Research article

Soil Organic Carbon Stabilization on Forested and Deforested Red-yellow Soil under Different Temperature Conditions

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Abstract Soil organic carbon (SOC) has an important role as a key indicator for soil health due to its contributions on mitigation and adaptation to climate change. Tropical areas cover with Red-yellow soil (Udults) such as Amazon represents the highest amount of soil carbon sources in the earth. Although it is affected by human impacts due to deforestation, it is important to maintain and increase SOC of tropical Red-yellow soil toward an optimal level for meeting challenges such as mitigating climate change effects. The aim of this study is to analyze the stabilization of soil organic carbon from Red-yellow soil under different temperatures conditions. A detailed comparison was made between forested and deforested conditions of Red-yellow soil. In order to analyze the temperature sensitivity, each treatment was kept under 25ºC and 35ºC, and the soil respiration ratio (SRR) was measured as well as SOC content by spectrophotometry method. Lastly, a treatment of biochar at 5% was added as part of stabilization mechanisms of carbon. The experimental results showed that there were significant differences in SOC content between forested conditions in contrast to deforested conditions, where 7.25 mg C/g was found in forest conditions while deforested conditions was 5.68 mg C/g. Although it was not found significant change in SOC under different temperature, SRR increased at 39% from 8.87 μL CO_2/h/g to 11.90 μL CO_2/h/g with temperature changes from 25ºC to 35ºC. Additionally, biochar application contributes to increase the value of SOC at more than 2.66 mg C/g in all treatments, however, it did not make a significant difference in SRR by temperature changes. Thus, biochar works as carbon sources to maintain and increase SOC content, but stabilization effects on Soil Respiration Ratio (SRR) should be observed in long term.

Keywords soil organic carbon, soil respiration rate, temperature sensitive, biochar

INTRODUCTION

The SOC represents between 50% to 58% of the soil organic matter content, which has an important function of storing nutrients for plants, improving soil structural stability to enhance soil fertility and providing mechanism to mitigate climate change effects. Turnover of SOC in terrestrial ecosystems is dynamic and human impacts can turn SOC into either a net sink or a net source of greenhouse gases (GHG) to the atmosphere (Trivedi et al., 2018).

The impact of climate change on SOC stocks is variable according to the soil type and location, however temperature changes and increasing frequency of extreme drought events are probably leading to increased loss of SOC. Although significant scientific progress has been achieved related to understanding of SOC dynamic, mechanism of protection and stabilization of SOC stocks in short-term and at different conditions still face complicated challenges impeding effectives conservation strategies (Pribyl, 2010).

The Red-yellow soil (Udults), mainly located in Amazon area, has an important role in global carbon changes, making this area as a considerable interest to quantify emissions when deforestation converts these forests into pasture or other land uses (de Oliveira Marques et al., 2017). Maintaining carbon stocks in Red-yellow soils of tropical forests such as Amazon area has increasingly become a justification for governments to take measures of reforesting rather than allowing them to be deforested. Nevertheless, deforestation has accelerated the process of forest fragmentation in Amazon area, resulting in changes in carbon stocks in biomass and soil (Barros and Fearnside, 2016).

The enhance of soil microbe's activity is stimulated by increasing of environment temperature, causing a higher release of microbial CO_2 (Lloyd and Taylor, 1994), leading to soil C losses, higher soil respiration rate and a positive contribution to global warming. In the short-term, increasing of temperature results in a significant increase of microbial activity and decomposition rates. It has been shown that decomposition of SOC increases with temperature, with the greatest proportional increases being observed at low temperatures. It is a fundamental issue to estimate the extent to which rising temperatures could destabilize SOC and make it available to decomposing microorganisms. The proportion of SOC stored in the world's soils is still argued and how it is vulnerable to the impacts of warming of this century (Crowther et al., 2016).

Therefore, modeling approaches that consider changes in carbon availability and microbial activity may be needed to improve understanding under different conditions on Red-yellow soil. Forested and deforested conditions of soils have a significant effect on SOC that must be connected with respiration rate, decomposition and possible conservation strategies on Amazon area.

OBJETIVE

The present study aimed to analyze the quantity and stabilization of soil organic carbon from Red-yellow soil, under different temperatures (25ºC and 35ºC) and conditions (forested and deforested). Such study is important to provide information about potential carbon emissions and climate change effects.

