EFFECT OF SALINITY ON CARBON MINERALISATION UNDER DIFFERENT LAND USES IN *POKKALI* ECOSYSTEM

By

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(2019-11-169)

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THESIS

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2021

DECLARATION

I hereby declare that this thesis entitled "**Effect of salinity on carbon mineralisation under different land uses in *Pokkali* ecosystem**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or society.

Vellanikkara **Anju Sajan**

Date: 11-01-2022 (2019-11-169)

CERTIFICATE

Certified that this thesis entitled **"Effect of salinity on carbon mineralisation under different land uses in *Pokkali* ecosystem"** is a record of research work done independently by Ms. Anju Sajan (2019-11-169) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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11-01-2022

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We, the undersigned members of the advisory committee of Ms. Anju Sajan, a candidate for the degree of **Master of Science in Agriculture** with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled **"Effect of salinity on carbon mineralisation under different land uses in *Pokkali* ecosystem"** may be submitted by Ms. Anju Sajan (2019-11-169), in partial fulfillment of the requirement for the degree.

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Anju Sajan

DEDICATED TO MY DEAREST
PAPPA AND MOMMY

Abbreviations

% - Per cent
μ - micro
^0C - Degree Celsius
^0E - Degree East
^0N - Degree North
Al - Aluminium
ANOVA - Analysis of Variance
$BaCl_2$ - Barium chloride
BD - Bulk Density
C - Carbon
Ca - Calcium
$CaSO_4$ - Calcium Sulphate
CD - Critical difference
CEC - Cation exchange capacity
Cfu - Colony forming units
CH_4 - Methane
cm - Centimeter
CO_2 - Carbon di oxide
Cu - Copper
DHA - Dehydrogenase activity
DOC - Dissolved organic carbon
$dS\ m^{-1}$ - Deci Siemen per meter
EC - Electrical conductivity
ESP - Exchangeable sodium percentage
Fe - Iron
g^{-1} - Per gram
Gg - Gigagram
GHGs - Greenhouse gases

GI	-	Geographical Indication
Gt	-	gigaton
H	-	Hydrogen
ha^{-1}	-	Per Hectare
IPCC	-	Intergovernmental Panel on Climate Change
K	-	Potassium
kg	-	Kilo gram
$KMnO_4$	-	Potassium Permanganate
LC	-	Labile carbon
m	-	meter
M	-	molar
M^{-3}	-	Per cubic meter
MBC	-	Microbial biomass carbon
mg	-	milligram
Mg	-	Megagram
ml	-	milliliter
Mn	-	Manganese
N	-	Nitrogen
N_2O	-	Nitrous oxide
Na	-	Sodium
Na_2SO_4	-	Sodium sulphate
NaOH	-	Sodium hydroxide
Nm	-	nanometer
NOAA	-	National Oceanic and Atmospheric Administration
OC	-	Organic carbon
OM	-	Organic Matter
Pg	-	Peta gram
pH	-	Hydrogen ion concentration
POC	-	Particulate organic carbon

ppm	-	parts per million
ppmv	-	parts per million volume
PS	-	Paddy Straw
rpm	-	Revolutions per minute
RRS	-	Rice research station
SAC	-	Space Application Centre
SAR	-	Sodium Adsorption Ratio
SOC	-	Soil organic carbon
SOM	-	Soil organic matter
SSNM	-	Site Specific Nutrient Management
Tg	-	Teragram
TOC	-	Total carbon
TPF	-	Triphenyl Formazon
TTC chloride	-	2, 3, 5- Triphenyl tetrazolium
WEOC	-	Water extractable organic carbon
WSC	-	Water soluble carbon
Zn	-	Zinc

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Introduction

1. INTRODUCTION

The atmospheric concentrations of greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), have risen exponentially over the last two centuries. Amongst the various GHGs, CO_2 is the most important and contributes 60 per cent towards global warming followed by CH_4 (15%) and N_2O (5%) (Pathak *et al.*, 2003). The amount of carbon (C) in the atmosphere has increased at an alarming rate by 30 per cent. As a result, consistent warming trends and more frequent and intense extreme weather events have been observed across the globe. The impact of this climate change is projected to have a great influence on agriculture and food security. Hence, climate change mitigation has aroused as the greatest challenge of this century.

The terrestrial ecosystem is a major biological scrubber of atmospheric CO_2 that can be significantly increased by proper management. In the terrestrial C cycle, soil functions as the largest C reservoir. Soil C is the total amount of C present in soil which includes both inorganic and organic forms. The global soil C pool is estimated to be 2,500 Gt to 2 metres deep, with the soil organic carbon (SOC) pool accounting for 1,550 Gt and the soil inorganic C and elemental pools serving for the remaining 950 Gt (Batjes, 1996), which accounts for the vast majority of the terrestrial C reservoir. The SOC serves as a sensitive indicator of soil quality and environmental sustainability (Lal, 2002). SOC is considered essential to maintain fertility of soil, as it improves the physical, chemical, and biological characteristics of the soil. Because of the tremendous amount of carbon stored in soils, even tiny changes in soil C status can have a tremendous impact on the entire biogeochemical cycles and, as a consequence, unpredictable extreme weather events (Gonzalez *et al.*, 2004). The difference in land use and their management have a large impact on these organic C stocks.

The net balance between the rate of soil organic C inputs and indeed the rate of mineralization from each of the organic C pools defines the amount of organic C stored in the soil. The decomposition of SOC is reflected by its mineralization, a vital process in the ecosystem cycle (Bahn *et al.*, 2008). Soil C mineralization is an indicator of soil health and depending upon the land use type, SOC mineralization differs (Sun *et al.*, 2016; Zhu *et al.*, 2017). Mineralization determines the net flux of C between the soil and atmosphere by the conversion of SOC to CO_2 with the help of microbes and autotrophic respiration. The stability of SOC reflects C sequestration potential of the particular soil.

Wetlands are the prominent ecosystems that lie at the interphase between terrestrial and aquatic ecosystems and are ranked among the third most productive ecosystems across the world. Wetland soils play a pivotal role in the global C cycle (Choi and Wang 2004) and are estimated that the amount of C stored in wetland soils is 498 Pg, which contributes to more than one-third of the total world pool of soil C.

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* ecosystems are such tidal wetlands of Kerala, where a traditional indigenous organic method of rice-fish rotational cultivation with salt-tolerant rice variety locally called *Pokkali* is being practiced. These are distributed over Ernakulam, Alappuzha, and Thrissur districts of Kerala and soils are multi stressed with various conditions like acidity, salinity, and waterlogging. The rice cultivation begins with the southwest monsoon in the low saline phase till October and fish or prawn farming is followed in the high saline phase. The fluctuating physio-chemical parameters of water in these fields through tidal action allow them to be a sustainable ecosystem with rich biodiversity and can be considered as a classic example of sustainable agri– aqua integration providing a means of rural livelihood.

This ecosystem is naturally blessed with a high amount of organic C which attributes to most of its desired soil properties. But now this ecosystem is facing the challenge of prawn monoculture at the cost of the traditional rice-prawn farming system mainly because of profit obtained in the short run. Hence soil quality shows a decreasing trend from the traditional rice–prawn system to the monoculture of prawns (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 and mineralisation in different land uses of the *Pokkali* ecosystem helps to identify the C sequestration potential of these soils or the stability of soil organic C pools.

The response pattern of salinity on the C mineralisation process is an important aspect that needs more attention. Neutral salts in soils show variable effects on the processes of

C mineralisation in soils. But their information is limited. Hence this study is proposed to find out the effect of salinity on C mineralisation under different land uses in the *Pokkali* ecosystem.

Review of literature

2. REVIEW OF LITERATURE

An increase in CO_2 concentration in the atmosphere has started disrupting the ecological balance across the globe. Soil being an efficient natural resource to capture and store CO_2 has to be well maintained and conserved to handle this serious matter. But changes in land-use patterns have adversely affected the potential of soil to sequester carbon(C) and considerable loss of CO_2 is being witnessed. Hence this study was conducted to estimate different organic C pools present in the *Pokkali* ecosystem of Kerala and assess the impact of land-use changes on them. Along with this, the effect of salinity on C mineralization in different land uses of the *Pokkali* ecosystem had given prime importance in this study.

2.1 GLOBAL WARMING AND CO_2 INCREASE

Global warming has emerged as one of the most prominent global environmental issues which get accelerated by the increase in the concentration of greenhouse gases (GHGs) in the atmosphere. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), GHGs are expected to cause a temperature increase of between 1.1 and 6.4°C by the end of the twenty-first century. The CO_2 concentration in the atmosphere have surged from 280 ppmv in 1750 to 367 ppmv in 1999, and are currently escalating at a pace of 1.5 ppmv/year or 3.3 Pg C/year (IPCC, 2001 and Stern, 2006). The principal anthropogenic greenhouse gas CO_2, which accounts for 0.037 per cent of the atmosphere, has the potential to disrupt the earth's radioactive balance (IPCC, 2001). In 2019, the global average atmospheric CO_2 was estimated to be 409.8 ppm, with a range of uncertainty of plus or minus 0.1 ppm (NOAA, 2020). CO_2 levels today are much higher than at any point in at least the past 800,000 years and it is increasing at an alarming rate.

Carbon sequestration, in which C is captured and stored in another domain act as a potential climate change mitigation plan under these circumstances. The CO_2 has to be stored for several hundred or thousands of years so that it keeps its balance in the atmosphere. Since the Kyoto Protocol, there has been an emphasis on the contribution that sequestration could make (Purdy and Macrory, 2003) and effective strategical plans can bring out a huge influence on terrifying climate abnormalities.

2.1.2 Soil and carbon sequestration

Globally, terrestrial soils act as the major reservoir of atmospheric carbon (CO_2), which has the potential of storing approximately 1500 Pg of organic C. This accounts for roughly three times the amount of C stored in vegetation and twice the amount (750 Pg) in the atmosphere (Baldock, 2007; Lal, 2009; Liu *et al*., 2006). Soil organic C pools have the lowest turnover rate in terrestrial ecosystems which makes them a better resource to sequester C and slow down CO_2 emission to the atmosphere. Therefore, even minor changes in the SOC pool can have a critical effect on the global C cycle. Carbon sequestration in terrestrial soils also aids in improving the physical and chemical environments of the soil by holding moisture, supporting plant growth with nutrients (Reichstein *et al*., 2013).

Plants and autotrophic microorganisms fix atmospheric CO_2 in terrestrial environments through photosynthesis, converting it to organic molecules that are then consumed in various metabolic processes. Decomposition, a crucial activity in the C cycle, enters the soil through its two connected sub-processes, mineralization and humification. Mineralization is the conversion of organic molecules into inorganic forms that plants can assimilate, while humification is the process of maintaining soil organic matter levels. The respiration activities of soil microorganisms emit CO_2 during the mineralization process (Jimenez *et al*., 2007). Of the 120 Pg CO_2-C absorbed by photosynthesis, 60 Pg is returned to the atmosphere through plant respiration and decomposition of soil organic matter or soil respiration (Lal, 2008).

2.1.3 Wetlands and carbon storage

Wetlands are known as natural wonders, cover approximately 4 to 6 per cent of the earth's land surface. These ecosystems are distinguished by the presence of standing water and/or saturated soil for at least part of the year, a situation that allows aquatic plants (hydrophytes) and hydric soil to grow. These elements, such as hydrology, vegetation, and soil, as well as their interactions, shape the hallmark traits of wetland ecosystems and communities, and can be used to distinguish and classify different types of wetlands (Bernal and Mitsch, 2012). Higher biomass production and productivity rates of the vegetations are the most impressive features of the wetland ecosystems. Emergent macrophytes in swamps and marshes represent the most productive plant communities in these ecosystems.

Topography, geology, hydrology, ecology, climatology, and morphology greatly influence the balance between C input (organic matter development) and output (decomposition, methanogenesis, etc.) and the resulting storage of C in wetlands. Temperature, substrate availability, nutritional levels, and microbial populations are also all factors to consider (Adhikari *et al.*, 2009). This long list of factors indicates that C storage in wetlands is a delicate process influenced by many variables. However, wetlands represent a significant sink for C and are a crucial element to consider when managing and weighing the earth's C pedological pool (Bernal, 2008).

The capability of wetlands to serve as C sinks is greatly influenced by soil organic matter decomposition rate and resultant loss of CO_2 and methane (CH_4) (Inglett *et al.,* 2012). The significance of wetland C flux in the global C cycle is little understood, and more knowledge on different types of wetlands and how they function is needed (Mitra *et al.,* 2005).

Among agricultural systems, paddy wetlands are essential ecosystems extending around 153 million hectares. Globally paddy wetlands are recognized as crucial ecosystems capable of sequestering 466-2011 Gt of C and therefore a source of C contributing to major GHGs emissions (Smith *et al.,* 2008). The capacity of agriculture on SOC sequestration in Indian soils ranges between 12.7 and 16.5 Tg C y^{-1} (Lal, 2002; Bhattacharyya *et al*., 2013).

Even though paddy wetlands have considerable potential for sequestering CO_2 from the atmosphere (Bernal and Mitsch, 2012; Mitsch *et al*., 2013), they also tend to become a quick source of atmospheric C contributing significantly to the global flux of 68–75 Pg CO_2–C year^{-1} (Smith *et al.,* 2008). The majority of SOC that enters the soil surface is quickly absorbed, with some of it being respired by heterotrophic organisms predominantly found in the rhizosphere (upper 10–20 cm). This fast mineralization releases CO_2 into the atmosphere, which gets influenced by a variety of environmental conditions.

Undisturbed wetlands had a lower rate of C sequestration (15 per cent for mangrove and 55 per cent for saltmarsh) than disturbed wetlands, but the C store was larger for undisturbed wetlands (65 per cent for mangrove and 60 per cent for salt marsh) (Howe *et al.,* 2009).

Wetlands in Kerala are distributed all along the coast and the islands, which covers a total area of about 1,60,599 ha which represents 13 per cent of the total geographical area of the state. The major wetland types include river/ stream (65,162 ha), lagoons (38,442 ha) reservoirs (26,167 ha) and waterlogged areas (20,305 ha) (SAC, 2011).

2.2 *POKKALI* SOIL

Pokkali ecosystem is one of the tidal wetlands of Kerala where the oldest surviving traditions of rice cultivation in South India are being practiced. This land comprising of low-lying marshes and swamps is situated near the mouth of streams and rivers not far from the sea and extends from 9°00 to 10°40'N Latitude and 76°00' to 77°30' E Longitude where no other type of agriculture would ordinarily be possible other than cultivation of *Pokkali* rice (Dominic and Jithin, 2012). *Pokkali* fields are found in the coastal saline tracts of Kerala under agro-ecological unit 5 where rice and prawns are produced organically in rotation. Frequent ingression of tidal water from the Arabian sea through backwaters and canals results in perennial problems of salinity and high acidity. But these *Pokkali* lands are reported to be high in fertility status and hence additional manuring is not required for this farming system. The major land uses prevalent in the *Pokkali* tracts are rice alone, rice-prawn, prawn alone, mangroves, and fallow land. The rice cultivation is carried out in the *Pokkali* tract from June to early November when the fields are in the low saline phase and prawn farming takes over from mid-November to mid-April (high saline phase) (Deepa, 2014). These tall rice varieties are grown without additional application of chemical fertilizer and pesticide (Thampy, 2002) which influences their ecological sustenance.

2.2.1 Characteristics of *Pokkali* soils

According to Soil Taxonomy *Pokkali* soils belong to the order Inceptisols, suborder Aquepts, and great group Sulfaquepts. They are classified as coarse loamy over sandy, mixed, active, isothermic, Typic Sulfaquepts (Nidheesh, 2019).

Despite having stiff impenetrable clay, the soil is rich in organic materials. When dry, the soil is bluish-black and causes deep fractures, but when wet, it becomes sticky (Varghese *et al.,* 1970). Samikutty (1977) found that soil profile is devoid of concretions and mineral fragments and these have kaolinite as dominant clay mineral along with a fairly large amount of smectite and a small amount of halloysite. Quartz, mica, feldspar, and chloritic minerals form major components of fine and coarse sand fractions (Kuruvila, 1974).

Because of low-lying fields, seawater inundates and makes the soils saline during the high saline phase. This phase which is characterized by high salt content is mainly made use for prawn cultivation. During the monsoon, the salts get washed off by rainfall and fall into the low saline phase. During this phase, the inherent acidity of these soils dominates (Sreelatha and Shylaraj, 2017)

Pokkali cultivation starts by strengthening outer bunds and setting up sluices. Sluice gates help to control the flow of water to these fields. During low tide, the fields are drained and the sluices are closed at high tides which helps in drying of soil followed by mound preparation of about one-meter base and a half meter height. After salts get washed off from mounds by the rainfall, sprouted seeds are sown during May – June (Shylaraj *et al.*, 2013). When the seedlings reach 25 days old, mounds are cut into pieces, and seedlings with clods are uniformly spread in the entire area following a spacing of 20 × 15 cm with 2-3 seedlings per hill.

Although the rice plants grow up to two meters in these low-lying waterlogged fields, at the time of maturity crop stoops while the panicle stands upright. At the end of September, rice plants get matured and panicles are collected leaving the stalks intact in these fields for further decaying (Jayan and Sathyanathan, 2010). The decaying paddy stubbles act as a niche for forage organisms such as zooplankton and phytoplankton (Purushan, 2002) which helps in improving soil organic matter content of these soils.

Pokkali fields are used exclusively for fish/prawn cultivation after the harvest of rice. Prawn filtration is an indigenous technique of prawn culture developed and practiced by innovative farmers of the *Pokkali* region (Deepa, 2014). The bunds get strengthened and the sluice gates are fixed in locations where there is a medium flow of water from the canal or backwater to the fields. Bund top width of 1.0 m and height of 1.5 m is provided. The sluice is made of length width and height of about 3.5 m, 1.25 m, and 2.25 m respectively. Wooden shutter planks help to regulate the water flow into the field (Sudhan *et al.,* 2016). Backwaters and canals become saline after the monsoon, and vast amounts of juvenile prawns and fingerlings enter these canals. After preliminary preparations, this water is allowed into the fields through the sluice during high tide at night. Nylon net sluice screen prevents the escape of prawns or fishes from the field during water outflow and traps them inside these fields. Left out rice stalks on the fields serve as the natural feed material for prawn/fish culture (Sudhan *et al.,* 2016). No supplementary stockings or supplementary feeds are used in this type of farming system (Shylaraj *et al.,* 2013). Fish or prawns that are trapped in the field are harvested when they gain a marketable size. The subsequent rice crop in rotation makes use of nutrients from prawn's excrement and other remnants.

2.2.2 Fertility status

Diya and Sreelatha (2018) reported that *Pokkali* soil is deficient in available N, Ca, Mg and Cu, and remaining all other nutrients were at sufficiency level. Available phosphorus was also found deficient in these soils. Tacon (1987) reported that the amount of available calcium almost gets doubled after prawn harvest mainly because of calcium-rich exuvia deposition by prawns. Because the calcium in the *Pokkali* soils is water-soluble and in a complexed organic form, the quantity of available calcium is directly determined by tidal action and the amount of organic matter present (Bhindu, 2017). Due to the acid sulphate nature of *Pokkali* lands high content of sulphur was also reported. (Santhosh, 2013). *Pokkali* fields are also distinguished by the soluble salts accumulation of sodium over and underlying acidic soil with toxic levels of iron and manganese (Padmaja *et al.,* 1994).

The high tide and low tide occurring twice a day uphold the fertility and productivity of *Pokkali* soils. Tide carries nutrients to *Pokkali* soils and removes toxic concentrations during low tide (Sreelatha and Shylaraj, 2017). This tidal action also helps in the growth of beneficial microorganisms (Ranga, 2006). The occurrence of large numbers of *Pseudomonas sp.* in *Pokkali* fields during monsoon months was reported by Pramila and Chandrika (2001).

Rice fields are expected to have a huge potential for C sequestration from the environment (Huang *et al*., 2012), hence investigation into C accumulation and stabilisation is important (Weller *et al.,* 2016). Organic C builds up faster and more noticeably in rice fields than in other arable areas, owing to the extreme reduced conditions and lack of oxygen for microbial activity under submerged conditions, as organic matter breakdown is limited in lowland rice fields (Wu, 2011).

2.2.3 Rice-prawn farming

Rice-prawn farming in the *Pokkali* ecosystem is an ecologically viable integrated farming approach that improves the livelihood opportunities of the local population. Rice cultivated during the monsoon period while prawns cultivated post-monsoon period as in a rotation. The presence of perennial channels in the fields which provides easy passage for prawns into lands during low tides differ *Pokkali* fields from normal paddy fields (Shylaraj *et al.,* 2013).

Expenditure incurred for *Pokkali* rice farming is comparatively less compared to other rice-grown areas since farmers do not use any external inputs to these fields. Traditional prawn culture required maintenance cost of bunds and sluices only and economic analysis confirms high benefit: cost ratio from such integrated approaches (Shylaraj *et al.,* 2013).

But a drastic reduction in *Pokkali* farming is witnessed due to lack of modernized machinery for cultivation, acute labor shortage, and climatic aberrations. Along with, unsustainable prawn monoculture has increased considerably. Despite state government direct intervention, making the prawn monoculture illegal, the majority of these fields have changed to fallow-prawn and prawn – prawn land uses for the economic benefit obtained in the short run. These could possess a serious threat to ecological sustainability and indigenous farming practices (Joseph, 2014).

2.3 SOIL PROPERTIES

2.3.1 Soil reaction

Soil reaction has a great influence on soil quality and health. Being an acid sulphate soil *Pokkali* soils are usually acidic with low pH values. These soils exhibit pH values ranging from 3.0 to 6.8 (Nair and Money, 1968). Bhaskaran and Varghese (2009) arranged wetland soils of Kerala based on severity of acid as Kari > *Pokkali* > Karapadom > Vellayani > Kayal > Kole > Wayanad > Pattambi > Kaipad > Karamana > Kattampally > Chittoor.

Silpa *et al.* (2021) reported that the mean value of soil reaction in *Pokkali* fields in different months ranged from 3.87 (April) to 7.58 (October). An increasing trend of soil pH from June (6.41) to October (7.58) was observed in all the land uses of the *Pokkali* ecosystem. The neutral pH was observed in October which attributed to the removal of active acidity from topsoil by South West monsoon followed by the continued submergence of the soil.

Increased salt concentration in the soil tends to lower the pH by forcing exchangeable H^+ ions into the soil solution (Rengel, 2002). When Na^+ saline solution was added directly, Na^+ ions were exchanged for H^+ and Al^{3+} ions, resulting in acidification (Hindar *et al.,* 1994). Earlier studies in lowland soils and sediments have observed a decrease in pH with increasing salt concentration (Harriman *et al.*,1995)

Diya and Sreelatha (2018) reported that calcium compounds can increase the soil pH which consecutively reduces Fe^{2+}, Al^{3+}, $Mn^{2+,}$ and $SO4^{2-}$ in the soil solution. The addition of gypsum can lead to proton generation and further reductions in pH (Chorom and Rengasamy, 1997).

The addition of organic material can considerably increase microbial respiration, decreases the pH by organic acid production during its decomposition as a result of increased pCO_2 (Chorom and Rengasamy, 1997; Nelson and Oades, 1998). Due to the combined effects of gypsum incorporation and the additional generation of protons from fatty acid degradation of the materials, this effect was greatest when organic material was introduced in conjunction with gypsum.

Malik and Haider (1977) also found that pH and ESP declined after the addition of plant material due to decomposition processes, which enhanced CO_2 evolution and humic acid formation. Potential acid sulphate soils can be recognized by incubating moist samples where pH drops rapidly and may continue to drop for at least one year if the sample is kept moist (Dent, 1986)

2.3.2 Electrical conductivity

Electrical conductivity (EC) is one of the important soil chemical properties which measures soluble salts present in soil solution. The EC of *Pokkali* soils during the high saline phase ranges from 12 to 24 dS m^{-1}. The soil consists of soluble salts mainly of chlorides and sulphates of Na, Mg, and Ca. During the low saline phase, it varies from 0.01 to 7.8 dS m^{-1} (Sreelatha and Shylaraj, 2017) where the water becomes almost fresh and salt content decreases. The soil salinity varies from 0 to 31 ppt or more. The salinity of *Pokkali* fields decline rapidly up to August and was maintained till the end of December to January (Vanaja, 2013).

Silpa *et al.* (2021) reported the highest electrical conductivity in April (6.21 dS m^{-1}) and the lowest in October (2.21 dS m^{-1}). Continuous inundation of seawater into the fields caused high electrical conductivity in February and April (high saline phase). From June to October, the electrical conductivity began to decrease due to the dilution of soluble salt in water by the southwest monsoon. Among land uses, mangrove recorded electrical conductivity of 6.38 dS m^{-1} whereas paddy-shrimp land use recorded the lowest value (4.20 dS m^{-1}) of electrical conductivity

High ESP and SAR values were observed in *Pokkali* fields mainly due to the presence of soluble salts of sodium (Joseph, 2014). Although the integration of rice and prawn did not change the soil physico-chemical parameters, rotational prawn culture during summer causes positive changes in soil pH. Adverse changes like increases in electrical conductivity and Na^+ levels are mostly reversible and may not affect the sustainability of these systems.

