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Soil carbon pools in different land uses of *Pokkali* agro-ecosystem

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Abstract
Soil functions as the largest storehouse for terrestrial carbon and influences the global carbon cycle. Land uses have a significant effect on soil carbon storage and its dynamics. *Pokkali* agro-ecosystem represents unique tidal wetlands of Kerala where the land use consists of traditional way of rice and prawn rotational farming. The present investigation was conducted to assess the soil carbon pools from different land uses in the *Pokkali* agro-ecosystem. The composite soil samples collected from three different land uses in the *Pokkali* ecosystem namely rice-prawn, rice alone, and prawn alone from Kumbalangy, Rice Research Station, Vyttila, and Kadamakkudy respectively were analyzed for pH, electrical conductivity, bulk density, texture and cation exchange capacity. Soil carbon pools like soil organic carbon, labile carbon, water-soluble carbon, microbial biomass carbon, and total carbon were estimated. Land uses significantly influenced different carbon pools of the *Pokkali* agro-ecosystem. Different carbon pools such as soil organic carbon (16.49 g kg^{-1}), labile carbon (2153.56 mg kg^{-1}), water-soluble carbon (46.10 mg kg^{-1}), microbial biomass carbon (249.83 mg kg^{-1}) and total carbon (18.4 g kg^{-1}) were highest in rice-prawn land use which signifies the sequestering capacity of these soil due to abundance of organic matter. Higher soil organic carbon stock indicates the great potential of the *Pokkali* soil to store carbon and reduce greenhouse gases in the atmosphere.

Key words: Acid saline soil, Carbon pools, Land uses, Labile carbon, Organic matter, *Pokkali*

Soil, the largest carbon reservoir encompasses approximately two-thirds of the carbon in ecosystems and includes both organic and inorganic forms. The amount of organic carbon stored in soil results from the net balance between the rate of soil organic carbon inputs and the rate of mineralization in each of the organic carbon pools. Various land uses have different potentials for carbon sequestration due to differential soil organic carbon content and aggregation dynamics (Blanco et al., 2007). Even small modifications in soil carbon status may have a significant effect on the global carbon balance.

Thirteen per cent of the total geographical area of the Kerala state is occupied by the coastal wetlands which play a prominent role in the ecology, economy, and social well-being of people of the state. *Pokkali* agro-ecosystem is an integral part of the Vembanad wetland complex where salt-resistant rice variety "*Pokkali*" which has been upgraded into the status of registered Geographical Indication (GI) is cultivated in rotation with prawns or fishes (Joy, 2013) and sets an example for sustainable agri – aqua integration. These ecosystems which lie below the sea level extend over the coastal regions of Ernakulam, Alappuzha, and Thrissur districts of Kerala state and possess acid saline soils. After the *Pokkali* rice cultivation during the low saline phase (June to early November), naturally available prawns and fish seeds collected by trapping of natural saline waters from the Vembanad estuary, which enters the field during the high tides is used up for the farming on high saline phase (mid-November to mid-April) (Deepa, 2014). A complete organic way of farming is followed in these

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waterlogged soils naturally since the rice seedling grows without the addition of any fertilizers or pesticides. These acid saline soils had shown pH ranging from 3.0 to 6.8 (Nair and Money, 1968). The electrical conductivity of soils during the high saline phase ranges from 12 to 24 dS m^{-1} and during the low saline phase it varies from 0.01 to 7.8 dS m^{-1} (Sreelatha and Shylaraj, 2017).

In Kerala, the total area under traditional shrimp farming is 12,986.6 ha, of which 84% is under *Pokkali* fields (Pillai et al., 2002). There are about 4000 hectares of paddy fields under *Pokkali* cultivation in Ernakulam district, while about 3000 hectares and 2000 hectares in Alappuzha and Thrissur respectively. The *Pokkali* fields of Kerala have been declining from 25,000 hectares to 9000 hectares (Dominic and Jithin, 2012) and most of the integrated farming styles were shifted to the monoculture of prawns due to economic benefits in the short run which has brought a quality deterioration in these fields (Joseph, 2014). Land-use changes have paved the way for C emission of 1.7 Pg C yr^{-1} in 1980-1989 and 1.6 Pg C yr^{-1} in 1989-1998 (IPCC, 2000). Therefore, *Pokkali* land-use changes can also have a considerable effect on soil organic C pools due to change in salinity, primary productivity, litter quantity, and quality and soil structure. Hence study of C pools in different land uses of the *Pokkali* agro-ecosystem helps to identify the C sequestration potential of these soils or the stability of soil organic C pools. Estimation of soil carbon pools helps to identify the carbon fractions which are dominant in different land uses and helps to prioritize them for carbon sequestration thereby reducing the emission of greenhouse gas (CO_2).

