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# Soil Organic Carbon Responses under Different Forest Cover of Manipur: A Review

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## A B S T R A C T

The relentlessly increase of atmospheric carbon dioxide ($CO_2$) concentration due to release from different sources leads to global warming and climate change which are a cause for great concern demanding in-depth research on $CO_2$ emission from soil under different forest cover. Forest cover can reverse the increasing $CO_2$ in the atmosphere, thus, contributes to mitigate climate change. Forest stored about half of the organic carbon (C) contained in terrestrial ecosystems. The role of forests has a great impact on the global biogeochemical cycles and in particular, the carbon cycle. Larger parts of the global C stock are stored in forest ecosystems. So, identifying the tree species in a forest with high SOC, soil organic carbon stocks (SOCS) and high C sequestration with low $CO_2$ emission is a priority for mitigating the global climate change. Carbon sequestration in forest occurs in both aboveground and below ground biomass. But, the below ground C sequestration was quite low in comparison to the above ground. The rate of C sequestration in *Schizostachyum pergracile* dominant forest was 22.03 Mg $ha^{-1}$ $year^{-1}$ whereas for *Dipterocarpus tuberculatus* dominant forest was only4.64 Mg $ha^{-1}$ $year^{-1}$. The annual organic C input ($gCm^{-2}year^{-1}$) as litter fall of forest dominated by *Quercus serrata* + *Schima wallichii* and *Ficus virens* + *Cinnamomum zeylanicum,* were 424.21 and 374.83 respectively. The naturally standing forest with dominant tree species of *Quercus serrate* or combination with other species was found to be most efficient in C sequestration as well as low efflux of $CO_2$followed by *Schizostachyum pergracile* bamboo forest. Any land use change of these forest cover can leads to more efflux of $CO_2$ making more vulnerable to global warming and climate change. SOC showed negative correlation with soil bulk density but with clay content in soil it is positively correlated. From the present investigation most of the naturally standing oak tree forest contributes high rate of SOC, SOCS and carbon sequestration, hence it is suitable for mass plantation to mitigate against human induced climate change.

## Introduction

In the present scenario of global warming, the most important challenge is to reduce the concentration of the carbon dioxide ($CO_2$) which acts as a greenhouse gas that trap the long wave radiation reflected from the earth making the earth atmosphere warmer and influences the climate change. As recorded in February 2013, the $CO_2$ concentration in the atmosphere has been gradually increasing from 280 ppm to 396.80 ppm since preindustrial times (Blunden and Arndt, 2014) which is continually increasing at the rate of 3.2 x $10^{15}$ g C $year^{-1}$ (IPCC, 1996). Soil is a major reservoir of carbon which plays a key role in the contemporary carbon cycle and a chief component of sustaining food production (Schulze and Freibauer, 2005).

SOC is an important source of carbon as well as a sink for carbon sequestration. It plays key role in mitigating global climate change and improves land productivity through improved soil properties such as nutrient supply and moisture retention (Van Keulen, 2001). It is also an energy source for organism decomposition. Global estimate of SOC stock is about 684 - 724 Pg to a 0.3 m depth, 1550 Pg to a 1m depth, 2376 - 2456 Pg to a 2m depth, which are higher than the atmospheric carbon pool and biota (Batjes, 1996; Lal, 2008). SOC generally diminishes with depth regardless of vegetation, soil texture, and size fraction (Trujilo *et al.,* 1997). In the United Nation on Convention on Climate Change (UNFCCC) and Kyoto Protocol at international level and National Action Plan on Climate Change, India, decided forest carbon management strategy as one of the objective to mitigate the present climate change (NAPCC, 2008). So, it is of great importance to estimate carbon stock of different forest cover and to enhance C sequestration by identifying the tree species with high capacity for fixing $CO_2$ are increasing interest worldwide (Zhou *et al.,* 2011).