The incorporation of organic material enhanced the EC in both gypsum-amended and non-gypsum-amended soils. At both sites, the rise in EC of soils treated with organic material alone was most likely due to an increase in ions in solution, which may have occurred from mineral dissolution driven by an increase in PCO_2 (Sekhon and Bajwa, 1993) or the generation of organic acids.

2.3.3 Texture

Kong *et al.* (2009) revealed that soil texture has a significant role in improving soil C concentrations in different land uses under various management intensities. Soils with a large proportion of fine particles have a greater ability to sequester atmospheric C.

Telles *et al.* (2003) stated that soil texture especially clay content has a greater influence in slowing down the C cycle which in turn improves the storage and dynamics of C in tropical forest soils.

A greater percentage of total soil C was estimated in < 2 μm fractions in the cultivated soils (30%) against natural vegetation (18%) in which total C was associated with 2 to 20 μm fractions to a greater extent than in the cultivated soil (Caravaca *et al.*,1999)

2.3.4 Bulk density

The organic matter content greatly affects the bulk density of soil, which is mainly attributed to the enhancement of aggregation of soil particles (Ladd, 1996). Soil compaction increases bulk density and can lead to poor aeration and root growth thereby resulting in low C accumulation (Smith and Doran, 1996). Soil with low bulk density provides desirable soil properties for the growth and development of plants.

Shreshta *et al*. (2004) found that soil bulk density is negatively correlated to SOC. Bhattacharya *et al*. (2007) reported that bulk density of black soil decreases as the SOC content increases for 0-30 cm depth of soil. Gajri and Majumdar (2002) observed low bulk density in forest systems having no disturbance to the soil which might have contributed to the retention of organic matter.

2.3.5 Cation exchange capacity

There was a trivial effect of interaction between clay minerals and organic matter on soil CEC (Parfitt *et al.,*1995).

Soils with abundant biomass-derived black C have higher CEC than adjacent soils with low black C content. The high surface charge density and specific surface area of the black C are responsible for the magnified CEC of soils rich in black C (Liang *et al.,* 2006).

Papini (2011) reported that organic matter can increase the CEC of soils and the soil C pools were positively correlated with CEC.

2.4 SOIL CARBON POOLS

The rate of C accumulation or loss mainly depends upon the balance between the amount of C input and C loss. Carbon inflow is primarily in the form of soil organic carbon (SOC) from plant inputs and biomass accumulation, which is dominated by litterfall and root deposition. The direct effects of toxic ions and increases in osmotic potential, as well as indirect consequences such as deteriorating soil structure, are expected to lower carbon inputs in salt-affected soils as vegetation growth declines. Although SOC is made up of several compounds, it could be divided into multiple pools of varying magnitudes and turnover rates. Soil C pools constitute an active fraction, a slow fraction, and a resistant fraction. Fresh plant and animal detritus, as well as quickly decomposable substances from leaf litter and roots with short turnover times (from week to years), make up the active (labile) or fast pool. A slow or resistant fraction contains the active fraction which has not been decomposed. The slow pool, which is partially resistant to decomposition, is made up of decomposed material cells and tissues with turnover times ranging from 10 to more than 100 years, whereas the resistant, inert, or passive pool is made up of highly humified organic compounds with a turnover time of 1000 years or more (Trumbore *et* *al.,* 1989). The active fraction of a pool is less than 10 per cent, the slow fraction is 40-80 per cent, and the passive portion is 10-50 per cent (Amundson, 2001).

2.4.1 Organic carbon

The SOC includes the remains of plants, animals, and microorganisms in various stages of decomposition, but consists mainly of strongly altered material of unrecognizable origin. About 58 per cent of the mass of the organic matter of soil exists as organic C and it acts as a source of energy for plant growth and triggers nutrient availability through mineralisation process. Organic C greatly influences the physical and chemical properties of the soil and helps to maintain soil health.

According to IPCC (2001), rice farming management for a positive climate impact must address the combined effects of C storage and greenhouse gas emissions in soil. One of the most important pools of soil organic matter is discovered to be the SOC. The quantity and kind of SOC are critical aspects that serve as a soil quality indicator (Larson and Pierce, 1991). Zhang (2004) reported that SOC was higher in surface soils and decreased as one gets deeper into the soil profile; this could be attributed to the deposition of C in surface soil through agricultural residues, stubbles, and rice stalks. Yadav *et al.* (2000) reported a decline of more than 50 per cent in soil loss and an increase in SOC when crop residues were applied as mulch.

The presence of vegetation and its inputs of organic C ameliorates soil physical, chemical, and biological properties, and is conducive to soil organic C accumulation in the profile as compared to the site without vegetation (Ghosh *et al.,* 2010). Exotic straw application increases C input, which may result in a corresponding increase in soil C concentrations if the soil is not saturated with C (Chung *et al.,* 2010).

When fields are inundated, standing water and soil saturation slow the breakdown of organic waste, acting as substantial C and nutrient sinks (Mitsch and Gosselink, 2007). With increasing soil clay concentration, maximum and average SOC content increased across several sites on Great Plains (Nichols, 1984; Burke *et al.,* 1989). Even though variations in total SOC content occur over a long time scale and are hard to detect over a short time (Wissing *et al.,* 2011), it's important to distinguish the active C fraction from the entire SOC pool when evaluating the impact of field management on soil C dynamics (Purakayastha *et al.,* 2008). Total SOC is known to be less responsive than SOC fractions such as labile carbon, particulate organic carbon (POC), and microbial biomass carbon (MBC) (Chan, 2001; Gong, *et al.,* 2009).

2.4.2 Labile carbon

Labile carbon (LC) pool is defined as the C with a turnover time of less than a few years (residence time 1–5 years) and responds more quickly, therefore, its oxidation emits CO_2 per unit time from soils to the atmosphere (Needelman *et al*., 1999; Chen *et al*. 2016). The LC pool has an impact on soil quality and productivity, and it is regarded to be the most important source of nutrition in the soil (Chan *et al*., 2001; Mandal *et al.,* 2008).

Yang *et al*. (2009) found that labile fractions are the more susceptible indicators of SOC resulting from forest transition. These are active C pools that change by the microbial activities easily. Transforming native forests to intensively managed plantations decrease LC, which could be due to various factors such as litter materials, microorganism activity, and practices.

Land use has a great influence on the LC fractions in the topsoil (0-20 cm) which is a vital indicator of soil quality. The labile fraction of organic C reduced as soil depth increased, particularly in wetlands. However, as soil depth increased, the labile fraction organic C in upland forest, abandoned, and cultivated soils decreased slightly (Jinbo *et al*., 2006).

Agricultural soils also had a significantly higher proportion of soil organic matter as LC (Hu *et al*., 1997). Land use categories have a significant impact on the quantity of labile and non-labile C pools (Stecio *et al.,* 2007) and the C balance in the soil is also dependent on microbial communities from diverse environments (Steenworth, 2003). SOM turnover is affected by microbial biomass which constitutes 1 per cent of SOC (Moore *et al.,* 2000) and is the most labile fraction of SOM, and the pool size in rice soil accounts for 2-4 per cent of total C (Reichardt *et al.,* 1997)

As reported by Mc Lauchlan and Hobbie (2004), the labile fractions of C were greatly dependent on the amount of SOC. In rice-based cropping systems, the yield was decided by the labile fractions or active pools of soil C viz., LC and microbial biomass carbon (Nath *et al.,* 2016)

2.4.3 Water soluble carbon

Water-soluble carbon or dissolved organic carbon is the most vigorously cycling SOC pool and can easily be decomposed by micro-organisms and functions as an energy source. Chantigny (2003) revealed that the change in management practices has a short-term influence on dissolved organic matter and water-extractable organic matter, while the vegetation type and quantity of litter incorporated into the soil have a long-term effect.

Water-soluble organic carbon (WS-OC) is regarded as the immediate organic substrate for soil microorganisms (McGill *et al*., 1981) and helps to maintain their population in the soil. Changes in WS-OC, which is the most labile and mobile form of SOC, have received much less attention. Concentrations of water-soluble and bio-available SOC have been reported to be high in the case of agricultural soils (Boyer and Groffiman, 1996).

Zsolnay (1996) reported that dissolved organic matter concentration is higher in the forest than in agricultural soils. The concentration of dissolved organic carbon (DOC) in forest soil ranges from 5 to 440 mg L^{-1}, whereas water-extractable organic carbon (WEOC) is 1000 to 3000 mg L^{-1}. These range from 0 to 70 mg L^{-1} for DOC and 5 to 900 mg L^{-1} for WEOC in agricultural soils.

Christ and David (1996) observed that DOC production was relatively faster in the first two days of incubation, and then declined to almost 90 µg g^{-1} week $^{-1}$. But when warmer conditions prevailed, production rates in the first two days of incubation were higher.

Souza and Melo (2003) revealed that WS-OC reflects the initial stage of degradation of organic residues in the soil. The data found on increased production of water-soluble carbon suggested that agricultural soils might support a greater rate of microbial activity than forest soils. The WS-OC accounts for less than one per cent of the total C in the soil. Liming had also shown a marked effect on this C fraction.

2.4.4 Microbial biomass carbon (MBC)

Soil MBC contributes a greater portion of the LC pool which along with climate controls the turnover rate of LC. Prabha *et al.* (2013) found that in wetland rice soils, application of biochar in appropriate proportion has a great influence over the soil C dynamics by enhancing the major soil C sequestration parameters like SOC, POC, and MBC and can combat global warming without affecting rice productivity.

Soil MBC has a crucial role in SOM decomposition and nutrient cycling. Thus, it helps in maintaining the function and sustainability of the terrestrial ecosystem. The pool size of MBC in rice soils accounts for only 2-4 per cent of total C that accounts for an important and most labile fraction of SOM which could turn over rapidly (Richardt *et al.,* 1997).

Benbi *et al.* (2012) reported that the MBC in the selected benchmark soil series of Punjab ranged between 125 and 249 μg C g^{-1} soil, which contributed to 1.7 to 4.1 per cent of SOC. The ratio of MBC to SOC is a sensitive indicator for finding the degree of disturbance of soil C cycling and a low ratio indicates a reduced pool of available C in soil (Klose *et al*., 2004).

In *Pokkali* soils, George *et al.* (2017) reported that the bacterial population ranged from 2.8 x 10^7 to 4.8 x 10^7 cfu, with a mean value of 4.3 x 10^7 cfu. Even though the soil was quite saline, the *Pokkali* ecosystem showed amazing fungal activity, which was positively associated with soil organic matter and had an average population of 2.3 x 10^4 cfu. The mean population of actinomycetes was 3.2 x 10^4 cfu, which was larger than that of fungi, indicating that actinomycetes may thrive well in stressful environments.

Potential C mineralisation and MBC are biologically active fractions of SOC that change quickly over time, and could better signal changes in soil quality and productivity that alter nutrient dynamics due to immobilisation-mineralisation (Saffigna *et al.,* 1989; Bremner and Van Kissel, 1992).

2.4.5 Dehydrogenase activity

Soil enzymatic activity is a measure of soil microbial activity and it is frequently assessed due to the ease with which it can be measured and the speed with which it responds to management strategies (Okur *et al*., 2009). Soil dehydrogenases activity (DHA), phosphatase, protease, and urease are often determined, while DHA is used as an index of activity of soil micro-organisms (García-Orenes *et al.,* 2016).

Monitoring of soil DHA, a respiratory enzyme that is also found in all soil organisms, provides a measure of the biological activity of soil at any particular time. The role of soil DHA is to catabolize soil organic matter. Rather than SOC, enzymatic activity in the soil can be correlated to labile organic C (Shao *et al*., 2015). Organic inputs to soil improve SOC, DHA, and nutrient availability (Adak *et al*., 2014).

Ray (1984) found enhanced DHA in both non-flooded and flooded soils after lime addition due to increased microbial population in two acid sulphate soils of Kerala, locally known as *Pokkali* and *Kari*.

2.4.6 Soil organic carbon stock

Guo and Gifford (2002) reported that Soil organic carbon (SOC) stock in soil ranged between 101.5 to 127.4 Mg ha^{-1}. Land-use changes have turned down the c stocks from pasture to plantations (-10%), native forest to plantations (-13 %), native forest to crop (-42 %), and pasture to crop (-59%). Soil C stocks perked up after land-use changes from native forest to pasture (+8%), crop to pasture (+19 %), crop to plantation (+18%), and crop to a secondary forest (+53 %). The broadleaf tree plantations established into a prior native forest or pasture did not influence SOC stock, whereas pine plantations decreased SOC stock by 12-15 per cent.

Datta *et al.* (2015) reported that the total SOC stock considerably decreased with an increase in depth. Among the land uses, TOC stock at the surface soil (0-20 cm) in descending order followed as guava (28.80 Mg C ha^{-1}) > Jamun (27.30 Mg C ha^{-1}) > litchi (25.70 Mg C ha^{-1}) and mango (19.20 Mg C ha^{-1}) and in subsurface soil (40-60 cm) 13.9, 8.1, 9.6 and 9.0 Mg C ha^{-1} respectively.

A minor change in SOC stock can have a big influence on CO_2 emissions in the atmosphere (Lal, 2008). Fine-textured soils' SOC stock is observed to be less vulnerable to heterotrophic respiration than coarse-textured soils' SOC stock (Conant *et al.,* 2008). SOC stock estimates range from 684 to 724 Pg for 0.3 m depth, 1550 Pg for 1 m depth, and 2376 to 2456 Pg for 2 m depth, all of which are higher than atmospheric C pool and biota (Batjes, 1996; Lal, 2008).

2.4.7 Influence of land use on soil carbon pools

Land-use change is a global concern because of its negative impact on climate through soil-based GHG emissions (Post *et al.,* 1982), as well as its influence on the C cycle and fluxes. Human activities such as deforestation and changing land use from forest to grazing or agricultural land are examples of human activities that increase atmospheric concentrations of GHGs, particularly CO_2 and CH_4 (Shrestha *et al.,* 2004).

The type of ecosystem and land use had a major role in the amount, decomposability, and placement of above-ground and below-ground inputs. There existed an overall balance between the rate of SOC inputs and the rate of mineralisation which decides the amount of organic C accumulated in the soil (Post and Kwon, 2000)

Don *et al.* (2007) opined that the type of land use has a great influence on SOC stock in the soil. Davidson and Janssens (2006) observed that the wetlands, peatlands, and permafrost soils contain higher C densities than upland mineral soils normally and together they build up enormous stocks of C globally. Hansen and Nestlerode (2014) reported that wetlands can accumulate 11517 Gg C year $^{-1}$ and efficiently store 34-47 Mg C ha^{-1}.

From the findings of Dhanya (2017), rice and rice-fish land use contributed to maximum SOC stock and C pools showing the prevalence of a conducive environment in the Kuttanad ecosystem for the storage of organic C.

Due to their higher turnover rate than that of the SOC pool as a whole (Dalal, 1998; Sparling, 1992), organic C substrate utilisation and partitioning are more sensitive to management-induced effects and consequently signal changes in soil quality quicker than total SOM.

2.5 CARBON MINERALISATION

2.5.1 Influence of salinity on carbon mineralisation

Carbon mineralisation measurements by laboratory incubations are regarded as biological fractionation of organic matter whereby labile fractions are readily mineralised and subsequent C fractions are more slowly mineralized. Soil C mineralisation is regarded as an important aspect of soil functional quality. The SOC loss through heterotrophic respiration is one of the main reasons for global CO_2 emission from the terrestrial ecosystem to the atmosphere (Bond-Lamberty and Thomson, 2010). Rey *et al.* (2005) observed that the C mineralisation rate of topsoil is almost 12 times faster than bottom layers and the sensitivity of C mineralisation to varying soil moisture is reliant on temperature. A sudden fluctuation in soil moisture has increased C mineralisation during dry summer.

The terrestrial C pool absorbs 120 Gt C from the atmosphere per year as gross primary productivity (or photosynthesis). Soil respiration, the flux of microbially and plant-respired CO_2 from the soil surface to the atmosphere, is next greatest terrestrial C flux, estimated to be 75 to 100 Gt C per year. It is roughly 60 times the yearly release of land-use change emissions and about 11 times the annual release of fossil fuel emissions to the atmosphere. As a result, even a little difference in soil respiration can have a big impact on the balance of atmospheric CO_2 concentration as compared to soil C reserves (Raich and Potter, 1995). Wang *et al.* (2003) reported that higher soil respiration under appropriate conditions could be due to better substrate availability rather than to the size of the MBC pool.

When the CO_2 evolution rate of soil was dealt with, more positive conditions existed in incubations than in a real environment. So the values estimated to longer periods were overestimated and could not represent the real loss of organic matter but can be used for comparisons between the soils (Saviozzi *et al.,* 2014). Hence, the CO_2 evolution from the incubation experiment can be considered for analysing the short-term C mineralization pattern of the soil among the different treatments.

Giardina *et al*., (2001) found a decline in C and N mineralization rate with an increase in clay content. Litter quality also influences the C mineralisation rate. Aspen litter quality is s superior to pine litter quality, but pine soils emitted an average of 238 g C kg $^{-1}$ soil compared with 103 g C kg $^{-1}$ soil C for aspen soils.

Shiny and Byju (2020) estimated an increase in CO_2-C evolution and which in turn relates to microbial activity in continuous site-specific nutrient management (SSNM) treatment for 10 years in Cassava grown Ultisols. The addition of farmyard manure and an increase in litterfall have attributed to an increase in microbial activity and an increase in CO_2-C evolution. According to them, SSNM treatment also showed the presence of stable organic C in the soil. The initial potential rate of C mineralization (C_ok) was also found to be highest for SSNM treatment indicating that the organic matter quality has increased in continuous SSNM treatment against other treatments. The stability of organic C also indicated the C sequestration potential of the SSNM.

Several works have reported that salinity decreased SOC mineralization (Laura, 1974, 1977; McCormick and Wolf, 1980; Sarig and Steinberger, 1994; Garcia and Hernandez, 1996; Pathak and Rao, 1998; Sardinha *et al.,* 2003; Wichern *et al.,* 2006; Tripathi *et al.,* 2006; Ghollarata and Raiesi, 2007; Yuan *et al.,* 2007; Walpola and Arunakumara, 2010). On the other hand, sodicity can increase mineralization of added C due to dispersion of soil which releases organic matter from inside of aggregates which then becomes available to microorganisms (Nelson *et al*., 1996). Dendooven *et al*. (2010) observed that decomposition of easily degradable organic material (such as glucose) was even inhibited in extremely alkaline saline soil.

Increasing salinity has detrimental effects on the biologically mediated process in the soil, such as respiration (Ghollarata and Raiesi, 2007). The hydrological process of saline and sodic soil is modified by the presence of soluble salts which affects soil chemistry, C and nutrient cycling, and organic matter decomposition (Wong, 2010). The response pattern of C mineralisation to salinity stress depended on the plant residue quality and duration of the incubation (Farshad and Ahamad, 2006).

Soil salinity not only decreases plant productivity and C inputs to the soil, but microbial activity and SOC decomposition rates also. CO_2 evolution was generally depressed substantially with increased salinity (Laura, 1974). It has been reported that high salinity and alkalinity positively influence the CO_2 absorption capacity of salt-affected soils (Xie *et al.,* 2009).

Jha *et al.* (2012) conducted an incubation study for 74 days to assess the sole and combined effect of $CaCl_2$ and $CaSO_4$ on wheat straw amended soil C mineralisation. The residue C mineralisation in soil decreased as salinity increased. The amount of residue C mineralisation was reduced to the extent of 42 per cent when $CaSO_4$ and $CaCl_2$ were applied in higher doses. The results suggest that C mineralisation was affected by both $CaCl_2$ and $CaSO_4$ either alone or in combination by influencing soil osmotic properties and DHA. The study indicates that saline soils offer an opportunity to sequester C because decomposition of added wheat straw was more strongly decreased under higher EC value.

The rate of C and N mineralization in the soil is greatly influenced by the C/N ratio of the crop residues (Mohanty *et al.,* 2013).

According to Weston *et al.* (2011), saltwater intrusion into tidal freshwater marsh (TFM) soils can dramatically enhance rates of microbial C mineralization, and the increased rates of organic matter decomposition in salt-water amended soils resulted in a loss of soil organic C (44.1 mol m^{-2}).

2.5.2 Influence of neutral salts and organic matter on mineralisation

The order of dominance of exchangeable cations in *Pokkali* soils reported by Aryalekshmi (2016) is Ca=Na>Al>Mg>K>Fe. *Pokkali* soils recorded the absence of carbonate ions and sulphate and phosphate were the predominant anions in these soils

(Mohan, 2016). Gypsum ($CaSO_4.2H_2O$) is the most often utilised ameliorant in sodic or saline-sodic soils to balance soil electrolyte levels and improve soil physical and hydraulic properties (Keren, 1996). Li *et al.* (2006) estimated that cumulative CO_2 evolution decreased with increasing NaCl concentration but increased with Na_2SO_4 salinity.

Following the harvest of prawns, the amount of available calcium nearly increased, possibly due to the deposition of calcium-rich shrimp exuvia (Tacon, 1987). According to Haynes and Naidu (1998), liming might generate a brief increase in soil microbial activity.

Diya and Sreelatha (2018) reported that the effect of calcium salt application on *Pokkali* soil characteristics differed depending on the season. In the case of soil pH, available K, Fe, exchangeable Na, and Al, effects were more evident after rice harvest than after prawn harvest. Calcium salts invariably raised soil pH and microbial biomass carbon while inactivating Fe, Mn, and Al in the soil solution. Carter (1986) reported that gypsum increased soil microbial biomass, which attributed to changes in the physicochemical environment.

Soil organic matter (SOM) status is widely used as an index of soil quality or health. Soil organic matter is the repository for approximately 60 per cent of the global terrestrial C pool and is sensitive to agricultural land management practices (West and Post, 2002). SOM also helps to improve soil structure and aggregation (Oades, 1988; Tisdall and Oades, 1982), uplift hydraulic conductivity (Baldock *et al.,* 1992), enhance nutrient levels and promote greater cation exchange capacity (von Lutzow *et al*., 2002). Incorporation of organic material, in the form of crop residues, has been shown to improve soil aggregation and uplift SOC stocks (Lal *et al.,* 1999), and retaining stubble increases SOM and soil faunal activity (Valzano *et al*., 2001). The presence of SOM can serve as a buffer to the soil solution and soil microorganisms and their activity, especially where salinity or sodicity increases (McCormick and Wolf, 1980).

In a 360 days laboratory incubation study conducted by Schmatz *et al.* (2017) with different crop residues on sandy loam and clay textured soils recorded positive priming effect on C mineralisation for all the treatments.

When compared to gypsum alone, Vance *et al.* (1998) found that adding organic matter and gypsum to the surface soil reduced spontaneous dispersion and EC down to the subsoil. Organic matter may further increase soil structural stability by raising EC and hence enhancing flocculation (Tejada *et al.,* 2006), while also providing physical protection to SOM.

Datta *et al.* (2019) noticed that crop residues with low N and high C/N ratios, such as maize, wheat, rice, and their mixtures, can be applied to the soil surface for faster C and N mineralization, aiding in the management of high volumes of residues in northwest India using conservation agriculture. Except for treatments where maize residue was applied, cumulative C mineralization was higher for residues incorporated into soils than for residues applied on the soil surface.

According to Wichern *et al.* (2020), organic amendments, such as rice straw to paddy soils under saline conditions, minimize the adverse impacts on soil microbial processes by producing osmolytes, which counterbalance the osmotic effects of increased salinity.

When SOM is solubilized, the increased availability of substrate can help to alleviate some of the microbial population's environmental challenges and reduce the negative effects of NaCl (McCormick & Wolf, 1980; Pathak & Rao, 1998). With increasing salinity and sodicity levels, Jandl and Sollins (1997) reported that concentrations of dissolved SOC increase due to increased solubility of SOM, providing an additional easily decomposable substrate for microbial development. Wong *et al.* (2008) reported higher levels of soil microbial biomass (SMB) in high-salinity soils due to increased substrate concentrations, which contribute to SOM solubility, decomposability, and accessibility. Similarly, Wong *et al.* (2009) reported that providing OM to a highly saline-sodic soil enhanced microbial biomass and respiration at first. It could also be attributed to more substrate becoming accessible for decomposition as SOC is freed from clays as salinity rises. Because increasing ionic strength can affect the makeup of exchange sites, SOM sorbed on clays is released due to a solvation effect of the salt (Wiklander, 1975; Kaiser *et al.,* 1996).