METHODOLOGY

Soil Sample Source and Preparation

The current investigation involved sampling and analyzing two sites of Red-yellow soil to measure SOC and SRR. The sites were selected from Miyako Island, which is located in Okinawa Prefecture, south of Japan. The soil sample was collected from a deforested and forested area with four samples each site as repetitions (Carter and Gregorich, 2008). Air-dried soil at 1,000 g were sieve and weighed into a labeled tray followed by adding 5% (w/w) of biochar as a biochar treatment. Samples were kept at approximate a field capacity moisture condition. Each treatment was divided into soil at ambient conditions (25ºC) and warm conditions (35ºC), and by conditions (Forested and Deforested) and biochar rate (0% and 5%).

Soil Organic Carbon Determination

Each one of the treatments and repetitions were analyzed by Spectrophotometric Procedure of Organic Carbon Contents of Soil (Wallinga et al., 1992). The soil at 50 mg were weight precisely, and it was transferred carefully to a dry 100 mL volumetric flask. 10.0 mL of 0.333 M potassium dichromate solution ($K_2Cr_2O_7$) was added to each flask. 16.0 mL of concentrated sulphuric acid were added following by putting the flasks in a boiling water bath for 45 min. The samples were cooled in the sink made up to the volume with distilled water. The samples were centrifuged for 10 min at 3,000 rpm.

For the preparation of standard series, 100 mL flasks containing sodium oxalate ($Na_2C_2O_4$) with volumes of 0, 25.0, 50.0, 75.0 and 100.0 mL were used as standard into the volumetric flask. These standard series worked as 0, 5, 10, 15 and 20 mmol Cr^{+3} per litter of solution of standard series. The absorbance was measured in a 1 cm cuvette at a wavelength of 590 nm within 2 hours after oxidation.

SOC percentage were calculated by multiplying the Cr^{+3} concentrations found by 0.2250/w, where "w" is the weight of the air-dry soil sampled.

Soil Respiration Rate Determination

Air-dried soil at 10 g were weighted from each treatment into a 450 mL glass bottle followed by adding 3 mL of distilled water. The soil and water were mixed in the bottles then covered with perforated films to reduced evaporation. The SRR was determined by using the infrared gas analyzer at time zero and measure again at the end of 1 h incubation (Sparda et al. 2016). The soil respiration rate (SRR, μL CO_2/h/g air-dried soil) was calculated as:

$$SRR = \left(CO_{2f} - CO_{2i}\right) * V * \frac{1000}{S} \quad (1)$$

Where CO_{2i} and CO_{2f} are the initial and final CO_2 concentrations (ppm) of the 1 h incubation, respectively, and V is the space volume of the bottle with the soil sample (450 mL). The amount of soil (S) was 10.0 g. Four repetition were measured for each one of the treatments.

Statistical Analysis

The comparison of the average of each one of the treatments were analyzed through Shapiro-Wilk Normality and Levene Homogeneity test. The one-way ANOVA test were performed to determine if there are differences through variance analysis. Then, Tukey test was applied to determine the differences between treatments. In addition, a Box-Cox transformation was performed to fit the ANOVA test. All the tests were performed using RStudio (version 1.2.5042) for statistical analyses of the data. Analyses were performed at the significant level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Mean values and standard deviation of Soil Organic Carbon (mg/g) and Soil Respiration Rate (μLCO_2/h/g) of treatments at Forested and Deforested condition, biochar rates and temperature, are shown in Table 1. The amount of organic carbon obtained in this study indicated significant differences ($P<0.05$) between treatments (Forested vs Deforested). In previous studies, the amount of Soil Organic Carbon has been analyzed at Forested and Deforested conditions (Fujisaki et al., 2017), where the values on Forested condition were found higher that Deforested condition. The theoretical basis for this is as follows. The forest keeps equilibrium between incomes and outcomes of carbon while deforestation cuts incomes and increase outcomes in the short term.

