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Research article

Soil organic carbon stocks in different land uses in Pondicherry university campus, Puducherry, India

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Abstract: Soil Organic Carbon (SOC) stocks (30 cm soil depth) were assessed in different land uses (teak plantation, eucalyptus plantation, acacia plantation, shrub land and grass land) in Pondicherry University campus by using Walkley & Black's method. The soil bulk density was found to increase significantly ($P<0.05$) with increasing soil depth in all sites except acacia plantation and shrub land. Grass land and shrub land showed significantly ($P<0.05$) greater bulk density than other study sites. The stock of SOC percent and soil organic matter significantly ($P<0.001$) decreased with increasing soil depth. Acacia and eucalyptus plantations showed significantly ($P<0.05$) greater SOC percent than other study sites. This may be due to higher litter inputs and greater biological activity. The stock of total SOC was significantly greater in the grass land and shrub land than the other study sites. This could be attributed to more bulk density in these study sites. The present study suggests that maintaining diverse land uses would enrich the carbon stock of the institution in addition to preservation of biodiversity.
Keywords: Bulk density - Grass land - Plantation - Shrub land - Soil organic matter.

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INTRODUCTION

Forests have a vital role in the global carbon cycle and provide various ecosystem services to the society. India has a vast range of forest types, weather and soil conditions and it is often very difficult to conclude which forest type is best in carbon sequestration. Long-rotation forests store more carbon in forest biomass and in associated carbon pools than the short-rotation plantations (Kaul *et al.* 2011). Carbon sequestration by plantations serves as a sizeable sink for atmospheric CO_2 both in temperate and tropical regions (Houghton *et al.* 2000, Fang *et al.* 2001). Carbon stocks have received considerable attention in the recent past as a result of its commoditization. Plantation programmes are often initiated to create carbon credits that generate significant income for the developing countries (Niles *et al.* 2002). Although in the first commitment period of Kyoto Protocol (2008–2012), the market for CDM (Clean Development Mechanism) sinks was limited, the importance of CDM sinks lies largely in reforestation and afforestation activities in the developing countries beyond 2012 (De Koning *et al.* 2005). In India, several workers have published biomass estimations using allometric equations for few tree species, which had diameter above 10 cm at breast height (Bargali *et al.* 1992, Lodhiyal *et al.* 1992) that are grown in plantations. However, soil carbon stock assessments in these plantations are very limited and scattered and the studies are mostly concentrated only on aboveground biomass carbon.

The carbon in the tropical forest soils is roughly equivalent to or less than the aboveground biomass due to degradation (Ramachandran *et al.* 2007). Ravindranath *et al.* (1997) reported that the ratio of soil organic carbon (SOC) to biomass carbon was 1.25. Tree plantations are known to increase the carbon pool in biomass and soil (Arora & Chaudhry 2014). Kaul *et al.* (2010) found that in plantations, the carbon content in the soil was almost double the biomass carbon but not 2.5 to 3 times the biomass carbon as recorded earlier.

Forest ecosystems adjacent to the cities are more significant as they provide clean environment, have aesthetic value, act as storehouse of medicinal plants etc. Union territory of Pondicherry is a small piece of land

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with alarming population growth rate. This leads to conversion of agricultural land and areas of aquifers into real estates, industrialized and institutional areas. Pondicherry University is one of the institutions with a large land cover of 760 acres. Hence, the university has taken steps to green the entire campus except the built-areas and paths. Even though the disaster of Thane cyclone in December 2011 uprooted and damaged several large and very old trees, huge patches of forest still exists. The Flora of the university campus has been documented by Parthasarathy *et al.* (2010). Influence of Thane cyclone on tree damage has been assessed by Sundarapandian *et al.* (2014a). Biomass and carbon stock assessments of woody vegetation in the University campus have been done by Sundarapandian *et al.* (2014b). Recently, many educational institutes in the western world have assessed their carbon footprints. Recent advances reveal that instead of carbon footprint, ecological footprint would be more reasonable and applicable. Based on the assessment of ecological footprint, Canada decided to withdraw from the Kyoto Protocol. At present, Indian institutes also take initiatives to green their campuses and assess their carbon footprints. Pondicherry University has endeavoured to construct a solar campus in silver jubilee buildings. Several initiatives are under discussion. At this crucial time, baseline data of carbon stocks of the campus is one of the important parameters to plan green campus initiatives and estimate ecological footprint. The present study will be more important in terms of baseline data generation and documentation. This baseline data will also be helpful to estimate the carbon sequestration potential of forest ecosystems in the campus in the near future. Therefore, the present study was intended to evaluate the following objectives: (1) to examine the variations in soil C stock in different land uses and (2) to examine the relationship of soil C stock with various edaphic factors.