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled “effect of salinity on carbon mineralisation under different land uses in *Pokkali* ecosystem” was conducted at Rice Research Station, Vyttila during 2019-2021. The methodology followed for the present study is detailed in this chapter.

3.1 Selection of study area

Pokkali ecosystem is the salinity prone coastal wetlands located as small patches along the coastal tract of Kerala state in Ernakulam, Alappuzha, and Thrissur districts between a latitude of 9°45" N and 10°15" N and a longitude of 76°10" E and 76°20" E. These are mainly low lying waterlogged soils where salt-tolerant *Pokkali* rice variety which had received Geographical indication (GI) tag in the year 2007 is extensively grown. These agro-ecosystems are famous for their rich biodiversity and are sustainable enough to manage pests and diseases through natural enemies. During the summer months, saline water enters these coastal wetlands through estuaries of rivers and streams makes the soil highly saline and unfit for cultivation. However, during the monsoon season rainwater washes excess salts away from the soils and makes it less saline, and allows rice cultivation. Since rotational rice-fish or prawn culture is a general practice in these fields, the farmers cut only the panicle along with a small portion of rice stem at the time of harvesting. After rice harvest, saline water flows and crop stubbles left unharvested in the field get decomposed. Rice- fish/prawn agriculture in salinity-prone coastal wetlands is more than just a farming technique for the society's farmers, it's a culture deeply entwined with the people's way of life.

But *Pokkali* cultivation has started to shrink these days due to several reasons. The substantial income from subsidiary prawn cultivation tempted farmers to concentrate on prawn cultivation alone without going for paddy cultivation. Acute labor shortage and lack of machinery accelerated this shift from mixed farming to prawn monoculture. Though this prawn monoculture provides economic benefit in the short run, they are unstable in long run and could adversely affect the ecological balance of this system. Considering all these factors, this study assessed the carbon pools and the effect of salinity on carbon mineralisation under different land uses in *the Pokkali* ecosystem. Different land uses considered for this particular study includes

1. Rice -prawn (Kumbalangi)
2. Rice alone (RRS, Vyttila)
3. Prawn alone (Kadamakkudy)

3.1.2 Soil sampling

Georeferenced soil samples were collected from rice-prawn, rice alone, and prawn alone land uses using a core auger. Table 1 shows different land uses under study and their respective geographic location. Samples were collected during January 2020. Altogether 5 composite samples were collected from each land use at a depth of 0-20 cm. The collected samples were immediately sealed in plastic covers and labelled. Estimation of different carbon pools and organic carbon stock were carried out using these composite samples. Later these soil samples were mixed to get one composite sample and a carbon mineralisation experiment was carried out.

Table 1: Different land uses and their respective geographic location under this study

Land use	location	Co-ordinates
Rice-Prawn	Kumbalangi	$9^0$53’25.60704” N $76^0$16’37.6284” E
Rice alone	RRS, Vyttila	$9^0$58’40.0224” N $76^0$19’21.8712” E
Prawn alone	Kadamakkudy (Moolampilly)	$10^0$2’18.1602” N $76^0$16’1.851” E

Plate 1: Soil sample collection from rice-prawn land use of *Pokkali* ecosystem

Plate 2 : Soil sample collection from rice alone land use of *Pokkali* ecosystem

3.2 Soil properties

3.2.1 Soil reaction

Soil reaction was measured potentiometrically with the help of pH meter, after equilibrating the soil with water in the ratio of 1: 2.5 soil: water suspension (Jackson, 1958).

3.2.2 Electrical conductivity

Electrical conductivity in soil samples was estimated using a conductivity meter from the supernatant of the soil water suspension used for pH estimation (Jackson, 1958).

3.2.3 Cation exchange capacity

The cations (Ca, Mg, Na, K, Al, Fe, Mn, Cu, and Zn) present in exchangeable sites in the soil were estimated by replacing them with 0.1M $BaCl_2$ solution (Hendershot and Duquette,1986). The sum of exchangeable cations expressed in cmol(p+)kg^{-1} was recorded as the cation exchange capacity of the soil.

3.2.4 Bulk density

Soil samples were collected by using a core sampler at a depth of 0-20 cm and dried to a constant weight in a hot air oven at 105°C. The bulk density of the sample was estimated by dividing the mass of dry soil by the total volume of soil (Dakshinamurti and Gupta,1968; Blake and Hartge,1986).

3.2.5 Particle size analysis

The particle size distribution of the soil sample was determined by the International Pipette method according to Stoke's law (Piper, 1966).

3.3 Soil Carbon pools

The major soil carbon pools studied include organic carbon, labile carbon, water-soluble carbon, and microbial biomass carbon.

3.3.1 Soil organic carbon (SOC)

Wet oxidation followed by ferrous ammonium sulphate titration was used to estimate the organic carbon content of the soil, as described by Walkley and Black (1934).

3.3.2 Labile carbon

Three grams of soil was mixed with 30 ml of 20 mM $KMnO_4$ in a 50 ml centrifuge tube and kept in a reciprocating shaker for 15 minutes. The soil suspension was then centrifuged for 5 minutes at 2000 rpm. Two ml aliquot from the supernatant solution was made up to 50 ml and absorbance was determined using a spectrophotometer at 560-565 nm. By determining the $KMnO_4$ concentration from the standard calibration curve, labile carbon was calculated (Blair *et al.,* 1995).

3.3.3 Water-soluble carbon (WSC)

Field moist samples were extracted with distilled water in the ratio of 1:3 for 30 minutes on an end-over-end shaker and centrifuged for 20 minutes at 9,000-10,000 rpm. The extract was analysed for water-soluble carbon using the dichromate oxidation technique after the supernatant was filtered (Ghani *et al.*, 2003).

3.3.4 Microbial biomass carbon (MBC)

Microbial biomass carbon was determined by the chloroform fumigation extraction method by estimating the amount of CO_2-C evolved from the soil samples as described by Voroney and Paul (1984). Ten-gram soil sample was taken in a 250ml conical flask and fumigated with 10 ml chloroform. Both fumigated and non -fumigated (without chloroform) samples were kept at incubation for 24 h. These samples were transferred into 250 ml conical flasks and shaken for half an hour after adding 25 ml of 0.5 M K_2SO_4. After filtration 10 ml of filtrate was taken and 2 ml 0.2 N $K_2Cr_2O_7$, 10ml conc. H_2SO_4 and 5 ml o-phosphoric acid were added to each flask. These flasks were kept on a hot plate at 100^0C for half an hour under refluxing conditions. Then 250 ml of distilled water was added and cooled to room temperature. These contents were titrated against 0.005N Ferrous Ammonium Sulphate after adding ferroin indicator to get a brick red color.

MBC (µg g^{-1} soil) = $\frac{EC_F - EC_{NF}}{K_{EC}}$

Where EC_F and EC_{NF} represents the total weight of extractable C in fumigated and non-fumigated soil and $K_{EC}=0.25\pm0.05$ (Jenkinson and Pawlson, 1976)

3.3.5 Soil organic carbon stock

Soil organic carbon (SOC) stock was determined by multiplying organic carbon content with bulk density and soil depth. The SOC stocks were calculated as follows,

SOC stocks (Mg ha^{-1}) = SOC x ρ x d x 10,000

Where, SOC is the soil organic carbon measured in g g^{-1}; ρ is the soil bulk density (g cm^{-3}), d is the depth of soil layer (m). The value of 10,000 indicates the stock for 1 ha of land. (Sharma *et al.,* 2014)

3.3.6 Dehydrogenase activity

Dehydrogenase activity was estimated colorimetrically using a spectrophotometer. One gram of fresh soil sample was treated with 0.1 per cent 2, 3, 5- triphenyl tetrazolium chloride (TTC) and 0.5 per cent glucose solution and incubated for 24 hrs. In this process, TTC gets reduced to a pink-coloured compound triphenyl formazon (TPF) which was extracted quantitatively by methanol and measured using a spectrophotometer at 485 nm (Cassida *et al.,* 1964, Page *et al.,* 1982).

3.4 Carbon mineralisation experiment

Carbon mineralisation was studied in a laboratory incubation experiment for 74 days. One composite sample from each location was used for the study. Two sets of 200 g soil with moisture correction were taken in 500 ml bottles, in which one set was amended with 1 per cent of finely ground paddy straw (PS) on a dry weight basis and each set replicated 3 times. These samples were further amended with different concentrations of $CaSO_4$ and Na_2SO_4 alone or both in combinations of 40 and 80 mmol per kg soil to get desired change in electrical conductivity similar to field conditions. The details of the treatment combination are given in table 2.

Table 2: Details of treatment followed in carbon mineralisation experiment

Treatment details:
T_1 – soil only
T_2 – soil + PS
T_3 – soil + PS + $CaSO_4$ (40 mmol kg^{-1})
T_4 – soil + PS + $CaSO_4$ (80 mmol kg^{-1})
T_5 – soil + PS + Na_2SO_4(40 mmol kg^{-1})
T_6 – soil + PS + Na_2SO_4(80 mmol kg^{-1})
T_7 – soil + PS + $CaSO_4$ (40 mmol kg^{-1}) + Na_2SO_4 (40 mmol kg^{-1})
T_8 – soil + PS + $CaSO_4$ (80 mmol kg^{-1}) + Na_2SO_4 (40 mmol kg^{-1})
T_9 – soil + PS + $CaSO_4$ (40 mmol kg^{-1}) + Na_2SO_4 (80 mmol kg^{-1})
T_{10} –soil + PS + $CaSO_4$ (80 mmol kg^{-1}) + Na_2SO_4 (80 mmol kg^{-1})

A vial containing 10 ml of 2M NaOH was placed in the bottles and was tightly sealed. The vials were taken out after 1, 3, 6, 11, 17, 25, 35, 50, 68, and 74 days from the beginning of incubation study and titrated with standardized 0.5M HCl after the addition of 1 ml of saturated $BaCl_2$ using phenolphthalein as indicator. At each sampling interval, CO_2-C evolved was determined and vials were refilled and replaced with 10 ml of 2M NaOH. The amount of CO_2 -C evolved was calculated using the formula:

CO_2 -C evolved (mg $100g^{-1}$) = (A-B) × N × 6 (Jha *et al.*, 2012)

Where, A and B are the volumes of HCl consumed for titrating 10 ml of 2 M NaOH in control and amended soil.

Plate 3: Experimental setup

Plate 4: Carbon mineralisation experiment

3.4.2 Total carbon content (TOC)

A weighed amount of oven-dried soil sample (105ºC; 24 h) was placed in a high-form porcelain crucible and set in a muffle furnace (± 5ºC precision) for combustion at 600^0C for 6 hours (Goldin, 1987). The organic matter content was determined through the mass difference with the original soil sample. Total organic carbon content was obtained by dividing organic matter by a factor of 1.72

3.5 Statistical analysis

Analysis of variance (ANOVA) was used to assess the interactive effects of $CaSO_4$ and Na_2SO_4 on soil pH, EC, dehydrogenase activity, water-soluble carbon, and cumulative CO_2-C over different incubation periods.

Results

4. RESULTS

The present study identified three different land uses of the *Pokkali* ecosystem and characterized their basic soil properties and estimated different organic carbon pools of these soils. The carbon mineralisation under these land uses through incubation study was carried out. The effect of salinity on carbon mineralisation was also studied. The analytical data generated were subjected to statistical analysis and the experimental results are presented below.

4.1 SOIL PROPERTIES

4.1.1 Soil reaction

Soil reaction recorded from rice-prawn, rice alone and prawn alone land uses of *Pokkali* ecosystem is represented in table 3. The pH values of soil ranged from 6.14 to 7.25 under different land uses of the *Pokkali* ecosystem during January. The pH of rice alone land use was significantly lower than rice-prawn and prawn alone land uses. The pH observed was closer to neutral values irrespective of land-use systems. The soil pH of rice-prawn land use ranged from 6.76 to 6.9 with a mean value of 6.88. The observed soil pH from rice alone land use ranged from 6.14 to 6.61 with a mean pH of 6.42. Prawn alone land-use system recorded pH values ranging from 6.44 to 7.25 with a mean pH of 6.84. Soil pH of prawn alone land use registered relatively higher values than other land uses.

Table 3. Soil reaction of composite samples from different land uses in *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	6.96	6.35	7.15
Sample 2	6.91	6.61	6.44
Sample 3	6.76	6.59	6.83
Sample 4	6.89	6.14	6.55
Sample 5	6.90	6.39	7.25
Mean	6.88^{a}	6.42^{b}	6.84^{a}
CD (0.05)	0.33*		

4.1.2 Electrical Conductivity

Electrical conductivity (EC) represents a direct measure of soluble salts which have a significant effect on soil health. It has a great influence on crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influences key soil processes including emission of greenhouse gases such as nitrogen oxides, methane, and CO_2. The EC recorded from rice-prawn, rice alone, and prawn alone land uses of *Pokkali* ecosystem is given in table 4. The EC values observed from different land uses ranged from 1.1-3.2 dS m^{-1}. The EC of prawn alone land use was significantly higher than rice-prawn and rice alone land uses. The highest EC value of 3.2 dS m^{-1} was observed in prawn alone land use and the lowest (1.1 dS m^{-1}) was reported from rice alone land use. The mean EC values observed from rice - prawn, rice alone, and prawn alone land uses were 1.82, 1.34, and 2.44 dS m^{-1} respectively. The EC values recorded were less than 4 dS m^{-1}.

Table 4: Electrical conductivity (dS m^{-1}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite Samples	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	1.8	1.6	2.3
Sample 2	2.0	1.5	2.3
Sample 3	1.5	1.2	3.2
Sample 4	1.6	1.3	2.3
Sample 5	2.2	1.1	2.1
Mean	1.82^b	1.34^c	2.44^a
CD (0.05)	0.45*		

4.1.3 Particle size analysis

Particle size or texture analysis provides the percentage distribution of particles that make up the mineral fraction of the soil. Particle size analysis of rice-prawn, rice alone, and prawn alone land use of *Pokkali* ecosystem is presented in table 5. It revealed that rice-prawn and rice alone land use recorded clay texture with 53.47 and 56.82 per cent clay content respectively. While prawn alone land use registered sandy clay loam texture with 33.54 per cent clay content. The proportion of coarse sand fraction was found higher in prawn alone land use followed by rice - prawn and rice alone land uses. But a higher proportion of fine sand was found in rice alone followed by rice - prawn and prawn alone land uses. Higher silt percentage was found in rice alone followed by rice-prawn and prawn alone land uses.

Table 5: Particle size analysis (%) from different land uses in the *Pokkali* ecosystem

Land uses	% Coarse sand	% fine sand	% clay	% silt	Texture
Rice - prawn (Kumbalangi)	19.35	16.04	53.47	11.34	clay
Rice alone (RRS, Vyttila)	5.54	19.51	56.82	18.12	clay
Prawn alone (Kadamakkudy)	53.12	4.06	33.54	9.75	sandy clay loam

4.1.4 Cation exchange capacity

Cation exchange capacity (CEC) of soils is an inherent soil characteristic that represents the total capacity of a soil to hold exchangeable cations. It influences the ability of soil to hold essential nutrients and buffer against soil acidification. The CEC recorded from rice-prawn, rice alone, and prawn alone land uses of *Pokkali* ecosystem is represented in table 6. The CEC varied from 9.5 to 12.38 cmol (p+) kg^{-1}. The lowest CEC of 9.59 cmol(p+)kg^{-1} was recorded in prawn-alone land use. The highest CEC of 12.38 cmol(p+)kg^{-1} was observed in rice - prawn land-use system followed by rice alone land use (11.01 cmol(p+)kg^{-1}).

Table 6: CEC (cmol(p+)kg^{-1}) of different uses in the *Pokkali* ecosystem

Land uses	CEC (cmol(p+)kg^{-1})
Rice - prawn (Kumbalangi)	12.38
Rice alone (Vyttila)	11.01
Prawn alone (Kadamakkudy)	9.59

Table 7: Bulk density (Mg m^{-3}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	0.74	1.08	1.19
Sample 2	0.73	0.89	1.59
Sample 3	0.58	0.73	0.96
Sample 4	0.57	0.89	1.29
Sample 5	0.77	0.85	1.13
Mean	0.68^{b}	0.89^{b}	1.2^{a}
CD (0.05)	0.22*		

4.1.5 Bulk density

Bulk density greatly influences soil aeration and bulk density values obtained from rice-prawn, rice alone, and prawn alone land use of *Pokkali* ecosystem is represented in table 7. The bulk density of prawn alone land use was significantly higher than rice-prawn and rice alone land uses. Bulk density values from different land use ranged from 0.57 to 1.5 Mg m^{-3}. Among different land uses, the lowest bulk density was registered for rice-prawn land use which ranged from 0.57 to 0.77 Mg m^{-3} with a mean value of 0.684 Mg m^{-3}. The highest bulk density values were recorded from prawn-alone land uses, which varied from 0.96 to 1.59 Mg m^{-3} with a mean value of 1.24 Mg m^{-3}. Bulk density values varied from 0.73 to 1.08 Mg m^{-3} in rice alone land use with a mean value of 0.89 Mg m^{-3}.

4.2 SOIL ORGANIC CARBON POOLS

4.2.1 Soil organic carbon

Soil organic carbon (SOC) estimated from rice-prawn, rice alone, and prawn alone land uses of the *Pokkali* ecosystem is listed in table 8. The SOC of prawn alone land use was significantly lower than rice alone and rice-prawn land uses. Organic carbon in all the land uses of the *Pokkali* ecosystem ranged from 0.63 to 1.7 per cent. The SOC ranged from 1.53-1.70 per cent in rice-prawn land use and the highest mean of 1.65 per cent was recorded in this land use. The lowest SOC among these land uses was recorded in prawn-alone land use, where a mean value of 0.98 per cent was registered and SOC ranged from 0.63-1.29 per cent. Soil organic carbon from rice alone land use recorded a mean value of 1.47 per cent where SOC ranged from 1.38-1.61 per cent.

4.2.2 Labile carbon

Labile carbon (LC) represents the easily degradable fraction of soil organic matter and table 9 shows LC present in soils of rice-prawn, rice alone and prawn alone land uses of *Pokkali* ecosystem. It varied from 1149.21 to 2645.98 mg kg^{-1}. The LC of prawn alone land use was significantly lower than other land uses. The highest amount of LC was found in rice-prawn land use with an average of 2153.56 mg kg^{-1} and LC ranged from 1774.10 to 2645.97 mg kg^{-1}. The lowest value recorded for LC was in prawn alone land uses with a mean of 1547.81mg kg^{-1} and ranged from 1149.21 to 1696.48 mg kg^{-1}. The LC estimated in rice alone land use followed rice-prawn land use which ranged from 1615.93 to 2444.52 mg kg^{-1} with a mean value of 1949.66 mg kg^{-1}. The LC also followed the same trend as that of SOC.

Table 8: Soil organic carbon (%) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	1.53	1.53	0.63
Sample 2	1.69	1.38	1.21
Sample 3	1.61	1.38	0.76
Sample 4	1.70	1.46	1.29
Sample 5	1.69	1.61	1.0
Mean	1.65^{a}	1.48^{a}	0.98^{b}
CD (0.05)	0.25*		

Table 9: Labile carbon (mg kg^{-1}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS,Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	2061.61	1941.77	1642.26
Sample 2	1963.80	1780.33	1907.99
Sample 3	1774.10	1615.93	1343.08
Sample 4	2645.97	1965.75	1696.48
Sample 5	2322.33	2444.52	1149.21
Mean	2153.56^{a}	1949.66^{ab}	1547.81^{b}
CD (0.05)	436.93*		

4.2.3 Soil organic carbon stock

Soil organic carbon (SOC) stock helps to identify high potential of soil for sequestering C and SOC stock found in rice-prawn, rice alone, and prawn alone land uses of *Pokkali* ecosystem has been listed in table 10 and it ranged from 15.02 Mg ha^{-1} to 38.73 Mg ha^{-1}. Rice alone land use system recorded a mean SOC stock of 26.46 Mg ha^{-1} while rice-prawn land use and prawn land use registered 22.5 Mg ha^{-1} and 24.9 Mg ha^{-1} respectively. Even though there was a difference in bulk density and soil organic carbon content in land uses, there was not much difference in SOC stock. A significant positive correlation was observed between bulk density and SOC stock among all these land uses (Appendix I). Also, a significant positive correlation was observed between OC and SOC stock except in rice alone land uses (Appendix I).

4.2.4 Microbial biomass carbon

Microbial biomass carbon (MBC) represents the living SOC fraction and an estimate of biological activity present in the soil. The MBC estimated from rice-prawn, rice alone and prawn alone land uses is depicted in table 11 which ranged from 145.65 µg g^{-1} soil to 292.80 µg g^{-1} soil. Mean microbial biomass carbon from rice-prawn land use was significantly higher than prawn alone and rice alone land uses. Highest MBC was recorded in rice- prawn land use which ranged from 210.09 µg g^{-1} soil to 292.80 µg g^{-1} soil with a mean value of 249.83 µg g^{-1} soil. Rice alone land use observed MBC in the range of 170.56 µg g^{-1} soil to 238.96 µg g^{-1} soil with a mean value of 208.87 µg g^{-1} soil. The lowest MBC was recorded in prawn alone land use which varied between 145.65 µg g^{-1} soil to 249.18 µg g^{-1} soil with a mean value of 180.07 µg g^{-1} soil.

4.2.5 Water-soluble carbon

Water-soluble carbon (WSC) represents a soluble and readily available substrate for micro-organisms and WSC observed from composite samples of rice-prawn, rice alone and prawn alone land uses of *Pokkali* ecosystem is given in table 12. The values ranged from 25.63 mg kg^{-1} to 54.52 mg kg^{-1}. Water-soluble carbon from prawn alone land use was significantly lower than rice-prawn and rice alone land uses and the highest WSC was observed in rice-prawn land use. The WSC of rice-prawn was in the range of 39.65 mg kg^{-1} to 54.52 mg kg^{-1} and recorded a mean value of 46.1 mg kg^{-1}. The WSC of rice alone land use was on par with rice-prawn land use which recorded a range of 40.44 mg kg^{-1} to 51.23 mg kg^{-1} with a mean of 44.548 mg kg^{-1}. The lowest WSC was obtained for prawn alone land use with a range of 25.63 mg kg^{-1} to 37.75 mg kg^{-1} and a mean value of 32.386 mg kg^{-1}.

Table 10: SOC stock (Mg ha^{-1}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	22.95	33.45	15.02
Sample 2	24.75	24.78	38.73
Sample 3	18.96	20.28	14.86
Sample 4	19.79	26.02	33.59
Sample 5	26.20	27.77	22.74
Mean	22.53	26.46	24.99
CD (0.05)	NS		

Table 11: Microbial biomass carbon (µg g^{-1}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	292.80	170.57	145.65
Sample 2	250.93	211.81	164.12
Sample 3	210.09	231.65	249.19
Sample 4	281.02	238.96	172.83
Sample 5	214.28	191.37	168.56
Mean	249.82^{a}	208.87^{ab}	180.07^{b}
CD (0.05)	49.16*		

Table 12: Water-soluble carbon (mg kg^{-1}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	54.52	43.14	28.58
Sample 2	39.65	42.60	35.01
Sample 3	52.04	51.23	37.75
Sample 4	39.65	40.44	25.63
Sample 5	44.61	45.30	34.95
Mean	46.10^{a}	44.54^{a}	32.39^{b}
CD (0.05)	7.57*		

4.2.6. Total carbon

Total carbon (TOC) is the amount of carbon found in an organic compound and is of utmost importance for soil health and sustainable agriculture. Total carbon recorded for composite samples from rice-prawn, rice alone, and prawn alone land use of the *Pokkali* ecosystem is given in table 13. Total carbon content from prawn alone land use was significantly lower than other land uses in the *Pokkali* ecosystem and the highest TC was recorded for rice-prawn land use. The TC values from rice- prawn land use ranged from 1.5 to 2.2 per cent with a mean value of 1.84 per cent. The lowest TC values were recorded from prawn alone land use which ranged from 1.01 to 1.41 per cent with a mean value of 1.19 per cent. Rice alone land use registered TC values ranging from 1.02 to 2.07 per cent and with a mean value of 1.54 per cent.

