

Effects of Human Induced Activities on Carbon Emission in Chittagong District, Bangladesh

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Abstract The study was conducted in the Chittagong Division including Hasnabad, Feni, Heyanko, Ichamoti, Chuniti, Fatickchari and Mandakini area. The aims of this study were to find out the effects of deforestation and clear felled effects on carbon sequestration in upland watershed of Bangladesh. Soil bulk density was 1.40 g cc⁻¹ in natural forest, 1.52 g cc⁻¹ in clear felled area and 1.33 g cc⁻¹ in deforested land. Mean carbon storage in natural forest was 21.85 t ha⁻¹ of which Hasnabad block, 22.56 t ha⁻¹, Feni block 21.76 t ha⁻¹, Heyanko Block 22.17 t ha⁻¹, Ichampti Block 19.80 t ha⁻¹, Chuniti Block 21.17 t ha⁻¹, Fatickchari Block 23.26 t ha⁻¹ and Mandakini Block 21.57 t ha⁻¹; in clear felled area mean carbon was 17.67 t ha⁻¹ of which Hasnabad block, 16.68 t ha⁻¹, Feni block 20.58 t ha⁻¹, Heyanko Block 14.47 t ha⁻¹ and Ichampti Block 18.92 t ha⁻¹; mean carbon sink in deforested land was 17.71 t ha⁻¹ for Chuniti Block 16.33 t ha⁻¹, Fatickchari Block 17.67 t ha⁻¹ and Mandakini Block 16.33 t ha⁻¹.

Keywords Natural Forest, Deforested Land, Bulk Density, Moisture Content, Carbon Emission, Organic Carbon Stock

1. Introduction

Carbon dioxide (CO₂) cycles naturally between the atmosphere and the biosphere as a result of photosynthesis, respiration, decomposition and combustion. The amount of carbon in an ecosystem changes as it develops and evolves[1]. Carbon is absorbed by water, phytoplankton and vegetation, creating significant stores in the oceans, biomass and soils. Globally, soils contain about three times the amount of carbon in vegetation and twice that in the atmosphere[2,3].

Human activities are changing directly and indirectly the rate of CO₂ exchange[2] and the amount of stocks[1] by reducing the capacity of ecosystems to sequester and store CO₂ and by producing significant greenhouse gas (GHG) emissions due to the burning of fossil fuels and to land clearance and deforestation[4]. Agriculture is the second largest source of greenhouse gases in the UK but emissions in this sector have been declining steadily since 1990[5], mainly as a result of changes in agricultural practices, such as reducing the use of synthetic fertilizers[6]. Land management choices can either maintain or increase the carbon store for long periods of time or result in net emissions. Therefore, land use and management choices can have an important role in determining the amount of carbon

released into the atmosphere or stored in the soil (mitigation) and, as a consequence, in global climate regulation[7, 8].

Land use change, such as deforestation and agricultural intensification, is a major source of global emissions (about 1.8 Gt C yr⁻¹)[2]. There is also increasing evidence that degraded peatlands are a significant source of CO₂ emissions[8]. Carbon storage by marine and coastal habitats has been less studied than terrestrial stores, but recent evidence[9] indicates that they may be of comparable importance to terrestrial stores.

In addition to local impacts on ecosystems, deforestation causes global impacts by emitting carbon dioxide and other greenhouse gases that cause climate change. Greenhouse gas emissions from human activities have increased to 9 billion ton carbon per year entering the atmosphere at twice the rate at which vegetation and oceans can naturally sequester carbon[10]. The increase in atmospheric carbon dioxide has raised global mean surface temperature 0.7 ± 0.2 °C in the 20th Century, while continued emissions at current rates could raise global temperatures 1.8–4°C in the 21st Century[10]. Climate change is damaging ecosystems and human wellbeing by shifting vegetation, increasing wildfire, raising sea level, and intensifying storms[10]. Fossil fuel power plants, vehicles, and cement plants produce approximately 80% of global carbon emissions while deforestation produces approximately 20%[10]. At the same time, deforestation decreases the provision of ecosystem services, including watershed protection and biodiversity conservation. In response, natural resource management agencies and conservation organizations are implementing

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forest conservation and reforestation projects to conserve ecosystem functions and to reduce climate change through carbon sequestration. For this reason measurement of carbon storage in soil is very important. Thus this study was launched to find out carbon storage in different type of land use.