MATERIAL AND METHODS

Study area

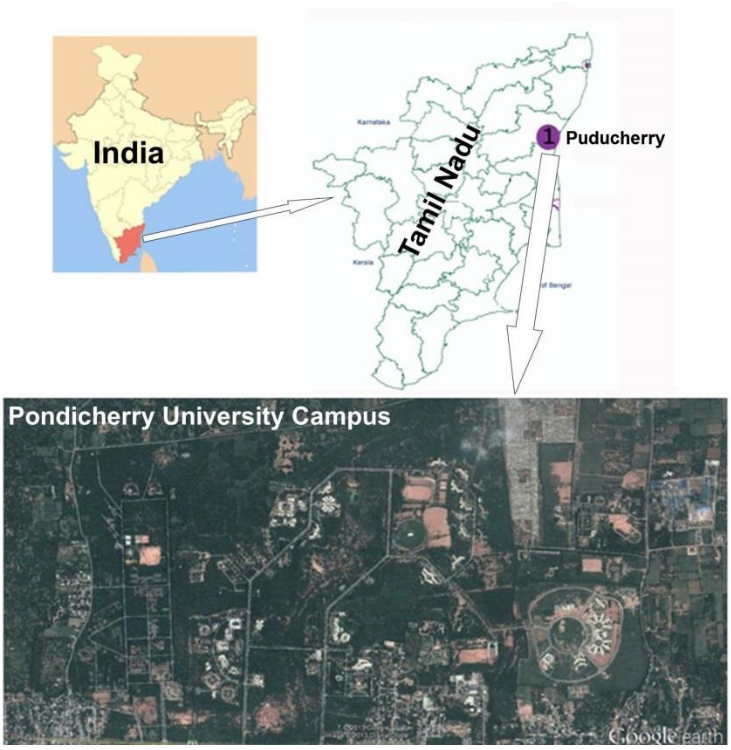

Figure 1. Aerial view of Pondicherry University Campus. (Source: Google Earth)

Pondicherry University (12° 0.97' N, 79° 51.33' E) is situated 10 km north of Puducherry town, on the Coromandel coast (Fig. 1) and spans an area of 780 acres, of which the built-areas occupy approximately 1,80,000 m^2. The climate is tropical with most rainfall during northeast monsoon (October–December) and very less and inconsistent rainfall during southwest monsoon (June–September). The mean annual rainfall is 1282 mm for the last two decades (1990–2010).The mean annual maximum and minimum temperatures of Puducherry are 32.58°C and 24.51°C. The soil is red ferrilitic, sandy and heavily drained. The vegetation of Pondicherry University is mainly composed of tropical dry evergreen scrub and palm savannas in the west and south and cashew plantations, rice, sugarcane and groundnut cultivation in the east. For the present study, five different land uses in the university *viz.*, teak plantation, eucalyptus plantation, acacia plantation, shrub land and grass land were selected.

Soil sampling and laboratory analysis

Soil samples were collected at 0–10, 10–20 and 20–30 cm depths from each land use using a core sampler during January and February of the year 2013. Ten sets of samples were collected from each study site and are mixed together to form a composite soil sample, from which six replicate samples were brought to the laboratory for further analysis. Before analysis, soil samples were sieved through a 2 mm mesh and then mixed thoroughly. Soil organic carbon was estimated by using Walkley and Black's method (Walkley 1947). In this method, about 60–86% of SOC is oxidized and therefore a standard correction factor of 1.32 was used to obtain the corrected SOC values (De Vos *et al.* 2007).

