International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 187-192, 2022; Article no.IJPSS.94144
ISSN: 2320-7035

Qualitative Assessment of Soil Organic Carbon Pools using UV-Vis Spectroscopy

Kolagani Hari Kumar [a] and M. C. Kundu [a*]

[a] Department of Soil Science and Agricultural Chemistry, Institute of Agriculture (Palli Siksha Bhavana), Visva-Bharati, Sriniketan - 731 236, West Bengal, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242628

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/94144

Original Research Article

Received: 18/10/2022
Accepted: 20/12/2022
Published: 22/12/2022

ABSTRACT

Soil acts as the niche of Carbon (C). Soil carbon sequestration is of paramount importance for sustaining soil health as well as mitigating global warming. Studies on soil organic C content of both surface as well as deep subsoil are very important. Besides, studies on C in rice soil, as well as non-rice upland soil of tropical India, are also of principal importance. With this background, the present experiment was undertaken to recognize qualitative characteristics of water-soluble soil C in rice soil and non-rice soil along depth using UV-Vis spectroscopy. Soil sampling was done from representative rice and non-rice soil ecologies in West Bengal from 0-20 cm, 100-120 cm and 120-140 cm soil depths. Quality and stability of C can be estimated by studying the nature of absorbance of water-soluble C in UV-visible range. Results indicated a higher absorbance of C in the subsurface than that of surface soil. Similarly, higher absorbance of C was recorded in soil collected from rice ecology compared to non-rice ecology. Irrespective of soil depth, it was noted that there was more humified as well as aromatic C in rice ecologies than that in non-rice ecologies. Thus soil of lower depth as well as rice ecologies acts as a better niche for sequestrating C in soil.

**Corresponding author: E-mail: mckundu@gmail.com;*

Keywords: Soil carbon; rice ecology; non-rice ecology; soil depth; UV-visible spectroscopy.

1. INTRODUCTION

Soil is kenned as the most immensely colossal terrestrial carbon pool on the Earth where soil organic matter (SOM) constitutes the consequential biologically active form [1]. Organic matter (OM) content in soil plays a paramount role to amend the soil's biological, chemical and physical properties and is also an indicator of the quality and productivity of soils [2, 3]. In India, the area under rice cultivation is approximately 43.7 m ha. Majorly under submerged rice soil avails methane emission and submerged rice soils are kenned to hold higher magnitudes of resilient C among all terrestrial ecosystems than drylands [4,5]. Submerged rice soil have the highest C density and act as a paramount niche for C sequestration in lowland soils, these soils recorded higher C density compared to upland non-rice soils [4,6,7].

Most of the physical and chemical procedures used in assessing DOC characteristics cannot be utilized while assessing the water soluble C present in soil [8]. Thus, utilization of ultraviolet-visible (UV-Vis) absorption spectrophotometry was utilized to categorize the aromaticity, hydrophobic content, and biodegradability of soil organic carbon (SOC) [9, 10,11].

2. MATERIALS AND METHODS

2.1 Soil Sampling

Representative soil samples were collected during 2019-2020 from Gayeshpur, Nadia district of West Bengal from representative rice-rice (Rice ecology) and vegetable-vegetable (Non-rice ecology) cropping systems which were supposed to be existed in that site for at least the last 15 (fifteen) years to have a look on the trend of soil carbon as affected by cropping system and management practices [12]. Representative soil samples were collected from five sites of each cropping system from three depths viz., 0-20 cm, 100-120 and 120-140 cm. Thus, a total of 30 (2 cropping systems x 5 sites x 3 depth) representative soil samples were collected from the study sites. The soil samples collected from representative rice and non-rice ecologies were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of water-soluble C and other soil properties. GPS was used for noting the latitude and longitude of the sampling sites.