2. Material and Method

2.1. Site Description

The study included four pair of natural or plantation forest and clear felled Blocks of Chittagong North Forest Division, namely, Hasnabad Block, Feni Block, Heyanko Block and Ichamati Range under Chittagong North Forest Division. Thus, four pair of blocks lies between $22^{\circ}18'N$ to $22^{\circ}38' N$ latitudes and $91^{\circ}58' E$ to $92^{\circ}00' E$ longitudes. And three pair of natural or plantation forest and deforested blocks, namely Fatickchari, Mandakani and Chuniti blocks range under Chittagong Forest Division. Thus, three pairs of blocks lies between $22^{\circ} 08'N$ to $22^{\circ} 48'N$ latitude and $91^{\circ} 58'E$ to $92^{\circ} 05'E$ longitude.

2.1.1. Hasanabad Block

Hasanabad Forest Block was under Chittagong North Forest Division. This block contained a pair of site, representing one natural forest and one clear felled area.

Natural forest site: This site was near to the office of Hasnabad Forest Range having a patch 10 year old natural garjan forest on flat hill top at 37 m elevation of 37 m. Previously this site was under mixed forest of *Dipterocarpus turbinatus* (garjan), *Syzygium grande* (dhaki jam) and *Artocarpus chaplasha* (chopalish). Canopy coverage of natural garjan forest was 90% with few scattered undergrowth. Undergrowth was mainly of *Calamus guruba* (jalibet) and seedlings of *Dipterocarpus turbinatus*. Forest floor was covered with thick layer of fresh and partially decomposed litter.

Clear felled area: Clear felled site was 50 m west of the patch of natural garjan forest having similar elevation and topography. Previously clear felled area was covered with garjan, which felled in 2006. Undergrowth coverage of clear felled area was 10% with few scattered vegetation, mainly of *Calamus guruba* (jail bet). Litter coverage thickness at this area was very thin compared to natural forest.

2.1.2. Feni Block

Feni Forest Block was also in Chittagong North Forest Division. This contained a pair site, representing one plantation and one clear felled area.

Plantation site: This plantation was situated at the southern side of the Bhanga to wer under the Feni block at Korerhat sadar Beat and Range. This was 41 year old *Tectona grandis* (teak) plantation and established in 1966. Plantation site was lying on the middle part of 17% hill slope. Coverage of plantation was 60% with *Imperata cylindrica*

(sungrass) as characteristic undergrowth in the plantation. Other under growth species were bhat, dhumki etc.

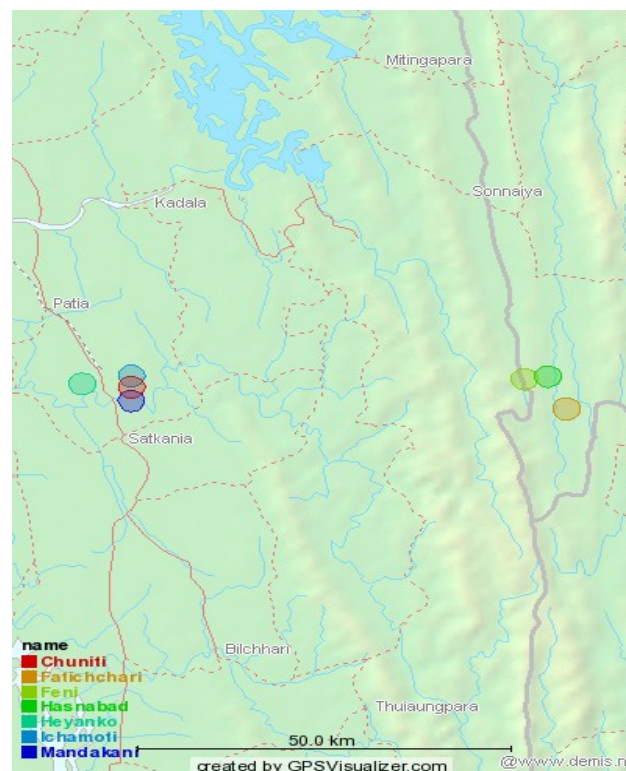


Figure 1. Map of the study area

Clear felled area: This was a 2007 clear field area, 70 m west of teak plantation. Before clear felling of this site, 40 year old teak plantation was there, which felled in 2007. This site was also on mid hill of 20% slope. Tree canopy coverage at this site was 8% and undergrowth mainly *Imperata cylindrica* (sungrass), dhumki and *Citrus lemon* (lemon).

