C (Equation 10)

SOC: Soil Organic Carbon stock per unit area (t/ha), BD: Soil Bulk Density (g/cm^3), d: The total depth at which the samples were taken (30 cm), and %C: Carbon fraction of soil samples, which was determined in the laboratory.

Estimation of total carbon stock density: The total carbon stock density of the study area was calculated using the equation of Subedi, et al. by summing the carbon stock densities of the individual carbon pools of the study area.

CT=AGC+BGC+LC+SOC (Equation 11)

CT: Carbon stock density for all carbon pools (t/ha), AGC: Carbon stock in above ground tree and shrub biomass (t/ha), BGC: Carbon stock in below ground tree and shrub biomass (t/ha), LC: Carbon stock in Litter biomass (t/ha), and SOC: Soil Organic Carbon

Data analysis

The collected data, like DBH of trees, height of trees, dry weight, and carbon fraction of litter samples and soil samples, were recorded on a Microsoft excel data sheet of 210 and those were analyzed using Statistical Package for Social Science (SPSS) software version 26. The relationships between different dependent variables (AGC, BGC, LC and SOC) and an independent variable (soil texture) were processed and tasted by descriptive statistics and analysis of variance (independent t-test) at a 95% confidence interval. Descriptive statistics were used to summarize the data, including the mean, maximum, minimum and standard deviations of the carbon stock of each carbon pool in the study area, while an independent t-test was used to determine the statistical significance of the difference in carbon stock among plant species and the carbon stock of each carbon pool among the soil texture differences between the two study areas in t/ha.

Results

Soil organic carbon and soil texture

The main factors taken into account for the estimation of Soil Organic Carbon (SOC) are soil depth, soil bulk density, soil texture and SOC concentration. As the laboratory results indicated, in Shilabo district at site 1, the soil texture among 30 soil samples was 69%–74% sand, 17%–19% clay and 9%–12% silt. This soil texture also has a range of 0.624%–1.385% carbon fraction (Table 1). The soil texture laboratory results on the same number of samples at study site 2 were 96%–97% sand, 2.2%-2.5% clay and 0%-1.8% silt. The carbon fraction of this soil texture has a range of 0.1%-0.254%. According to the soil class triangle, site 1, soil and site 2, soils were grouped into sandy loam and sandy soil texture, respectively. According to the laboratory results, the amount of carbon fraction in the soil increased as the percentage of clay soil texture increased.

Table 1: Soil characteristics in terms of texture, carbon fraction and bulk density.

Carbon stock factors		Site 1	Site 2
Soil texture	Sand	69%-74%	96%-97.5%
	Clay	17%-19%	2.2%-2.5%
	Silt	9%-12%	0-1. 8%

Carbon fraction	0.624%-1.385%	0.1%-0.254%
Bulk density	1.39%-1.57 g/cm^3	1.66%-1.67 g/cm^3

Estimation of above ground and below ground carbon stocks and CO_2 eq

Sandy loam soil texture of shrub land area: The minimum and maximum ranges of the AGC and BGC stock of sandy loam texture soil in Shilabo district were calculated as 98.69, 658.79 and 20.74, 121.76, with a mean value of 379.50 t/ha and 71.45 t/ha, respectively. The minimum and maximum CO_2 eq above ground biomass and below ground biomass sequestered in trees and shrubs of the study area were also estimated to be 38.00, 2118.77, and 60.79, 503.75 with a mean of 1074.64 t/ha and 280.94 t/ha, respectively. This was taken from 30 samples of sandy loam-textured soil in Shilabo district.

Litter contributes to environmental quality by mitigating climate change. Based on the results, the minimum and maximum Carbon Litter (LC) sequestered in litter biomass were 0.67 and 3.60, respectively, with an average of 2.071 t/ha. Carbon dioxide equivalent (CO_2 eq) was calculated in this biomass as 0.67, 3.60, and 7.72 t/ha and stored at an average of 7.72 t/ha in the Shilabo district sample taken from sandy loam textured soil, as shown in Table 2.

Soil supports an eco-system that houses macro- and microorganisms. According to this, the researchers conducted this study to estimate the amount of carbon stored in the soil. The minimum and maximum Soil Organic Carbon (SOC) were calculated as 32.54 and 78.25 t/ha, respectively, and the mean SOC of sandy loam-textured soil was 54.34 t/ha .