For bulk density, in each site, six aggregated undisturbed soil cores were taken by a soil corer with 5 cm internal diameter. The soil samples were weighed immediately and transported to the laboratory where they were oven-dried at 105°C for 72 h and re-weighed. In the soils containing coarse rocky fragments, the coarse fragments were separated by a sieve and weighed. The bulk density of the mineral soil core was calculated with the help of the formula described by Pearson *et al.* (2005). Soil carbon stocks were then calculated for each soil depth based on the thickness of the soil layer, bulk density and carbon concentration. The total carbon content upto 30 cm depth was finally estimated by summing the carbon concentration of all the layers (Pearson *et al.* 2005).

Statistical Analysis

The variation in SOC stocks among different land uses and soil depths (0–10, 10–20, 20–30 cm) was examined with analysis of variance (ANOVAs). The relationship between SOC stock and three edaphic factors (soil moisture, soil pH and bulk density) were examined with correlation analysis followed by linear regression.

RESULTS

The soil moisture (%) in different land uses of Pondicherry University campus ranged from 2.98 (shrub land) to 5.63 (acacia) up to 30 cm soil depth (Fig. 2). The soil moisture (%) was found to significantly vary ($P<0.001$) among the study sites. Eucalyptus plantation and grass land showed almost same soil moisture (%) *i.e.* ≈4.0%. The soil pH in different land uses of Pondicherry University campus ranged from 5.50 (grass land) to 7.34 (teak) up to 30cm soil depth (Fig. 3). The pH was significantly ($P<0.001$) greater in teak plantation compared to grass land and other plantations.

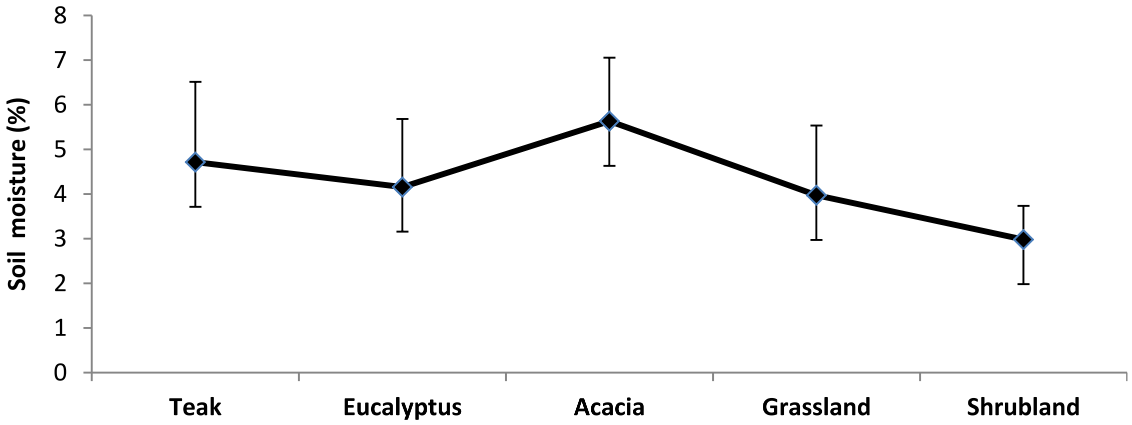

Figure 2. Soil moisture in different land uses in Pondicherry University campus, Puducherry, India.

The soil bulk density (BD) in different land uses of Pondicherry University campus ranged from 1.18 (teak) to 1.49 (grass land) up to 30 cm soil depth (Fig. 4). The soil bulk density increased significantly ($P<0.05$) with increasing soil depth in all the sites except acacia plantation and shrub land. Grass land and shrub land showed a significantly ($P<0.05$) greater bulk density than the other study sites. The mean range of bulk density in different depths was 1.16 (shrub land) to 1.26 (acacia) at 0–10 cm, 1.13 (acacia) to 1.70 (shrub land) at 10–20 cm and 1.15 (acacia) to 1.67 (grass land) at 20–30 cm. Significant differences ($P<0.05$) were found to exist in the soil profile of all the sites except acacia plantation.