2.1.3. Hyanko Block

Hyanko Forest Block was situated at Chittagong North Forest Division. This contained a pair of site, representing one plantation and one clear felled area.

Plantation: This plantation was situated at the southern part of the Koila Bazaar under the Hyanko Block and Beat in Korerhat Forest Range. This was 25 year old garjan plantation, established in 1982. This site was on middle part of 19% hill slope. Canopy coverage of site was 90% and undergrowth consisted of *Calamus guruba* (jalibet), *Melastoma malabathricum* (bon tejpatha) and different kinds of herbs.

Clear felled area: This was a 2003 clear felled area, 200 m south side of garjan plantation. Before clear felling 40 year old teak plantation was present there and then planted with teak, garjan, mahagoni, dhaki jam, champa, chickrassi, arjun, haritaki etc. This site was on middle of 15% hill slope. This site possessed 60% canopy coverage with undergrowth mainly of *Imperata cylindrica* (sungrass), *Melastoma malabathricum*, *Calamus guruba* etc.

Feni Forest Block was also in Chittagong North Forest

Division. This contained a pair site, representing one plantation and one clear felled area.

2.1.4. Ichamoti Block

Study sites both 1956 teak plantation and clear felled areas were situated at Thandachori block of Ichamoti beat. Administratively, this site is situated at Rajanagar union under Rangunia Upazilla in Chittagong District. Rangunia Upazilla lies between 22°18'N to 22°38' N latitudes and 91°58' E to 92°9' E longitudes.

Plantation site: Plantation began in 1949 with Teak Garjan, Horitaki, Bohera, Arjun, Jarul, Telsur, and Sal, which till now continued. Plantation site was lying on the middle part of 17% hill slope. Coverage of plantation was 60% with *Imperata cylindrica* (sungrass) as characteristic undergrowth in the plantation. Other under growth species were bhat, dhumki etc.

Clear felled area: This was a clear field area, 70 m west of teak plantation. This site was also on mid hill of 20% slope. Tree canopy coverage at this site was 8% and undergrowth mainly *Imperata cylindrica* (sungrass), dhumki and *Citrus lemon* (lemon).

2.1.5. Hazarikhil

The present study site is situated at Hazarikhil Beat and Range, under Chittagong North Forest Division. The total forest area in Hazarikhil Range is 4255 ha, legal status of which is a reserve forest. The Hazarikhil Range is situated at 45 km north of Chittagong city.

Deforested land: Hazarikhil was under Chittagong North Forest Division. This location contained 5 pair sites representing natural forest and deforested land. The deforested sites were of 15, 23, 33, 38, and 43 years old. Sampling points in the natural forest and deforested land were at least 50 m inside from the boundary to avoid interaction between the two land use types.

Natural forest: Natural forest consisted of a mixture of different species in association with bamboo jungle having 97% vegetation coverage. In deforested land coverage was 20%, each for trees, shrubs and herbs. At Hazarikhil soil sampling was done from 0-5 cm and 5-15 cm depth.

2.1.6. Mandakini

Mandakini was under Chittagong North Forest Division. This location contained a pair of site representing one natural forest and one deforested land. Both deforested land and forest land covered an area of 25 ha.

Plantation site: Plantation was 9 year old mixed species consisted of *Acacia auriculiformes* (Akashmoni) and *Acacia mangium* (Mangium). This site was situated on the southern side of Mandakini Beat office on 15% slope with 70% canopy coverage. Undergrowth covered area was not uniform over the whole plantation. Undergrowth in this plantation included *Mimosa pudica* (Lajjabati), *Caealpinia cristael* (Kootumkanta), *Hyptic sauveolens* (Tokma), *Eupatorium odoratum* (Assamlata) etc. with a number of

vines and creepers. Spacing of the trees in the plantation was 2 m × 2 m. The number of trees were 1650 /ha with an average height of 9.5 m.

Deforested land: In deforested land had no tree and undergrowth consisted of *Mimosa pudica* (Lajjabati), *Caealpinia cristael* (Kootumkanta), *Eupatorium odoratum* (Assamlata), *Mikania cordata* (Tarakanta) etc. At Mandakini soil sampling was done from 0-10 cm and 10-30 cm depth both from plantation and deforested land.