Table 13: Total organic carbon (%) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	1.56	1.02	1.01
Sample 2	1.87	1.53	1.31
Sample 3	1.87	1.27	1.03
Sample 4	2.23	1.75	1.16
Sample 5	1.68	2.07	1.41
Mean	1.84^{a}	1.53^{ab}	1.19^{b}
CD (0.05)	0.41*		

Table 14: Dehydrogenase activity (µg TPF h^{-1} g^{-1}) of composite samples from different land uses in the *Pokkali* ecosystem

Composite sample	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
Sample 1	3737.81	4033.48	1608.64
Sample 2	2927.53	3163.77	1968.98
Sample 3	2326.61	2955.93	2557.51
Sample 4	2200.76	4612.08	2839.54
Sample 5	3605.75	4110.74	1687.77
Mean	2959.69^{ab}	3775.20^{a}	2132.49^{b}
CD (0.05)	898.86*		

4.2.6. Dehydrogenase activity

Dehydrogenase functions as a respiratory enzyme and plays a prominent role in the global C cycle. Dehydrogenase activity (DHA) of composite samples from rice-prawn, rice alone, and prawn alone land use of *Pokkali* ecosystem is represented in table 14. The dehydrogenase activity of prawn alone land use was significantly lower than rice-prawn and rice alone land uses of the *Pokkali* ecosystem. Highest DHA was recorded in rice alone land use and ranged from 2955.93 µg TPF h^{-1} g^{-1} soil to 4612.08 µg TPF h^{-1} g^{-1} soil with a mean of 3775.21 µg TPF h^{-1} g^{-1} soil. The lowest DHA was reported in prawn alone land use with a range of 1608.64 µg TPF h^{-1} g^{-1} soil to 2839.54 µg TPF h^{-1} g^{-1} soil and a mean of 2132.49 µg TPF h^{-1} g^{-1} soil. Rice -prawn land use recorded a mean value of 2959.69 µg TPF h^{-1} g^{-1} soil and a range of 2200.76 µg TPF h^{-1} g^{-1} soil to 3737.81 µg TPF h^{-1} g^{-1} soil.

4.2.7 Effect of different land uses on soil carbon pools

Table 15 represents the overall influence of land uses on different soil carbon pools such as SOC, LC, WSC, MBC, and TOC under the *Pokkali* ecosystem. The highest soil carbon pools were recorded from rice-prawn land use (Kumbalangi) followed by rice alone (RRS, Vyttila) and the lowest was recorded from prawn alone (Kadamakkudy) land uses. The highest fraction of TOC was made from SOC followed by an easily degradable labile fraction of the soil carbon. The WSC pool was the lowest among all other pools in different land uses. All the C pools showed a consistent trend in which rice-prawn recoded the maximum, followed by rice alone and minimum from prawn alone land uses.

Table 15. Influence of different land uses on soil carbon pools

Land uses	SOC (%)	WSC (mg kg^{-1})	MBC (mg kg^{-1})	LC (mg kg^{-1})	TOC (%)
Rice-prawn	1.64^{a}	46.10^{a}	249.82^{a}	2153.56^{a}	1.84^{a}
Rice alone	1.48^{a}	44.54^{a}	208.87^{ab}	1949.66^{ab}	1.53^{ab}
Prawn alone	0.98^{b}	32.38^{b}	180.07^{b}	1547.81^{b}	1.19^{b}
CD (0.05)	0.25*	7.57*	49.16*	439.93*	0.41*

4.2.8 Percentage contribution of different C pools to TOC

The results represented in table 16 indicated that the percentage contribution of different C pools such as WSC, LC, MBC, and SOC to TOC in different land uses under the *Pokkali* ecosystem. The percentage contribution of WSC to TOC was very less and the lowest was recorded in rice-prawn (0.25%) and the highest was recorded in rice alone (0.29%) land uses. Considering the percentage contribution of LC to TOC, the highest was recorded from prawn alone (13.02%) and the lowest was recorded from rice-prawn (11.68 %) land uses. The contribution of MBC to TOC was reported highest from prawn alone (1.51%) and lowest from rice-prawn (1.35%) land use. The SOC contributed highest to TOC in rice alone (96.73%) and lowest in prawn alone (82.35%) land uses. The SOC contributed the highest to TOC followed by readily decomposable LC fraction of soil.

Table 16. Percentage contribution of different C pools to TOC

Land uses	WSC as % of TOC	LC as % of TOC	MBC as % of TOC	SOC as % of TOC
Rice-prawn	0.25	11.68	1.35	89.13
Rice alone	0.29	12.70	1.36	96.73
Prawn alone	0.27	13.02	1.51	82.35

4.3 CARBON MINERALISATION

4.3.1 Cumulative CO_2 evolved from carbon mineralisation experiment

The mean cumulative CO_2 observed from carbon mineralisation incubation experiment for rice-prawn, rice alone and prawn alone land uses of the *Pokkali* ecosystem is shown in table 17. The cumulative CO_2 evolved from T_1 (control) was significantly lower than rest of the treatments irrespective of land uses. Cumulative CO_2 mineralisation in unamended (without paddy straw and salts) soil was 7.2, 25.15, and 26.48 mg $100g^{-1}$ for rice-prawn, rice alone, and prawn alone land use of *Pokkali* soils respectively. But the same soil amended with paddy straw (PS) recorded cumulative CO_2 mineralisation of 242.93, 235.73, and 258.91 mg 100 g^{-1} for rice-prawn, rice alone and prawn alone land uses of *Pokkali* soils respectively. The highest cumulative CO_2 was observed in prawn alone land use followed by rice alone and rice-prawn alone land uses. A significant positive correlation was observed between pH, DHA, and TOC with cumulative CO_2 in all land uses of the *Pokkali* ecosystem (Appendix II).

Table 17: Cumulative CO_2 (mg 100 g^{-1}) evolved from different land uses in the *Pokkali* ecosystem

Treatments	Cumulative CO_2 (mg 100 g^{-1})		
	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
T_1	7.2^c	25.15^b	26.48^b
T_2	242.93^a	235.73^a	258.91^a
T_3	232.91^{ab}	231.95^a	243.8^a
T_4	206.4^b	223.05^a	251.46^a
T_5	237.31^{ab}	215.86^a	264.22^a
T_6	227.13^{ab}	206.83^a	272.8^a
T_7	215.26^{ab}	229.41^a	254.61^a
T_8	206.08^b	232.61^a	233.13^a
T_9	212.26^{ab}	226.36^a	251.38^a
T_{10}	239.65^{ab}	212.56^a	259.53^a
CD(0.05)	33.90*	45.57*	44.75*

The CO_2-C evolved from the soil over 74 days of the incubation period of rice-prawn, rice alone and prawn alone land uses is given in table 18, 19, and 20 respectively. Carbon mineralisation decreased with time and carbon evolution increased up to 17 days of incubation. After that, it started to decrease slowly in each land use. In the rice-prawn land use, a sharp increase in carbon evolution was observed up to the 11th day of incubation. Later on, it started to decrease slowly. Rice alone land use recorded a sharp increase up to the 17th day of incubation, before its decline. Prawn alone land use followed rice-prawn land use in the CO_2 evolution trend and peak was shown at 11th day of incubation. Compared to rice-prawn and prawn alone land uses, the rice alone land use recorded a much slower decline in CO_2 evolution. The highest CO_2 was evolved on the 11th day in rice-prawn and prawn alone land uses of *Pokkali* ecosystem while day 17 recorded the highest CO_2 in rice alone land uses. The CO_2-C evolved from control (soil only) was significantly lower than the rest of the treatments in all land uses of *Pokkali* ecosystem.

Table 18: Soil CO_2-C (mg 100 g^{-1}) evolved in rice- prawn (Kumbalangi) land use

Treatment	CO_2-C (mg 100 g^{-1}) evolved									
	Days									
	1	3	6	11	17	25	35	50	68	74
T_1	-14.2^{e}	-11.5^{e}	-5.9^{c}	16.0^{d}	7.3^{c}	7.0^{b}	13.6^{d}	7.5^{b}	2.4^{e}	-8.86
T_2	6^{bc}	9.6^{b}	13.1^{ab}	46.0^{abc}	43.4^{a}	39.0^{a}	38.0^{a}	27.0^{a}	22.2^{bc}	4.63
T_3	7.7^{b}	9.2^{bc}	13.5^{ab}	50.5^{a}	39.5^{ab}	36.0^{a}	33.8^{c}	26.8^{a}	23.25^{bc}	-1.2
T_4	4.3^{cd}	6.8^{c}	10.4^{ab}	42.3^{c}	37.4^{ab}	33.0^{a}	34.6^{bc}	27.2^{a}	16.2^{d}	0.16
T_5	6.5^{bc}	8.5^{bc}	12^{ab}	48.8^{ab}	37.5^{ab}	33.0^{a}	35.4^{abc}	29.4^{a}	29.85^{a}	2.4
T_6	7.1^{b}	8.9^{bc}	12.8^{ab}	47.0^{abc}	35^{b}	33.2^{a}	34.5^{bc}	30.2^{a}	30.3^{a}	-5.9
T_7	5.5^{bc}	7.9^{bc}	11.5^{ab}	47.3^{abc}	38.1^{ab}	36.1^{a}	36.8^{ab}	28.2^{a}	19.8^{bcd}	-9.9
T_8	2.3^{d}	4.1^{d}	6.5^{b}	45.0^{bc}	33.5^{b}	34.6^{a}	35.5^{abc}	27.9^{a}	22.95^{bc}	-0.23
T_9	4.2^{cd}	6.7^{c}	10.2^{ab}	48.9^{ab}	33.9^{b}	38.2^{a}	34.5^{bc}	28.6^{a}	17.4^{cd}	-4.2
T_{10}	11.6^{a}	12.8^{a}	17.7^{a}	48.3^{ab}	38.9^{ab}	36.3^{a}	37.9^{a}	28.9^{a}	24.45^{ab}	-11.1
CD(0.05)	2.54*	2.56*	10.06*	5.26*	6.58*	8.34*	2.86*	5.66*	5.9*	-

Table 19: Soil CO_2-C (mg 100 g^{-1}) evolved in rice alone (RRS, Vyttila) land use in the *Pokkali* ecosystem

	CO_2-C (mg 100 g^{-1}) evolved									
	Days									
Treatment	1	3	6	11	17	25	35	50	68	74
T_1	-10.4^{d}	-9.0^{e}	-7.7^{b}	-7.7	10.8^{c}	10.3^{b}	16^{b}	6.2^{b}	9.4^{e}	13.26
T_2	10.7^{ab}	13.0^{ab}	16.8^{a}	33.5	37.2^{ab}	38.7^{a}	36.6^{a}	31.9^{a}	13.8^{de}	9.4
T_3	12.1^{a}	13.4^{ab}	18.1^{a}	27	38.4^{a}	37.2^{a}	34.5^{a}	30.1^{a}	23.2^{abc}	3.83
T_4	9.5^{abc}	12.2^{abc}	15.6^{a}	25.2	37.9^{a}	37.5^{a}	37.1^{a}	27.4^{a}	19.3^{cd}	20.5
T_5	10.2^{ab}	12.8^{ab}	15.9^{a}	16.2	37.8^{a}	38.2^{a}	34.3^{a}	27.4^{a}	20.4^{bc}	8.6
T_6	8.8^{bc}	9.9^{cd}	14.1^{a}	14.5	35^{ab}	35.5^{a}	35.1^{a}	27.0^{a}	26.7^{a}	6.16
T_7	8.6^{bc}	11.4^{bcd}	14.7^{a}	24.6	37.6^{a}	34.2^{a}	40.7^{a}	28.7^{a}	22.6^{abc}	12.26
T_8	11.3^{ab}	14.5^{a}	18.4^{a}	24.3	38.1^{a}	37.1^{a}	38.5^{a}	29.8^{a}	20.5^{bc}	8.25
T_9	10.5^{ab}	11.2^{bcd}	15.2^{a}	26.1	35.7^{ab}	34.3^{a}	36.1^{a}	27.5^{a}	24.3^{abc}	11.4
T_{10}	7.2^{c}	9.4^{d}	12.6^{a}	18.7	31.8^{b}	36.6^{a}	37.4^{a}	32.0^{a}	25.5^{ab}	7.33
CD (0.05)	2.98*	2.34*	6.33*	-	5.49*	5.44*	8.43*	5.9*	5.72*	-

Table 20: Soil CO$_2$-C (mg 100 g^{-1}) evolved in prawn alone (Kadamakkudy) land use in the *Pokkali* ecosystem

Treatments	CO$_2$-C (mg 100 g^{-1}) evolved									
	Days									
	1	3	6	11	17	25	35	50	68	74
T$_1$	-12.2^{e}	-10.4^{f}	-8.1^{c}	21.6^{b}	14.6	10.3^{b}	11.9^{c}	5.5^{c}	7.9^{c}	-8.3
T$_2$	10.1^{bc}	11^{d}	16.1^{ab}	52.2^{a}	41.7	40.0^{a}	39.5^{a}	29.8^{ab}	22.9^{ab}	1.83
T$_3$	7.7^{cd}	11.3^{cd}	14.7^{ab}	48.9^{a}	45.7	35.3^{a}	35.4^{ab}	30.0^{ab}	20.4^{ab}	0.67
T$_4$	10.6^{abc}	13.3^{bcd}	17.7^{ab}	44.9^{a}	45.7	37.9^{a}	35.7^{ab}	29.0^{ab}	19.5^{ab}	3.4
T$_5$	13.5^{a}	16.1^{ab}	19.1^{a}	46.5^{a}	44.1	37.3^{a}	37.3^{ab}	32.0^{ab}	24.7^{a}	-0.13
T$_6$	12.3^{ab}	14.2^{abc}	18^{ab}	49.4^{a}	45.7	37.1^{a}	36.7^{ab}	34.0^{a}	29.1^{a}	2.66
T$_7$	4.9^{d}	7.6^{e}	11.0^{b}	47.6^{a}	47.4	42.2^{a}	38^{ab}	35.0^{a}	29.8^{a}	-2.63
T$_8$	11.9^{ab}	13.2^{bcd}	17.3^{ab}	43.7^{a}	45.5	39.5^{a}	33.4^{b}	24.9^{b}	12.0^{bc}	-1.96
T$_9$	10.1^{bc}	12.4^{cd}	17^{ab}	44.9^{a}	44.1	37.5^{a}	36.4^{ab}	31.0^{ab}	19.35^{ab}	4.83
T$_{10}$	13.1^{ab}	17.1^{a}	20.8^{a}	45.3^{a}	46.8	37.0^{a}	35.4^{ab}	27.09^{ab}	25.8^{a}	-3.5
CD (0.05)	3.07*	2.99*	7.93*	15.27*	-	7.45*	5.79*	7.34*	11.1*	-

4.3.2 Soil reaction

Soil reaction after treatment application before incubation [pH (0)] and at the end of the incubation period [(pH (74)] for different land use is given in Table 21. The soil pH(74) was significantly lower in control compared to other treatments in all land uses of *Pokkali* ecosystem. Soil pH recorded just after the treatment application was in the range of 6.17 to 7.02 for all land use. Soil pH observed after 74 days of incubation study was in the range of 4.76 to 7.32 for all land use. Soil pH recorded a slight increase after 74 days of incubation in all the land use for all the treatments except control (T_1-soil only). In T_1, pH decreased at the end of incubation

Table 21: Soil pH at 0 and 74 days after incubation from different land uses in the *Pokkali* ecosystem

Treatments	Rice-prawn (Kumbalangi)		Rice alone (RRS, Vyttila)		Prawn alone (Kadamakkudy)	
	*pH(0)	*pH(74)	pH(0)	pH(74)	pH(0)	pH(74)
T_1	6.72	5.84^{d}	6.17	4.93^{f}	6.31	4.76^{c}
T_2	6.47	6.81^{bc}	6.27	6.44^{e}	6.30	6.82^{ab}
T_3	6.47	6.55^{c}	6.3	6.6^{cd}	6.44	6.76^{ab}
T_4	6.61	6.72^{a}	6.43	6.34^{d}	6.33	6.8^{ab}
T_5	6.80	7.32^{a}	6.25	6.87^{abc}	6.50	7.25^{a}
T_6	6.59	7.15^{ab}	6.99	7.12^{a}	6.57	7.18^{ab}
T_7	6.75	6.72^{bc}	6.54	6.73^{c}	6.57	6.69^{b}
T_8	6.72	6.78^{bc}	6.71	6.69^{cd}	6.9	6.91^{ab}
T_9	6.81	6.82^{bc}	6.50	6.77^{bc}	6.77	7.10^{ab}
T_{10}	7.02	6.88^{abc}	6.61	7.01^{ab}	6.65	7.19^{ab}
CD (0.05)		0.45*		0.277*		0.53*

*pH (0): pH at 0 days of incubation

*pH (74): pH at 74 days of incubation

4.3.3 Electrical conductivity

The EC values obtained from different land uses of the *Pokkali* ecosystem are shown in table 22. The EC values recorded after the incubation study was significantly lower in control and T_2 against other treatments in different land uses of *Pokkali* ecosystem. The EC values recorded after application of treatments before incubation (EC (0) lies in the range of 1.5 to 13.9 dS m^{-1}. The EC values observed after 74 days of incubation ranged (EC (74)) between 1.53 to 7.53 dS m^{-1}. The highest EC value observed after the treatment application was in T_6 (soil+ PS+ Na_2SO_4 (80 mmol per kg)) for all land uses. But after 74 days of incubation EC values showed a decreasing trend for all the treatments except control (T_1 -soil only) and T_2 (soil + PS).

Table 22: Electrical conductivity of soil samples at 0 and 74 days after incubation from different land uses in the *Pokkali* ecosystem

Treatments	Rice-prawn (Kumbalangi)		Rice alone (RRS, Vyttila)		Prawn alone (Kadamakkudy)	
	*EC(0)	*EC(74)	EC(0)	EC(74)	EC(0)	EC(74)
T_1	1.66	3.36^{f}	1.53	2.43^{d}	2.33	4.56^{e}
T_2	1.63	3.36^{f}	1.33	2.36^{d}	2.16	4.60^{e}
T_3	5.40	3.83^{ef}	4.66	2.86^{d}	8.30	4.66^{de}
T_4	4.50	3.83^{ef}	4.53	3.16^{d}	8.56	4.96^{cde}
T_5	7.46	4.13^{def}	6.53	4.13^{c}	8.96	6.03^{bc}
T_6	11.23	6.33^{ab}	13.1	5.13^{ab}	13.9	7.70^{a}
T_7	6.66	5.20^{bcd}	6.96	4.43^{bc}	11.73	5.83^{bcd}
T_8	6.43	5.00^{cde}	8.26	4.43^{bc}	11.23	6.56^{ab}
T_9	7.46	5.83^{abc}	9.86	5.60^{a}	11.4	7.26^{a}
T_{10}	9.46	6.53^{a}	9.00	5.53^{a}	9.86	7.53^{a}
CD (0.05)		1.297*		0.91*		1.22*

*EC(0): Electrical conductivity at 0 days of incubation

*EC(74): Electrical conductivity at 74 days of incubation

4.3.4 Water-soluble carbon

Water-soluble carbon estimated after 74 days of incubation experiment from different land uses of *Pokkali* ecosystem is shown in table 23. The WSC was significantly higher in T_6 compared to other treatments in all land uses of *Pokkali* ecosystem. Lowest WSC observed for rice-prawn land use was in T1. The treatments T4 [Soil + PS + $CaSO_4$ (80 mmol kg $^{-1}$)] and T10 [Soil+ PS+ $CaSO_4$ (80 mmol kg $^{-1}$) + Na_2SO_4 (80 mmol kg $^{-1}$)] recorded lowest WSC for rice alone and prawn alone land use of *Pokkali*.

Table 23: Soil WSC (mg kg^{-1}) after the incubation period (74 days) for different land uses in the *Pokkali* ecosystem

Treatments	WSC (mg kg^{-1})		
	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
T_1	29.27^{d}	40.29^{cd}	56.59^{def}
T_2	58.26^{b}	27.41^{d}	87.95^{b}
T_3	58.16^{b}	34.75^{cd}	61.22^{cde}
T_4	40.77^{cd}	21.72^{d}	69.13^{cd}
T_5	82.49^{a}	119.31^{b}	75.35^{bc}
T_6	83.13^{a}	157.09^{a}	108.30^{a}
T_7	35.71^{cd}	62.45^{c}	68.16^{cd}
T_8	49.01^{bc}	46.09^{cd}	62.95^{cde}
T_9	61.36^{b}	50.72^{cd}	45.78^{ef}
T_{10}	78.71^{a}	64.36^{c}	41.61^{f}
CD (0.05)	16.92*	32.60*	17.37*

4.3.5. Dehydrogenase activity

Dehydrogenase enzyme activity estimated for different land uses in *the Pokkali* ecosystem has depicted in table 24. The control recorded significantly lower DHA compared to other treatments in all land uses. Enzyme activity was in the range of 40.38 to 216.8 µg TPF h^{-1} g^{-1} soil for rice-prawn land use of Kumbalangi whereas, rice alone and prawn alone registered a range of 8.48 to 140.01 µg TPF h^{-1} g^{-1} soil and 11.30 to 191.20 µg TPF h^{-1} g^{-1} soil respectively. The lowest DHA was recorded in control(T_1)

irrespective of land uses. A positive significant correlation was found between EC and DHA in rice-prawn (0.67), rice alone (0.69), and prawn alone (0.79) land use of the *Pokkali* ecosystem. Also, a positive correlation was recorded between DHA and cumulative CO_2- C among different land uses (Appendix II).

Table 24: Soil DHA (µg TPF h^{-1} g^{-1}) after the incubation period (74) for different land uses in the *Pokkali* ecosystem

Treatments	DHA (µg TPF h^{-1} g^{-1})		
	Land uses		
	Rice-prawn (Kumbalangi)	Rice alone (RRS, Vyttila)	Prawn alone (Kadamakkudy)
T_1	40.38^{e}	8.48^{c}	11.30^{f}
T_2	133.11^{bcd}	34.22^{c}	152.04^{bcd}
T_3	95.16^{d}	118.58^{ab}	118.63^{de}
T_4	133.64^{bcd}	98.08^{b}	123.51^{de}
T_5	116.56^{cd}	138.55^{a}	160.37^{abc}
T_6	127.24^{bcd}	122.90^{ab}	191.20^{a}
T_7	131.23^{bcd}	115.99^{ab}	185.67^{ab}
T_8	167.71^{b}	120.14^{ab}	111.37^{e}
T_9	155.77^{bc}	138.82^{a}	134.87^{cde}
T_{10}	216.82^{a}	140.01^{a}	178.95^{ab}
CD(0.05)	42.92*	31.69*	36.45*

4.3.6. Total carbon (TOC)

Total organic carbon of different land uses of *Pokkali* after 74 days of incubation is represented in table 25. Significant lower TOC was recorded for control against other treatments irrespective of land uses. The TOC recorded in control treatment are 2.18, 2.07, and 1.86 per cent for rice-prawn, rice alone, and prawn alone respectively. All other treatments recorded higher TOC than control. The highest TOC recorded for rice-prawn land use was in T_6 (9.12 per cent), while T_8 (7.37 per cent) and T_2 (8.73 per cent) registered the highest values for rice alone and prawn alone land uses.

Cumulative CO_2 and TOC showed a positive significant correlation in all the land uses of *Pokkali* ecosystem (Appendix II) and positive significant correlations between pH in rice-prawn (r=0.808) and rice alone (r=0.815) land uses were recorded.

Table 25: The TOC (%) after 74 days of incubation from different land uses in the *Pokkali* ecosystem

Treatments	TOC (%)		
	Land uses		
	Rice- prawn (Kumbalangi)	Rice alone (RRS,Vyttila)	Prawn alone (Kadamakkudy)
T_1	2.18^{f}	2.07^{c}	1.86^{c}
T_2	6.12^{de}	5.86^{ab}	8.73^{a}
T_3	5.49^{e}	7.30^{a}	6.94^{ab}
T_4	6.08^{de}	7.10^{a}	8.55^{a}
T_5	8.42^{ab}	5.94^{ab}	7.11^{ab}
T_6	9.12^{a}	6.94^{a}	7.14^{ab}
T_7	8.31^{abc}	5.08^{b}	7.58^{a}
T_8	6.86^{bcde}	7.37^{a}	4.69^{b}
T_9	7.65^{abcd}	6.84^{a}	6.60^{ab}
T_{10}	6.49^{cde}	6.95^{a}	6.21^{ab}
CD(0.05)	1.92*	1.53*	2.80*

Discussion

5. DISCUSSION

Soil carbon pools have a significant role in global carbon(C) cycling. The atmospheric CO_2 can be effectively captured and stored in the soil system. But different land uses have a considerable effect on soil C sequestration. Also, the carbon mineralisation process aids in removing soil C and interacts with the C cycle. So an investigation was carried out to assess the soil C pools and to find out the effect of salinity on C mineralisation under different land uses in the *Pokkali* ecosystem. This chapter discusses the results of the entire experiment with support from the relevant literature.