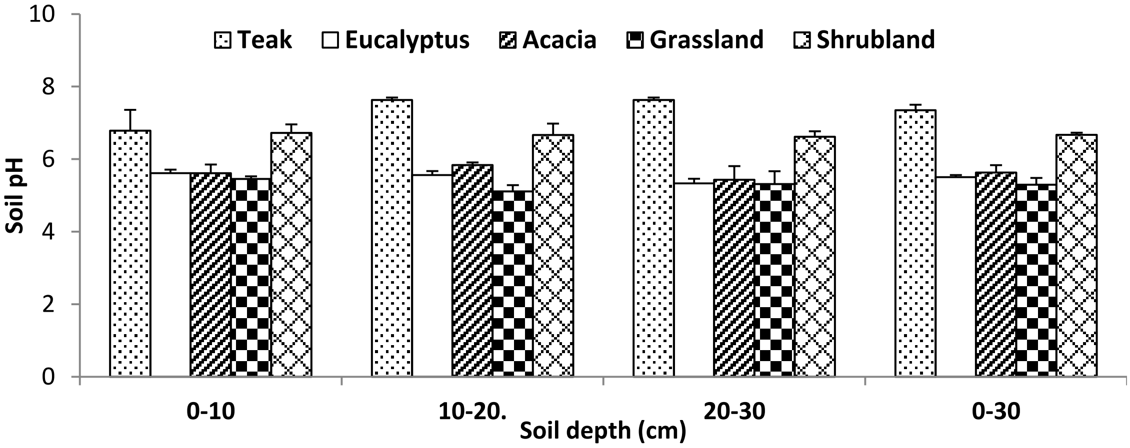

Figure 3. pH in different land uses in Pondicherry University campus, Puducherry, India.

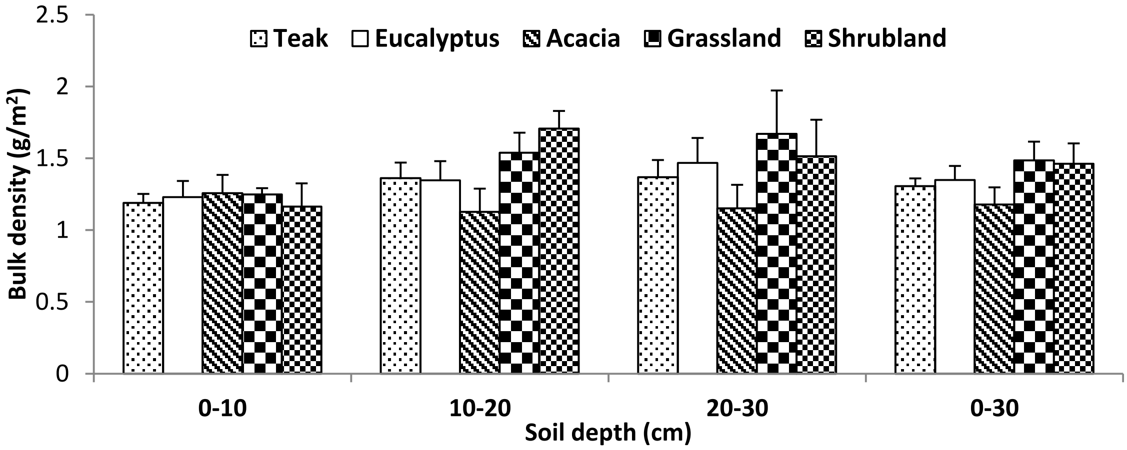

Figure 4. Soil bulk density in different land uses in Pondicherry University campus, Puducherry, India.

The SOC percent in different land uses of Pondicherry University campus ranged from 1.53 (teak) to 2.1 (acacia) up to 30 cm soil depth (Fig. 5). The SOC stock percent significantly ($P<0.001$) decreased with increasing soil depth. Acacia and eucalyptus plantations showed significantly ($P<0.05$) greater SOC percentage than the other sites. The mean range of SOC percent in different depths was 0.64 (shrub land) to 1.05 (acacia) at 0–10 cm, 0.47 (teak) to 0.63 (shrub land) at 10–20 cm and 0.27 (teak) to 0.58 (shrub land) at 20–30 cm.