2.2 Spectroscopic Analysis Dissolved C Pools of Soil

Spectroscopy has been identified as the most essential tool in studying and characterizing the structure of intricate organic compounds [13]. The aliphatic and aromatic compounds of DOC can be characterized/estimated by UV-Vis spectroscopy [14] which is also capable of estimating the hydrophobic content and biodegradability of DOC. Here, absorbance characteristics as well as functional groups as affected by soil depth and rice and non-rice soil ecologies were studied in details. The various wavelengths of light with their property and supporting references are indicated hereunder:

Table 1. The list of wavelengths with their property and reference

Wavelength (nm)	Property determined	Reference
250	Aromaticity, apparent molecular weight	Peuravuori and Pihlaja, [15]
254	Aromaticity	Abbt-Braun and Frimmel, [16], Hur and Schlautman [17]
260	Hydrophobic C content	Dilling and Kaiser, [10]
272	Aromaticity	Traina et al., [18]
280	Hydrophobic C content, Humification index, Apparent molecular size	Chin et al., [19], Korshin et al., [20], Kalbitz et al., [21]
285	Humification index	Kalbitz et al., [22]
300	Characterization of humic substances	Artinger et al., [23]
350	Apparent molecular size	Korshin et al., [20]
365	Aromaticity, apparent molecular weight	Peuravuori and Pihlaja, [15]

3. RESULTS AND DISCUSSION

3.1 UV-Vis Spectroscopy to Characterize Water-Soluble C Pools

While comparing the water-soluble C pools using UV-Vis spectroscopy along soil depths, it showed a higher residence time of C in deep subsoil compared to surface soil layers irrespective of cropping systems studied. Again, the soils of rice-rice cropping systems (rice-ecology) also designated recalcitrant C pool compared to non-rice soil ecologies.

Using UV-Vis, estimation of the aromatic moiety is much easier and accurate as UV absorption of organic solutes is directly proportional to their content of aromatic compounds [18, 19]. The stability and quality of C in soils can be determined by the absorbance characteristics of water-soluble C pools in different wavelengths (in UV- visible range). The higher aromaticity and larger molecular weight of soil organic matter was noted in higher absorbance in 250, 254, 272, and 365 nm wavelengths [15,20,17]. Similarly, greater absorbance in 260 and 280 nm gives an indication of higher hydrophobic C and greater humification [19,20,10,24]. Likewise, the molecular size of the organic compounds can be indicated by the absorbance at 280 and 350 nm [19,20,10,24].

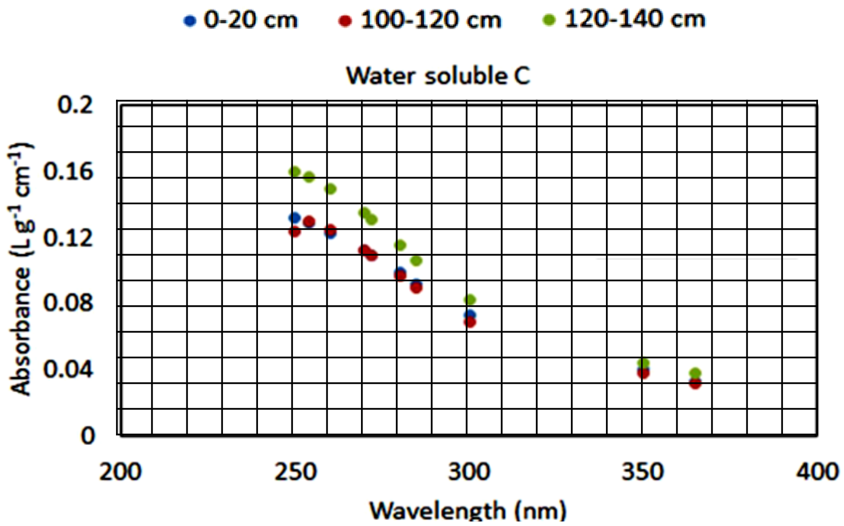

Fig. 1. The absorbance of water-soluble C pool in different soil depths in various discrete points

