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Soil organic carbon in an abandoned rubber plantation in Mt. Makiling, Laguna, Philippines

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ABSTRACT. Vegetation cover change may positively and negatively affect soil carbon sequestration and storage. It can drive changes in soil organic carbon, which is critical in managing soil health and productivity and mitigating global warming. Any plantation activity that could affect tree crop population and their ability to contribute litter to the soil would result in soil organic carbon stock instability, affecting soil organic matter content. Data on soil organic carbon (SOC) fluctuations during the early stage of rubber plantation establishment is scarce, hence the conduct of this study. This study collected the SOC content of an abandoned rubber plantation as a benchmark for future initiatives and site development. Soil samples were taken from 0–20 cm, representing the topsoil, and 21–50 cm, representing the subsoil, and analyzed for SOC content using wet combustion, Walkley-Black Method. The result gathered an estimated total amount of 71.12 tC ha^{-1} from topsoil and subsoil. This study recommends conducting a complete carbon stock assessment and regular monitoring of soil organic carbon every time silvicultural treatments are done to better understand the soil organic carbon dynamics in rubber plantations.`

Keywords: marginal areas, silvicultural practices, soil carbon sequestration

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INTRODUCTION

Significant impacts have been made through land-use change by shifting forested lands to cultivated lands (Lal, 2005). Since then, cultivation and land-use change influenced some of the ecosystem's dynamics, resulting in environmental disturbances and decreased ecosystem services. Soil is a part of the ecosystem that experiences such disturbance every time land-use change occurs, affecting soil organic carbon dynamics (Layke, 2009; Evans *et al*., 2013). Soil organic matter is the main source of soil organic carbon; reducing organic matter input In the soil by changing land cover may affect soil carbon sequestration. Soil organic carbon dynamics include storage, decomposition, and organic carbon turnover over time. This process is critical in managing soil health and land productivity as well as mitigating climate change.

In CALABARZON, sometimes referred to as Southern Tagalog and Region IV A, Philippines, rubber tree (*Hevea brasiliensis*) plantations were being established on marginal and degraded lands, known as non-traditional areas, with low soil nutrient status and harsh weather conditions not favorable for rubber growth (Vrignon-Brenas *et al*., 2019). However, Predo (2021) reported that these non-traditional areas in the Philippines, including CALABARZON, have comparable growth and yield with those in traditional areas like Mindanao, attributed to the quality of planting materials and management practices. Thus, planting rubber trees in non-traditional areas but managed properly during their immature state can still provide favorable latex and rubberwood yield in the future (Vrignon-Brenas *et al*., 2019). Planting rubber trees in marginal and denuded areas, if adequately stocked, will create sinks that will counteract carbon emission; it can also support environmental improvement like additional soil organic matter that further enhances carbon storage in the soil (Johnson & Coburn, 2010; Lal, 2005).

However, in any tree plantation, management practices must be appropriately applied to attain the desired yield in those areas (Alcala, 2005) with improved ecosystem services. Planting trees on marginal lands does not always translate to increased soil organic carbon storage, especially without proper plantation management. Without maintenance activities, weeds could grow and claim the area. The presence of a high volume of weeds could turn a rubber plantation into a marginal area, and instead of being a carbon sink, it might act as a carbon source once weeding is applied. Studies about the impacts of weeding on soil organic carbon in rubber plantations are scarce. Data on SOC on various vegetation cover in the Philippines is almost impossible without rigorous laboratory analysis. Without baseline data on certain forest ecosystems, a positive or negative change in ecosystem services cannot be guaranteed without a reference point. This study aimed to estimate the soil organic carbon content of an abandoned rubber plantation in Mt. Makiling. The data could be used to monitor future site development and possible vegetation change. This basis makes it easier to interpret the enhancement or disturbance of ecosystem services like climate mitigation.

METHODOLOGY

Study area

The study site is located below the slopes of the University Housing Office (UHO) Guest House near the Learning Laboratory for Agroforestry (LLA), College of Forestry and Natural Resources, University of the Philippines Los Baños (UPLB-CFNR). The soil textural type of the area belongs to the Steep Phase Macolod Clay Loam. A medium-textured clay loam soil was found at 0-20 cm depth, while at 20–50 cm depth, sandy clay loam or coarse-textured soil was identified. According to the Modified Coronas Classification of Climate, Los Baños, Laguna is under Type III (more similar to Type I) with no pronounced maximum rain period, with a short dry season lasting only from one to three months, either from December to February or from March to May. Before the establishment of the rubber plantation, this area was used as an experimental site for the growth performance of tubang-bakod (*Jatropha curcas*) and antsoan-dilaw (*Senna spectabilis*). Other species that dominated the area even before the plantation of rubber were paper mulberry (*Broussonetia papyrifira*), igyo (*Dysoxylum gaudichaudianum*), ipil-ipil (*Leuceana leucocephala*), and lipang kalabaw (*Dendrocnide meyeniana*).