An investigation was conducted at Rice Research Station, Vyttila during January 2020 (high saline phase) to estimate the soil carbon pools in the different land uses under the *Pokkali* agro-ecosystem. Three different land uses considered for the study were rice-prawn, rice alone and prawn alone land uses. Five composite samples were collected from Kumbalangy, RRS, Vyttila, and Kadamakkudy respectively (Table 1). Surface soil samples from a depth of 0-20 cm were collected using a core auger and analysed for initial soil properties namely, pH (Jackson, 1958) electrical conductivity (EC) (Jackson, 1958), bulk density (BD) (Blake and Hartge, 1968), texture (Piper, 1966) and cation exchange capacity (Hendershot and Duquette, 1986) as per standard procedures. The soil carbon pools namely soil organic carbon (SOC) (Walkley and Black wet oxidation method, 1934), labile carbon(LC) (Potassium permanganate oxidation method by Blair et al., (1992). water-soluble carbon (WSC) (water dissolution and wet oxidation method by Ghani et al., 2003) microbial biomass carbon (MBC) (chloroform-fumigation extraction method by Voroney and Paul, 1984) and total carbon (TOC) (loss on ignition method by Goldin, 1987) were analyzed as per the standard procedures. Soil organic carbon stock was estimated by the equation SOC(%) × BD × depth (cm) (Wilson and Warren, 2015). The data obtained were analyzed statistically using analysis of variance for a completely randomized design using the SAS package.

Table 1: Different land uses and their respective geographic location

Land use	Location	Co-ordinates
Rice+Prawn	Kumbalangi	9°53’25.60704" N 76°16’37.6284" E
Rice alone	RRS, Vyttila	9°58’40.0224" N 76°19’21.8712" E
Prawn alone	Kadamakkudy	10°2’18.1602" N 76°16’1.851" E

The soil properties of different land use in the *Pokkali* agro-ecosystem are represented in table 2. The soil pH was slightly acidic to the neutral range for all land uses. The soils were non-saline with a mean EC less than 4 dS m^{-1}. Soils of rice-prawn and rice alone land uses were clay textured and prawn alone land use was sandy clay loam in texture. Cation exchange capacity was highest in rice-prawn and lowest in prawn-alone land use. The highest mean bulk density was observed in prawn alone and the lowest in rice-prawn land uses due to high organic matter accumulation in these soils.

Table 2: Soil properties of different land uses in *Pokkali* agro-ecosystem

Parameters	Rice-prawn (Kumbalangy)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
pH	6.88	6.41	6.84
EC (dS m^{-1})	1.82	1.34	2.44
CEC (cmol(p+)kg^{-1})	12.38	11.01	9.59
Bulk density (Mg m^{-3})	0.68	0.89	1.23
Texture	clay	clay	sandy clay loam

Table 3: Influence of land uses on soil carbon pools

Land uses	SOC (g kg^{-1})	WSC (mg kg^{-1})	MBC (mg kg^{-1})	LC (mg kg^{-1})	TOC (g kg^{-1})
Rice-prawn	16.49^{a}	46.10^{a}	249.82^{a}	2153.56^{a}	18.4^{a}
Rice alone	14.77^{a}	44.54^{a}	208.87^{ab}	1949.66^{ab}	15.3^{ab}
Prawn alone	9.82^{b}	32.38^{b}	180.07^{b}	1547.81^{b}	11.9^{b}
CD (0.05)	2.5	7.57	49.16	439.93	4.05

