Quantification of changes in soil carbon after the establishment of tea plantations replacing native ecosystems: A case from the low and mid country

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1. Introduction

Soil carbon has been identified as the largest terrestrial pool of carbon storage. Globally, its storage capacity is much larger compared with the pools of carbon in the atmosphere and vegetation (Lal, 2004). Soil organic matter (SOM) refers to organic matter constituent of the soil, consisting of plant and animal waste, soil cells and tissues, and soil synthesized by soil organisms at various stages of decay. Soil carbon has two types namely soil organic carbon (SOC) and soil inorganic carbon (SIC). The work presented in this manuscript is focused on SOC. Changes in land use cause changes in the SOC content and affect mainly the topsoil layers (Hobley, 2015). Theoretically, changes in land use would also affect SOC stocks below this depth, as land-use change usually implies a vegetation change and vegetation type (Don, 2011). In the Sri Lankan context, there are few studies carried out to assess the SOC stocks. Vitharana *et al*. (2019) mapped the SOC stocks across the country at a spatial resolution of 30 cm considering top and subsoils. The objective of the current work was to assess and quantify the change of SOC stocks in established tea plantations compared to native vegetation originally present in the study area: (a) Designing paired sampling strategies for SOC stock quantification, (b) accessing the depth and transactions, locations and finally (c) checking whether there is a statistically significant difference between the two types of land use are the sub-objectives.

2. Materials and Methods

Two locations in the mid-country (Sripada, 6.5317˚ N, 80.3965˚ E) and low country (Kalawana, 6.436300 N, and 80.419300 E) tea growing regions were chosen. Three paired sites of tea plantations (same age) adjacent to the native ecosystem were selected and three Transects were used to collect the samples (Transect 01, Transect 02, and Transect 03). At those sites, 200 m transect (100 m up into the forest and 100 m downwards into the tea land from the forest border) was demarcated considering both tea and native land-use type. Soil samples were collected at a distance of 20 m along the transect. At each sampling location, two fixed depths (0 - 0.10 m and 0.10 - 0.30 m) were chosen. Soils were initially air-dried and sieved using a 2 mm sieve before the analysis. Soil samples were analysed for key soil physical, chemical and biological properties namely pH (water); pH ($CaCl_2$); electrical conductivity (EC). Particle size analysis (Day, 1965); bulk density (Blake & Hartage, 1986) soil organic carbon (Walkley & Black, 1934) were the methods used in this study. In the current study, only the results related to the SOC stock calculations were presented.
The SOC stocks were calculated as below using Equation 1 (Benbi et al., 2015).

SOC Stock (Mg/ha) = C content (%) x BD (Mg/m3) x D (m) x 100 …………………. (1)

Where; SOC Stock is the soil organic carbon stock (Mg/ha), C content is the Soil Organic Carbon contents (%), BD is the bulk density (Mg/m^3) and D is the depth interval thickness (m).

The dataset was analysed using a linear mixed model considering land use, depth, location and transects as in fixed-effect terms and the sampling location as the random effect terms. The mean separation was carried out using the least-square means method.