2.1.7. Chuniti

The study area was located at Chuniti Beat and Range under Chittagong South Forest division. The Chuniti wildlife sanctuary covered a total area of 7764 ha of reserved forest under the Chittagong forest division[14].

Deforested land: The land was 500m apart and to the west of the first deforested land. The topography of this land was also hilly and lied at an elevation of 20m. The distance from the adjacent wildlife sanctuary land was 180m and to the east of the first deforested land. According to records of Chuniti Forest Range, the site was deforested in the beginning of 1978 and therefore the deforestation age of this land was 27years. The land was sampled on 5th January 2005.

Natural forest: On this land, only 20% species was natural and 80% species artificially planted by Forest Department in 1977. The land was also hilly with an elevation of 30m. the dominant species of this land was Garjan (*Dipterocarpus turbinatus*). The land was sampled on 13th January 2005.

2.2. Selection of Site

Two adjacent sites were selected from each Block, one from clearfelled area and another from adjacent natural forest or plantation and similarly one from deforested land and another from adjacent natural or plantation forest. Adjacent sites were having more or less similar topography and site conditions. Thus 14 sites were selected from 7 Blocks.

2.3. Soil Sampling

In both clear felled and plantation area, 8 soil profiles were dug at a distance of 20 m from each other. Sampling plots in clearfelled area and another from adjacent natural forest at least 50 m inside from the boundary to avoid any boarder effect. Similarly, 6 soil sample were collected in both deforested and natural or plantation forest. From each profile soils were sampled at a depth of 0-15 cm. About 1kg soil was collected from each depth into appropriately labeled air tight plastic bags and carried to the laboratory for subsequent analysis. About two kilogram of soil was collected from each depth into appropriately labeled air tight plastic bags and carried to the laboratory for subsequent analysis.

2.3.1. Determination of Bulk Density

For the determination of bulk density, 2 undisturbed soil cores were collected from each sample plot in the field from

upper 0 - 4 cm depth. Thus, 14 samples were collected from plantation/natural forest land and another 14 cores from clear felled and deforested areas in each sampling season. For bulk density sampling, cores were driven vertically into the soil using a wooden hammer. The cores were then carefully dug out using a sharp knife and excess soil from the bottom end was removed before the soil from each core placed into a labeled plastic bag. The field moist soil cores were then weighed, allowed drying in an oven at 105°C for 8 hours, cooled in a desiccator and reweighed. Both the field moist and oven dry weights of the cores were divided by the volume of each core (100 cm³) to determine wet and dry bulk density, respectively.

$$\text{Bulk density (g/cm}^3\text{)} = \frac{W_2 - W_1}{V}, \text{ where,}$$

W_1 = Weight of core

W_2 = Weight of core + dry soil

V = Volume of core (100 cm³)

2.3.2. Determination of Soil Moisture

For determination moisture content of soils at different depth, soil taken on the pre-weighted Petridis. It keeps in an oven at 105°C for 8 hours; cooled in a desiccators and weight again [16]. For calculating moisture content following calculations were used:

Calculation

$$\text{Field moisture content (\%)} = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where, W_1 = Weight of petridish

W_2 = Weight of petridish + field moist soil

W_3 = Weight of petridish + dry soil

2.3.3. Determination of Organic Carbon in Soil

For determination organic carbon of soils, washed silica crucibles were dried in oven at 105°C for 30 minutes, cooled in desiccators and then weight were taken. Dried soils were grind by pistol and then exactly 5g of grind soil were kept in silica crucibles and weighted by an electric balance. The crucibles with soils were then transferred to an electric muffle furnace for igniting at 850°C for one and half an hour. Then crucibles with soils were cooled in a desiccators and reweight to determine the percent loss of ignition (LOI %). Percentage of LOI was calculated as follows:

$$\text{LOI (\%)} = \frac{W_1}{W_2} \times 100$$

Where, W_1 = Loss in weight and

W_2 = weight of oven dry soil

Percentage of carbon calculated from the following relationship [15].

$$\text{Organic carbon (\%)} = 0.476 \times (\% \text{ LOI} - 1.87)$$

Data from each site were analyzed separately. Microsoft Excel was used for analyze each parameter. To analyze significance of different hypothesis, SPSS program was applied.

