

Carbon Dynamics in Rice based Farming Systems of *Kari* Soils

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ABSTRACT

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An experiment was carried out in rice field of Krishi Vigyan Kendra (KVK), Kumarakom during 2017 to 2018 to study the influence of rice-fish and rice-water fallow systems on carbon dynamics in *Kari* soil. The samples were analysed for bulk density, soil pH and soil C pools. Bulk density (BD) of the soil showed no significant difference between rice-fish and rice-water fallow systems. However significant difference was recorded between surface and sub surface soils with maximum in sub surface soils. Soil pH, soil organic C (SOC), Particulate organic C (POC) were found to be higher in rice-fish system compared to rice-water fallow system and surface soil contained higher pH, SOC, POC than sub surface soil. The treatments found to be non significant with respect to labile C (LC). The study revealed that the rice-fish system significantly increased the different C pools, soil pH compared to rice-water fallow system in *Kari* soils.

Introduction

The soil organic carbon (SOC) pool is of great concern because it may represent a source as well as a sink of atmospheric CO₂ (IPCC, 2007) and its storage has been widely considered as a measure to mitigate global climate change through carbon sequestration in soil (Huang *et al.*, 2010). The soil may be subjected to loss and gain of organic C, depending on soil type, vegetation type, temperature, erosion, and land management.

Land use and soil management practices play an important role in C sequestration in agricultural land as well. Some of the SOC fractions, such as labile carbon, particulate organic carbon (POC) and microbial biomass carbon (MBC) are known to be more sensitive indicators of soil management than total SOC (Chan, 2001; Gong, *et al.*, 2009). Changing patterns of land use and management practices have direct and indirect effects on soil organic pools, because of the changes in cropping practices, irrigation, tillage, fertilization

primary productivity, litter quantity and quality. Management practices or technologies that augment C input to the soil and reduce C loss or both, lead to net C sequestration in soil and reduce the greenhouse effect.

Rice is the major food crop in Asia and about 80 per cent of it is grown under flooded conditions. The flooded rice ecosystem has the capacity to store C in the soil and can behave as net C sink (Bhattacharyya *et al.*, 2013). In the flooded conditions, the presence of standing water and the soil saturation decreases the organic matter decomposition, acting as significant sinks for C and nutrients (Mitsch and Gosselink, 2007).

Kari soils are deep black in colour, heavy in texture, poorly aerated and ill drained. The name *kari* is derived from the deep black colour of soil where large mass of woody matter at various stages of decomposition occur embedded in these soils. In these soils the major rice based cropping system is rice followed by water fallow or rice followed by fish. The fish species usually reared is carp species which helps in reducing cost of tillage as the soil gets well puddled by the movement of fish. The addition of organic matter into the rice field as a result of fish culture helps to reduce the use of chemical fertilizers in paddy crop. The recycling of crop residue as a source of fish feed upon decomposition is another advantage of the system. Study on the influence of rice cultivation, fish culture or keeping land as water fallow on the organic C stock of soils of these two systems can bring light into the effective management of these lands as a C sink.

According to IPCC (2001), the management of rice farming for positive climate impact must consider the combined effects of C storage and greenhouse gas emissions in soil. Estimating soil C pools in these systems would help to identify the carbon fractions

which are dominant and help to prioritize land use system for C sequestration in soil which also has co-benefits of restoring soil fertility, improving crop productivity, profitability and reducing environmental pollution. Hence, an experiment has been undertaken to study the influence of rice-fish and rice-water fallow systems on C dynamics in *Kari* soils of Kuttanad.

Materials and Methods

The experiment was carried out at rice field of Krishi Vigyan Kendra (KVK), Kumarakom during 2017 to 2018. The major farming systems in *kari* soils of Kumarakom includes rice-fish and rice-water fallow system. The soil samples were collected from surface (0-20 cm) and subsurface soil depths (20-40 cm) at two different stages like before and after rice cultivation. The experiment was carried out in completely randomized design with 4 treatments and 10 replications (number of soil samples) which included, T₁- rice- fish system; soil samples from soil depth 0-20 cm, T₂- rice-fish system; soil samples from soil depth 20-40 cm, T₃- rice-water fallow system; soil samples from soil depth 0-20 cm, T₄- rice-water fallow system; soil samples from soil depth 20-40 cm. The samples were analysed for bulk density soil pH, soil C pools such as SOC, labile C, POC.

Analytical methods

The bulk density was determined by the core sampling method (Black *et al.*, 1965). The soil pH was measured using pH meter (Jackson, 1958). The SOC was determined by Walkley and Black's (1934) rapid titration method.

