*Original Research Article*

# Long-term effects of rice and non-rice ecology on pools of carbon in surface and deep soil in farmers' fields

## ABSTRACT

The greatest terrestrial sink of carbon (C) is soil. In addition to improving soil quality, carbon absorption in soil helps reduce atmospheric $CO_2$ loading. Not only the surface soil, but also the deep sub-soil act as a storehouse of C. Besides, the study of C dynamics in tropical rice soil is important in countries like India where rice is the predominant crop and soil C sequestration is at risk due to high temperatures. In this context, this study tried to understand the C dynamics in surface as well as deep soil under rice and non-rice ecology.Representative soil samples were collected from five sites of rice-rice (rice ecology) and vegetable-vegetable (non-rice ecology) cropping systems from three depths viz., 0-20 cm, 100-120 and 120-140 cm from long-term farmer's fields of Nadia district of West Bengal belonging to Alfisols to compare C dynamics of surface and deep soils as well as rice and non-rice ecology. Results indicated that surface soils exhibited higher amount of total C, total organic C and inorganic C in comparison to deep soil irrespective of crop ecologies. The rice ecology showed higher total C and total organic C in comparison to non-rice soil. As per water solubility, water-soluble (room temperature) C and hot water-soluble C which was highest in surface soil compared to deep soil as the former usually receive maximum amount of fresh C input compared to deep soil. Irrespective of crop ecology, water-soluble C (WSC), hot water-soluble C (HWC), recalcitrant C (RC) was highest in surface soil compared to deep soils. Again, irrespective of soil depth, WSC and RC was highest in rice ecology and lowest in non-rice ecology. But, HWC content was highest in non-rice ecology and lowest in rice ecology. Irrespective of crop ecology, per cent contribution of labile pool of C (WSC+ HWC) and that of recalcitrant pool of C (RC)towards TOC was highest and lowest respectively. However, irrespective of soil depth, per cent contribution of labile pool of C and that of recalcitrant pool of Ctowards TOC was highest and lowest insoilsundernon-riceecology and rice ecology respectively. Thus, this study conclusively indicated the potential of subsoil layer to act as a C sink in comparison to surface soil. The rice soil also has been identified as a niche for soil Csequestration.

***Keywords:****Carbon pools, deep soil, farmer's field, rice, surface soil, vegetable*

## 1. INTRODUCTION

Soil organic matter (SOM) is an essential form of biological activity in soil and is recognized as the Earth's greatest terrestrial carbon pool[1,2,3,4]. The SOM plays a significant role in improving the soil's biological, chemical, and physical properties and is also an indicator of the quality and productivity of soils [5]. The maintenance of SOM is very crucial for crop production and productivity; it improves soil fertility through various actions, viz., production of organic acids, phytohormones, solubilization of nutrients, and enhancing water holding capacity [6,7]. Generally, crop residue and animal residue are the chief sources of soil organic matter content. However, soil microorganisms act as secondary sources of organic matter, and they are helpful for decomposition. The SOM is present in various forms and stages; it might be changed due to the decomposition rate by microorganisms [8].

Both the primary component of soil organic matter and a major player in the global carbon cycle and climate change is soil organic carbon (SOC)[9] and it controls a number of soil characteristics, including bulk density, aggregate stability, porosity, aeration, and water retention capacity [10]. Organic carbon decomposition stimulates certain types of substances, and these substances act as regulators in the soil through ion exchange and retention, especially the NPK minerals [11]. A higher content of soil organic carbon indicates good quality and productivity soil, and it improves soil health, fertility, and sustainable crop production in long-term cropping systems. Tropical countries like India and Asian countries have lowest average of organic matter content than in comparison with other countries [12]. In India, in an average of 0.5% SOC content is present [13], however, it very less amount than the world average organic carbon content [14] and total carbon stock of Indian soil is 14 Pg (upper 30 cm) and 64 Pg (150 cm) [15].

In India, the area under rice cultivation is nearly 43.7 m ha majorly, and submerged conditions of rice cultivation help methane emission, rice cultivated soils are known to retain higher amounts of resilient C among all terrestrial ecosystems than drylands [16].

Based on its chemical characteristics and techniques of extraction, the entire soil C has been separated into many pools [2,17]. The pools include the inorganic pool, organic pool, water-soluble C (WSC), hot water-soluble C (HWC), and recalcitrant pool of C (RC).Understanding the dynamics of carbon cycling in soil ecosystems, including carbon storage, turnover rates, and possible reactions to environmental changes, is possible through the partitioning of soil carbon into different pools [2]. The various types of soil carbon and their functions in soil fertility, storage of carbon, and ecosystem functioning are characterized by a variety of extraction techniques and chemical characteristics.Given this context, the current investigation was carried out in order to evaluate the pools of C in surface and deep soils under both lowland rice and upland non-rice ecology.