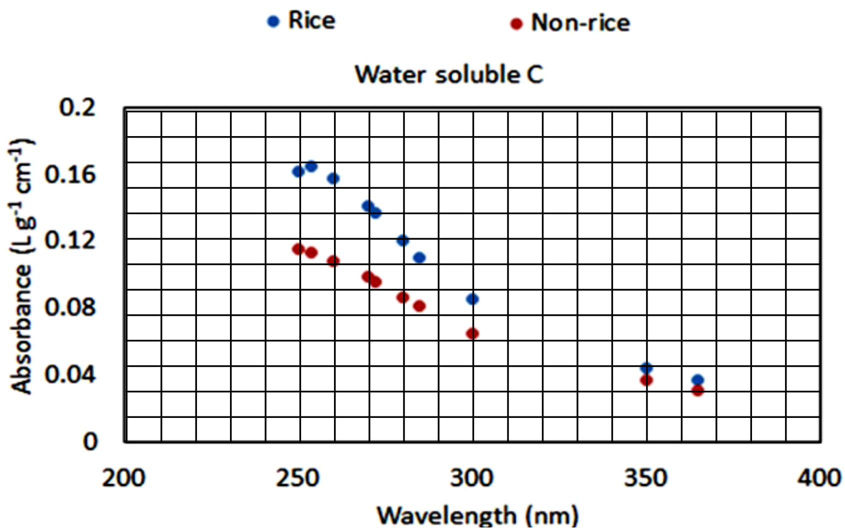

Fig. 2. The absorbance of water-soluble C pool in different soil ecologies in various discrete points

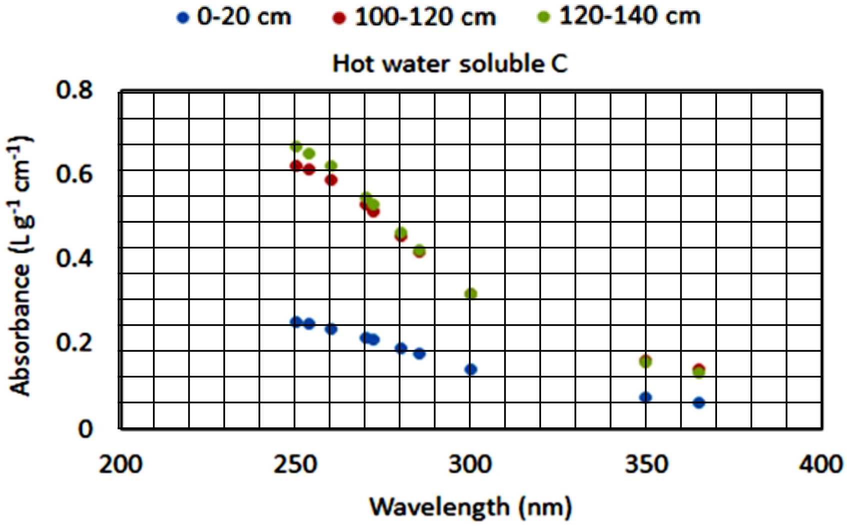

Fig. 3. The absorbance of hot water-soluble C pool in different soil depths in various discrete points