3. Results and Discussion

3.1. Natural Forest and Clear Felled Area

3.1.1. Bulk Density

Bulk density of the soil was lower in natural forest/plantation than the adjacent clearfelled sites in all the four blocks (Table 1). Mean bulk density of the surface soil was 1.39 g cc⁻¹, 1.27 g cc⁻¹, 1.31 g cc⁻¹ and 1.67 g cc⁻¹ respectively, for the natural forest/plantation sites, while their corresponding values in the clearfelled sites were 1.49 g cc⁻¹, 1.43 g cc⁻¹, 1.55 g cc⁻¹ and 1.59 g cc⁻¹ in four blocks of Hasnabd, Feni, Heyanko and Ichamoti respectively. Higher bulk density in the clearfelled sites may be due to lesser amount of organic matter, excessive erosion, logging operation in clearfelling etc., which increased the compaction of surface soil.

3.1.2. Moisture Content

Mean moisture content was higher in natural forest/plantation sites compared to clearfelled sites in all the four blocks (Table 1). Mean moisture content of the natural forest of Hasnabad Block was 15.62% while in adjacent clearfelled site it was 15.60%. In Feni Block mean moisture content was 22.04%, while their corresponding values in adjacent clearfelled site was 14.30%. In Heyakhon Block mean moisture content in plantation was 20.04%, while in adjacent clearfelled site it was 15.56%. In Ichamoti block mean moisture content in plantation was 16.21%, while in adjacent clearfelled site it was 14.84%. The lower value of moisture content in the clearfelled sites was due to the increased evaporation of soil moisture in absence of forest cover.

Table 1. Bulk density, moisture content and carbon stock of soil under natural forest/plantation and clearfelled sites at three blocks in Chittagong North Forest Division

Land use type	Location	Bulk density (g cc ⁻¹)	Moisture content (%)	Carbon stock (t ha ⁻¹)
Natural forest/ Plantation	Hasnabad	1.39	15.62	22.56
	Feni	1.27	22.04	21.76
	Heyanko	1.31	20.23	22.17
	Ichamoti	1.67	16.21	19.80
Mean		1.41	18.53	21.58
Clearfelled	Hasnabad	1.49a	15.60	16.68
	Feni	1.43	14.30	20.58
	Heyanko	1.55	15.56	14.47
	Ichamoti	1.59	14.84	18.92
Mean		1.52	15.08	17.67

3.1.3. Organic Carbon Stock

In all the four Blocks organic carbon content was higher in natural forest/plantation compared to clearfelled sites in both surface and sub-surface soil (Table 1). In natural forest of

Hasnabad Block organic carbon content was 22.56 t ha^{-1} , while their corresponding values were 16.68 t ha^{-1} in adjacent clearfelled site. In Feni Block organic carbon content of soil in plantation was 21.76 t ha^{-1} , while their corresponding values in adjacent clearfelled site was 20.58 t ha^{-1} . In Heyanko Block organic carbon content in plantation was 22.17 , while their corresponding value was 14.47 in adjacent clearfelled site. In Ichamoti block organic carbon content in plantation was 19.80 t ha^{-1} , while their corresponding value was 18.92 in adjacent clearfelled site. Reduction of organic carbon was associated with burning following clear felling and lesser amount of litter accumulation.

3.2. Natural Forest and Deforested Land

3.2.1. Bulk Density

Bulk density of the soil was higher in natural forest / plantation than the adjacent deforested sites in all the three blocks (Table 2). Mean bulk density of the surface soil was 1.47 g cc^{-1} , 1.37 g cc^{-1} and 1.41 g cc^{-1} respectively, for the natural forest/plantation sites, while their corresponding values in the deforested sites were 1.42 g cc^{-1} , 1.33 g cc^{-1} and 1.39 g cc^{-1} in three blocks of Hazarikhil, Mandakani and Chuniti respectively. Higher bulk density in the deforested sites may be due to lesser amount of organic matter, excessive erosion, logging operation in deforested etc.