## 2. MATERIALS AND METHODS

### 2.1 SoilSampling

Representative soil samples were collected during 2019-2020 from long-term farmer's fields of Nadia district of West Bengal belonging to Alfisols soil order 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 [18]. 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 to compare C dynamics of surface and deep soils as well as rice and non-rice ecology. Thus, a total of 30 (2 cropping systems x 5 sites x 3 depth) soil samples were gathered from the study sites. The composite soil sampling was done for each depth of each sites of representative rice and non-rice ecologies and were then air-dried, mixed well and passed through a 2 mm sieve and used subsequently for the analysis of different pools of C.

### 2.2 Soilanalysis

Soil samples were air-dried, sieved with 2 mm sieves and stored for determination of different pools of soil C.

#### *2.2.1 Total C*

To estimate the total C content, the soil samples were prepared following the method of Nelson and Sommers [19].

#### *2.2.2 Inorganic C*

Soil inorganic C i.e. total carbonates content in soil were determined by rapid titration method using dilute HCl and bromothymol blue as indicator [20].

#### *2.2.3 Total organic C*

The total organic C was obtained by subtracting the inorganic C from total C.

#### *2.2.4 Water-soluble C (WSC)*

It was estimated by mixing soil and distilled water in a 50 ml centrifuge tube at a ratio of 1:10 (in this study, 3 g of soil in 30 ml distilled water) followed by 30 minutes extraction at $20^{o}$ C and centrifugation at 3000 rpm for 20 minutes [21]. After centrifugation, the supernatant was filtered to get the WSC. The C remaining in this solution was named as labile pool 1($L_1$). The estimation of water-soluble C was done following the method of Nelson and Sommers [19].

#### *2.2.5 Hot water extractable C (HWC)*

After removing the WSC, second labile pool of C ($L_2$) was extracted from the remaining soil samples using hot water treatment [17]. The estimation of hot water-soluble C was done following the method of Nelson and Sommers [19].

### *2.2.6 Recalcitrant C (RC)*

The recalcitrant C was determined by subtracting the sum of two water soluble pools from the TOC. Recalcitrant C pool (RC) = TOC−($L_1$+$L_2$)

### 2.3 Statisticalanalysis

Statistical analysis has been conducted using SPSS 20.0 version.

## 3. RESULTS AND DISCUSSION

### *3.1 Total C, organic C and Inorganic C pools*

The status of soil total C, organic C and inorganic Cof soils of Nadia district of West Bengal, India is shown inTable1 and Fig. 1. The impactofsoildepthandcrop ecologyon the soil C pools has been presented in Table 1 and Fig. 1. It was noted from the table that surface soils exhibited higher amounts of total C, total organic C, and inorganic C in comparison to deep soil irrespective of the selected sites. This is quite natural as the surface soil receives the maximum C input in terms of discarded plant biomass. However, outcomes revealed a significantpresenceofTCandTOCinsubsoillayers.Again, it was observed that the amountofTCand TOC was higher in soils under rice ecology in comparison to upland soils of non-rice ecology. This was possibly due to capacity of rice soil to store high amount of C. The absence of $O_2$ as terminal electron acceptor in submerged rice soil resulted slow oxidation of C and higher turnover time [22]. All the soils stored a small amount of inorganic C. However, as evident from results, this C pool was also slightly higher in surface soils in comparison to subsoil layers.

**Table 1. Status of total C, total organic C and inorganic C at different depths and crop ecology**

| Soil depth (cm) | Soil C status (g kg$^{-1}$) |
|---|---|

| | **Total C** | **Total organic C** | **Inorganic C** |
|---|---|---|---|
| 0-20 | 6.34$^a$ | 6.16$^a$ | 0.18$^a$ |
| 100-120 | 3.45$^b$ | 3.35$^b$ | 0.10$^b$ |
| 120-140 | 2.65$^c$ | 2.54$^c$ | 0.11$^b$ |
| ***Significant level*** | ** | ** | * |
| **Cropping system** | | | |
| Rice | 4.32 | 4.18 | 0.14 |
| Non-Rice | 3.86 | 3.74 | 0.12 |
| ***Significant level*** | ** | ** | *ns* |
| ***Depth x cropping system*** | ** | ** | * |

** ≤ 0.01, * ≤ 0.05, ns: not significant according to F-value of ANOVA. Different lower-caselettersindicatesignificantlydifferentvaluesalongsoildepthat$P \leq 0.05$according to Duncan's test for separation ofmeans.