The rubber plantation

The stand was established in 2012 through the research grant of the Department of Agriculture–Bureau of Agricultural Research (DA-BAR) and UPLB-CFNR to determine the early growth performances of rubber trees and indigenous species like batino (*Alstonia macrophylla*), batikuling (*Litsea leytensis*), malapapaya (*Polyscias nodosa*), and cacao (*Theobroma cacao*) together with agricultural crops in a mixed agroforestry system planted along the contour. The spacing used was 4 m x 4 m throughout the area, with alternating rubber trees and indigenous trees going down the slope while agricultural crops were interplanted within the 4 m x 4 m spaces between the trees. During the project implementation (2012–2014), weeding was done every two weeks to maintain the production of agricultural crops; no commercial fertilizers or other soil amelioration was applied. After the project, from 2015–2016, it was used as a laboratory area for SFI courses under the Institute of Renewable Natural Resources (IRNR), and weeding was done twice a year. Then, starting in 2017 and continuing until now, the area was not attended to, and no silvicultural treatments were done. This was the period when the rubber trees were in their immature state and required the most care to survive into future crops. The species present in the area was now a mixture of antsoan-dilaw, ipil-ipil, lipang kalabaw, rubber trees, cacao, malapapaya, batino, paper mulberry, and sky flower (*Thunbergia grandiflora*). Paper mulberry is a fast-growing Moraceae species with a very prolific nature, and skyflower, a fast-growing vine, currently dominates the area.

Seedlings of rubber tree used were cloned and expected to be tappable five years after establishment. However, the absence of proper care and maintenance of the rubber trees and the native species initially planted have stunted growth, and their survival to maturity decreased.

Soil sampling and analysis

Soil sampling was done in December 2022. Three sampling plots were established 20 m apart to conduct the sampling, representing the study site's low, mid, and high elevations. Within each elevation, three 1 x 1 m sampling plots were randomly located approximately 20 m apart. Within each sampling plot, a 0.5 x 0.5 m frame was randomly laid where the soil samples and undisturbed cores for bulk density were collected, as illustrated in **Figure 1**. The study aimed to benchmark the SOC of a rubber plantation after it was abandoned, in which the rubber trees are already six (6) years old. It does not include the above-ground carbon stock and root biomass assessment.

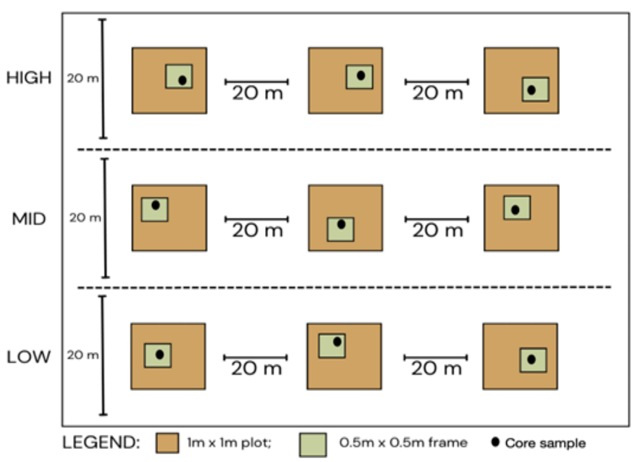

Figure 1. Soil sampling layout of the study in December 2022.

Analysis of the soil samples for soil organic carboncontent was done at the IRNR – Soils Laboratory using the Walkley-Black Method (PCAARRD, 1988), a wet oxidation process. To estimate the amount of soil organic carbon in the plantation, the following equations were used:

$$Soil\ mass\ (ton\ ha^{-1}) = BD \times \frac{10,000\ m^2}{1\ ha} \times depth\ (m) \quad (1)$$

$$Soil\ C\ (ton\ ha^{-1}) = Soil\ mass\ (ton\ ha^{-1}) \times \frac{\%OC}{100} \quad (2)$$

RESULTS AND DISCUSSION

Soil organic carbon (SOC), according to Hoyle (2013), is a quantifiable part of soil organic matter. Harrison *et al*. (2011) and Prietzel & Christophel (2014) stated that soil makes up most of the carbon stock in terrestrial ecosystems. In forest ecosystems, the SOC pool may be on par with or greater than the aboveground biomass (Lal, 2001). A vital element of healthy ecosystems and essential for food, soil, water, and energy security is soil carbon. Soils are significantly impacted by climate change and altering land use. These influences result in a dynamic interaction between the environment and the soil (Stockmann *et al*., 2015). As a source of latex during its productive age and rubberwood after 40 years, rubber plantations are promising prospects as carbon sinks. Litter input and soil organic matter loss rates (IPCC, 2006) could influence SOC stock. Enhancing litter input through planting trees could also enhance the carbon sequestration ability of the soil. In rubber plantation, it is important to understand the distributions and controls of SOC to predict and ameliorate the effects of global change (Jobbagy & Jackson, 2000) in local situations (Donovan, 2013; Ingram, 2014).