Table 2. Carbon pools above and below the ground, as well as CO_2 eq in sandy loam texture soil

	N	Minimum t/ha,	Maximum t/ha	Mean t/ha	Standrad deviation
AGC	30	98.69	658.79	379.5	165.14
BGC	30	20.74	121.76	71.45	36.13
AG CO_2 eq	30	38	2118.77	1074.64	476.66
BG CO_2 eq	30	60.79	503.75	280.94	156.24
LC	30	0.67	3.6	2.07	0.91
LCO_2 eq	30	2.46	13.21	7.72	3.45
SOC	30	32.54	78.25	54.34	14.53
SCO_2 eq	30	134.61	298.23	207.59	49.92

Sandy textured shrub land soil: According to a study conducted on a sandy textured soil, shrub land study site, SOC and CO_2 eq sequestered through biomass. The minimum and maximum AGC and BGC were calculated as 204.26, 270.78, and 35.54, 58.34 t/ha, respectively, corresponding to the means of 236.42 and 47.26 t/ha, respectively. The mean AGCO_2 eq and BG CO_2 eq sequestered in sandy textured soil were 995.72 and 163.97 t/ha, respectively, and the minimum and maximum AGCO_2 eq and BGCO_2 eq values calculated in this area were approximately 871.14, 1113.98, 121.25, and 201.67 t/ha.

The minimum and maximum litter biomass stored amounts of LC were 0.54 and 3.44 t/ha, respectively, as calculated at the sandy texture soil shrub land study area. The mean amount of carbon stocked on this site was 1.89. The mean sequestered LCO_2 eq in the litter biomass was 6.93 t/ha, and the minimum and maximum LCO_2 eq pools were 1.98 and 12.62 t/ha, respectively.

The organic carbon of sandy soil texture in Shilabo district ranged from 2.54 to 20.67 t/ha, and the average SOC was calculated at 11.67 t/ha. This study site sequestered a minimum and maximum of 18.81 and 63.67 t/ha of CO_2 eq, respectively, with a mean of 41.91 t/ha on sample plots 30 and 31, respectively. At the second site (site 2), Shilabo shrub land's average sum of AGC, BGC, LC and SOC biomass carbon stocks was calculated, and it gave a value of 297.24 t/ha and a sequestered average sum of AGCO_2 eq, BGCO_2 eq, LCO_2 eq and SCO_2 eq of about 1208.53 t/ha at the sandy soil texture site (Table 3).

Table 3. Above and below ground carbon pools and CO_2 equivalents in sandy textured soil.

	N	Minimum t/ha,	Maximum t/ha	Mean t/ha	Std. Deviation
AGC	30	204.26	270.78	236.42	19.02
BGC	30	35.54	58.34	47.26	5.49
AG CO_2 eq	30	871.14	1113.98	995.72	75.28

BG CO_2 eq	30	121.25	201.67	163.97	21.75
LC	30	0.54	3.44	1.89	0.83
LCO_2 eq	30	1.98	12.62	6.93	3.06
SOC	30	2.54	20.67	11.67	5.38
SCO_2 eq	30	18.81	63.67	41.91	13.71

Independent sample t test for carbon pool and CO_2 eq of soil texture

A mean difference in AGC, AGCO_2 eq, BGC, BGCO_2 eq, SOC, SCO_2 eq, LC and LCO_2 eq between sandy soil and sandy loam textured soil was determined using an independent sample t-test. Overall, the largest difference (143.08) with 1.67 of Cohen's value was observed for AGC of sandy loam texture soil (M=379.50, SD=165.14) and AGC of sandy texture soil (M=236.42, SD=19.02, t (58)=4.89, p=000, two-tailed). There is a statistically significant difference in texture between sandy loam and sandy soil. This implies that sandy loam-textured soil has more carbon than sandy soil. AGCO_2 eq of sandy loam texture soil (M=1074.64, SD=476.66, MD=78.92) with a strong effect of Cohen's value has a higher statistically significant difference than sandy texture soil (M=995.72, SD=75.28, t (58)=3.99, p=000).