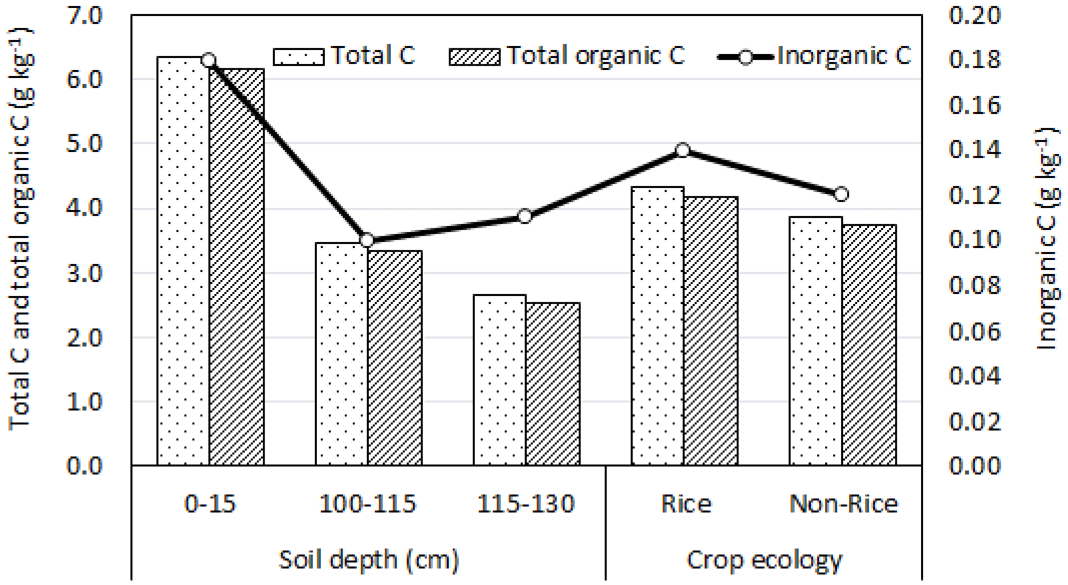

**Fig 1. Distribution of total C, total organic C and inorganic carbon at different depths and different crop ecology**

### *3.2 Water soluble C (WSC), hot water-soluble C (HWC), recalcitrant C in soils*

Analysis of water-soluble C pools represented that there was its higher content in surface soil than deep soil. This was true for both water-soluble C pool (L1) as well as hot water-soluble pool (L2). This is quite expected as these pools represent very labile fraction of soil C [23]andsurfacesoil,beingtherecipientofregular C input through leaf and litter fall has a large pool of labile C [24]. Apart from water and hot water-soluble C, recalcitrant pool which was derived by subtracting these two pools from TOC also showed decreasing trend along depth. While comparing the crop ecology irrespective of soil depth water-soluble and recalcitrant C was highest in rice ecology and lowest in non-rice ecology. But, hot water-soluble C content was highest in non-rice ecology and lowest in rice ecology. Irrespective of soil depth and crop ecology, the hot water-soluble Carbon pool was quantitatively much higher than the water soluble pool at room temperature.

However, the variation of water soluble, hot water-soluble C as well as the recalcitrant pool cannot be a representative of the true soil C dynamics, as the soil total organic C varied a lot with depth and ecology. To resolve this issue, the per cent contribution of the sum of water-soluble pools and hot water-soluble pool (i.e., L1+ L2) as well as recalcitrant pools towards TOC was calculated. The table 2 depicted higherper cent contribution of sum of WSC and HWC poolstowards TOC in surface soil compared to deep sub soil irrespective of crop ecology. On the contrary, recalcitrant C as a % of TOC got increased in the subsoil layers than surface soil irrespective of crop ecology. It indicated a higher residence time of C in subsoil, as found in earlier studies also[21].

The comparison of rice and non-rice ecology (irrespective of soil depth) resulted higher per cent contribution of sum of WSC+HWC towards TOC in soils under non-rice ecology (Table 4) than rice ecology. The percentage contribution of recalcitrant C pool towards TOC was more in soils under rice ecology. It means, a higher C stability in rice soils which possibly was due to thewater logging and subsequent anaerobic conditions of rice soils. The absenceof $O_2$ possibly resulted slower microbial decomposition and low C mineralization [25,26].