## Effect of land use change on C emission

Land use change highly affects soil quality and carbon transformation. It is responsible for 12.5% of the human-induced carbon emissions from year 1990 to 2010 (Houghton *et al.,* 2012).Land use change and agriculture together contributes 20% of the C emission from soil (Lal, 2001). Carbon dioxide emission from soil into the atmosphere is approximately six times the amount derived from fossil fuels (GSP, 2011). Cultivation of deforested land declined soil quality by decreasing carbon storage and resulting into net flux of $CO_2$ to atmosphere and conversion of native soil to agricultural soil resulted into the loss of soil organic carbon (SOC) mainly in form of $CO_2$ (Vanden Bygaart *et al.,* 2003). Land-use changes in the tropics are estimated to contribute about 23% to human-induced $CO_2$ emissions (Houghton, 2003).Soil releases approximately 4% of carbon pool into the atmosphere each year (Li *et al.,* 2014) and gross emission due to tropical land use change reached 1.3±0.7 Pg C $yr^{-1}$ during 1990-2007 (Pan *et al.,* 2011). The rate and extent of decline in SOC stocks is not uniform globally but varies in accordance with the difference of soil type, land use conversion type, climate and the specific management implementation.

The SOC varies with land use types (Gupta *et al.,* 2015), where tree based ecosystem are supreme to reduce the atmospheric $CO_2$ which is stored in parts of the trees (Yadav *et al.,* 2016). Forest soil is the main carbon sink as ~40% of total C-stock of the soils is stored in global forest ecosystems (Lal, 2015). Forest conversion into cropland, grassland and perennial crops reduced SOC stock by 5%, 12% and 30% respectively in tropics (Don *et al.,* 2011). Depletion of SOC stock when native forest is converted into cropland by 42% and 59% when pasture is converted to cropland (Guo and Gifford, 2002). 60% and 75% of SOC stock are depleted by the conversion of natural to agro ecosystems in temperate and tropical regions respectively (Lal, 2004). Major impact on SOC and soil is found when forest cover is removed (Don *et al.*, 2011). A better understanding to identify tree species having the highest potential to sequester $CO_2$ and produce biomass return to the soil could lead to recommendations for tree plantations in a degraded ecosystem. Therefore, the present investigation was undertaken to determine the effects of different forest cover and the dominant tree species in different district of Manipur, India, on SOC sequestration and its stock in soil.

## Importance of different tree species in forest for C sequestration

Carbon (C) sequestration is the uptake of C in the form of $CO_2$ from air/atmosphere into another reservoir (tree or soil biomass) with a longer residence time (IPCC, 2007), which contributes to mitigate the present climate change (Powlson *et al.*, 2011), by capturing $CO_2$ from atmosphere to soil that reverse the increasing $CO_2$ in the atmosphere. This article focuses on the relationship between SOC and different natural forest found in Manipur, which may affect long-term removal of $CO_2$ from the atmosphere to soil as SOC and contributes to climate change mitigation (Stockmann *et al.*, 2013). Carbon sequestration in forest occurs in both aboveground biomass (stem, branch, and foliage) and in belowground biomass (roots, and in soil). Nowadays attention has been increased especially in the large volume of aboveground biomass and deep root systems of trees for climate change adaption and mitigation (Nair, 2012). In above ground biomass of *Schizostachyum pergracile* bamboo forest situated in Chandel district, the rate of C sequestration was 22.03 Mg $ha^{-1}$ $year^{-1}$. Out of the total, 99% of the above ground biomass was contributed by the new culms of the bamboo and 1% by annual litter production (Thokchom and Yadava, 2017). The below ground C sequestration (4.93 Mg $ha^{-1}$ $year^{-1}$) was quite low in comparison to the above ground of 22.03 Mg $ha^{-1}$ $year^{-1}$ which account for 82% of the total (Thokchom and Yadava, 2017). And in another forest from the same district but dominated by *Dipterocarpus tuberculatus*, total aboveground biomass was recorded to be 15.601 Mg $ha^{-1}$ and out of the total biomass, 90.27 % was contributed by bole of the tree and the remaining by branch (4.91 %), and leaf (4.80 %). The rate of C sequestration varied from 1.4722 to 4.64136 Mg $ha^{-1}$ $year^{-1}$ and in this process, aboveground biomass contributes 68.51% and the remaining by shrubs (28.96 %) and herbs (2.5 %) found in the forest (Devi and Yadava, 2015). Another findings in forest dominated by *Quercus serrata* + *Schima wallichii* and *Ficus virens* + *Cinnamomum zeylanicum,* of Senapati district, the annual organic carbon input as litter fall ($gCm^{-2}year^{-1}$)in soils were 424.21 and 374.83 respectively (Devi and Gupta, 2015). Again, a study conducted in Senapati district, the total annual litter fall of a forest covered with mixed oak species was 958.9 $gCm^{-2}yr^{-1}$ (Devi and Singh, 2017). Of the above ground biomass leaf contributes 76.7% of the total and the remaining by non-leaf litter fall (23.3 %).