Sandal loam texture soil has a higher statistically significant difference than sandy texture soil (M=59.26, SD=5.49, t (58)=5.07, p=000).BGCO_2 eq sandy loam texture soil recorded (M=280.94, SD=156.24, MD=116.97, with the greatest effect of Cohen's value=1.82) has a more statistically significant difference than sandy texture soil (M=163.97, SD=21.75, t (58)=5.49, p=000). The mean difference between sandy loam texture soil carbon and CO_2 eq and sandy texture soil was compared using an independent sample t-test. The mean SOC of sandy loam texture soil (54.34, SD=14.53, MD=42.67, with the largest Cohen's effect value of 4.29), has a more statistically significant difference than sandy texture soil (M=11.67, SD=5.38, t (58)=15.1, p=0.000). The mean of SCO_2 eq for sandy loam texture soil (M=207.59, SD=49.92, MD=165.68, with the greatest effect size of Cohen=5.21) has a statistically significant difference from sandy texture soil (M=41.91, SD=13.71, t (58)=17.53, p=000).

The Litter Carbon stock (LC) of sandy loam texture soil (M=2.07, SD=0.912, MD=0.183 with a modest effect of Cohen=0.21) is higher than that of sandy texture soil (M=1.89, SD=0.834, t (58)=0.801). The mean deflection of LC in sandy loam texture soil has not shown a statistically significant difference relative to sandy texture soil (P=0.422>0.05). The mean of LCO_2 eq (M=7.72, SD=3.45, MD=0.791 with the modest effect of Cohen's value=0.24) has not a statistically significant mean difference compared to sandy texture soil (M=6.93, SD= 3.06, t (58)=0.940, p=0.351) (Table 4). Based on these results, both LC and LCO_2 eq have a non-significant mean difference between sandy loam texture soil and sandy texture soil.

Table 4. Results of an independent sample t-test for carbon pool and CO_2 eq of soil texture

Pools	Study sites	Soil texture	N	Mean	SD	MD	t	df	P	Cohen's d value
	site 1	Sandy loam	30	379.5	165.14					
AGC	site 2	Sandy	30	236.42	19.02	143.08	4.89	58	0	1.67
	site 1	Sandy loam	30	1074.64	476.66					
AG CO_2 eq	site 2	Sandy	30	995.72	75.28	78.92	3.99	58	0	1.36
	site 1	Sandy loam	30	71.45	36.13					
BGC	site 2	Sandy	30	47.26	5.49	24.19	5.07	58	0	1.69
	site 1	Sandy loam	30	280.94	156.24					
BG CO_2 eq	site 2	Sandy	30	163.97	21.75	116.97	5.49	58	0	1.82
	site 1	Sandy loam	30	54.34	14.53					
SOC	site 2	Sandy	30	11.67	5.38	42.67	15.1	58	0	4.29
	site 1	Sandy loam	30	207.59	49.92					
SCO_2 eq	site 2	Sandy	30	41.91	13.71	165.68	17.5	58	0	5.21
	site 1	Sandy loam	30	2.07	0.912					
LC	site 2	Sandy	30	1.89	0.834	0.183	0.81	58	0.422	0.21
	site 1	Sandy loam	30	7.72	3.45					
LCO_2 eq	site 2	Sandy	30	6.93	3.06	0.791	0.94	58	.0.351	0.24

Total carbon stock and CO_2 eq, and climate change mitigation potential of Shillabo shrub land

The total mean carbon stock potential of Shilabo shrub land among sandy loam soil texture was calculated by summing up all carbon pools of AGC, BGC, SOC and LC with 379.50, 71.45, 54.34 and 2.07 t/ha, respectively, which resulted in 507.36 t/ha. The total mean CO_2 eq sequestered in this study site was the sum of $AGCO_2$, $BGCO_2$, SCO_2, and LCO_2 eq, which were 1074.64, 280.94, 7.72 and 207.59 t/ha, respectively, which gave 1570.89 t/ha.

In the same way, the total mean carbon stock potential of Shilabo shrub land among sandy soil texture was calculated by summing up all carbon pools of AGC, BGC, SOC, and LC with 236.42, 47.26, 11.67, and 1.89 t/ha, respectively, which gave 297.24 t/ha. The total mean result of CO2 equivalence sequestration was the total mean carbon stock pool. The sum of $AGCO_2$ eq, $BGCO_2$ eq, SCO_2 eq, and LCO_2 eq with 995.72, 163.97, 41.91, and 6.93 t/ha, respectively, resulted in a total mean of 1208.53 t/ha.