5.1 SOIL PROPERTIES

5.1.1 Soil reaction

Soil pH recorded for rice–prawn land use revealed that the soils are neutral with a pH ranging from 6.76 to 6.96 (Fig.1). Rice alone land use exhibited a lower pH compared to other land uses. The pH values for rice alone land use belonged moderately acidic to neutral class. Prawn land use also recorded a neutral pH range of 6.55 to 7.25. Unni (2020) reported that the pH of the post-flood (2018) soils varied from 3.04 to 7.22 in *Pokkali* soils. Joseph (2014) found that the mean pH ranged from 5.69 to 7.26 in *Pokkali* soils and the highest pH was in prawn alone land use in Kuzhippally panchayath with abundant lime shells. The samples were collected during the high saline phase and inundation of saline water could have influenced soil pH. Wong *et al.* (2010) have opined that acidity found in acid sulphate soil can be neutralized through seawater inundation. This process involves the addition of bicarbonate alkalinity by seawater which contributed to the neutralization of acidity and immobilization of trace metals (Indraratna *et al.*,2002). Long-term studies also showed that the formation of Fe (II) sulfide minerals due to seawater intrusion in low-lying acid sulphate soils can be attributed to decreased soil acidity (Johnston *et al.*, 2009).

5.1.2 Electrical conductivity

The electrical conductivity of different land uses in the *Pokkali* ecosystem ranged from 1.1 to 3.2 dS m^{-1} (Fig.1). The highest mean EC was observed for prawn alone followed by rice-prawn and rice alone land use. Joseph (2014) reported that the *Pokkali* soils recorded mean EC ranging from 2.40 to 4.05 dS m^{-1} in different land uses and the highest mean EC was reported from mangrove and fallow followed by prawn alone land uses. Unni (2020) reported that post-flood EC of soils ranged from 0.19 dS m^{-1} to 7.72 dS m^{-1} in *Pokkali* fields. Shylaraj *et al.* (2013) observed that EC values in *Pokkali* soils ranged from 0.001 dS m^{-1} to 7.80 dS m^{-1} during the low saline phase and 0.10 dS m^{-1} to 9.80 dS m^{-1} during the high saline phase. Many reports were indicating high EC (>4 dS m^{-1}) value during the high saline phase in the *Pokkali* ecosystem due to saltwater inundation from the sea (Varghese *et al.*,1970; Samikutty, 1977). Heavy rain might have flushed out excess salt present in the water and thereby reducing the salinity of these soil under investigation (Appendix III). Rainy season could make water present in these fields almost fresh, reduce salt content to traces and fit EC between 0.6 to 8 dS m^{-1} (Tomy, 1981)

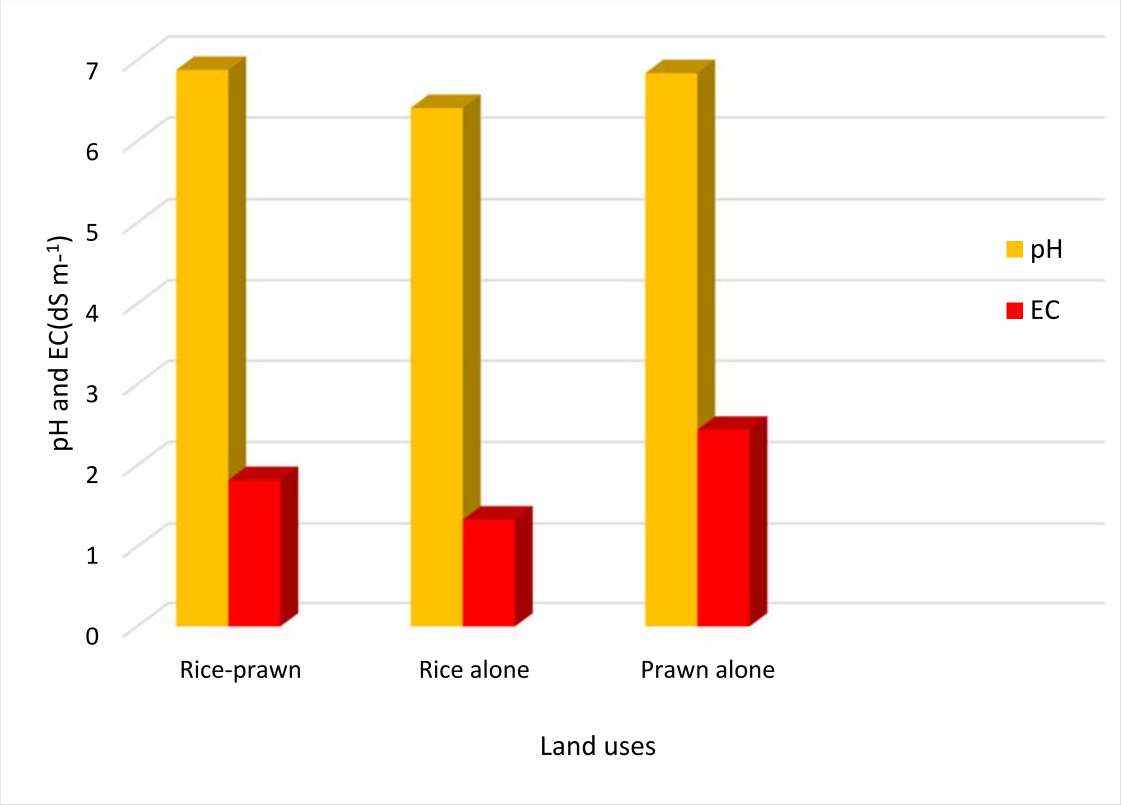

Fig. 1. Mean pH and EC from different land uses in the *Pokkali* ecosystem

5.1.3 Particle size analysis

There was a wide variation in particle size obtained from each land use of the *Pokkali* ecosystem. The clay content of rice alone as well as rice-prawn land use was found to be higher as compared to other land uses (Fig.2). Joseph (2014) reported that paddy-shrimp land use recorded higher clay content than other land uses. Varghese *et al.* (1970)

observed a clay content of 16 percent in *Pokkali* soil. Silt content varied from 9.75 to 18.12 per cent. Joseph (2014) reported generally a low amount of silt in all land uses which ranged from 1.2 to 20.8 per cent. As per Varghese *et al.* (1970), *Pokkali* soil contained 13.2 per cent silt. Joseph (2014) reported 0.1 to 76.9 per cent coarse sand in different land uses of *Pokkali* ecosystems and the highest was recorded in rice alone land uses. Coarse sand content varied from 5.54 to 53.14 per cent and the highest was recorded in prawn alone land use. Fine sand varied from 4.06 to 19.51 per cent and recorded lowest in prawn alone land use. Joseph (2014) reported that sandy loam and clay texture was dominant among different land uses of the *Pokkali* ecosystem. In this study rice-prawn and rice alone land use registered clay texture while prawn alone recorded sandy clay loam texture.

Soil texture which is an inherent property of soil is directly linked to fundamental soil-forming factors and shows slight changes over time (Sharma and Mandal, 2009). Since these *Pokkali* soils are tidal wetlands, their origin, genesis, and development are under peculiar climatic environmental conditions (Padmaja *et al*.,1994). Being a tidal wetland, these soils are subjected to continuous tidal action throughout the year and sediments get deposited as well as washed away from them (Joseph, 2014). This can be attributed to the variation in particle size distribution in the *Pokkali* ecosystem.

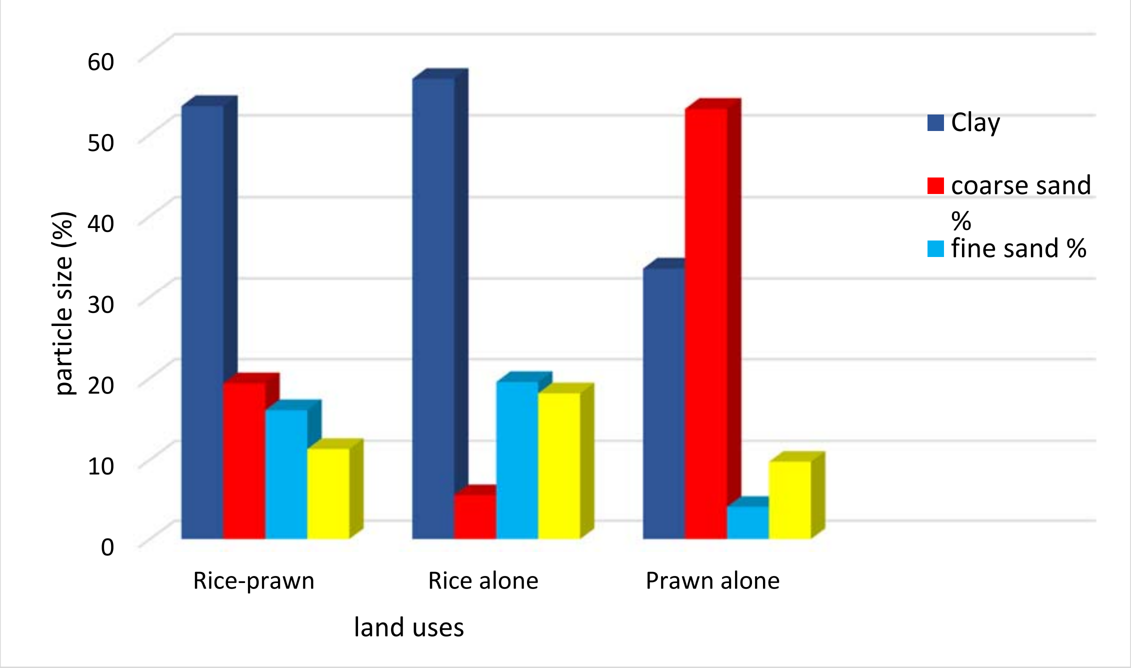

Fig.2. Particle size analysis from different land uses in *Pokkali* ecosystem

5.1.4 Cation exchange capacity

Cation exchange capacity (CEC) of soils from different land uses of *Pokkali* recorded a decreasing trend from rice-prawn to prawn alone land use (Fig. 3). Mean CEC of soil estimated from different land uses of *Pokkali* varied from 10.75 to 20.07 cmol(p+)kg^{-1} (Joseph, 2014). Effective cation exchange capacity of the post-flood soils in AEU 5 varied from 9.41 cmol(p+)kg^{-1} to 71.32 cmol(p+)kg^{-1} (Unni, 2020). High CEC in *Pokkali* soils might be due to the high organic matter and clay content present in the soil. The presence of a large quantity of Na and K cations in soil that can be found easily extracted by $BaCl_2$ from soil solution is also a reason for high CEC (Santhosh, 2013).

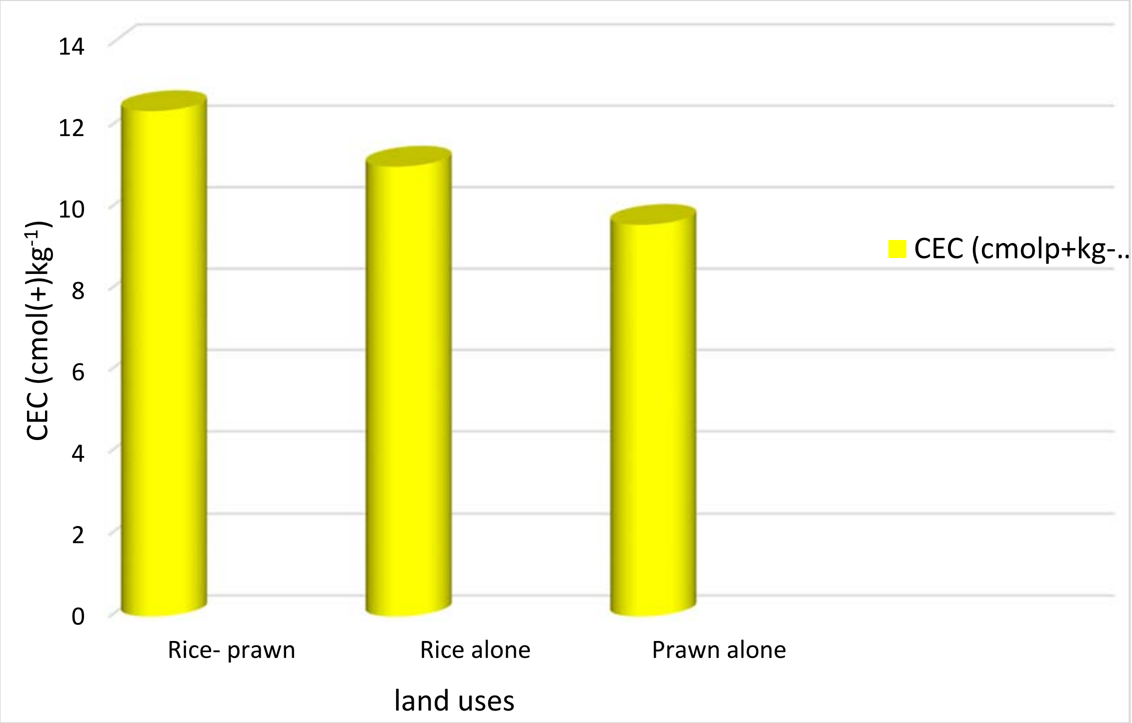

Fig.3. CEC from different land uses in the *Pokkali* ecosystem

5.1.5 Bulk density

Bulk density was generally low and varied significantly among different land uses in the *Pokkali* ecosystem. Mean values of bulk density were 0.68 Mgm^{-3} (rice-prawn), 0.89 Mg m^{-3} (rice alone), and 1.23 Mg m^{-3} (prawn alone) (Fig.4). Joseph (2014) estimated the mean value of bulk density in *Pokkali* soils and it varied from 0.56 to 1.17 Mg m^{-3} while analysis of post-flood *Pokkali* soils by Unni (2020) observed bulk density variation from 0.23 Mg m^{-3} to 1.53 Mg m^{-3}. High organic matter content present in *Pokkali* soils could have been attributed to low soil bulk density. Sasidharan (2004) reported a low bulk density value of 0.67 Mg m^{-3} in *Pokkali* soils. Joseph (2014) also found that bulk density values were higher in prawn alone land use where organic matter content was low. The absence of rice crop and the lack of cultural operations in prawn alone land use increased the bulk density of these soils.

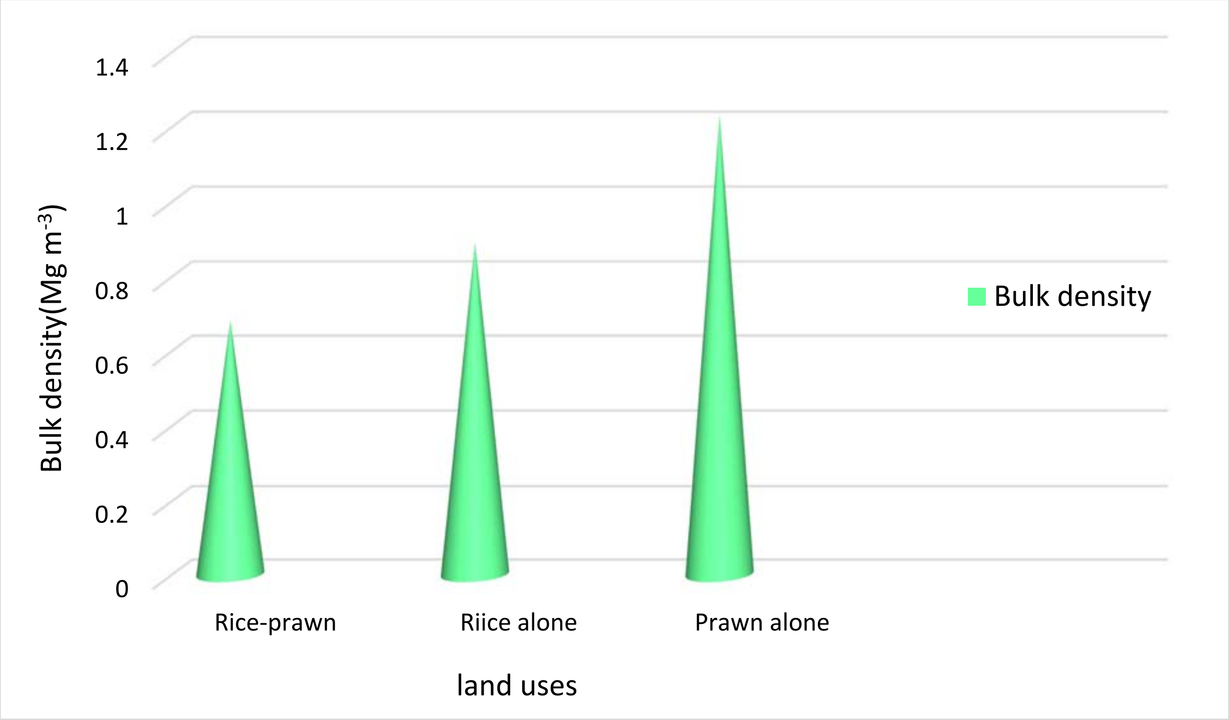

Fig. 4. Mean bulk density from different land uses in the *Pokkali* ecosystem

5.2 SOIL CARBON POOLS

5.2.1 Soil organic carbon

The SOC has a vital role in the overall functioning and improvement of soil properties. A significant difference was observed between different land uses of the *Pokkali* ecosystem. The mean values obtained for SOC were 1.64, 1.47, and 0.98 per cent (Fig. 5). Joseph (2014) reported organic carbon content in the range of 0.26 to 3.05 per cent in *Pokkali* soils. But Unni (2020) reported organic carbon content of 1.07 to 4.63 per cent after the 2018 flood in these soils. Anilkumar and Annie (2010) estimated an organic carbon content of 0.79 to 2.09 per cent during the low saline phase in the *Pokkali* ecosystem. The presence of high organic matter content in these soils due to increased organic matter accumulation and the chemical stabilization of organic C in the soil matrix of these soil could have been attributed to the high SOC content. The highest organic C was found in rice-prawn land use followed by rice alone and prawn alone land uses of the *Pokkali* ecosystem. The absence of rice crops or any other vegetation might have contributed to low SOC content in prawn land use due to low organic matter deposition. Krishnani *et al.* (2011) found higher organic carbon content (0.22 to 3.74%) in traditional rice culture than shrimp culture. Joseph (2014) also reported the lowest mean organic C content (0.79 %) in prawn-alone land use in the *Pokkali* ecosystem.

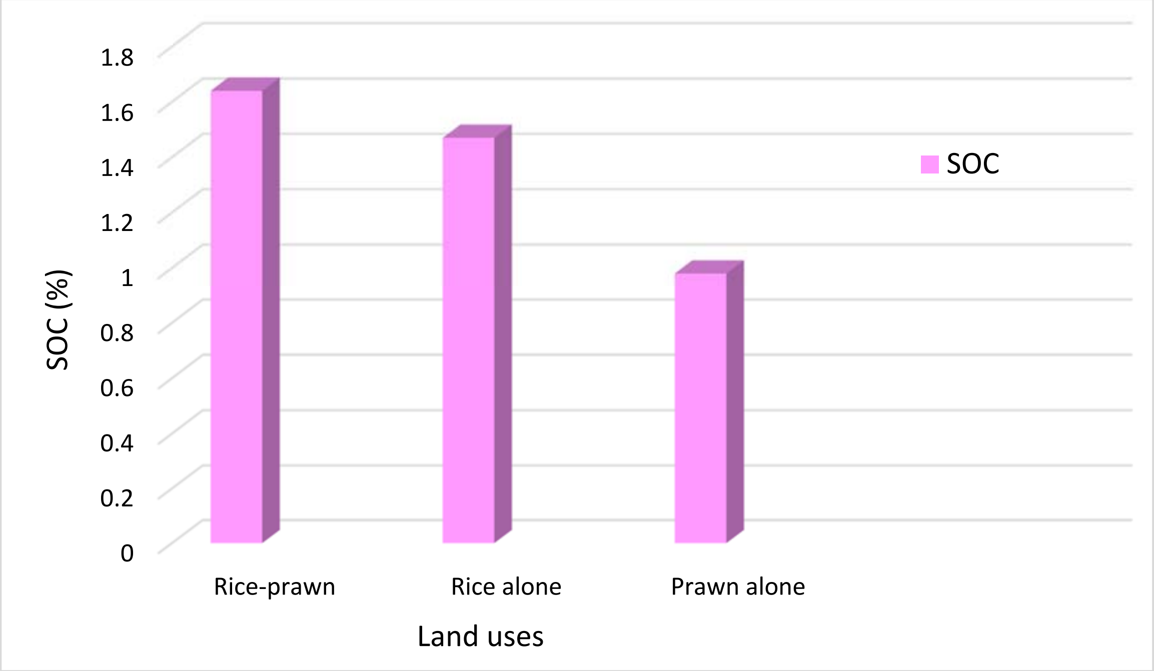

Fig. 5. Mean SOC from different land uses in *Pokkali* ecosystem

5.2.2 Labile carbon

Labile fraction of organic C reflects an easily decomposable fraction of soil organic matter and influences soil health and quality. Mean labile carbon (LC) content estimated from rice-prawn, rice alone, and prawn alone were 2153.56, 1949.66, and 1547.80 mg kg^{-1} (Fig.6) respectively and a significant difference was registered among different land uses. The LC also followed the same trend as that of SOC and the highest LC was reported in rice-prawn land use. Higher organic matter turnover rate and nutrient availability could be the reason for higher labile carbon in these soils. Gladis *et al*. (2019) reported the highest concentration of LC in soils from coconut plantation site (2516 mg kg^{-1}), followed by rice field (2187mg kg^{-1}), whereas the lowest concentration was detected in homestead site (940 mg kg^{-1}) in south Kerala. Active carbon content (modified Blair method) under the different land-use systems ranged from 311.8 (soybean–wheat agricultural land use) to 1816.8 (forest land use) µg g^{-1} (Jha *et al.*, 2014).

The presence of high SOC in this soil greatly influenced the LC of the soil. The enhanced protection of soil organic matter by aggregates also leads to an accumulation of more LC in this soil. The LC fractions are the active carbon pools that are readily oxidizable and prone to management-induced changes in SOC and their higher level indicates the greater turnover rate of organic matter and higher availability of nutrients.

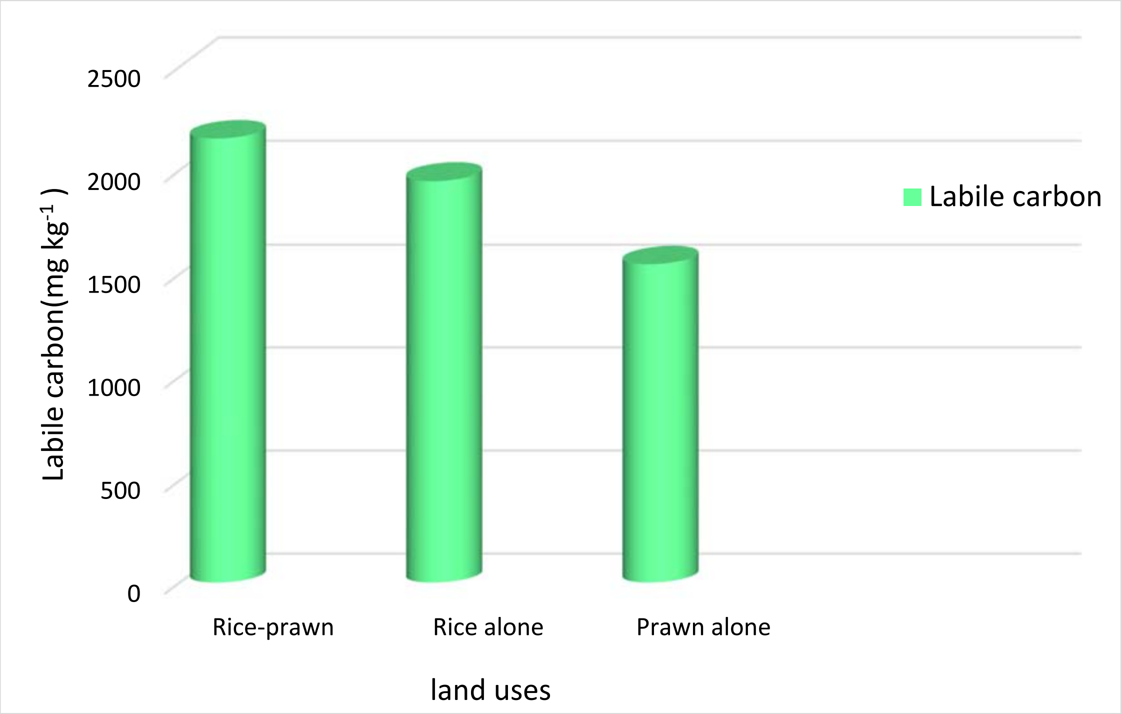

Fig.6. Mean labile carbon from different land uses in *Pokkali* ecosystem

5.2.3 Water-soluble carbon

Water-soluble carbon (WSC) also functions as a sensitive indicator of organic matter quality which gets vigorously utilized by micro-organisms for their energy requirement. Mean WSC recorded from rice-prawn, rice alone, and prawn alone were 46.1, 44.54, and 32.38 mg kg^{-1} respectively (Fig.7). These values were also found in the same order as of SOC content where the highest was recorded in rice-prawn land use. Jha *et al*. (2014) reported the highest WSC in forest land use (101.6 µg g^{-1}) followed by horticulture (70.6 µg g^{-1}) and agriculture land use (13.8-36.1µg g^{-1}). Low water-soluble organic carbon under the agricultural land use was probably due to low SOC content. As small-sized soil particles have higher sorptive potential, soils rich in clay content (rice-prawn and rice alone) have shown higher WSC and the C fractions that eluted down the soil profile would have got sorbed on the clay surface.