3.2.2. Moisture Content

Table 2. Bulk density, moisture content and carbon stock of soil under natural forest/plantation and deforested land sites at three blocks in Chittagong

Land use type	Location	Bulk density (g cc^{-1})	Moisture content (%)	Carbon stock (t ha^{-1})
Natural forest/ Plantation	Hazarikhil	1.47	19.57	23.61
	Mandakani	1.37	24.25	21.57
	Chuniti	1.41	23.87	21.17
Mean		1.39	22.57	22.12
Deforested land	Hazarikhil	1.42	13.47	17.26
	Mandakani	1.33	18.47	19.53
	Chuniti	1.39	19.02	16.33
Mean		1.38	16.98	17.71

Mean moisture content was higher in natural forest / plantation sites compared to deforested sites in all the three blocks (Table 2). Mean moisture content of the natural forest of Hazarikhil Block mean moisture content was 19.57% , while their corresponding values in adjacent deforested site was 13.47% . In Mandakani Block mean moisture content in plantation was 24.25% , while in adjacent deforested site it was 18.47% . In Chuniti block mean moisture content in plantation was 23.87% , while in adjacent deforested site it was 19.02% . The lower value of moisture content in the deforested sites was due to the increased evaporation of soil moisture in absence of forest cover.

3.2.3. Organic Carbon Stock

In all the three Blocks organic carbon content was higher in natural forest/plantation compared to deforested sites in both surface and sub-surface soil (Table 2). In natural forest of Hazarikhil Block organic carbon content was 23.26 t ha^{-1} , while their corresponding values were 17.67 t ha^{-1} in adjacent deforested site. In Mandakani Block organic carbon content of soil in plantation was 21.57 t ha^{-1} , while their corresponding values in adjacent deforested site was 19.53 . In Chuniti Block organic carbon content in plantation was 21.17 t ha^{-1} , while their corresponding values were 16.33 t ha^{-1} in adjacent deforested site. Reduction of organic carbon was associated with deforested land and lesser amount of litter accumulation.

3.3. General Discussion

Many areas of upland watershed in Bangladesh are now being clear felled or deforestation. Few studies so far have been conducted to find out clear felling and deforestation effects on soil properties in this region. From the study, it is clear that both the clear felling and deforestation have negative impact on soil. Both the practices reduce the quality of soils. A better quality soil ensures a better forest cover. But in our country both the practices are increasing day by day. For facing the population pressure, most of the forests are being destroyed by clear felling. This practice gives possibility for the human encroachment which is dangerous for the protection of forest.

In the clear felled area, there was no undergrowth as well as ground vegetation at the time of initial sampling i.e. just after clearfelling. In teak plantation area, negligible amount of undergrowth or ground vegetation was present. In the clearfelled site due to clearing of the vegetation had no vegetative cover and in the teak plantation, naturally coming vegetation was less. After one and half year, the clear felled area was covered with grass and various weeds heavily which indicated that sunlight made the environment favourable for weed growth. Takahashi and Ikeda[12] also reported that weed vegetation regrew quickly from the second year of clearfelling. Presence of lesser amount of organic matter in the later sampling also suggested that clear felling decrease humus content of soil. Findings of litter thickness and accumulation of dry litter value also suggested for the presence of lesser amount of humus layer. Leblance[13] also reported that clearfelling teared up the humus layer and exposed the mineral soil. Sienkiewicz (1988) also reported a small but degraded trend for changes in humus content.

Deforestation is a problem not only confined to Bangladesh but also a problem of global concern. World's forest recourses are now depleting at an alarming rate. The problem is more serious in Bangladesh comparing to global perspectives. The most striking evidence of this is high and increasing rate of deforestation that has reached 3.3% during 1981- 1990, thus resulting in a total loss of 8300 ha . The corresponding rate for south Asian countries is 0.6% .the

estimated annual loss due to deforestation presently varies 0.5-to 1.5% of GDP.

4. Conclusions

Forestry appears to offer a relatively low-cost approach to sequestering carbon. The most serious problems with using forestry to sequester carbon would occur if forestry activity were truly undertaken on a very large scale. Rapid deforestation and clear felling reduce the opportunity to absorb carbon from atmosphere and stored in soil. For that cause create different environmental problem such as climate change and global warming. Plants acts as a medium for transfer of atmospheric carbon into the soil in the form of carbon-containing compounds. It's contribute significant quantities of carbon deposited in sub-surface soil. These deposits have the potential for a greater contribution to long-term soil carbon sequestration due to slow oxidation than surface soil. The exact amount of sequestration depends on land-management practices, climate and the amount and quality of plant and microbial inputs. Carbon sequestration will certainly contribute in reducing atmospheric CO₂ concentration and will mitigate drought, salinity stress and desertification. Thus, sequestered soil carbon may be used for agriculture, forestry and help to mitigate global climate change.

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