To determine LC, three grams of air-dried soil (<2 mm) sample was taken in a 50 ml centrifuge tube and to that 30 ml of 20 mM KMnO₄ was added. Run a blank without taking soil. The content was shaken for 15

minutes and it was centrifuged for 5 minutes at 2000 rpm and 2 ml aliquot of supernatant solution was transferred into 50 ml volumetric flask and read the absorbance at 560-565 nm and concentration of KMnO_4 was determined from standard calibration curve and the labile C calculated (Blair *et al.*, 1995).

Particulate organic C (POC) was determined by sodium hexa meta phosphate dissolution method as described by Camberdella and Elliott (1992) and Hassink (1995). Ten gram of soil sample was taken in a conical flask and 30 ml of 0.5 percent sodium hexa meta phosphate solution was added and shaken for 15 h on a reciprocal shaker.

The dispersed soil sample was passed through 53 μm sieve. After rinsing several times with water, the material which was retained on sieve and the fine fraction that was collected in the beaker were dried at 50°C overnight. The POC fraction of >53 μm (coarse fraction) and <53 μm (fine fraction) were analysed for carbon content by Walkley and Black's (1934) rapid titration method. The results were statistically analyzed using ANOVA technique.

Results and Discussions

The results of the study showed that the treatments differed significantly for bulk density, soil pH, SOC and POC.

The data pertaining to the effect of treatments on bulk density of soil at different stages are given in table 1. The treatments found to be significantly different during both the stages, however the bulk density between surface soils (T_1 and T_3) was found to be on par during both before rice and after rice cultivation and also the bulk density between sub surface soils (T_2 and T_4) was found non significant during both the stages. The significant difference was only observed between surface (0-20 cm depth) and sub

surface soil (20-40 cm depth). BD was higher in subsurface soil in both the systems. This was in agreement with the findings of Ahukaemere and Akpan (2012).

Higher pH was observed in rice-fish system compared to rice-water fallow system (Table 2). As reported by Han (2007) soil pH changed in the following orders among various land use practices: catfish pond soils > paddy soils > forest soils. Omofunmi *et al.*, (2016) investigated the impact of fish pond effluents on soils, the results shown that pH of effluent discharged soils were relatively higher or alkaline than that of non-effluent discharged soils.

The soil pH decreased with increase in depth (Table 2). This might be due to high organic matter in sub soil which is a peculiarity of kari soils, which might result in increase or decrease in the soil pH as reported by Tan *et al.*, (2007). The presence of weakly acidic chemical functional groups of soil organic molecules makes soil organic matter an effective buffer. The subsoil showed higher potential acidity compared to surface soils (Indira, 2013).

The soil organic C (SOC) content in two different farming systems varied from 50.09 to 57.01 g kg^{-1} and 40.13 to 48.5 g kg^{-1} before rice and after rice respectively (Table 3). The Kari soils are high in organic C. Thampatti (1997) recorded higher OC content of 10 to 30% in kari soil. The rice- fish system was found to be having higher SOC than rice-water fallow system which might be due to the additional C input from decomposing dead fish and fish faeces (Cagauan, 1995) along with the contribution from rice residues.

The surface soils (0-20 cm) recorded significantly higher SOC than the sub surface soils (20-40 cm) (Table 3). Zhang (2004) found greater SOC in surface soils and it was found to decrease with increase in depth, this

might be due to input of C through crop residues, stubbles and stalks of rice in surface soil. Every year there is addition of crop residue on the surface soil in the kari soil which makes the organic matter into a easily available form.

Table.1 Effect of treatments on bulk density of soil at different stages (g cm⁻³)

Treatments	Before rice	After rice
T1 (rice-fish system; soil samples from soil depth 0-20 cm)	0.86	0.88
T2 (rice-fish system; soil samples from soil depth 20-40 cm)	1.04	1.06
T3 (rice-water fallow system; soil samples from soil depth 0-20 cm)	0.87	0.87
T4 (rice-water fallow system; soil samples from soil depth 20-40 cm)	1.04	1.05
SE(m)±	0.01	0.006
CD(0.05)	0.029	0.015

Table.2 Effect of treatments on soil pH at different stages

Treatments	Before rice	After rice
T1 (rice-fish system; soil samples from soil depth 0-20 cm)	4.21	3.88
T2 (rice-fish system; soil samples from soil depth 20-40 cm)	3.61	3.42
T3 (rice-water fallow system; soil samples from soil depth 0-20 cm)	3.89	3.56
T4 (rice-water fallow system; soil samples from soil depth 20-40 cm)	3.42	3.33
SE(m)±	0.041	0.036
CD(0.05)	0.263	0.235