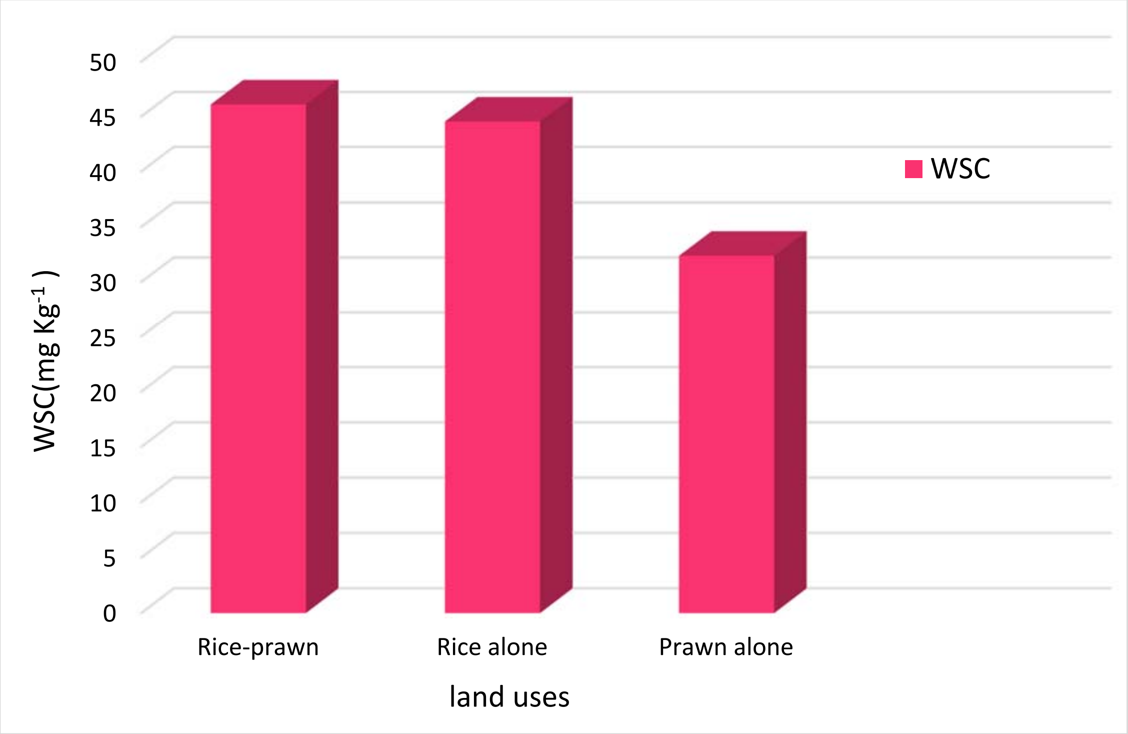

Fig. 7. Mean WSC of different land uses in *Pokkali* ecosystem

5.2.4 Microbial biomass carbon and dehydrogenase activity

The microbial biomass carbon (MBC) significantly differed among different land uses of the *Pokkali* ecosystem and the mean values estimated from rice-prawn, rice alone, and prawn alone were 249.82, 208.87, and 180.07 µg g^{-1} soil respectively (Fig.8). Unni (2020) reported MBC content ranging from 10.09 µg g^{-1} soil to 870.91 µg g^{-1} soil in *Pokkali* soils. *Pokkali* soils have cohabited with a wide variety of microorganisms and that could have been attributed to higher levels of MBC. George *et al*. (2017) reported that MBC in the *Pokkali* soil sample varied from 125.2 to 260.3 µg g^{-1} soil with a mean value of 201.5 µg g^{-1} soil. Though high organic C content was reported, it was not adequately reflected in the MBC status, probably due to the shift from aerobic to an anaerobic condition in *Pokkali* soil. The diversity and richness of the fungal and bacterial population in these soils have a great influence on MBC. Soils that have high organic matter accumulation, optimum soil moisture, and aeration could provide a conducive environment for the growth and development of microorganisms (Kennedy *et al*., 2005). The tidal action helps to maintain the fertility and productivity of *Pokkali* soils and thereby influences the growth of enormous microorganisms in these soils. Relatively higher MBC found in rice-prawn land use might be due to higher organic matter accumulation against other land uses.

Dehydrogenase activity (DHA) observed in rice-prawn, rice alone, and prawn alone land use varied significantly with mean values of 2959.6, 3775.2, and 2132.49 µg TPF^{-1} g soil^{-1} 24hr^{-1} respectively (Fig.9). *Pokkali* soils recorded DHA ranging from 213.22 to 9135.82 µg TPF^{-1} g soil^{-1} 24hr^{-1} (Joseph, 2014), whereas Unni (2020) reported DHA ranging from 2.02 µg TPF^{-1} g soil^{-1} 24hr^{-1} to 2090.90 µg TPF^{-1} g soil^{-1} 24hr^{-1} in post-flood soils. George *et al*. (2017) found that the DHA ranges between 1985.48 µg TPF^{-1} g soil^{-1} 24hr^{-1} and 2300 µg TPF^{-1} g soil^{-1} 24hr^{-1}, which was comparatively higher than non-flooded soil. Flooding the soil which creates anaerobic conditions helps to accelerate DHA in the soil (Chendrayan *et al.,* 1980). Chandrika (1996) reported that specific, non-pathogenic, pigmental species of *Bacillus* were also noticed in *Pokkali* soils. The presence of marine fungi in these fields and its degradation helped coastal paddy fields to improve soil fertility status (Nambiar and Raveendran, 2009). Though the shift from aerobic to anaerobic respiration due to submergence can adversely affect MBC (Inglett *et al.,* 2005), it could also improve DHA like in rice alone land use under the *Pokkali* ecosystem.

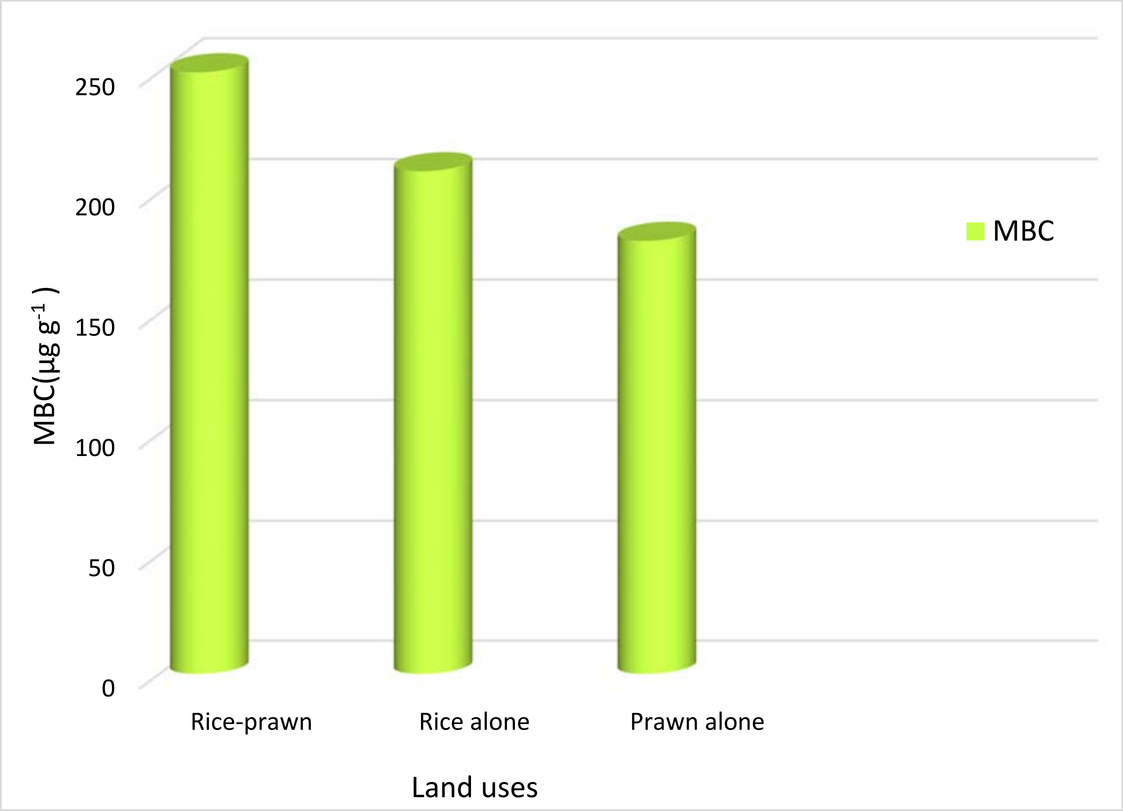

Fig. 8. Mean MBC from different land uses in *Pokkali* ecosystem

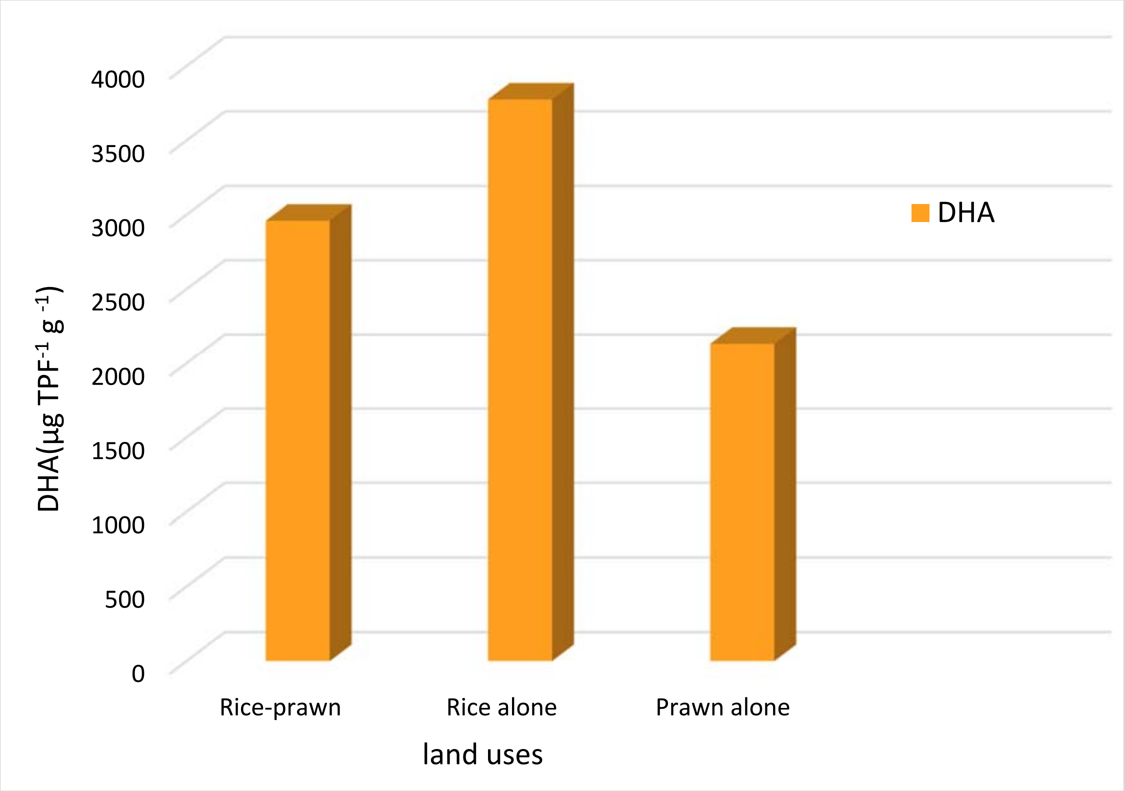

Fig. 9. Mean DHA from different land uses in the *Pokkali* ecosystem

5.2.4 Soil organic carbon stock

Mean soil organic carbon (SOC) stock estimated from rice-prawn, rice alone, and prawn alone land uses of *Pokkali* ecosystem (Fig.10) were 22.53, 26.46, and 24.99 Mg ha^{-1} respectively. Even though there was a difference in bulk density and SOC content in land uses, there was not much difference in SOC stock. Bulk density positively correlated with SOC stock among different land uses (Appendix I). Higher C stock in these soils reflects the C sequestration capacity of these soil. Gladis *et al*. (2019) recorded the highest carbon stock of 23.02 kg m^{-2} from rubber land use in Kallar soil of South Kerala and a SOC stock of 21.22 kg m^{-2} in coastal sandy rice soils of Kazhakkuttam series. Nideesh *et al*. (2021), studied the SOC stock in the 0–30 cm layer of acid sulphate wetlands soils of Kole lands and found that SOC content of 3.42 per cent and bulk density of 1.40 Mg m^{-3} has SOC stock of 57.46 Mg ha $^{-1}$ and higher C stocks were found in deeper layers.

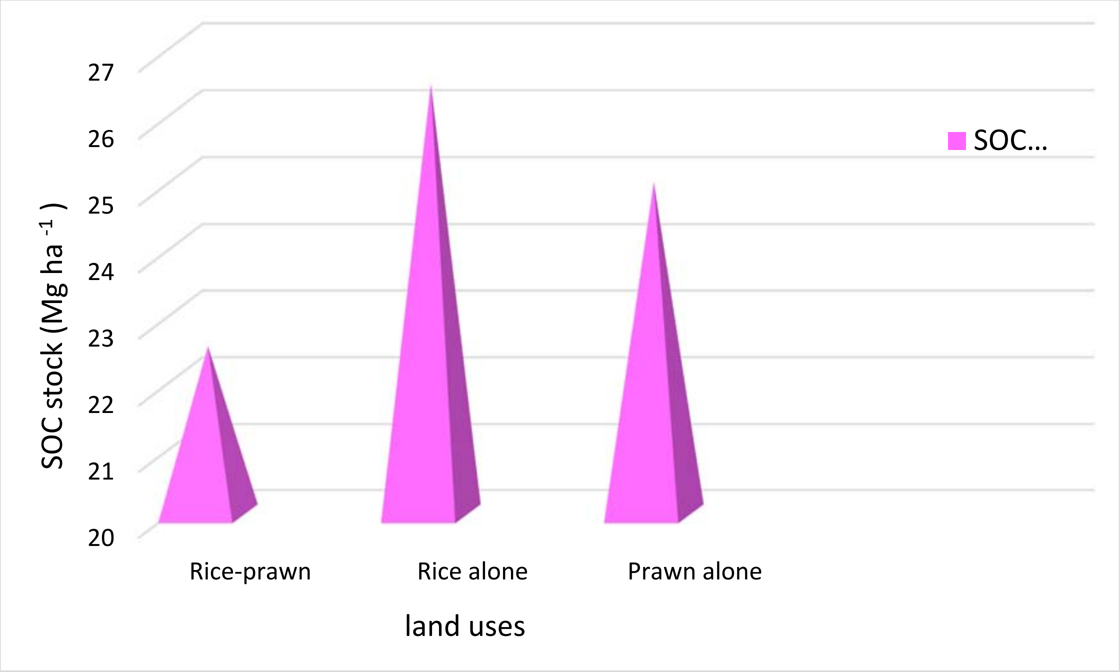

Fig. 10. Mean SOC stock from different land uses in the *Pokkali* ecosystem

5.3 CARBON MINERALISATION

Carbon mineralisation study through incubation experiment reflects biological fractionation of organic matter. The CO_2 evolved from different land uses on the application of different treatments are illustrated in Fig 11, 12, and 13.

All land uses recorded higher CO_2 -C evolution from treatments other than control (T_1-Soil only). This could be due to the addition of paddy straw in all the treatments except control which could have provided substrate to microbes in the soil. This enhanced availability of energy-rich C sources allowed soil microorganisms to synthesize osmolytes counteracting the osmotic pressure from elevated salinity or to invest in metabolic processes for detoxification and cell repair (Killham and Firestone, 1984; Schimel *et al.,* 1989; Wichern *et al.,* 2006). Then it favored microbial respiration in soil and CO_2 evolved. Datta *et al.* (2019) also reported that crop residues with low N and high C/N ratios such as maize, wheat, rice, and their mixtures can be applied on the soil surface for faster C and N mineralization in Alfisols of Northwest India. Fontaine *et al.* (2007) reported that the absence of fresh carbon addition might prevent the decomposition of the organic carbon pool in deep soil layers. Priming effect due to paddy straw addition influenced soil organic matter decomposition and C mineralisation.

The C mineralisation decreased over incubation time. In rice- prawn land use and prawn land use, CO_2-C evolved from all treatment was highest on day 11 and thereafter it reduced gradually. But in rice alone land use the peak was shifted to day 17 and thereafter it started decreasing. This distinctly indicated that SOC is composed of easily mineralizable (active pool) and slowly mineralizable (intermediate pool) compounds. The initial increase in CO_2-C evolution could be due to the decomposition of available labile carbon by micro-organisms. As time advanced, the decomposition rate of soil OM also decreased. The decrease in decomposition rate in the latter phase is probably due to the increasing concentration of structural carbohydrates (such as lignin and hemicelluloses) as a result of the loss of other constituents (sugars and starches) in the organic matter. The structural carbohydrates often build the chief portion of the detrital biomass which are very resistant to decomposition (Mfilinge *et al*., 2004)

Jha *et al.* (2012) reported that cumulative carbon mineralisation in unamended soil (without straw and salts) increased after 11 days of incubation and reached the value of 53.92 mg 100 g^{-1} soil, whereas when the same soil was amended with wheat straw the value reached 155.90 mg 100 g^{-1} in 74 days of incubation.

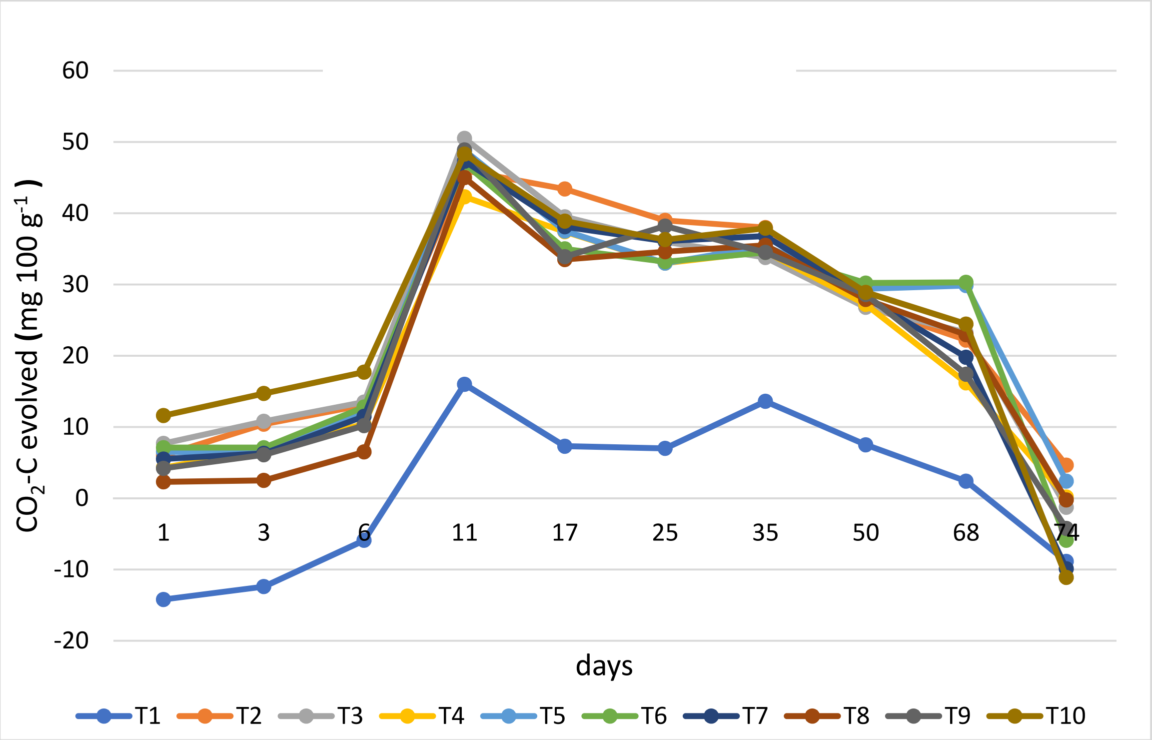

Fig 11. Mean CO_2-C evolved from rice-prawn land use of the *Pokkali* ecosystem

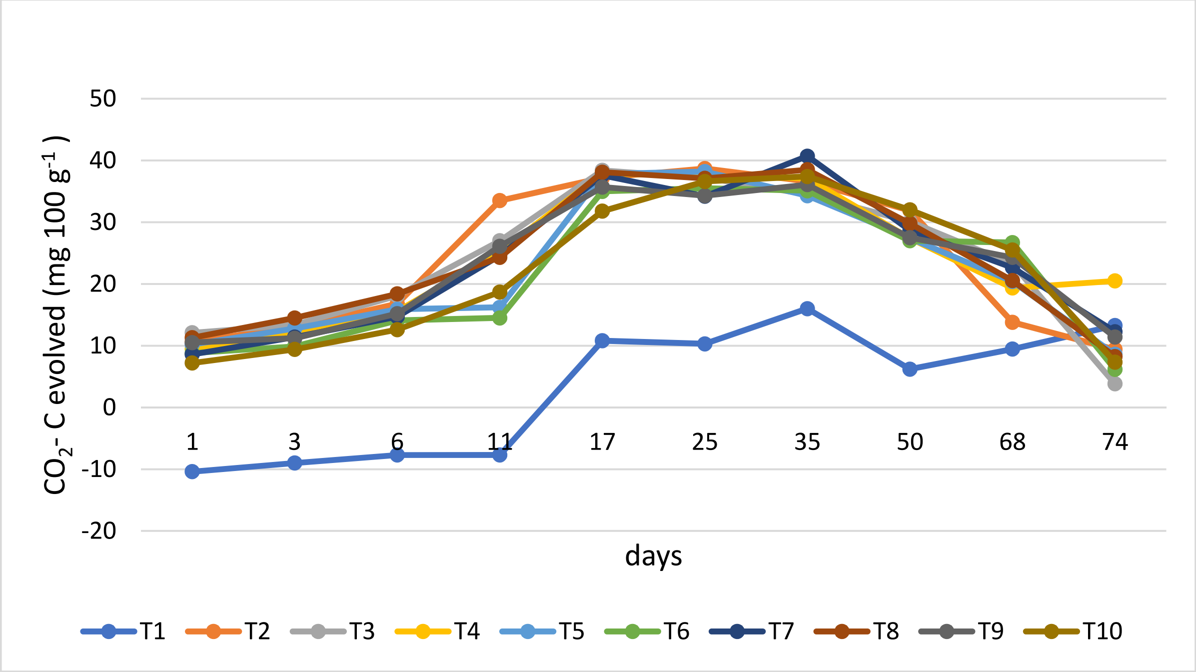

Fig 12. Mean CO_2-C evolved from rice alone land use of *Pokkali* ecosystem

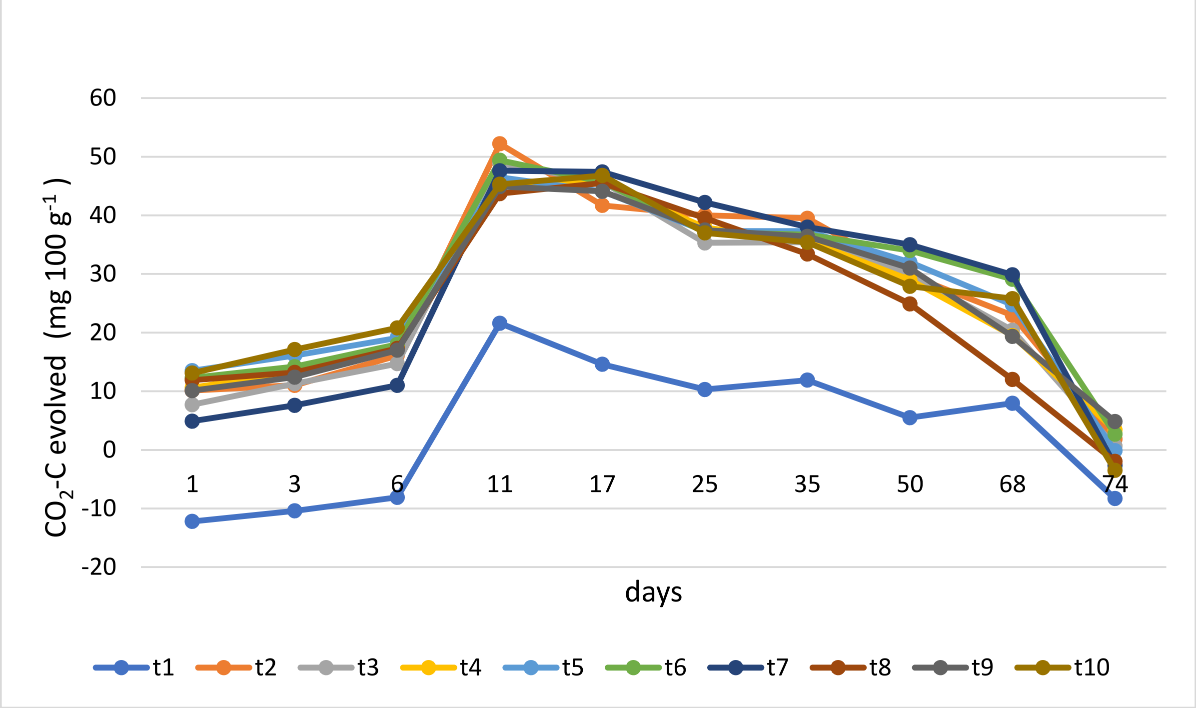

Fig 13. Mean CO_2-C evolved from prawn alone land use of *Pokkali* ecosystem

Cumulative CO_2-C data obtained from rice-prawn, rice alone, and prawn alone land use were depicted in Fig 14, 15, and 16. Cumulative CO_2 from all land uses recorded in the control were much lower compared to other treatments involving paddy straw incorporation. Sarma *et al*. (2018) also observed higher cumulative CO_2 release with the addition of organic amendments, and the highest increase was reported when vermicompost was incorporated into the soil.