The various land uses of the *Pokkali* agro-ecosystem recorded a significant effect on carbon pools (Table 3). The SOC of rice-prawn, rice alone, and prawn alone land use ranged from 15.3 to 17.0g kg^{-1}, 13.8 to 16.1 g kg^{-1} and 6.3 to 12.9 g kg^{-1} respectively. The highest mean SOC was recorded in rice-prawn (16.5 g kg^{-1}) and lowest in prawn alone (9.82 g kg^{-1}) land uses (Fig.1). The *Pokkali* agro-ecosystem is rich in organic matter and this could have been attributed to high soil organic carbon content in these land uses. After the paddy harvest, left-out rice stalks on the fields serve as the natural feed material for prawn/fish culture (Sudhan et al., 2016).The subsequent rice crop in rotation makes use of nutrients from prawn excrement and other remnants. Due to this abundant organic matter accumulation, SOC content was reported highest in rice-prawn compared to other land uses. The build-up of SOC under any land use is the function of organic matter turnover, their quality, and decomposition rate (Sariyildiz and Anderson, 2003). Krishnani et al. (2014) reported higher organic carbon content (0.22 to 3.74%) during paddy culture than shrimp culture in this ecosystem. The low SOC in prawn-alone land use is due to the absence of paddy crop or vegetation which led to a reduction in organic matter accumulation.

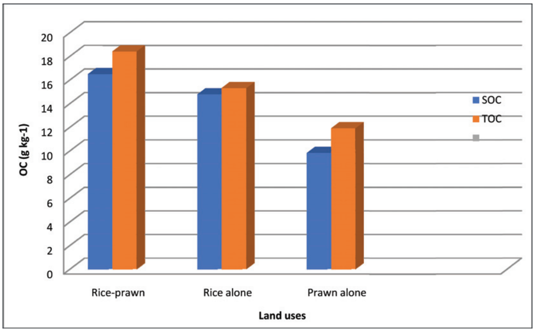

Figure 1. Mean SOC and TOC from different land uses in *Pokkali* agro-ecosystem

Labile carbon (LC) represents the easily decomposable fraction of soil organic matter with rapid turnover rates and serves as early and sensitive indicators of management-induced change in SOC and hence soil quality and sustainability. The LC observed in rice-prawn land use ranged from 1774.1 to 2645.98 mg kg^{-1} whereas it ranged from 1615.93 to 2444.52 mg kg^{-1} in rice alone and 1149.2 to 1907.99 mg kg^{-1} in prawn alone land uses. Mean LC was highest in rice-prawn (2153.56 mg kg^{-1}) and lowest in prawn alone (1547.81 mg kg^{-1}) (Fig. 2). A significant difference in LC content was detected among different land uses and was largely dependent on the amount of SOC in the soil. A higher level of LC in rice-prawn indicates greater turnover of organic matter which influences the availability of other nutrients. According to Mathew (2016) higher value of labile carbon was recorded at the surface and non labile carbon at the sub surface layer indicated its conversion to recalcitrant pool so as to prevent emission into atmosphere.

Water-soluble carbon (WSC) is regarded as the immediate organic substrate for soil microorganisms

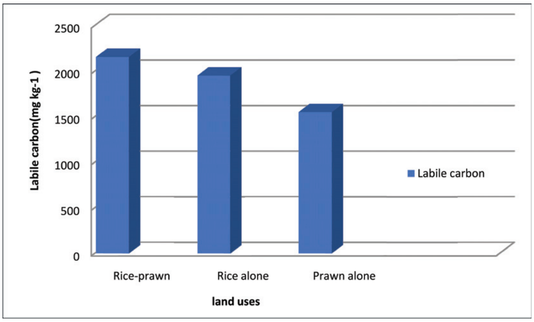

Figure 2. Mean LC from different land uses in *Pokkali* agro-ecosystem

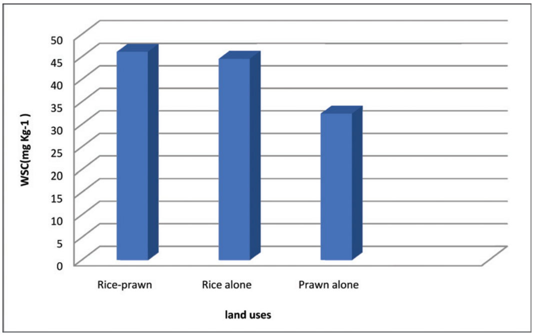

Figure 3. Mean WSC from different land uses in *Pokkali* agro-ecosystem

and the most vigorously cycling soil organic carbon pool. It followed the same trend and recorded the highest mean in rice-prawn (46.10 mg kg^{-1}) and lowest in prawn alone (32.38 mg kg^{-1}) land uses (Fig. 3). The WSC ranged from 39.65 mg kg^{-1} to 54.52 mg kg^{-1} in rice-prawn whereas it ranged from 40.44 mg kg^{-1} to 51.23 mg kg^{-1} and 25.63 mg kg^{-1} to 37.75 mg kg^{-1} in rice alone and prawn alone land uses respectively. Jha et al. (2012) reported the highest WSC (101.6 mg kg^{-1}) in forest land use