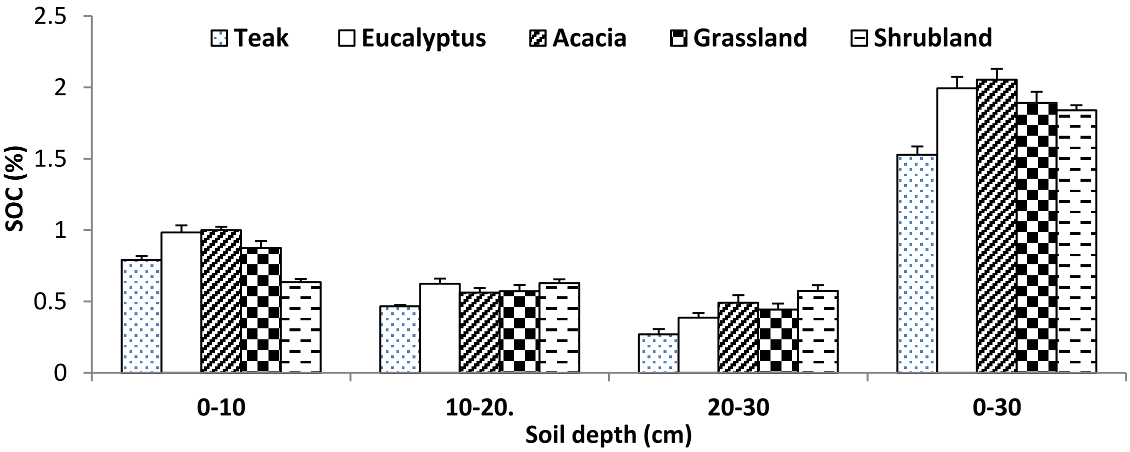

Figure 5. Soil organic carbon (SOC) in different land uses in Pondicherry University campus, Puducherry, India.

The Soil Organic Matter (SOM %) in different land uses ranged from 4.54 to 6.10 in 0–30 cm soil depth (Fig. 6). SOM stocks (%) significantly ($P<0.001$) decreased with increasing soil depth. Acacia and eucalyptus plantations showed significantly ($P<0.05$) greater SOM percentage than the other study sites. Teak plantation had the least SOM (%). The observed mean range of SOM percentage in different depths was 1.9 (shrub land) to 2.96 (acacia) at 0–10 cm, 1.38 (teak) to 1.86 (shrub land) at 10–20 cm and 0.80 (teak) to 1.70 (shrub land) at 20–30 cm.

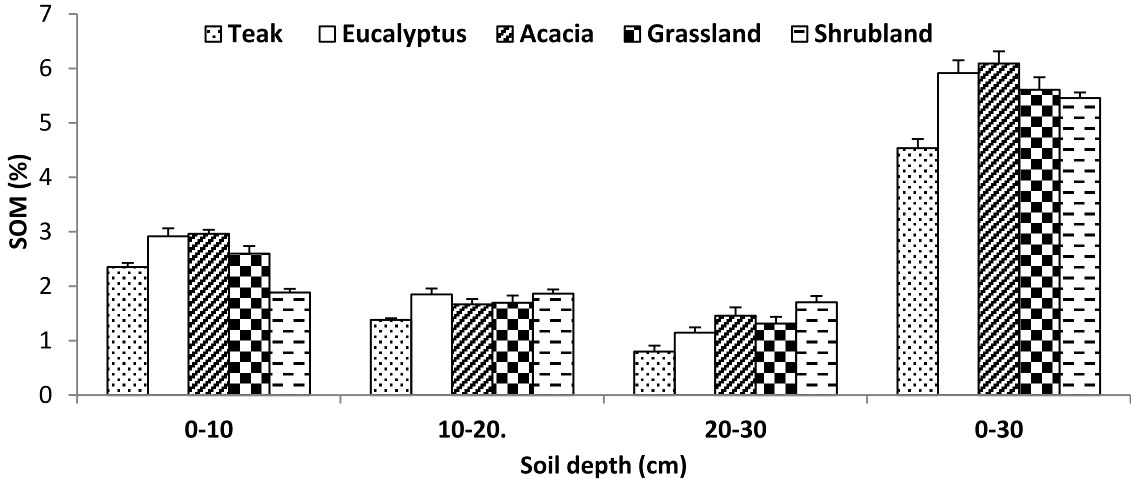

Figure 6. Soil organic matter (SOM) in different land uses in Pondicherry University campus, Puducherry, India.

The total SOC stocks up to 30 cm soil depth in the studied different land uses ranged from 19.47 (teak) to 27.06 (grass land) Mg C ha^{-1} (Fig. 7). The mean range of total soil carbon in different depths was 7.39 (shrub land) to 12.56 (acacia) Mg C ha^{-1} at 0–10 cm, 6.35 (teak) to 10.74 (shrub land) Mg C ha^{-1} at 10–20 cm and 3.69 (teak) to 8.72 (shrub land) Mg C ha^{-1} at 20–30 cm. The total SOC stocks were significantly greater in grass land and shrub land than the other study sites.