Table 1 Soil Organic Carbon (SOC) content and Soil Respiration Rate (SRR) of different conditions, biochar rate and temperature

Condition	Biochar	Tº	SOC (mg/g)		SRR (μL CO_2/h/g)	
Forested	0%	25º	7.24 ± 0.04	a	8.87 ± 0.20	a
		35º	7.61 ± 0.43	a	12.14 ± 0.20	b
	5%	25º	10.27 ± 0.39	b	8.53 ± 0.04	a
		35º	10.97 ± 0.37	b	11.9 ± 0.13	b
Deforested	0%	25º	5.68 ± 0.46	c	6.57 ± 0.02	c
		35º	6.6 ± 0.44	cd	4.93 ± 0.13	d
	5%	25º	4.99 ± 0.09	c	5.51 ± 0.09	d
		35º	5.52 ± 0.53	c	4.88 ± 0.24	d

The letters indicate the significant different of result among the treatments at 95% of confidence level.

On the other hand, the addition of biochar at 5% rate on soil showed a considerable different on SOC rather than 0% treatment. Biochar is composed by high values of organic matter which includes organic carbon (Oladele and Adetunji, 2020). The biochar increased values of SOC in Forested conditions at 5% rate in contrast of 0%, however, there were not differences found on Deforested at 5% in contrast of 0%. Temperature changes did not show significant difference between treatments in short term. Liu et al. (2021) described the degradation of organic carbon in long-term by microbes at warm conditions as a reduction in the amount of SOC, this explain the non-significant change in the values of SOC by temperature in short-term.

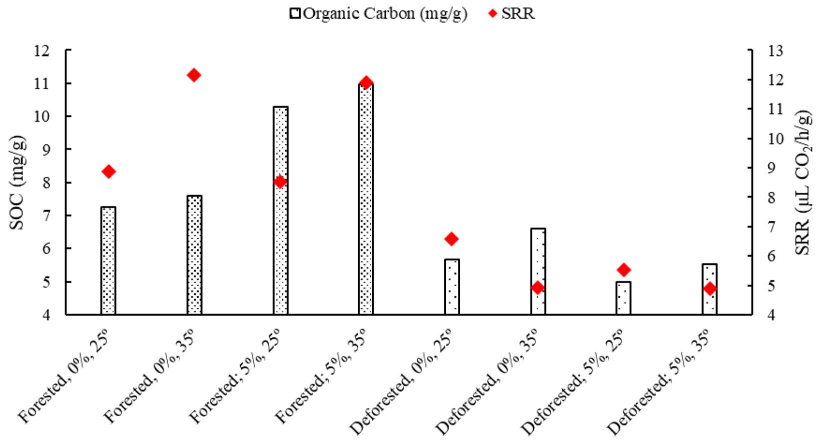

Fig. 1 Soil Organic Carbon content and Soil Respiration Rate of each treatment

It can be seen in Fig. 1 that the Soil Respiration Rate was altered by temperature in the short-term. In Forested conditions, values of SRR reached 12 μL CO_2/h/g in contrast to values lower than 9 μL CO_2/h/g (39% higher in warm conditions). The increased of temperature in soil reflects a considerable change in microbial activity in the short-term, which means an increase of CO_2 released. Although biochar addition shows a considerable increase of SOC, there is not stabilization of SRR under warm conditions. Xu et al. (2019) describe the activation and stabilization of carbon by biochar in the middle-term, which not only increase carbon but also reduce the release of it.

Deforested conditions showed values of SRR lower in comparison with Forested. It is clear due to the low amount of carbon in the Red-yellow soil and the relation with microbial activity. The SRR reached values of 6.57 μL CO_2/h/g and the lowest 4.93 μL CO_2/h/g with significant differences (25% lower than Forested conditions). Effect of temperature on Deforested conditions showed an increased in SRR values, but in the same way, biochar did not have a significant effect. Biochar application has affected the SOC but the effects on SRR stabilization in the short-term is depending by temperature and the microbial activity (Xu et al., 2019).

CONCLUSIONS

It is demonstrated that Deforested condition reduces significantly the amount of organic carbon in the soil. Although Red-yellow soil has a low organic carbon content, this reduction can be recovered by biochar addition. The loss of carbon by microbial activity increases by the effect of temperature which has an important role through Soil Respiration Rate. The Forested conditions of Red-yellow soil showed an increase of microbial activity due to the high carbon content, thus, the changes on respiration are easily affected by weather such as temperature conditions. This process of organic carbon degradation is not stabilized by biochar addition in the short-term. Finally, biochar works as carbon sources to maintain and increase SOC content, but stabilization effect on Soil Respiration Ratio (SRR) should be observed in long term under warm and ambient conditions as part of the stabilization process.

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