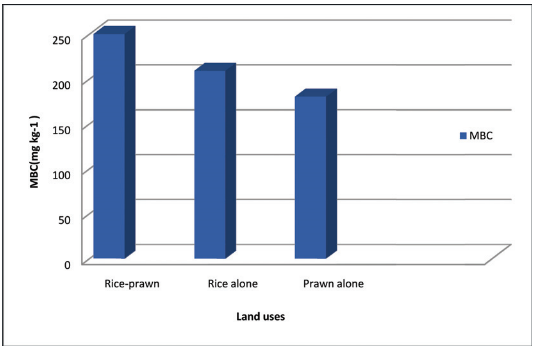

Figure 4. Mean MBC from different land uses in *Pokkali* ecosystem

(101.6 mg kg^{-1}) followed by horticulture (70.6 mg kg^{-1}) and agriculture land use (13.8-36.1 mg kg^{-1}) and low WSC under the agricultural land use was probably due to low SOC content. Higher WSC indicates higher turnover of soil microbial biomass in rice-prawn land uses and mechanisms involved include desorption from soil colloids, dissolution from litter, exudation sloughing and exfoliation from plant roots, or hydrolysis of insoluble soil organic polymers (McGill, 1986).

Soil microbial biomass carbon (MBC) has a crucial role in organic matter decomposition and nutrient cycling. Rice-prawn land use recorded MBC in the range of 210.09 mg kg^{-1} soil to 292.80 mg kg^{-1} soil whereas rice alone and prawn alone ranged from 170.56 mg kg^{-1} soil to 238.96 mg kg^{-1} soil and 145.65 mg kg^{-1} soil to 249.18 mg kg^{-1} soil respectively. Mean MBC was highest in rice-prawn (249.83mg kg^{-1}) followed by rice alone (208.8702 mg kg^{-1}) and the lowest in prawn alone (180.07 mg kg^{-1}) (Fig. 4). The high tide and low tide occurring twice a day uphold the fertility and productivity of *Pokkali* soils. The tide carries nutrients to *Pokkali* soils and removes toxic concentrations during low tide and helps to increase the microbial activity in these soils (Sreelatha and Shylaraj, 2017), and contributed to high MBC in these multi stressed soils. Joseph (2014) reported MBC content ranged from 50.12 mg kg^{-1} to 658.52 mg kg^{-1} and the lowest was recorded from prawn alone land use (148.81 mg kg^{-1}) under the *Pokkali* agro-ecosystem.

Total carbon (TOC) was highest in rice-prawn (18.4 g kg^{-1}) and lowest in prawn alone (11.9 g kg^{-1}) land uses of the *Pokkali* agro-ecosystem (Fig. 1). The TOC in *Pokkali* soils was also found in the same order as of SOC content and was highest in rice-prawn land use. Rice alone land use recorded a mean SOC stock of 26.46 Mg ha^{-1} while rice-prawn land use and prawn alone land use registered 22.5 Mg ha $^{-1}$ and 24.9 Mg ha^{-1} respectively. Bulk density was significantly higher in prawn alone land use and lowest in rice-prawn land use. Whereas organic carbon was highest in rice-prawn land use and lowest in prawn alone. Since SOC stock is the product of bulk density and soil organic carbon, there was no significant differences among the land uses. Higher soil organic carbon stock in the surface soils of different land uses of the *Pokkali* agro-ecosystem indicated a higher carbon storage capacity of these soils.

Conclusion

Different land uses recorded a significant influence on SOC, LC, WSC, MBC, and TOC. Rice-prawn land use registered the highest organic carbon pools due to the high organic matter and prawn alone land use recorded the lowest organic carbon pools. A shift from traditional rice-prawn farming to the monoculture of prawn could adversely affect the carbon storage and fluxes in this ecosystem. It is important to conserve this traditional integrated rice-prawn farming in order to store carbon for better sustainability of the *Pokkali* agro-ecosystem.

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