Short Communication / Mini Review

Understanding soil carbon processes in the Indian Sundarbans to abate climate change

Suvadip Neogi
Independent Researcher, India

Abstract
Tidal estuarine mangrove wetlands in the Indian Sundarbans form one of the most carbon (C) rich forest types in the tropics. Although there is a paucity of data for magnitude of different organic carbon (OC) fractions, distribution and their spatio-temporal dynamics in soils of the Indian Sundarbans. Studies need to address insights of long-term potentials of wetland mangrove soil C sequestration vis-à-vis climate change mitigation. This will have significant implications to wetland mangrove management. Results of such studies will improve currently limited understanding of the effects of soil physico-chemical-biological properties, vegetation attributes on the relative magnitude of varied soil organic C (SOC) fractions along different soil profiles in wetland mangrove ecology. This might prove to be helpful for devising management plans for adaptation, resilience and mitigation of climate change.

Keywords: Indian Sundarbans; Wetland mangrove; Soil organic carbon; Carbon fraction; Climate change; Adaptation and mitigation

IJSER

Introduction

The Sundarbans mangrove ecosystem covering about one million ha in the deltaic complex of the Rivers Ganga, Brahmaputra and Meghna is the world's largest coastal wetland and is shared between Bangladesh and India. The Indian Sundarbans is bordered by Bangladesh in the east, the Hooghly River in the west, the Dampier and Hodges line in the north, and the Bay of Bengal in the south [1]. Tidal estuarine mangrove wetlands in the Indian Sundarbans form one of the most productive ecosystems in the world due to high rate of nutrient turnover and form one of the most C rich forest types in the tropics [2,3]. Enormous load of sediments carried by the rivers contribute to its expansion and dynamics [4]. The important morphotypes of deltaic Sundarbans include beaches, mudflats, coastal dunes, sand flats, estuaries, creeks, inlets and mangrove swamps. The ecosystem is extremely prone to erosion, accretion, tidal surges and several natural disasters, which directly affect the top soil and the subsequent C density [4]. The OC stored in mangrove wetland soil sediments could exist in various chemical pools that are different in their susceptibility to microbial breakdown and hence their effects on soil C storage capacity [5]. The dynamics of SOC storage in mangrove wetlands is highly responsive to variations in natural and anthropogenic disturbances [6,7]. Increasing human disturbances viz. agricultural expansion and eutrophication could reduce the C sequestration potential of coastal estuarine mangrove wetlands considerably [6,7,8]. Yet, there is paucity of studies that examine the impacts of anthropogenic perturbations and land cover-land use management on the distribution of various SOC fractions in tidal estuarine mangrove wetlands in the Indian Sundarbans.

Soil organic carbon (SOC) pools and dynamics vis-à-vis ecological sustenance in the wetland mangrove ecosystems of Indian Sundarbans

The SOC pools and its dynamics are complex, heterogeneous, and consisting of different fractions including active/labile, slow, and passive, respectively. These vary in turnover time from hours to centuries, as well as their effects on the rate of organic matter (OM) decomposition, energy transfer, and nutrient cycling [9]. The labile organic C (LOC) fraction in soils is highly dynamic with a short turnover time, great ease to be broken down and utilized by microorganisms and has a good water solubility, high transport rate, and poor stability [10]. The LOC fraction is not only a driving force of soil nutrient supply with active involvement in soil biochemical reactions, but also a sensitive index of soil quality and potential productivity [11]. Changes in the slow and passive C pools are not easily detected, as they are manifested in few years to centuries in response to natural and long-term land cover-land use and management practices. Characterizing the relative magnitude of different SOC fractions is crucial to understand the C sequestration potential of mangrove wetland soils. Identification of the labile, more sensitive SOC fractions can contribute to the elucidation of changes in total SOC content at the early stage of perturbations [12] and the LOC fraction has a much greater contribution to SOC decomposition and greenhouse gas (GHG) production and is a better indicator of short-term changes in soil quality in comparison with the slow and passive fractions [13]. Mangrove ecosystems in the Indian Sundarbans are presently facing threats due to adverse effects of climate change associated with sea level rise (SLR), shift in the pattern of sediment deposition, nutrient enrichment (salt water intrusion i.e. SWI and high salinity) [14,15]. Besides, increasing salinity adversely affects biomass accumulation, and finally leading to the deaths of plants [16]. The SOC storage or loss in estuarine mangrove wetland are related to several factors including SLR, accumulation rate, nutrient enrichment, boundary conditions, subsidence and rate of wetland loss [17]. Coastal tidal inundation in conjunction with high salinity primarily affects SOC loss from mangrove soils in form of enhanced soil respiration as carbon dioxide (CO_2) flux, methane (CH_4) flux and export of dissolved organic carbon (DOC) to other systems [18]. Organic C inputs can be altered by SLR as a result of mangrove species' tolerance and growth response to changes in salinity or general shifts in plant community composition [19,20]. Holistic studies covering the afore-mentioned aspects are still limited in the coastal wetland mangrove ecosystem in the Indian Sundarbans.