**Table 2. Status of water-soluble C (WSC), hot water-soluble C (HWC), recalcitrant C in different depth and crop ecology and their contribution towards total organic C**

| **Pools of C** | **WSC (mg kg$^{-1}$)** | **HWC (mg kg$^{-1}$)** | **Recalcitrant C (g kg$^{-1}$)** | $\frac{WSC + HWC}{TOC}\ X\ 100$ | $\frac{Recalcitrant\ C}{TOC}\ X\ 100$ |
|---|---|---|---|---|---|
| **Soil depth (cm)** | | | | | |
| 0-20 | $46.24^a$ | $194.64^a$ | $5.97^a$ | $3.88^a$ | $96.12^a$ |
| 100-120 | $14.20^b$ | $30.96^b$ | $3.30^b$ | $1.35^b$ | $98.65^a$ |
| 120-140 | $10.36^c$ | $26.44^b$ | $2.50^c$ | $1.45^b$ | $98.55^a$ |
| ***Significant level*** | ** | ** | * | * | ***ns*** |
| **Crop ecology** | | | | | |
| Rice | 24.96 | 70.52 | 4.08 | 2.28 | 97.72 |
| Non-rice | 19.72 | 90.88 | 3.63 | 2.96 | 97.04 |
| ***Significant level*** | ** | ** | * | ** | ***ns*** |
| **Depth × cropping system** | | | | | |
| ***Significant level*** | * | ** | * | * | ***ns*** |

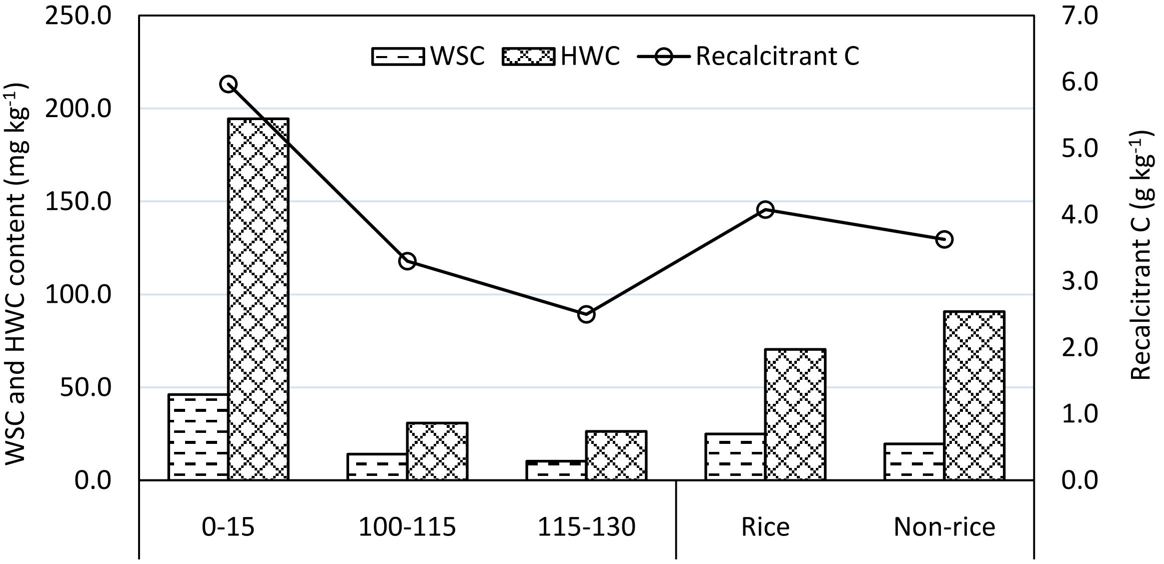

**Fig 2. Status of water-soluble C (WSC), hot water-soluble C (HWC), recalcitrant C at different soil depth and crop ecology**

## 4. CONCLUSION

The results revealed higher total C and total organic Cin surface soil in comparison to deep soil. The rice ecology showed higher total C and total organic C in comparison to non-rice soil. As per water solubility, water-soluble (room temperature) C and hot water-soluble C which was highest in surface soil compared to deep soil as surface soil usually receive maximum amount of fresh C input compared to deep soil.Irrespective of crop ecology, water soluble C (WSC), hot water-soluble C (HWC), recalcitrant C was highest in surface soil compared to deep soils. Again, irrespective of soil depth, water-soluble and recalcitrant C was highest in rice ecology and lowest in non-rice ecology. But, hot water-soluble C content was highest in non-rice ecology and lowest in rice ecology.Irrespective of crop ecology, per cent contribution of labile pool of C (WSC+ HWC) and that of recalcitrant pool of C towards TOC was highest and lowest respectively. However, irrespective of soil depth, per cent contribution of labile pool of C (WSC+HWC)and that of recalcitrant pool of C towards TOCwas highest and lowest insoilsundernon-riceecology and rice ecology respectively.

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