## $CO_2$ efflux from different forest cover

Soil $CO_2$ efflux is considered to be an immediate soil respiration (Maier *et al.*, 2011) which is a second major component of global C flux after photosynthesis in most of the ecosystem and it can makes up60-90%of total respiration in an ecosystem (Longdoz *et al.*, 2000; Schlesinger and Andrews, 2000). Different abiotic (most importantly precipitation, soil temperature and soil moisture) and biotic factors (soil micro-organisms) influences the $CO_2$ efflux from the soil. The abiotic factors can significantly affect the seasonal variability of soil $CO_2$ flux (Hanpattanakit *et al.*, 2009) and its primary source is temporal heterogeneity. In a forest dominated by tree species *Quercus serrata* + *Schima wallichi*, of Imphal West district, soil $CO_2$ emission ranged from 120.26 to 324.47 mg$CO_2$ $m^{-2}h^{-1}$ and another with *Q. serrata* +*Lithocarpus dealbata*, ranged from 112.12 to 267.67 mg $CO_2$ $m^{-2}$ $h^{-1}$ in different months throughout the year (Devi and Yadava, 2009). Rate of $CO_2$emission (mg $CO_2$ $m^{-2}$ $h^{-1}$) at a natural forest and plantation sites dominated by *Quercus serrate* varied between 102-320 and 99-543, respectively. Another results with tree species dominated by *Castanopsis indica, Lithocarpus dealbata, L. fenestrata, Quercus polystachya, Quercus. serrata and Schima wallichii*, showed that soil $CO_2$ emission was 345.98 mg$CO_2$$m^{-2}$$hr^{-1}$ which was highest during the rainy season and minimum during the winter season (195.71 mg $CO_2$ $m^{-2}$ $hr^{-1}$), which showed a positive correlation ship with the microbial population with the rate of soil respiration (Devi and Singh, 2016). A significant positive correlation of soil $CO_2$ emission with abiotic factors (soil moisture and temperature) and biotic factors (bacteria, fungi etc.) has been reported in different forest ecosystems (Laishram *et al.*, 2002; Devi and Yadava, 2009;Devi and Singh, 2016).

## Soil Organic Carbon Stock (SOCS)

SOC stock at a point of time reflects the long term balance between additions of organic carbon from different sources and its losses through different pathways. Information on such SOC stock is important because of its impacts on climate change and effects on crop production. Any attempt to enrich this reservoir through sequestration of atmospheric C is likely to minimize global warming and also ensure global food security to a great extent (Lal, 2004). 40% of the total SOC stock of the global soils lies in forest ecosystem (Lal *et al.,* 1999) and because of their higher organic matter content forest soils are known to be one of the major carbon sinks on earth (Dey, 2005). So, identifying the tree species in a forest with high SOCS is a priority for mitigating the global climate change. The SOCS (up to the depth of 30 cm) of different forest found in Manipur are presented in the pie chart (Fig. 1). All the forest cover in the present investigation showed high SOCS. But forest cover with *Quercus serrate* species inclusion was highest (62.5 $Mgha^{-1}$), contributing 20% of the total for the present investigation, which is followed by bamboo forest (53.25 $Mgha^{-1}$) and the least was under pine forest (40.64 $Mgha^{-1}$). High rate of litter production and faster decomposition maybe the reason for overall high value of carbon stock in the upper layer of all the forest in study.

## Soil organic carbon and physical properties

There lies a significant relationship between the SOC and certain soil physical properties (most importantly texture and BD) in a given land use practices. Considering its importance in affecting directly or indirectly in the emission or sequestration of C from the soil, it is wise to understand their effect. Different forest covers with their SOC content are presented in table 1. The SOC (%) were in the range of 1.2 to 3.44 which is categorized as high in organic C (Musinguzi *et al.,* 2013). The soil was clay loam to sandy loam in texture for all the forest stand. But maximum of the studied forest soil was sandy loam in texture. For accumulation of SOC in soil, clay content is a very important factor (Christensen, 1992), it is evidence from the table that their lies a positive relation between the clay content in soil and the SOC.