Conclusion

Studies on the dominant controls of the relative magnitudes of different SOC fractions would help improve future management in enhancing the capability of mangrove wetland soils in long-term C storage in the Indian Sundarbans. Mangrove restoration and conservation goals in the Indian Sundarbans may provide a critical opportunity to incorporate 'blue carbon sequestration' as part of future wetland ecosystem services.

IJSER

References

1. Biswas S, Zaman S, Mitra A. 2017. Soil Characteristics of Indian Sundarbans: The Designated World Heritage site. Sci J Biomed Eng Biomed Sci. 1(2): 053-059.
2. Ray, R., Ganguly, D., Chowdhury, C., Dey, M., Das, S., Dutta, M.K., Mandal, S.K., Majumder, N., De, T.K., Mukhopadhyay, S.K., Jana, T.K.. 2011. Carbon sequestration and annual increase of carbon stock in a mangrove forest. Atmospheric environment. 45, 5016-5024.
3. Alongi, D.M., and Mukhopadhyay, S.K. 2015. Contribution of mangroves to coastal carbon cycling in low latitude seas. Agricultural and Forest Meteorology. 213, DOI: 10.1016/j.agrformet.2014.10.005.
4. Mitra, A., Banerjee, K., Sett, S. 2012. Spatial Variation in Organic Carbon Density of Mangrove Soil in Indian Sundarbans. National Academy Science Letters. 35, 147-154.
5. Köchy, M., Hiederer, R., Freibauer, A. 2015. Global distribution of soil organic carbon-Part 1: Masses and frequency distributions of SOC stocks for the tropics, permafrost regions, wetlands, and the world. Soil. 1, 351–365.
6. Jia, G., E. Shevliakova, P. Artaxo, N. De Noblet-Ducoudré, R. Houghton, J. House, K. Kitajima, C. Lennard, A. Popp, A. Sirin, R. Sukumar, L. Verchot, 2019: Land–climate interactions. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M, Belkacemi, J. Malley, (eds.)]. In press.
7. IPCC, 2019: Summary for Policymakers. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.
8. Hopkinson, C.S., Cai, W.J., Hu, X. 2012. Carbon sequestration in wetland dominated coastal systems-a global sink of rapidly diminishing magnitude. Current Opinion in Environmental Sustainability. 4, 186-194.

9. Wang, Q.K., Wang, S.L., Gao, H., Yu, X. 2005. Dynamics of soil active organic matter in Chinese fir plantation. Chinese Journal of Applied Ecology. 16, 1270–1274.
10. Neogi, S., Bhattacharyya, P., Roy, K.S., Panda, B.B., Nayak, A.K., Rao, K.S., Manna, M.C. 2014. Soil respiration, labile carbon pools and enzyme activities as affected by tillage practices in a tropical rice-maize-cowpea cropping system. Environmental Monitoring and Assessment. 186, 4223-4236.
11. Haynes, R.J. 2005. Labile Organic Matter Fractions as Central Components of the Quality of Agricultural Soils: An Overview. Advances in Agronomy, 85, 221–268.
12. Purakayastha, T.J., Rudrappa, L., Singh, D., Swarup, A., Bhadraray, S. 2008. Long-term impact of fertilizers on soil organic carbon pools and sequestration rates in maize–wheat–cowpea cropping system. Geoderma. 144, 370–378.
13. Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. Science. 304, 1623–1627.
14. Padhy, S.R., Bhattacharyya, P., Dash, P.K., Reddy, C.S., Chakraborty, A., Pathak, H. 2020. Seasonal fluctuation in three mode of greenhouse gases emission in relation to soil labile carbon pools in degraded mangrove, Sundarban, India. Science of the Total Environment. 705, 135909.
15. Bhattacharyya P, Dash PK, Padhy SR and H Pathak. 2020. Estimation of Greenhouse Gas Emission in Mangrove-Rice Ecosystem. NRRI Research Bulletin No. 22, ICAR-National Rice Research Institute, Cuttack, Odisha, 753006, India, pp 20+viii.
16. Mukhopadhyay, S.K., De, T.K., Jana, T.K. 2006. Fluxes of nutrients from the tropical river Hooghly at the land-ocean boundary of Sundarbans, NE coast of Bay of Bengal, India. Journal of Marine System. 62, 9-21.
17. DeLaune, R.D., and White, J. R. 2012. Will coastal wetlands continue to sequester carbon in response to an increase in global sea level?: a case study of the rapidly subsiding Mississippi river deltaic plain. Climatic Change. 110, 297-314.
18. Liu, Jiangong and Lai, Y.F. Derrick. 2019. Subtropical mangrove wetland is a stronger carbon dioxide sink in the dry than wet seasons. Agricultural and Forest Meteorology. 278, 107644.
19. Chambers, L.G., Davis, S.E., Troxler, T., Boyer, J.N., Downey-Wall, A., Scinto, L.J. 2014. Biogeochemical effects of simulated sea level rise on carbon loss in an Everglades mangrove peat soil. Hydrobiologia. 726, 195-211.
20. Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson, 2019: Changing Ocean, Marine Ecosystems, and Dependent Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.
IJSER