In Shilabo district, at site 1, above ground biomass, below-ground biomass, litter biomass, and soil organic biomass each have the capacity to remove 1074.64, 280.94, 7.72 and 207.59 t/ha CO_2 eq, respectively, for a total global climate change mitigation potential of 1570.89 t/ha CO_2 eq. In the same way, at site 2, above-ground biomass, below ground biomass, litter biomass, and soil organic biomass have the capacity to remove 995.72, 163.97, 6.93 and 41.91 t/ha of CO_2 eq, respectively, with a total mean of 1208.53 t/ha.

Discussion

Effects of soil texture vegetation cover on carbon stock

The study showed how carbon stock varies among different soil textures, vegetation and land uses. Clay rich soils have a higher capacity for carbon sequestration. In contrast to Soil Organic Carbon (SOC), which is governed by abiotic factors including the chemical and physical processes of soil formation, SOC is directly tied to biological processes such as biomass input and litter buildup. The SOC pool made up 91% of the Total Carbon (TC) storage in these alpine steppe soils, according to SOC and SIC densities [38].

As the Shilabo district is a desert, it is covered with shrubs and has a rich, sandy textured soil. However, the actual soil and vegetation differences in this district were clearly confirmed by this study. As a result, a scientific study was conducted to determine the amount of carbon sequestration at two sites in the Shilabo district based on differences in soil texture and vegetation.

The soil had a high proportion of clay, was able to store more carbon, and was suitable for vegetation growth. This study agrees with the study of Solomon, et al., who stated that clay content was higher in dense forest soils than in open forest soils [39]. In the study of Zhang, et al., who reported a significant variation among soil types, these types could be regarded in most cases as a surrogate for cover [40]. The amount of vegetation cover also played an important role in determining soil carbon stores. The differences between the types of forest cover, with broadleaf woods having the greatest SOC mean and conifers and evergreen forests having greater and lower SOC values, were similar to prior calculations [41].

In the study area, soil physicochemical properties and organic carbon levels were influenced by land use type. Soil organic carbon concentrations were higher in dense shrubs than the thinner categories. Organic carbon concentrations ranged from 0.624%–1.385% at site 1 and from 0.1%-0.254% at site 2, with the highest concentrations found in deep vegetation and the lowest on thinner land (Table 1).

Previous studies have shown litter carbon stores of 7.2 for coniferous forests and 4.8 for deciduous forests at the national scale [42]. As well as litter carbon stocks, those for coniferous species are generally greater than those for deciduous species [43]. Furthermore, the literature reveals that the composition and breakdown rates of different species have an impact on litter carbon supply [44,45]

The patterns of maximum forest biomass increase are influenced by the species composition of the trees [46]. Mixed tree species increase biomass accumulation and SOC storage in the forest [47]. Vijayakumar, et al., found that annual SOC accumulation increased with age and was related to vegetation type (deciduous or coniferous) and soil texture (clay or loam). In both clay and loamy soils, trees have a greater capacity to retain carbon than coniferous trees [48]. The carbon pool is determined by tree biomass, which accumulates with the variety and growth of tree species [49]. The carbon that is stored in the biomass of the shoots and over the roots is referred to as "biomass." Iranmanesh and Sadeghi looked at how much carbon is stored in *Tamarix aphylla* and found that the leaves and stems hold the majority of the plant's total carbon. Kurgat et al. found that in the rangelands of northern Kenya, vegetation cover explained 89 percent of the variability in soil organic carbon [50]. In the Qinghai-Tibetan Plateau, Liu, et al. found a significant correlation between above ground biomass and soil organic carbon [51].

In the northwestern Himalaya and northern Ethiopia, Rajput, et al.; Solomon, et al. discovered that forest ecosystems had more biomass carbon than other land cover categories. The large differences in biomass carbon between land cover types could be explained by differences in the number of stems, density, and size of trees in each land cover type. This is consistent with Solomon, et al. finding that tree density and diameter influence biomass carbon in northern Ethiopia. Furthermore, overgrazing techniques and human intervention influenced the recovery and expansion of herbaceous plant species, as well as negatively smothered tree and shrub growth [52-57]

The major differences in carbon stock potential and CO_2 eq between the two sites were due to the existence of a variety of soil textures, organic matter, parent materials, vegetation species and densities, heights of trees and shrubs, DBH and management activities. The study looked at how carbon stores in vegetation, litter, and soil varied over time and land cover types. Overall, a study of two selected sites in Shilabo district found that the main reason for the difference in the average carbon concentration observed in Tables 1 and 2 was the high correlation between soil texture, biomass, and soil carbon content [58,59].