3. Results and Discussion

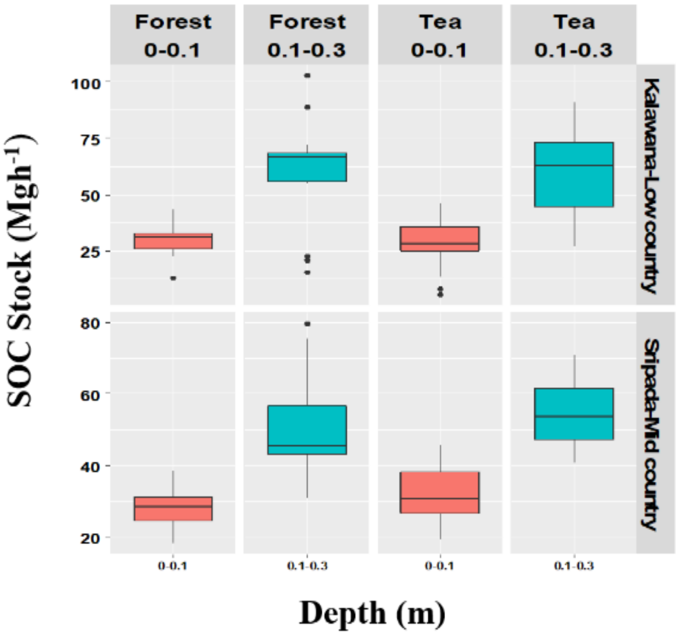

Figure 1. Distribution of soil organic carbon stock with depth for considered two locations

Figure 1, shows the distribution of SOC stocks across land-use types and depths considering two locations in Kalawana (low country) and Sripada (mid country). Despite the geographically distinct locations, the SOC distribution was almost similar based on its depth and land use type. However, the mean SOC at Kalawana (low country) tea plantations was almost similar irrespective of its depth level. When the two areas are considered, the forest topsoil has the higher mean SOC. According to figure 1, the mean SOC of Kalawana (low country) is higher based on each depth level and the land use type compared to Sripada (mid country) area. The highest SOC distribution at Sripada (mid country) and Kalawana (low country) were seen in the topsoil of forest and tea plantation respectively. As per the general distribution of SOC stocks in a soil profile, topsoil reports higher SOC content (Li et al., 2011). This is mainly due to the accumulation of carbon through the decomposition of surface litter and generally a high concentration of fine roots in topsoil. Out of several higher-order interactions and individual fixed effect terms such as land use, sampling depth (0.1 - 0.3 m), and the location was considered statistically significant ($p< 0.05$). It should also be noted that the intercept of the model was significant where other categorical variables were represented. Mean separation was carried out considering land use and depth interaction considering individual locations. For Kalawana (Low country) location, for the depth interval, 0 - 0.1 m both forest and tea confidence intervals were overlapping each other and similar results were reported for 0.1 - 0.3 m depth interval. Similarly, Sripada (mid-country) location reported a similar pattern (Table 1).

Table 01. Mean separation for the fitted linear mixed model

Location	Depth (m)	Land use	LS mean	Lower. CL	Upper. CL
Kalawana (Low country)	0-0.1	Tea	28.3^{bc}	21.5	35
		Forest	30^{c}	23.3	36.8
	0.1-0.3	Tea	58.7^{a}	51.9	65.4
		Forest	60^{ab}	53.2	66.7
Sripada(Mid country)	0-0.1	Tea	32.5^{bc}	25.8	35
		Forest	28.2^{c}	21.5	43.5
	0.1-0.3	Tea	54.5^{a}	47.7	61.3
		Forest	51^{ab}	44.3	57.8

LS - Least square; CL - Confidence interval; Means with same superscript letters are significantly not different at $P<0.05$.

In general, when land-use changes from native ecosystems to agricultural production systems, it records lower SOC stocks values unless high biomass pasture production systems. One possible reason for the accumulation of higher SOC stocks under tea plantations is possibly due to the addition of high biomass through agronomic practices such as periodic pruning of tea bushes (Li et al., 2011). As a result, the SOC stocks present under the two study sites that represented low and upcountry reported SOC stocks similar to their native vegetation types.
Previous work by Twongyirwe et al. (2013) revealed that SOC contents stored in soils under tea were similar to the forest in terms of SOC content. Further Li et al. (2011) reported that tea plantations maintain high carbon density in their increased carbon inputs caused by the high amount of pruning material returned back to the soil.

4. Conclusions

Despite the land-use change from the native forest ecosystem to the tea plantations for the time intervals considered at locations and depth intervals, no significant difference was reported between the reported SOC stocks. Future studies require a large number of samples covering a large spatial extent to quantify the SOC stocks across the landscape.

5. References

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