Cumulative CO_2 evolved from incubation study for different land uses plotted against various treatment is illustrated in fig 17. It is evident that in prawn alone land use, CO_2 evolution was relatively higher in all treatments against other land uses. In the case of control also, the highest cumulative CO_2 evolved was seen in prawn alone land use followed by rice alone and rice-prawn alone. The mineralizable carbon in different land uses was found inversely correlated with total organic carbon. This could be due to its low potential to sequester carbon and the presence of low organic carbon content with easily degradable C in prawn alone land use. Gladis *et al.* (2020) also showed similar results where the Kallara series and rice land-use system recorded the minimum mineralizable carbon, the highest total organic carbon, and the maximum storage of soil organic carbon.

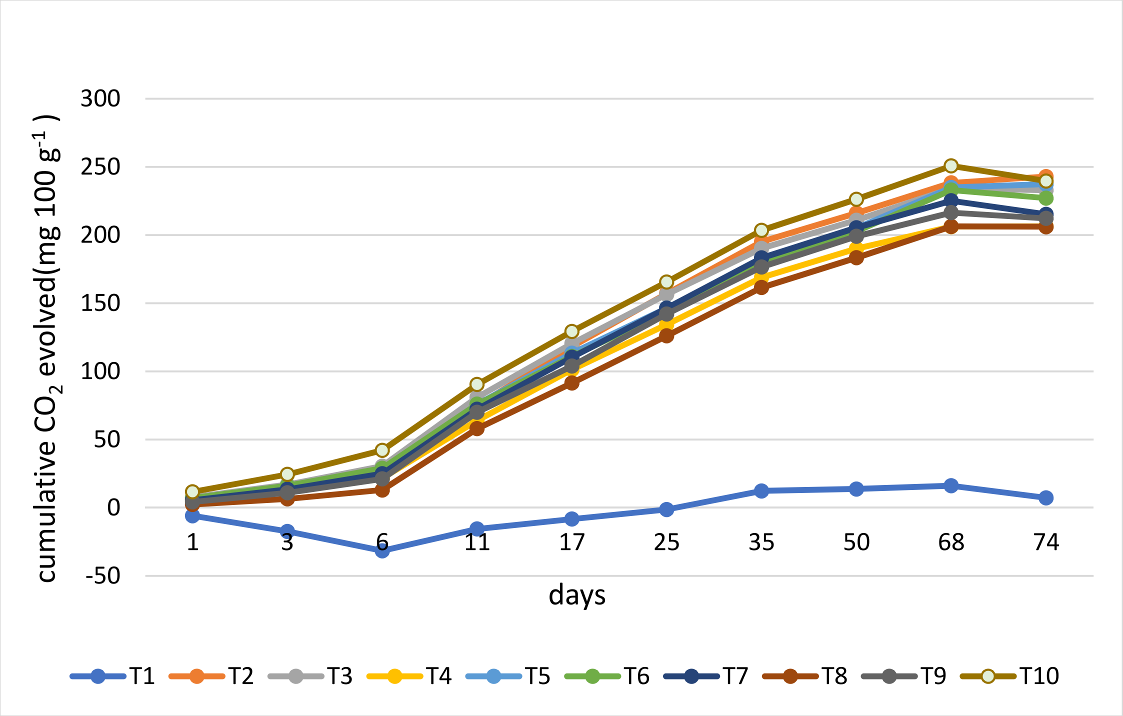

Fig 14. Mean cumulative CO_2 evolved from rice-prawn land use of the *Pokkali* ecosystem

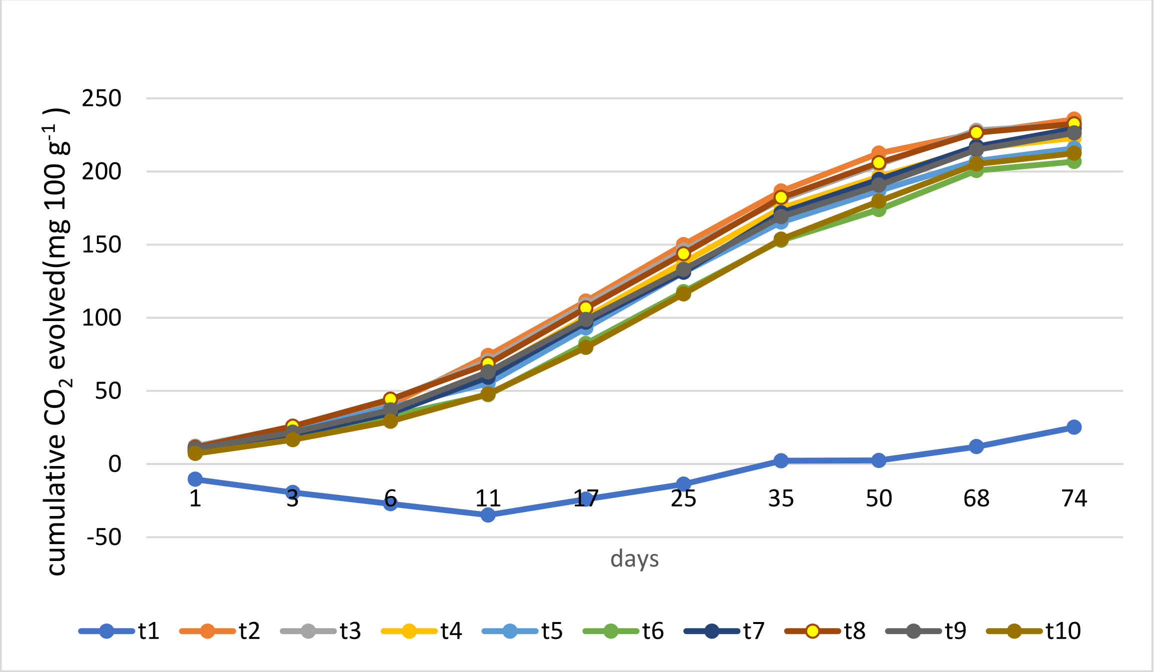

Fig 15. Mean cumulative CO_2 evolved from rice alone land use of *Pokkali* ecosystem

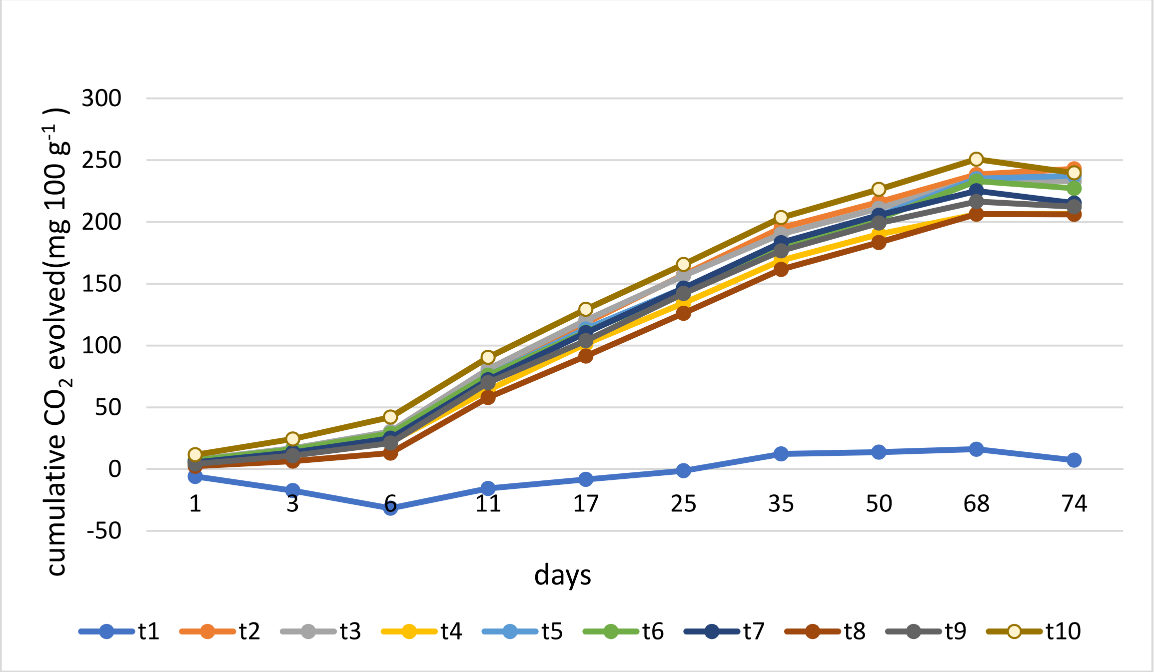

Fig 16. Mean cumulative CO_2 evolved from prawn alone land use of *Pokkali* ecosystem

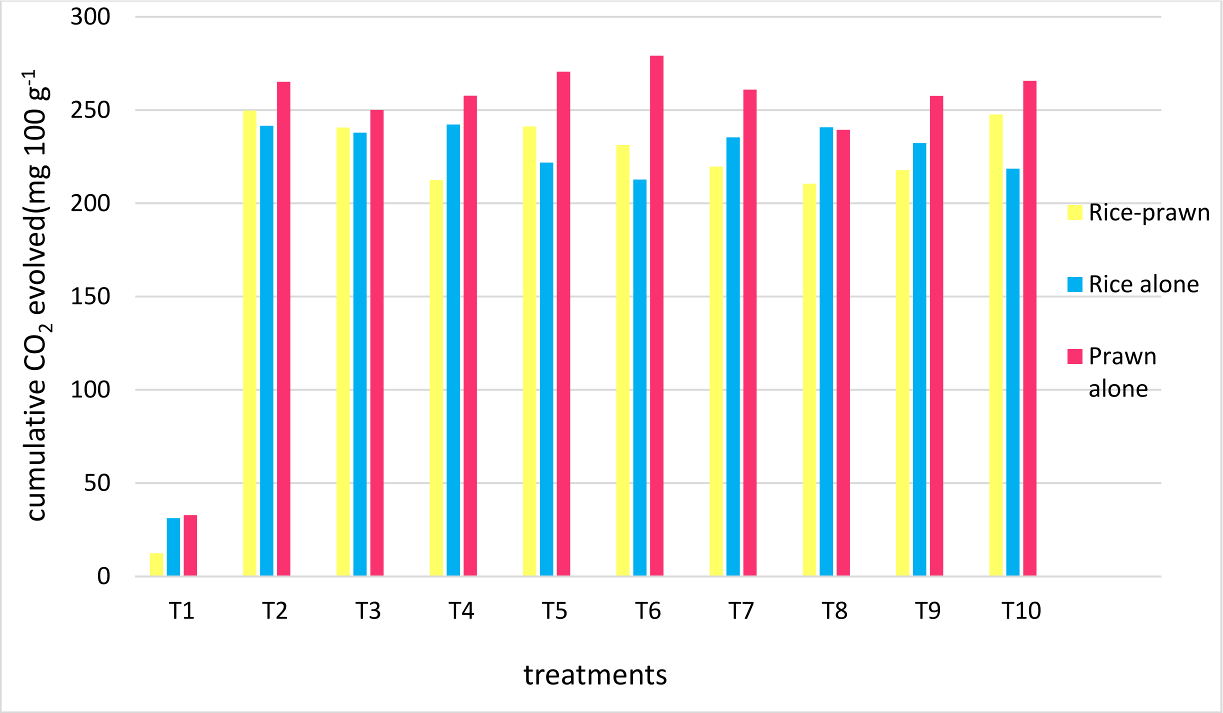

Fig 17. Mean cumulative CO_2 evolved from different land uses in the *Pokkali* ecosystem

5.3.2 Influence of pH on carbon mineralisation

It was found that pH recorded just after incubation period decreased in control than all other treatments in rice-prawn, rice alone and prawn alone land uses (Fig.18, 19, 20). The addition of paddy straw could have helped the soil to buffer pH and maintain neutral ranges. Amendment of soil with neural salts of Ca and Na increased soil pH in all other treatments except control. The pH also recorded a positive significant correlation with cumulative CO_2 obtained from different land uses of the *Pokkali* ecosystem. Diya and Sreelatha (2018) reported that the addition of calcium salts invariably increased the soil pH and microbial biomass carbon and inactivated Fe, Mn, and Al in the *Pokkali* soil solution. Application of $Ca(OH)_2$ increased the pH of the Swinton and Melfort soils from 5.7-5.8 to 7.3-7.4 at the highest rate and it stimulated C and N mineralisation (Curtis *et al.*,1998).

Beena (2005) reported a decline of 0.5 units in pH of acid sulphate soil during incubation which might be due to the oxidation of the pyrite layer in the soil thereby contributing to sulphuric acid production and the low pH in soils. The decrease in pH of control might be due to oxidation of pyrites in the acid sulphate soils found in the *Pokkali* ecosystem.

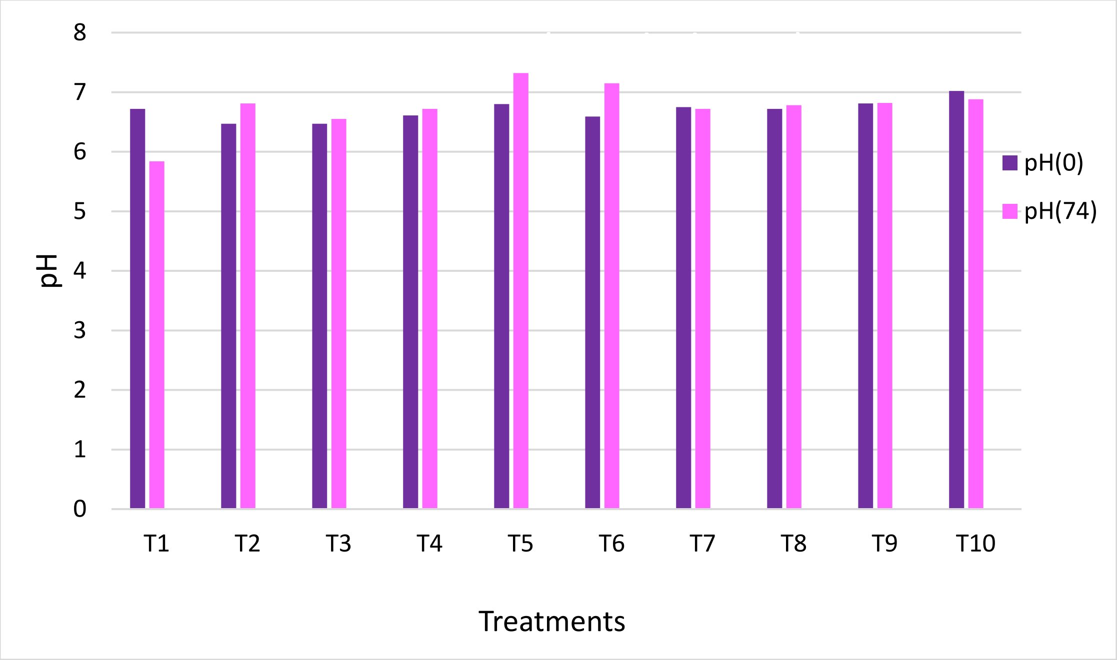

Fig 18. **Mean pH before and after incubation period from rice-prawn land use of *Pokkali* ecosystem**

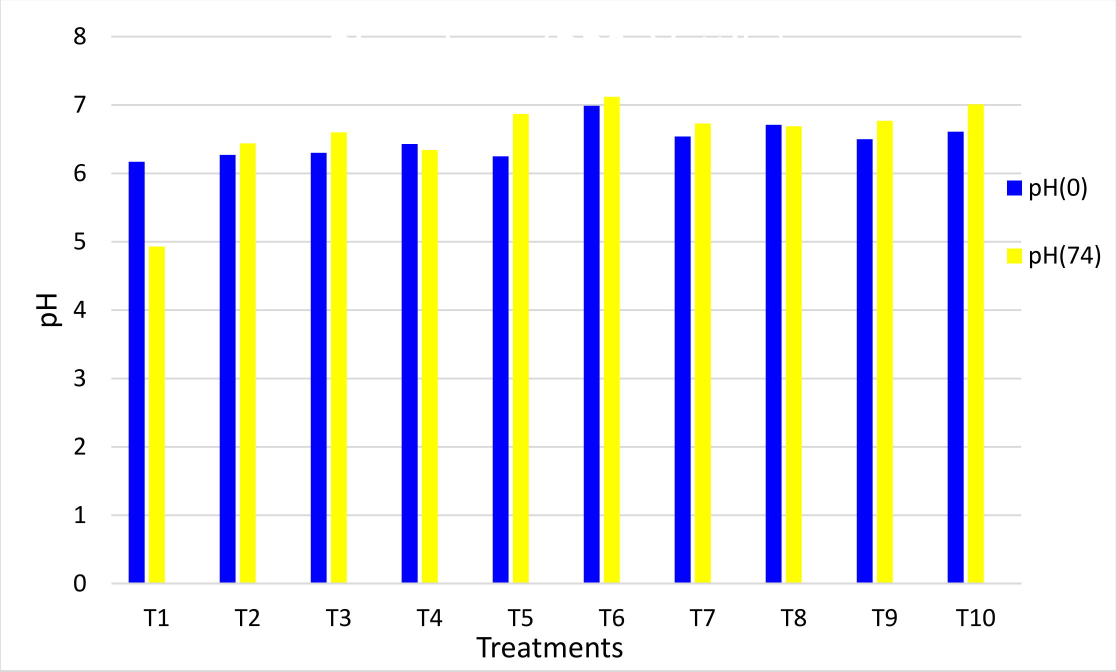

Fig 19. **Mean pH before and after incubation period from rice alone land use of *Pokkali* ecosystem**

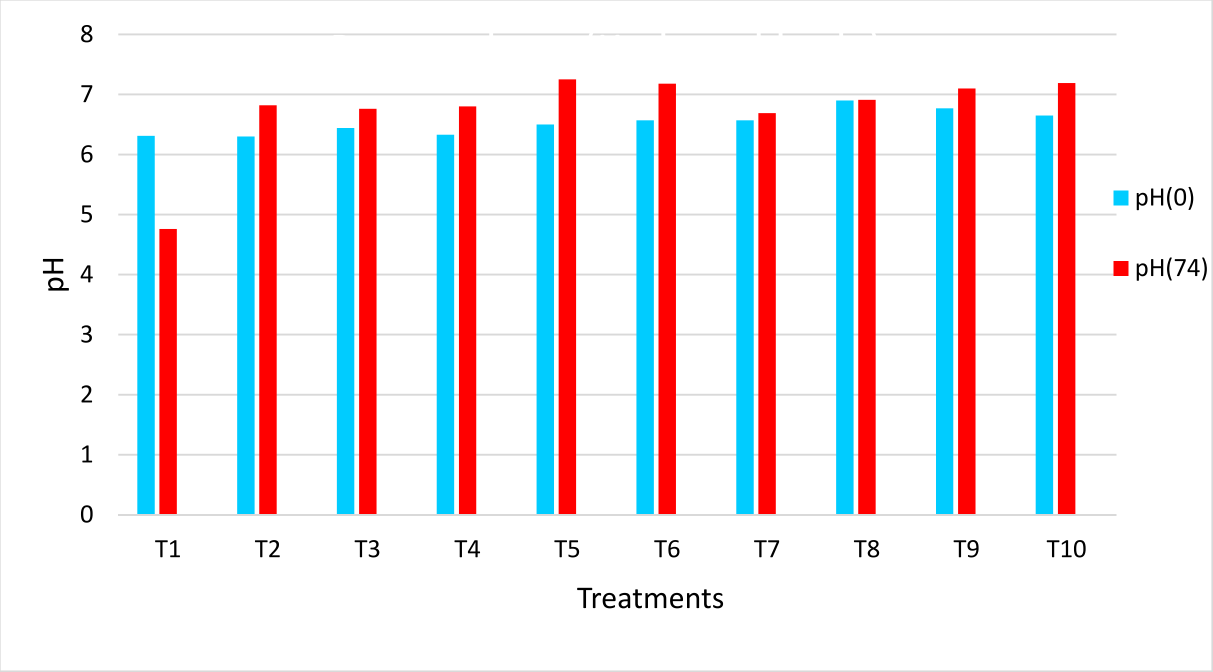

Fig 20. Mean pH before and after incubation period from prawn alone land use of *Pokkali* ecosystem

5.2 Electrical conductivity

Electrical conductivity recorded just before and after incubation period for all treatments in rice-prawn, rice alone and prawn alone land uses is illustrated in Fig 21, 22, and 23 respectively. An increase in EC was observed just after treatment application before incubation except in control (T_1- Soil only). It is recorded that EC of T_1 and T_2 where there is no addition of neutral salts recorded an increase with incubation time. The rest of the treatments showed a considerable decrease in EC with incubation time. The EC significantly and positively correlated with DHA in these land uses. Even under high salinity conditions, fungal activity was higher in *Pokkali* soils (George *et al.*, 2017). Jha *et al.* (2012) reported that EC values showed a significant enhancement when Ca salts were applied either alone or in combinations. Li *et al.* (2006) had observed a significant increase in EC values after the addition of neutral salts.

Negative charges provided by decomposition of organic matter content (paddy straw) of the soil facilitated the adsorption of cations from soil solution (Ponnamperuma, 1972) which could be resulted in a decrease in EC of treatments with time. Also, the buffering capacity of soil resulted in adsorption of ions when neutral salts were added and decreased the EC of treatments. But in T_1 and T_2, the desorption process could have gained momentum with the decomposition process and CO_2 loss and resulted in increased EC of these soils.