In the study, SOC is higher on the topsoil (0–20 cm) with 44.92 tC ha^{-1} (63.13%) than that of the subsoil with 26.20 tC ha^{-1} (36.85%) in this abandoned plantation at its immature state. This could be attributed to the higher accumulation of above-ground plant litter from the growing vegetation than root biomass accumulation in the subsurface soil (IPCC, 2006). The middle elevation accumulated a higher amount of SOC compared with high and low elevation. Based on ocular inspection, the middle elevation has a higher concentration of plant growth and more even terrain than other elevations. The data agrees with the common knowledge that SOC is a product of net plant productivity (Weil & Brady, 2016; Nadal-Romero *et al*., 2021) as seen on the study site that topsoil and middle elevation had the highest SOC concentration due to the presence of higher plant growth.

The estimated amount of SOC from the abandoned rubber plantation is 71.12 tC ha^{-1} from topsoil (0–20 cm) and subsoil (21–50 cm). The data summary is shown in **Table 1**.

Table 1. Estimated SOC (tC ha^{-1}) of abandoned immature rubber plantation in December 2022.

Elevation	Low		Middle		High	
Soil depth (cm)	0–20	21–50	0–20	21–50	0–20	21–50
Mean SOC (%)	2.07	0.91	2.21	0.91	2.07	0.86
Mean SOC (tC ha^{-1})	43.93	27.99	48.88	27.06	41.95	23.53
Total (0–50 cm)	71.93		75.95		65.48	
Total mean SOC (tC ha^{-1})	71.12					

SOC is directly proportional to plantation age (Chapman *et al*., 2013; Petsri *et al*., 2013). Since the study site is in its early stage, an increase in SOC later could be a good indicator that the area is a carbon sink. However, de Blécourt *et al*. (2013) documented some soil carbon losses in rubber plantations, but the decline is related to management practices, and this gives the idea that proper plantation management practices must be applied to increase SOC and make a plantation a carbon sink as it matures.

The growth of weeds can compete with rubber trees for available sunlight, moisture, and soil nutrients. Plants absorb carbon as carbon dioxide and, with the aid of the sun, can assimilate it into carbohydrates. Carbon assimilation will be hindered with less sunlight, moisture, and nutrients due to competition. This will affect the growth and development of rubber trees. As the plantations grow older, nutrient cycling is very efficient without weeds (Alcala 2005). Domination of weeds, however, might destabilize the soil's organic carbon, causing emissions (Dijkstra *et al*. 2020). Rehabilitation of such areas by weeding could also mean carbon emission due to the removal of aboveground biomass contributed by weeds. To reduce such emissions that could contribute to climate change, silvicultural treatments must be planned accordingly, and slash as mulch or input on making organic soil amendments must be considered. Growing economically important crops that do not need harvesting can improve soil carbon sequestration and ecosystem services of degraded and marginal lands (Ingram, 2014; Harrison *et al*., 2011; Johnson & Coburn, 2010; Lal, 2005).

CONCLUSIONS

In measuring the change in SOC, several countries implemented periodic soil sampling programs, relying on resampling previously sampled sites after varied periods. This should be done in the case of rubber plantations. The study concludes that of the current soil carbon stock, 71.12 tC ha^{-1} in the abandoned rubber plantation, 63.16% is stored in the topsoil (0–20 cm), and 36.84% is in the subsoil (21–50 cm). The middle elevation of the area has a higher concentration of SOC (0–50 cm) compared to high and low elevation, and based on ocular inspection, plant growth is concentrated in this area with more even terrain. Paper mulberry and sky flower vine competed with the rubber trees for sunlight, moisture, and soil nutrients, affecting carbon assimilation. These two prolific weeds could consume soil nutrients, including soil organic carbon, that would result in either emission of stock carbon in the soil if no proper plantation maintenance is applied. The data collected at this site is a benchmark that could be used to evaluate future activities in this area.

It is highly recommended for future studies to consider other plantation components both in below and aboveground biomass for a better understanding of soil organic carbon dynamics of rubber plantation. Carbon stock monitoring and maintaining a database is also favorable for monitoring the conduct of various silvicultural treatments against the impact of these activities on the soil organic carbon dynamics in rubber plantations.

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