Table.3 Effect of treatments on soil organic C at different stages (g kg⁻¹)

Treatments	Before rice	After rice
T1 (rice-fish system; soil samples from soil depth 0-20 cm)	57.01	48.50
T2 (rice-fish system; soil samples from soil depth 20-40 cm)	53.61	43.84
T3 (rice-water fallow system; soil samples from soil depth 0-20 cm)	52.82	45.40
T4 (rice-water fallow system; soil samples from soil depth 20-40 cm)	50.08	40.13
SE(m)±	0.490	0.544
CD(0.05)	3.148	3.499

Table.4 Effect of treatments on labile C in soil at different stages (mg kg⁻¹)

Treatments	Before rice	After rice
T1 (rice-fish system; soil samples from soil depth 0-20 cm)	6249.11	5996.29
T2 (rice-fish system; soil samples from soil depth 20-40 cm)	6117.55	5930.92
T3 (rice-water fallow system; soil samples from soil depth 0-20 cm)	6076.45	5988.74
T4 (rice-water fallow system; soil samples from soil depth 20-40 cm)	6057.13	5903.24
SE(m)±	25.857	17.756
CD(0.05)	NS	NS

Table.5 Effect of different treatments on particulate organic C in soil at different stages (g kg⁻¹)

Treatments	Before rice		After rice	
	<53 µm	>53 µm	<53 µm	>53 µm
T1 (rice-fish system; soil samples from soil depth 0-20 cm)	15.10	6.25	14.27	5.97
T2 (rice-fish system; soil samples from soil depth 20-40 cm)	13.10	5.29	12.64	5.10
T3 (rice-water fallow system; soil samples from soil depth 0-20 cm)	14.03	5.40	13.69	5.45
T4 (rice-water fallow system; soil samples from soil depth 20-40 cm)	11.58	4.61	12.33	4.70
SE(m)±	0.322	0.064	0.128	0.071
CD(0.05)	2.062	0.417	0.827	0.456

Though there is large deposits of partially decomposed or undecomposed wooden materials in the sub surface of kari soils these are not in the immediately available form. Also under flooded condition the organic matter in the surface soil are more exposed to the atmospheric air making it more available than that under the subsurface soil condition.

There was no significant difference in labile C (LC) between the treatments at before and after rice (Table 4). Labile C represents the easily decomposable part of soil organic matter that gets decomposed within few weeks or months. Greater turnover of soil organic matter and greater availability of other soil nutrients are

associated with higher level of labile C.

Labile C fractions are more sensitive indicators of the effect of land use than soil organic C due to their significant effect on soil quality as reported by He *et al.*, (2008). As reported by Mc Lauchlan and Hobbie (2004), the labile fractions of C were heavily dependent on the amount of soil organic C.

Before rice cultivation, higher fine (<53 µm) POC fractions were recorded in surface soil depth with 15.1 and 14.03 g kg⁻¹ in rice-fish and rice-water fallow system respectively (Table 5) and they were on par with each other. The POC values of sub surface soil showed no significant

difference. The rice-fish system contained more coarse (>53 µm) POC fractions at both surface and sub surface soil depths than rice water-fallow system (Table 5). After rice, the values of fine (<53 µm) POC fractions for surface soil depths of both farming systems were not significantly different, however higher value was observed in rice-fish system. The fine fraction POC values for sub surface soil depths of both the systems were found to be not significantly different.

The coarse (>53 µm) POC fractions were found to be higher in surface soil depths than sub surface soil depths in both the systems with the highest being in the rice fish system (5.97 g kg⁻¹) (Table 5).

In general, the POC was found to be higher in rice-fish system compared to rice-water fallow system (Table 5) and surface soil (0-20 cm) contained higher POC than sub surface soil (20-40 cm). Among the fractions, POC in fine (<53 µm) fraction was found to be higher than coarse (>53 µm) fraction (Table 5). POC represents the non-complexed organic matter that mainly contains partially decomposed residues of plants and animals, root fragments etc.

POC is the highly active pool of soil organic C and is the most sensitive indicator of management effects on SOC (Elliott *et al.*, 1994). Coarse fraction of POC represents the unprotected pool of soil organic matter, which is said to be labile fraction consisting of plant residues at various stages of decomposition (Cambardella and Elliott, 1992).

The study revealed that the rice-fish system significantly increased the soil pH and different C pools compared to rice-water fallow system in *Kari* soils.

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