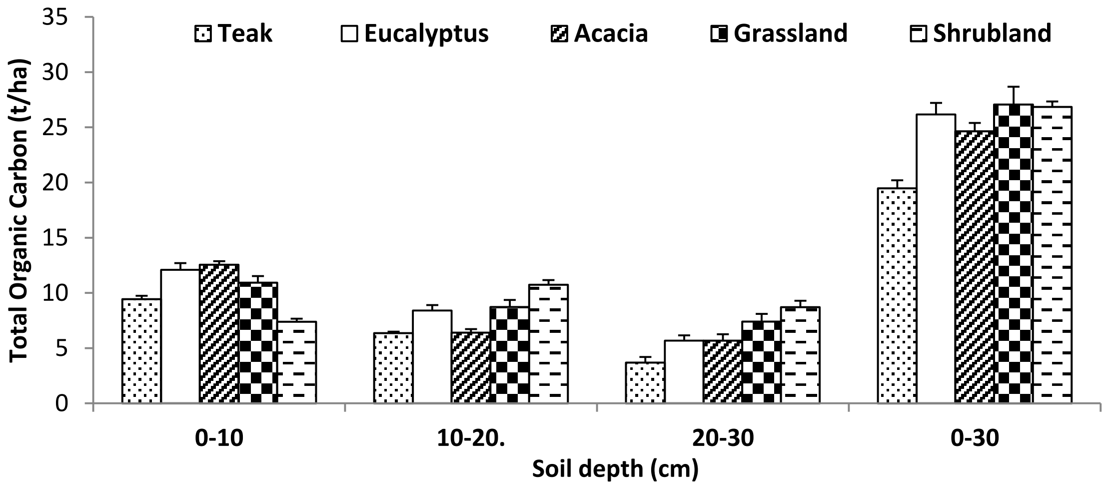

Figure 7. Total soil organic carbon (t/ha) in different land uses in Pondicherry University campus, Puducherry, India.

Regression analysis indicated that soil pH and soil moisture had a negative relationship with SOC percent, SOM and total carbon (Mg C ha^{-1}) in Pondicherry University campus (Fig. 8). However, bulk density showed a positive relationship with total carbon (Mg C ha^{-1}).

DISCUSSION AND CONCLUSION

SOC showed a decreasing trend with increasing soil depth in all the study sites. This may be due the greater decomposition rate in the upper layer compared to other layers. Similar results have been observed by other workers as well (Jobbagy & Jackson 2000). The higher percentage of carbon in acacia and eucalyptus plantations may be due to high litter inputs and more biological activity. In addition, the leaves of acacia and eucalyptus trees have high lignin content which slows down the decomposition rate, which might have led to the accumulation of humus throughout the year. This might be one of the reasons for high SOC stocks in these sites. The range of SOC in tropical dry deciduous and moist forests ranged between 8.9 and 177 Mg C ha^{-1} in the top 50 cm soil depth (Chhabra *et al.* 2003) and our results are consistent with the above-stated values. The changes in SOC stocks might also be due to different vegetation types, litter quality and quantity, soil type and texture, soil chemistry, soil moisture, decomposition rates and also landscape position as stated by Beets *et al.* (2002), Vesterdal *et al.* (2008) and Twongyirwe *et al.* (2013). The change in total SOC stocks (Mg C ha^{-1}) could also be due to differences in soil bulk density at different soil depths (Jobbagy & Jackson 2000).