**Table.1** Soil organic carbon (SOC), texture (%) and Bulk density (BD) of different forest cover in Manipur

| Location (District) | Dominant Species | SOC % | Sand % | Silt % | Clay % | BD ($gcm^{-3}$) | References |
|---|---|---|---|---|---|---|---|
| **Imphal West** | Mixed Oak forest | 2.75 | 51.6 | 30.7 | 14.8 | 1.38 | Devi and Yadava, 2009 |
| **Imphal West** | Mixed Oak forest | 2.60 | 51.0 | 32.0 | 17.0 | - | Pandey *et al.*, 2010 |
| **Imphal West** | Managed oak plantation | 3.20 | 36.0 | 29.0 | 34.0 | - | Pandey *et al.*, 2010 |
| **Senapati** | *Castanopsis tribuloides* | 1.20 | 69.0 | 17.5 | 13.5 | - | Binarani and Yadava, 2010 |
| **Chandel** | *D. tuberculatus* | 3.44 | 70.9 | 17.9 | 12.0 | - | Devi and Yadava, 2015 |
| **Senapati** | *Quercus serrata* | 1.41 | 68.8 | 18.7 | 12.3 | 1.28 | Devi and Gupta, 2015 |
| **Senapati** | *Ficus virens* | 1.56 | 72.7 | 16.7 | 10.7 | 1.33 | Devi and Gupta, 2015 |
| **Senapati** | Undisturb oak forest | 2.51 | Sandy loam | | | 1.10 | Niirou *et al.*, 2015 |
| **Senapati** | Disturb oak forest | 2.14 | Sandy loam | | | 1.20 | Niirou *et al.*, 2015 |
| **Senapati** | *Pinus kesiya* | 2.36 | Sandy loam | | | 0.94 | Niirou *et al.*, 2015 |
| **Senapati** | Orchard Plantation Forest | 1.94 | Sandy clay loam | | | 1.22 | Niirou *et al.*, 2015 |
| **Imphal East** | Mix oak forest | 3.20 | 35.0 | 24.0 | 41.0 | 1.40 | Devi and Singh, 2016 |
| **Senapati** | Mixed Oak forest | 2.37 | 40.3 | 29.0 | 30.7 | 1.35 | Meetei *et al.*, 2017 |
| **Chandel** | Bamboo forest | 1.52 | Clay loam | | | 1.19 | Thokchom and Yadava, 2017 |

**Fig.1**

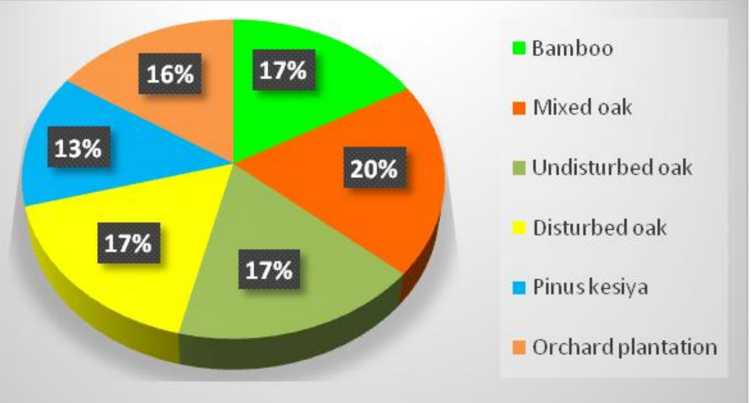


Fig 1. Soil organic carbon stock (Mg/ha) under different forest cover of Manipur

The value of bulk density in different forest stand of ranges 0.94 to 1.40 gcm$^{-3}$ (Table 1). SOC showed negative correlation with soil bulk density but positively correlated with clay content (Pandey *et al.,* 2010).

In conclusion, $CO_2$ efflux is one of the important natural processes that needs to be kept in checked in order to mitigate the global warming. This can be done with the process of C sequestration using different land use systems in the soil. Forest soil are more efficient in sequestering C compared to cropland, thus identifying efficient combination of tree species is important to capture the additional C present in the atmosphere. The naturally standing forest with dominant tree species of *Quercus serrate*or combination with other species was found to be most efficient in C sequestration followed by *Schizostachyum pergracile* bamboo forest. Any land use change of these forest cover can leads to more efflux of $CO_2$ making more vulnerable to global warming and climate change. Thus, from these results, we can identify the most efficient forest system or the tree species particularly in the north eastern side of Manipur and it can be incorporated it in the present forest system so as to minimize the effect of global warming.

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