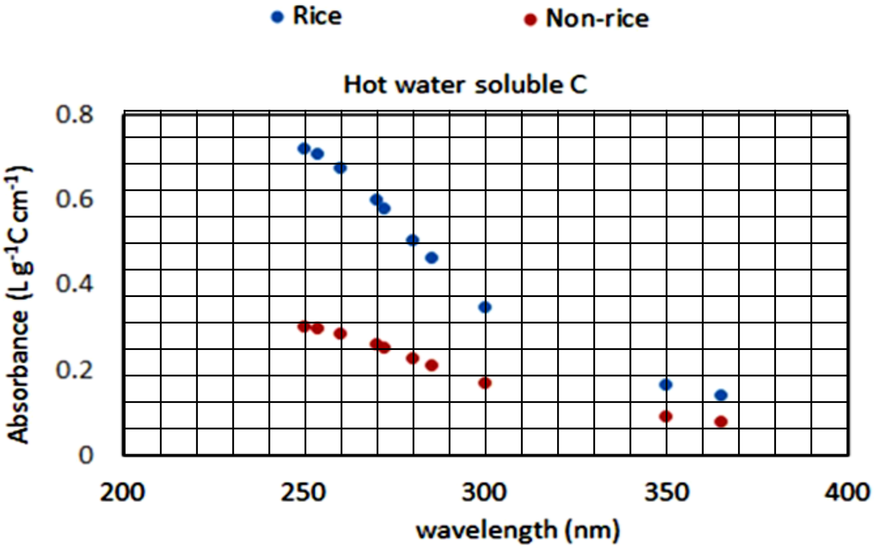

Fig. 4. The absorbance of hot water-soluble C pool in different soil ecologies in various discrete points

Following this, when spectral values (of these specific wavelengths) of the water-soluble (both normal water soluble and hot water soluble) pools of soil C were studied, it clearly indicated a higher absorbance of the subsurface soil C in comparison to soils of surface layers (Figs. 1, 3). Likewise, higher absorbance of C pools was noted in soils collected from rice soil ecology compared to non-rice soil ecologies (Figs. 2, 4). It also specifies that soil of lower depths has greater aromaticity, higher humification, and a larger molecular size of organic matter compared to surface soil. It was observed that irrespective soil depths, soil collected from rice-rice cropping systems (rice ecology) had an organic matter with higher aromatic and humified characteristics than that of soil collected from vegetable-vegetable (non-rice ecology) cropping systems. Finally, it can be said that soil of lower depth (deep soil) can acts as a better niche for C sequestration compared to surface soil, while the soil of rice ecology can also act as a better sink for soil C sequestration compared to non-rice ecologies.

