SRI LANKA

First National Research Symposium
National Research Council of Sri Lanka
2022

Proceedings

NRC
SRI LANKA

Proceedings of the
1st Research Symposium
National Research Council of Sri Lanka

14th & 15th November 2022

SOIL CARBON DISTRIBUTION AND CONTROLLING FACTORS IN PADDY-GROWING SOILS OF SRI LANKA

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1.INTRODUCTION

The planet is warming, and it is considered the most threatening and controversial environmental issue in this century. Since the industrial revolution, a drastic increment in atmospheric CO2 and other greenhouse gases has been identified. The contribution of soil towards reducing atmospheric carbon dioxide concentration through the process of carbon sequestration has become more prominent with the recognition of its role as a long-term carbon reservoir. Carbon sequestration means the transfer of atmospheric CO2 into long-term carbon pools, which are stored steadily without re-emitting in a short run. Hence soil carbon sequestration refers to the increment of soil organic carbon (SOC) and soil inorganic carbon (SIC) stocks through careful land use and recommended management practices Lal (2004). Nearly 1500 Pg of organic carbon is preserved within soils of the global terrestrial ecosystems, and the quantity is more than twice that in the atmosphere while 2-3 times greater than that in terrestrial vegetation Wang et al. (2007).

The maintenance of SOC ensures that C remains are sequestered in the soil, which helps reduce carbon emissions and improve agricultural productivity. Soil carbon sequestration would revitalize the soil quality, thereby enhancing harvest quality via increasing essential nutrient uptake while restricting pollutants uptake. Carbon sequestration would be more beneficial for the tropical soils that exist in a highly weathered nature, exhibiting very low soil fertility. Therefore, estimates of soil carbon content and associated soil properties in tropical ecosystems are highly important for managing ecosystems that facilitate more carbon to be sequestered in soil.

Paddy (Oryza sativa) is primarily grown as a staple food in most Asian countries, including Sri Lanka. Paddy covers approximately 34% of the cultivated lands in Sri Lanka. Soil organic carbon accumulation in paddy ecosystems is faster and more pronounced than in other arable ecosystems Wu (2011) because soil organic matter decomposition rates are considered smaller under anaerobic conditions than aerobic conditions. Furthermore, high content of silt and clay in paddy soils than those in upland soils leads to more considerable SOC accumulation Lal (2002). Studying the C status and recording them is important regarding two aspects of mitigating global climate change and managing paddy-growing ecosystems. The current study aimed to identify the spatial drivers and estimate total soil carbon concentration across the paddy-growt carbon fractions. The information gain from the study will be vital for the region-al-scale planning to enhance the soil carbon and provide a baseline for designing a future land-based carbon accounting system for Sri Lanka.

2.MATERIALS AND METHODS

The soil samples were collected across the three major climatic regions (wet, intermediate, and dry) in the paddy-growing soils of Sri Lanka. Two sampling strategies were used to collect soil samples for model calibration and validation purposes. First, the Conditioned Latin Hypercube sampling design was employed to determine calibration locations, and a stratified random sampling design was aided to determine the validation locations. A total of 987 topsoil samples were incorporated into the study. Composited soil samples were collected at each sampling site at 0-15 cm soil depth level using a soil augur of 5 cm width. The GPS locations of all the sampling sites were recorded using a Garmin eTrex 30 handheld GPS receiver.

In the laboratory, all visible organic debris, plant roots, and stones were removed by handpicking. Then the soil samples were air-dried at room temperature and sieved through a 2mm mesh sieve. The chloroform fumigation and extraction method was used to determine MBC content Anderson and Ingram (1993). Further, the fresh soil samples were analyzed for soil pH (1:2.5 soil: water suspension) and Electric conductivity (EC) (1:5 soil: water suspension) Anderson and Ingram (1993). Then the rest of the soil samples were ground to a less than 0.15 mm powder for the dry soil analyses. The Permanganate Oxidizable Carbon (POXC) fraction was estimated by the Modified KMnO4 oxidizable C method Weil et al., (2003), and the Dissolved Organic Carbon (DOC) fraction was determined using the titration method using acidified ferrous ammonium sulphate Anderson and Ingram (1993). The available nutrient cations (Ca, Mg, K, Fe, Mn, Cu, Zn) were determined using Atomic Absorption Spectrophotometer (GBC 933 AA). Total C and total nitrogen (TN) contents were analyzed by automated combustion using the 2400 Series II CHN elemental analyzer by using standard laboratory protocols.

Rainfall, maximum temperature (MXT), mean temperature (MT), elevation, vapour pressure deficient (VPD), MODIS enhanced vegetation index (EVI), minimum temperature (MIT), slope degree, and wetness index data were considered as the environmental predictors of soil C. Random Forest machine learning model framework was used for the current modelling and mapping work. A noval area of applicability concept was used to identify the reliability of current prediction. Moreover, a multivariate statistical approach (Redundancy analysis) was undertaken to explore the relationships between the considered explanatory variables and the variation in soil carbon.