According to Biadgligne, et al., the biomass carbon estimations of dense forests were within the worldwide range, ranging from 124.27 to 73.55 t/ha for semi-arid tropics. The results were likewise within the range of carbon stocks in tropical dry forests, which were between 50 and 350 t/ha [60]. The biomass carbon stock in the current study was larger than that reported by Solomon, et al. in the managed forest of Tigray, northern Ethiopia, which was 58.11 mg/ha and 349 t/ha in the Mount Zequalla monastery forest Girma, et al., 362 t/ha in Humbo forested areas Chinasho, et al., and 149 t/ha in Behertsige central closed park Tefera and Soromessa, et al. [61-64].

However, Shilabo shrub land's average sum of AGC, BGC, LC, and SOC biomass carbon stocks was higher than the above studies findings, which were 507.36 t/ha, and the sequestered average sum of $AGCO_2$ eq, $BGCO_2$ eq, LCO_2 eq and SCO_2 eq was about 1570.89 t/ha at the sandy loam soil texture site; 297.24 t/ha of CO_2 and 1208.53 t/ha of CO_2 eq at the sandy soil texture site [65, 66].

The carbon that can be stored in forest soil can help reduce greenhouse gas emissions. In total, soil has around 4.5 times as much carbon as living organisms and about 3 times as much carbon as the atmosphere. As a result, even a small increase in soil carbon could contribute significantly to lowering atmospheric carbon [67, 68].

Conclusion

Forests and shrubs can trap carbon dioxide and reduce its concentration in the atmosphere. The carbon stock potential of shrub land on sandy loam texture soil was estimated to be 507.36 t/ha, including the latter carbon in the total carbon pools of above-ground carbon pools and soil organic carbon. In the same manner, at a sandy soil texture site, 297.24 t/ha of pooled above ground, below ground, litter, and soil organic carbon were calculated. Sandy loam and sandy textured soil can both sequester about 2, 3971 t/ha and 13, 20.53 t/ha, respectively.

There was a statistically significant mean difference at $p<0.05$ between sandy loam texture soil (site 1) and sandy texture soil (site 2). This implies that sandy loam texture soil has a larger carbon pool and sequesters more carbon dioxide than sandy texture soil. There were dense and tall floristic bushes and shrubs at the site where sandy loam texture soil was found, and the soil carbon fraction was higher than at the site where sandy soil was found. The result of this discrepancy is determined by soil texture, soil carbon fraction, tree height, diameter at breast height, tree density, and other factors. In general, shrub lands stock large amounts of carbon, which removes CO_2 from the atmosphere. As a result, they contribute to the mitigation of climate change by providing greater environmental and ecological services.

Recommendation

Our world's temperature is alarmingly increasing over time due to agricultural expansion, deforestation, overgrazing, and urbanization. Forests, shrubs, and grasslands have the capacity to stock carbon pools and remove carbon dioxide from the atmosphere. In general, government and non-governmental organizations do not pay much attention to conserving and protecting shrub lands, but as this study revealed, shrubs have a greater contribution to creating convenient environments. Charcoal production is a common livelihood activity through shrub deforestation in the study area. Therefore, governmental and non-governmental organizations should look for shrub lands and give them attention to protect and conserve them. In order to save this shrub from extinction, all stakeholders need to provide a variety of livelihood options and assistance to the communities in the area.

Ethics approval and consent to participate

The study was conducted in accordance with the declaration of research office and approved by the ethics committee of Kebridehar university of Agriculture and date of approval: 21 October 2022.

Consent for publication

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to ethical or privacy restrictions.

Conflicts of Interest

The authors declare no conflict of interest relevant to the content of this article.

Author Contributions

Conceptualization, methodology, software, formal analysis, investigation resources, writing, the original draft preparation were done by Zemenu Tadesse Ayele. Data collecting, reviewing, editing, visualization, supervision, and funding acquisition were done by all authors.

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