4. CONCLUSIONS

In this study, water soluble C pools were assessed qualitatively using UV-Vis spectroscopy. The higher aromaticity, molecular weight, molecular size, and humification of organic matter were recorded in lower soil depth. The higher aromaticity and molecular weight of soil C were noted in rice soil ecology compared to non-rice soil ecology. Therefore, the potentiality of subsoil to act as a better sink for C sequestration was more than that of surface soil and rice soil acted as a better niche in soil C sequestration compared to non-rice soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhattacharyya T, Pal DK, Ray SK, Chandan P, Mandal C, Telpande B, Deshmukh AS, Tiwary P. Simulating change in soil organic carbon in two long fertilizer experiments in India: with the Roth C model. Climate Change and Environmental Sustainability. 2013;2:107-117.
2. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004;304:1623-1627.
3. Brahim N, Blavet D, Gallali T, Bernoux M. Application of structural equation modeling for assessing relationships between organic carbon and soil properties in semiarid Mediterranean region. Int J Environ Sci Tech. 2011;8(2):305–320.
4. Xie ZB, Zhu JG, Liu G, Cadisch G, Hasegawa T, Chen CM, Sun HF, Tang HY, Zeng Q. Soil organic carbon stocks in China and changes from 1980s to 2000s. Global Change Biology. 2007;13:1989-2007.
5. IPCC. Climate change 2013. In: the physical science basis. Contribution of working group i to the fifth assessment report of the intergovernmental panel on climate change in: Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (Eds.). Cambridge University Press, Cambridge, United Kingdom and New York; 2013.
6. Chen X, Hu Y, Xia Y, Zheng S, Ma C, Rui Y, He H, Huang D, Zhang Z, Ge T, Wu J, Guggenberger G, Kuzyakov Y, Su Y. Contrasting pathways of carbon sequestration in paddy and upland soils. Glob Chang Biol. 2021;27(11):2478-2490.
   DOI: 10.1111/gcb.15595.
7. Yan X, Cai Z, Wang S, Smith P. Direct measurement of soil organic carbon content change in the croplands of China. Global Change Biology. 2011;17:1487–1496.
   Available: 10.1111/j.1365-2486.2010.02286.x
8. Simonsson M, Kaiser K, Andreux F, Ranger J. Estimating nitrate, dissolved organic carbon and DOC fractions in forest floor leachates using ultraviolet absorbance spectra and multivariate analysis. Geoderma. 2005;124:157-168.
9. Hautala K, Peuravuori J, Pihlaja K. Measurement of aquatic humus content by spectroscopic analyses. Water Research. 2000;34:246-258.
10. Dilling J, Kaiser K. Estimation of the hydrophobic fraction of dissolved organic matter in water samples using UV photometry. Water Research. 2002;36(20): 5037-5044.
11. Croué JP, Benedetti MF, Violleau D, Leenheer JA. Characterization and copper binding of humic and non humic organic matter isolated from the South Platte River: Evidence for the presence of nitrogenous binding site. Environmental Science and Technology. 2003;37:328–336.
12. Carillo A, Sannino G, Artale V, Ruti PM, Calmanti S, Dell Aquila A. Steric sea level rise over the Mediterranean Sea: present climate and scenario simulations. Climate Dynamics. 2012;39:2167-2184.
13. Wang K, Li W, Gong X, Li Y, Wu C, Ren N. Spectral study of dissolved organic matter in biosolid during the composting process using inorganic bulking agent: UV–vis, GPC, FTIR and EEM. International Biodeterioration & Biodegradation. 2013; 85:617-623.
14. Li MX, He XS, Liu J. Study on the characteristic UV absorption parameters of dissolved organic matter extracted from chicken manure during composting. Spectroscopy and Spectral Analysis. 2010;30:3081-3085.
15. Peuravuori J, Pihlaja K. Molecular size distribution and spectroscopic properties of aquatic humic substances. Analytica Chimica Acta. 1997;337(2):133-149.
16. Abbt-Braun G, Frimmel FH. Basic characterization of Norwegian NOM samples— similarities and differences. Environment International. 1999;25(2-3): 161-180.

17. Hur J, Schlautman MA. Molecular weight fractionation of humic substances by adsorption onto minerals. Journal of Colloid and Interface Science. 2003; 264(2):313-321.
18. Traina SJ, Novak J, Smeck NE. An ultraviolet absorbance method of estimating the percent aromatic carbon content of humic acids. Journal of Environmental Quality. 1990;19(1):151-153.
19. Chin YP, Aiken G, O'Loughlin E. Molecular weight, polydispersity, and spectroscopic properties of aquatic humic substances. Environmental Science and Technology. 1994;28:1853-1858.
20. Korshin GV, Kumke MU, Li CW, Frimmel FH. Influence of chlorination on chromophores and fluorophores in humic substances. Environmental Science & Technology. 1999;33(8):1207-1212.
21. Kalbitz K, Schmerwitz J, Schwesig D, Matzner E. Biodegradation of soil-derived dissolved organic matter as related to its properties. Geoderma. 2003;113(3-4):273-291.
22. Kalbitz K, Geyer S, Geyer W. A comparative characterization of dissolved organic matter by means of original aqueous samples and isolated humic substances. Chemosphere. 2000;40(12):1305-1312.
23. Artinger R, Buckau G, Geyer S, Fritz P, Wolf M, Kim JI. Characterization of groundwater humic substances: influence of sedimentary organic carbon. Applied Geochemistry. 2000;15(1):97-116.
24. Kalbitz K, Schwesig D, Schmerwitz J, Kaiser K, Haumaier L, Glaser B, Leinweber P. Changes in properties of soil-derived dissolved organic matter induced by biodegradation. Soil Biology and Biochemistry. 2003;35(8):1129-1142.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/94144