3.RESULTS AND DISCUSSION

Based on the spatial estimates across the paddy-growing regions of Sri Lanka, the predicted total soil C concentration varied from 0.92% to 14.45%. The highest predicted soil C concentration range was in the wet zone (2.05% to 14.45%), followed by the intermediate zone (1.09% to 6.86%), and the lowest was reported in the dry zone (0.92% to 4.60%). The spatial distribution of soil carbon is depicted in Fig. 1. Soil carbon concentration was significantly explained by rainfall, MXT, MT, elevation, VPD, EVI, and MIT. The area of applicability approach identifies the areas where the application of model is problematic. According to the AOA results, the model can be successfully applied to 98% o the dry zone regions, 82% of the intermediate zone, and 65% of the wet zone of the country (Fig 2).

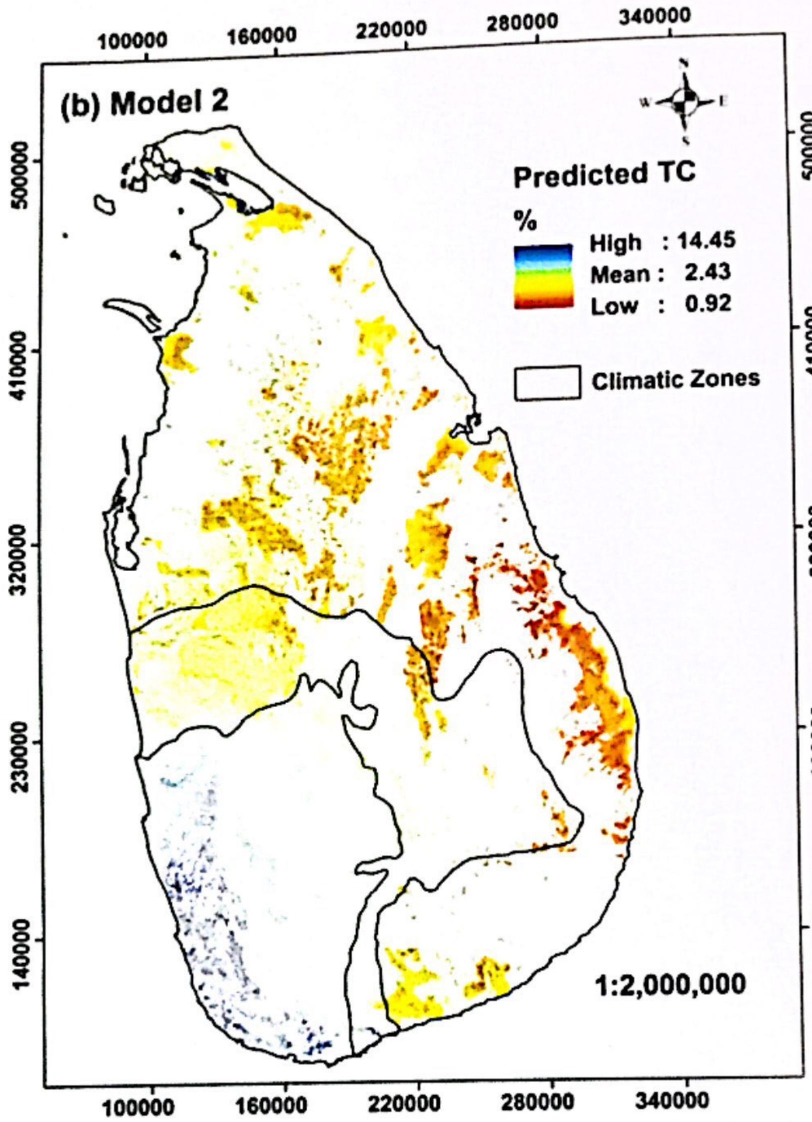

Fig. 1.Spatial distribution of predicted TC concentrations (%) in paddy-growing soils across Sri Lanka with the major climatic zone boundaries