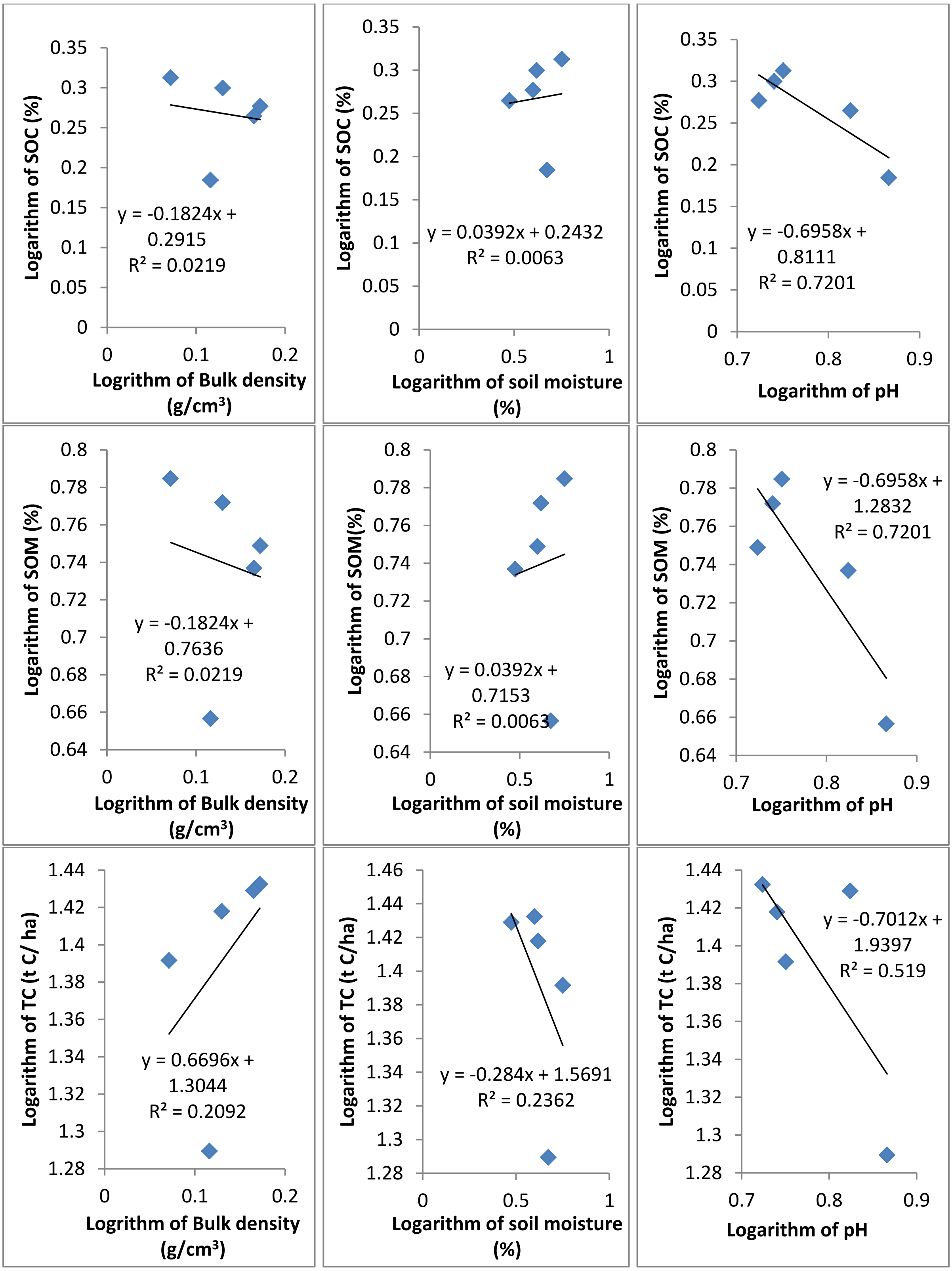

Figure 8. Regression analysis of soil organic carbon (SOC), soil organic matter (SOM) and total carbon (TC) with bulk density, soil moisture and soil pH in different land uses in Pondicherry University campus, Puducherry, India.

SOC (%) showed a negative correlation with soil pH, soil bulk density and soil moisture. SOM (%) also showed the same trend. To the contrary, the total carbon showed a positive correlation with bulk density, but not with soil pH and soil moisture. Jobbagy & Jackson (2000) and Li *et al.* (2010) have also observed a negative correlation of soil organic carbon with bulk density. The overall SOC was highest in grass land- than the other sites. Shoji *et al.* (1993) in Central France have also reported high SOC values in grass land. Gupta & Sharma (2014) have also concluded that grass lands have the maximum SOC pool based on their assessment of SOC stocks in different land use systems of Uttarakhand. The present study suggests that maintaining diverse land uses enriches the soil carbon stocks of the institution in addition to preserving biodiversity.

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