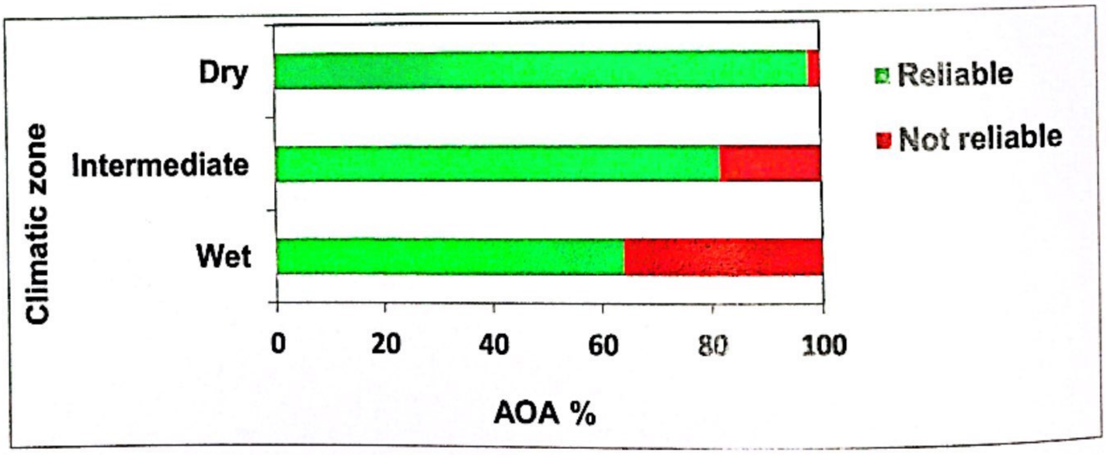

Fig. 2: Percentage of Area Of Applicability of current soil C prediction for major climatic zones of Sri Lanka.

According to the multivariate analysis, the rainfall positively correlated with soil C and its fractions, whereas EVI positively correlated with POXC, MBC, and total C. Moreover, total N, available K, Ca, Fe, Zn, and Cu contents showed positive correlations with soil carbon and its fractions (Fig.3). Cations that attach to negatively charged organic surfaces are responsible for cation-mediated soil C stabilization. On the other hand, significant negative trends were observed between Total C and carbon fractions with the soil pH, suggesting that higher pH levels negatively affect soil C stabilization. Interestingly, the factors related to MBC were more or less similar to that of POXC, indicating similar driving forces for both pools.

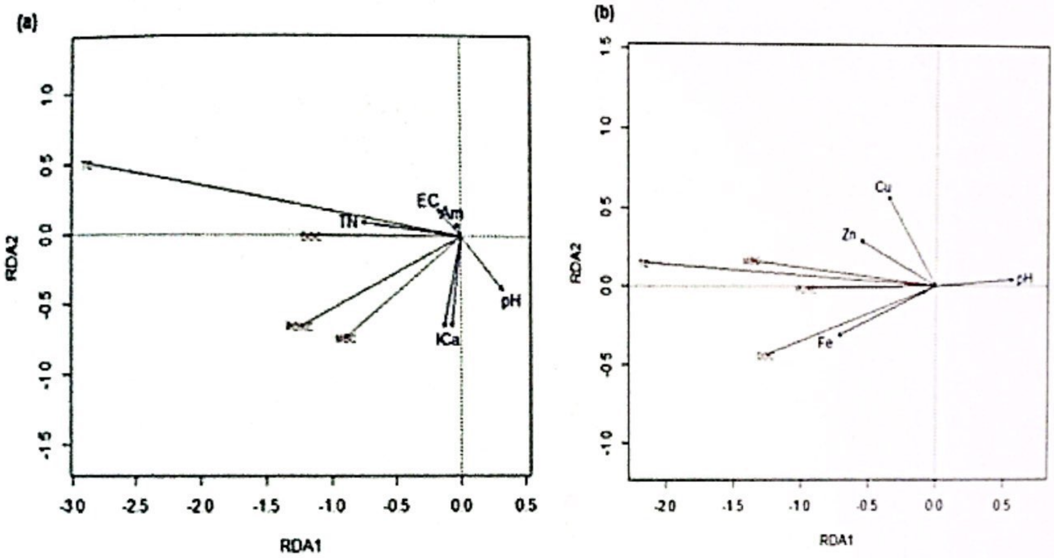

Fig. 3: Redundancy analysis (RDA) biplots of soil parameters versus soil carbon pools; Abbreviations of response variables; TC: Total Carbon, DOC: Dissolved Organic Carbon, MBC: Microbial Biomass Carbon, POXC: Permanganate Oxidizable Carbon

4.CONCLUSION

This study comprises a detailed field sampling campaign to collate ground truth datasets and derived the first-ever detailed baseline total C concentration spatial estimates across the paddy-growing soils in Sri Lanka. The derived AOA outputs can target additional samples first to improve the model quality, followed by the spatial estimates. Further, the study showed that soil carbon could be manipulated by soil chemical properties such as soil pH and soil N and nutrient cations of K, Ca, Fe, Cu, and Zn. The outputs generated from this study would provide the necessary information to nourish the country-specific data deficiency on carbon reservoirs and enhance the understanding of soil carbon drivers of tropical ecosystems. The findings will provide a successful initiative to improve the reliability of future spatial soil C predictions' by incorporating important soil carbon determinants.

5.ACKNOWLEDGMENT

We wish to acknowledge the financial assistance received from the National Research Council (NRC), Sri Lanka (Grant no: 17-011)

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