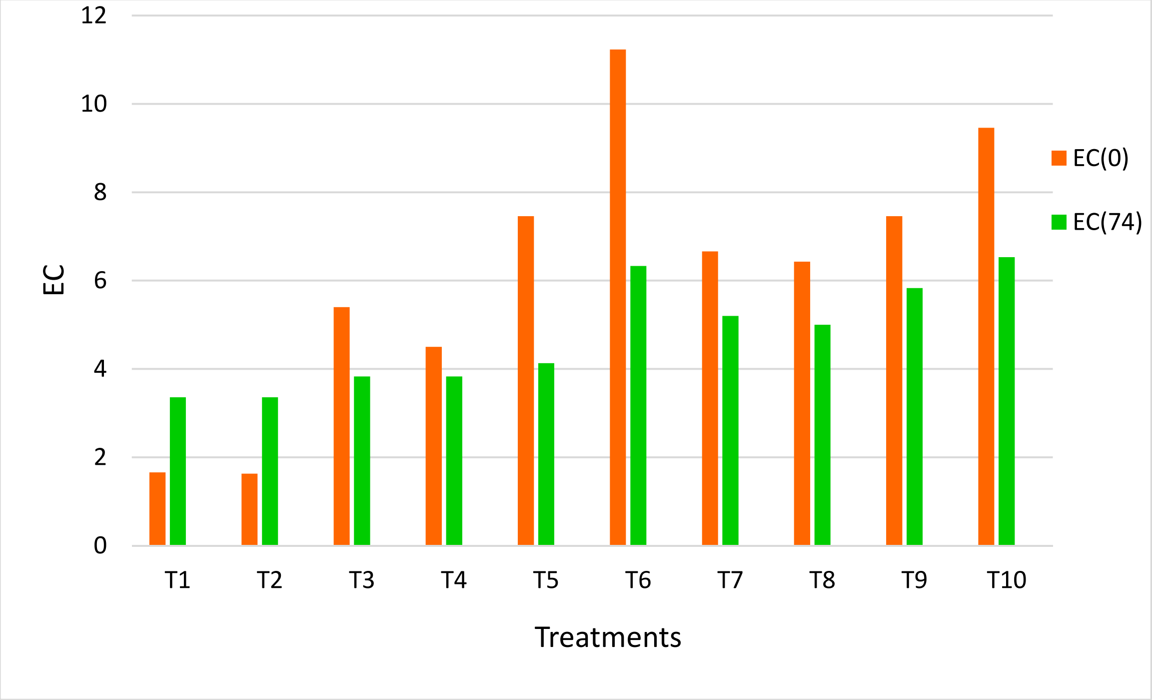

Fig 21. Mean EC before and after incubation period from rice-prawn land use of *Pokkali* ecosystem

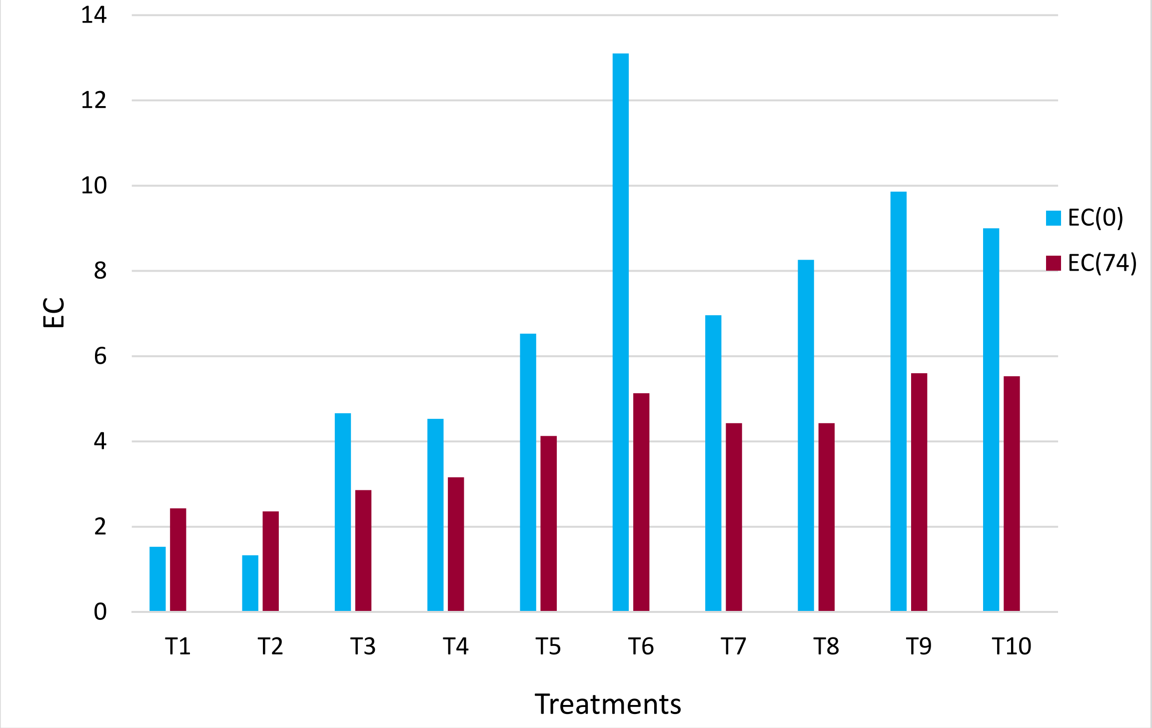

Fig 22. Mean EC before and after incubation period from rice alone land use of *Pokkali* ecosystem

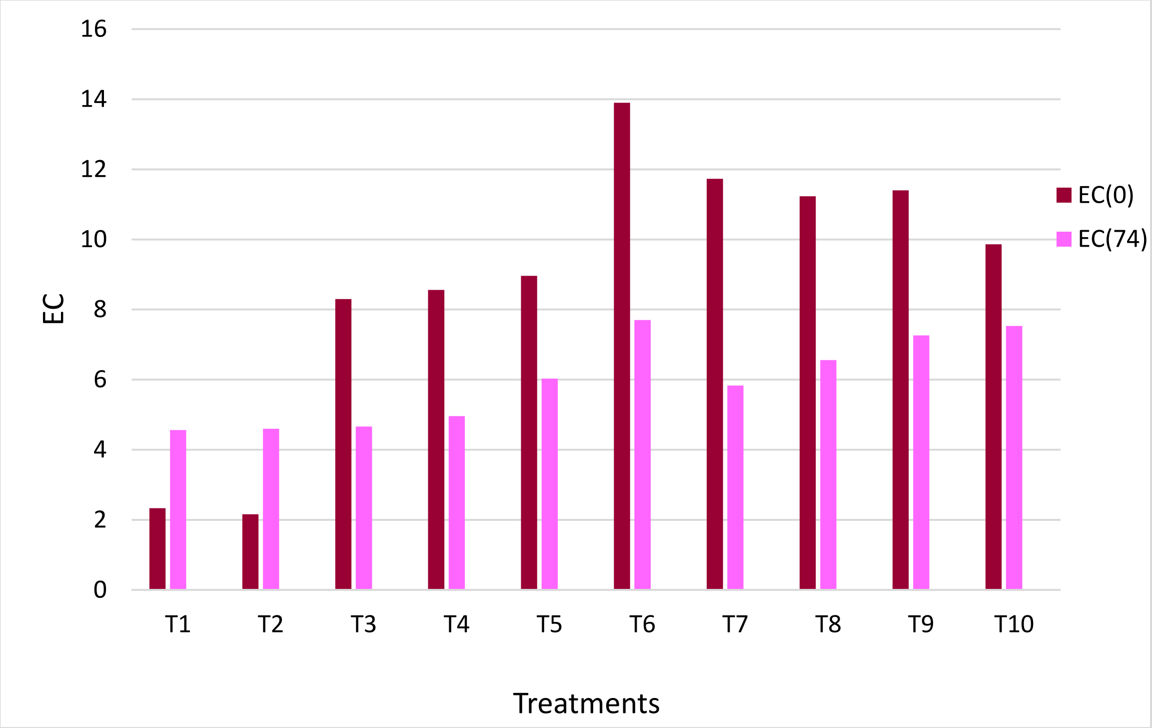

Fig 23. Mean EC before and after incubation period from prawn alone land use of *Pokkali* ecosystem

5.3 Total carbon (TOC) and dehydrogenase activity (DHA)

Mean TOC and DHA recorded from different land use after incubation period are illustrated in Fig.24 and 25 respectively. There was a significant positive correlation between TOC and cumulative CO_2 mineralized in all land uses of the *Pokkali* ecosystem. Lower mineralisation was recorded in control which might be due to lower TOC content. Paddy straw amendment would have attributed for high TOC in other treatments. Likewise, DHA also positively correlated with cumulative CO_2 mineralised from these soils. Since most dehydrogenases are anaerobic in origin, flooded soil recorded high in dehydrogenase activity and the addition of neutral salts and organic matter might have enhanced microbial activity and thereby DHA. Being a respiratory enzyme DHA could have increased the carbon mineralisation in these soils of the *Pokkali* ecosystem. Dehydrogenase plays a key role in the biological oxidation of soil organic matter by transferring hydrogen from organic substrates to inorganic acceptors. There will be a succession of microorganisms during the decomposition of organic substrates in soil normally, and fungi are pioneers among decomposers but can be replaced by bacteria later (Yu and Li, 1985). Different microbial communities that proliferated in specific decomposition phases would have different responses in both size and activity to salts and their combination.

Wichern *et al*. (2020) observed that rice straw addition with or without manure increased MBC and the fungal contribution significantly in the short term and this ultimately contributes to increased microbial necromass, which accounts for at least half of soil organic matter and is thus a prerequisite for SOC maintenance.

Ray (1984) reported that the addition of lime to both flooded and non-flooded soils increased the microbial (total bacteria and fungi) population which possibly resulted in the increased dehydrogenase activity in lime-amended soils. Rao and Pathak (1996) and Liang *et al.* (2005) reported that the addition of organic amendments to soil enhances dehydrogenase activity because of intracellular and extracellular enzymes present in them which stimulates the microbial activity. Weston *et al.* (2010) reported that salt-water intrusion stimulates microbial decomposition which accelerates the loss of organic C from tidal freshwater marsh (TFM) soils.

The addition of paddy straw enhanced total organic carbon and increased C availability for soil microorganisms and helped them to produce osmolytes, counteracting the osmotic effects of increased salinity in these soils. Even under high salinity dehydrogenase activity was recorded highest. These both have contributed to high mineralisation from treatments other than control. As the salinity increased dehydrogenase activity which has a significant role in C cycling also increased in these soils which resulted in increased C mineralisation from soils of different land uses under the *Pokkali* ecosystem. Prawn alone land uses where salinity remains throughout the year recorded high C mineralisation compared to other land uses of the *Pokkali* ecosystem. For increased C storage and reduced C mineralisation, rice-prawn land use should be prioritized among different land uses of the *Pokkali* ecosystem.

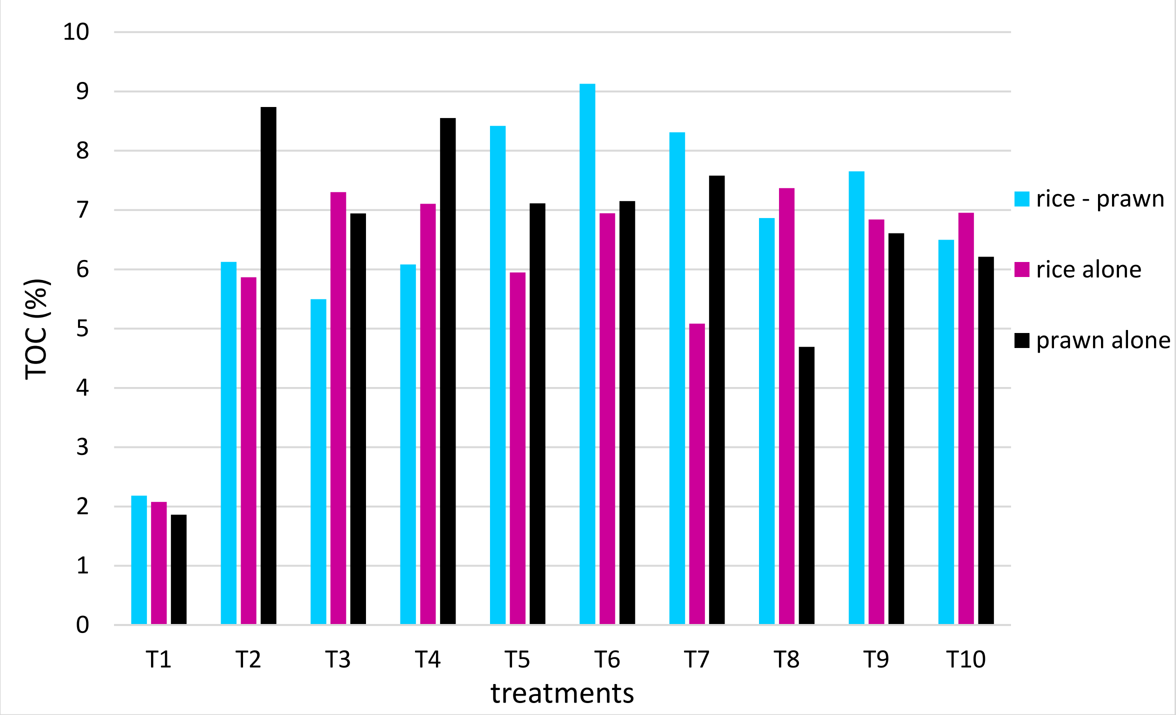

Fig.24 Mean TOC after incubation period from different land uses of *Pokkali* ecosystem

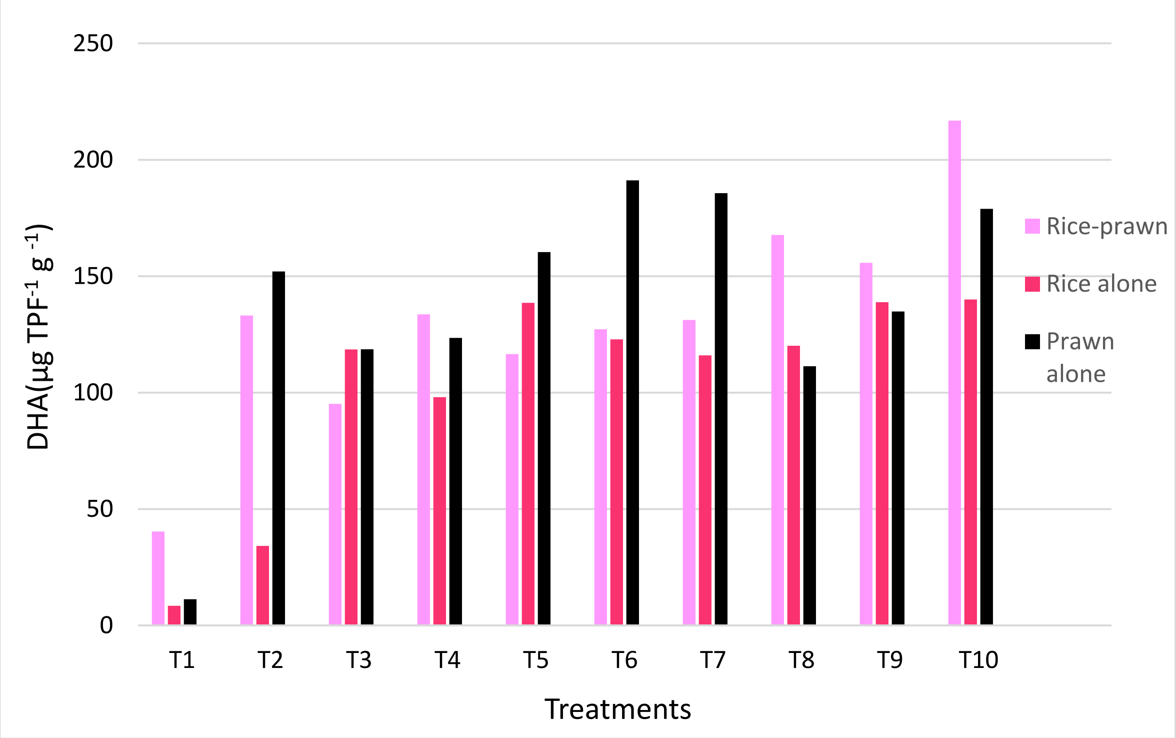

Fig.25 Mean DHA after incubation period from different land uses of *Pokkali* ecosystem

Summary

SUMMARY

Soil can function as a great biological scrubber for atmospheric CO_2 and thereby helps to reduce global warming and other related issues. Land uses have a significant role in soil carbon pools and fluxes. Carbon mineralisation from the soil can affect carbon sequestration in the soil. Salinity of soil could play a pivotal role in carbon mineralisation also. Hence the present study was carried out with specific objective to find out effect of carbon mineralisation under different land uses in *Pokkali* ecosystem. Soil samples were collected from three land uses of *Pokkali* ecosystem namely rice-prawn, rice alone and prawn alone land uses in Kumbalangi, RRS, Vyttila and Kadamakkudy respectively. The samples were analyzed for different soil properties such as pH, EC, particle size, CEC, bulk density and estimated soil organic carbon pools such as soil organic carbon, labile carbon, water soluble carbon and microbial biomass carbon. Soil organic carbon stocks and dehydrogenase activity were also estimated as per standard procedures. Carbon mineralisation was studied in a laboratory incubation experiment for 74 days where two sets of soil (with and without 1% paddy straw respectively) was amended with different concentrations of $CaSO_4$ and Na_2SO_4 either alone or in combinations of 40 and 80 mmol per kg soil weight basis in order to get desired change in electrical conductivity similar to field conditions. The conclusions arrived from the results are summarized in this chapter.

The mean pH values registered for rice-prawn, rice alone and prawn alone land uses were 6.884, 6.416 and 6.844 respectively. A significant difference was observed in the mean EC values with maximum value of 2.440 dS m^{-1} in prawn alone and minimum value of 1.340 dS m^{-1} in rice alone land use. Soil texture of rice-prawn and rice alone belonged to clay and prawn alone in sandy clay loam class. Highest cation exchange capacity was recorded from rice-prawn land use (12.38 cmol(p+)kg^{-1}) due to high organic matter and the lowest from prawn alone land use (9.59 cmol(p+)kg^{-1}). Highest mean bulk density value was observed in prawn alone (1.238 Mg m^{-3}) land use and the lowest value in rice-prawn (0.684 Mg m^{-3}) land use. Absence of rice crop and intercultural operations attributed to higher bulk density in prawn alone land uses.

The soil organic carbon from prawn alone (0.982%) land use was significantly lower than rice-prawn (1.649%) and rice alone (1.477%) land uses. Mean labile carbon recorded from prawn alone (1547.805 mg kg^{-1}) was the lowest and rice-prawn (2153.565 mg kg^{-1}) recorded the highest followed by rice alone (1949.661 mg kg^{-1}) land uses. Highest mean water-soluble carbon was recorded from rice-prawn (46.10 mg kg^{-1}) and lowest from prawn alone (32.386 mg kg^{-1}) land uses. Mean microbial biomass carbon was registered highest in rice-prawn (249.827 µg g^{-1}) followed by rice alone (208.8702 µg g^{-1}) and the lowest was registered from prawn alone (180.072 µg g^{-1}). Highest mean total organic carbon was recorded from rice-prawn (1.844 %) and lowest was recorded from prawn alone (1.189 %) land use. Different land uses registered significant influence on soil organic carbon, labile carbon, water soluble carbon and microbial biomass carbon. Rice-prawn land use recorded highest organic carbon pools and prawn alone land use recorded lowest organic carbon pools. Presence of high organic matter and microbial activity contributed to higher soil carbon pools in rice-prawn land uses.

Highest mean soil organic carbon stock recorded in rice alone (26.46 Mg ha $^{-1}$) land use and the lowest in rice-prawn (22.53 Mg ha $^{-1}$) land use. Highest mean dehydrogenase activity was recorded from rice alone (2959.697 µg TPF h^{-1} g^{-1}) and lowest from prawn alone (2132.491 µg TPF h^{-1} g^{-1}) land use.

Carbon mineralisation study revealed that CO_2-C evolved from soil decreased with time. Highest amount of CO_2-C was evolved on day 11 for rice-prawn and prawn alone land uses and day 17 for rice alone land use. After attaining peak values, they started to decrease gradually. Highest cumulative CO_2-C was recorded from treatments other than control (without paddy straw and salts). Lowest mean cumulative CO_2-C in control was recorded from rice- prawn (7.2 mg 100 g^{-1}) land use and highest recorded from prawn alone (26.48 mg 100 g^{-1}) followed by rice alone (25.15 mg 100 g^{-1}) land use. A significant positive correlation was observed between pH, dehydrogenase activity and total organic carbon with cumulative CO_2-C in all land use systems.

In carbon mineralisation study, pH of control was reduced and pH of other treatments (with paddy straw and salts) was increased after 74 days of incubation in all land uses. The EC values of treatments with salts amendments recorded > 4 dS m^{-1} in all land uses before start of incubation. After incubation period, EC values decreased in all salt amended treatments of different land uses and an increase in EC values were observed for control and paddy straw alone amended treatment. Dehydrogenase activity was found higher in treatments with paddy straw and salts than control. Relatively higher dehydrogenase activity was recorded from rice-prawn land use followed by prawn alone and rice alone land uses. The EC was positively correlated with dehydrogenase activity. Total carbon content was also recorded higher in treatments other than control.

A significant lower carbon mineralisation was recorded from control compared to other treatments in all land uses of *Pokkali* ecosystem. Carbon mineralisation increased with increasing salinity. Dehydrogenase activity and total carbon content influenced the carbon mineralisation process. Presence of paddy straw alleviated the salinity impacts and increased dehydrogenase activity which lead to higher carbon mineralisation.

Rice-prawn land use recorded highest soil organic carbon pools showing prevalence of conducive environment for build up of organic carbon in *Pokkali* ecosystem. As the salinity increased carbon mineralisation was also increased. Lowest carbon mineralisation was recorded from rice-prawn land use. This emphasizes the need to follow rice-prawn land use in *Pokkali* ecosystem for sequestering more carbon into the soil. The rice cultivation in the low saline phase reduces the salinity by leaching out the accumulated salts. But in the prawn alone land use, the salinity is not washed out in the low saline phase and the soils remain saline throughout the year which results in increased C mineralization and less C sequestration. This study emphasizes the importance of integrated rice-prawn farming system in *Pokkali* lands to maintain the soil quality and reduce global warming through increased C sequestration.

Reference

REFERENCES

Adak, T., Singha, A., Kumar, K., Shukla, S., Singh, A., and Kumar, S. V. 2014. Soil organic carbon, dehydrogenase activity, nutrient availability and leaf nutrient content as affected by organic and inorganic source of nutrient in mango orchard soil. *J. Soil Sci. Plant Nutr.* 2: 394–406.

Adhikari, S., Bajracharaya R. M., and Sitaula B. K., 2009. A review of carbon dynamics and sequestration in wetlands. *J. Wetlands Ecol.* 2: 42-46.

Amundson, R. 2001. The carbon budget in soils. Annual Review of Earth and Planetary Sciences., 29(1): 535-562.

Anilkumar, K. and Annie, K. 2010. Developing, protocol for organic rice production in *Pokkali* tracts. *Proceedings of Thirty first ZREAC Workshop, 12th August 2011,* Regional Agricultural Research Station, Kumarakom, Kerala Agricultural University, pp.8-9.

Aryalekshmi, V. 2016. Silicon availability of tropical soils with respect to rice nutrition. MSc. (Ag) Thesis, Kerala Agricultural University, Thrissur, 236p.

Bahn, M., Knapp, M., Garajova, Z., Pfahringer, N., and Cernusca, A. 2006. Root respiration in temperate mountain grasslands differing in land use. *Glob. Chang. Biol.*, 12: 995–1006.

Baldock, J. A. 2007. Composition and cycling of organic carbon in soil. *Nutr. Cycling in Terrestrial Ecosyst.* 10: 1–35.

Baldock, J. A., Oades, J. M., Waters, A. G., Peng, X., Vassallo, A. M., and Wilson, M. A. 1992. Aspects of the chemical structure of soil organic materials as revealed by solid-state 13C NMR spectroscopy. *Biogeochem.*16: 1-42.

Batjes, N. H. 1996. Total carbon and nitrogen in the soils of the world. *Eur. J. Soil Sci.* 47(2): 151-163. doi: 10.1111/j.1365-23891996.tb01386.x

Beena, V. I. 2005. Land evaluation and crop suitability rating of the acid sulphate soils of Kuttanad for sustainable land use planning. Ph.D. thesis, Kerala Agricultural University, Thrissur. 207p

Benbi, D.K., Brar, K., Toor, A.S., Singh, P., and Singh, H., 2012. Soil carbon pools under poplar-based agroforestry, rice-wheat, and maize-wheat cropping systems in semi-arid India. *Nutr. Cycling in Agroecosyst.*, 92(1): 107-118.

Bernal, B. and Mitsch, W. J. 2012. Comparing carbon sequestration intemperate freshwater wetland communities. *Global Change Bio.* 18: 1636–1647.

Bernal, B. S. B. 2008. Carbon pools and profiles in wetland soils: The effect of climate and wetland type. M.S. thesis, School of The Ohio State University.

Bhaskaran, U. P. and Varghese, T., 2009. Effect of submergence on alleviation of soil acidity and availability of nutrients in a rice-rice ecosystem.

Bhattacharyya, P., Neogi, S., Roy, K. S., Dash, P. K., Tripathi, R., and Rao, K. S. 2013. Net ecosystem CO_2 exchange and carbon cycling in tropical lowland flooded rice ecosystem. *Nutr. Cycling in Agroecosyst.* 95: 133–144.

Bhattacharyya, T., Pal, D. K., Easter, M., Batjes, N. H., Milne, E., Gajbhiye, K. S., Chandran, P., Ray, S. K., Mandal, C., and Paustian, K. *et al.* 2007. Modelled soil organic carbon stocks and changes in the Indo-Gangetic Plains, India from 1980 to 2030. *Agric. Ecosyst. Environ.* 122(1): 84-94.

Bhindu, P. S. 2017. Chemistry and transformations of calcium and magnesium in tropical acid soils of Kerala. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 285p.

Blair, G. J., Lefroy, R. D. B., and Lise, L. 1995. Soil carbon fractions based on their degrees of oxidation, and the development of a carbon management index for agricultural systems. *Aust. J. Agric. Res.* 46: 1459-1466.

Blake, G. R. and Hartge, K. H. 1986. Bulk density. In: Klute, A. (ed.), Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods (2nd Ed.). American Society of Agronomy Inc, Madison, pp. 363-375.

Bond-Lamberty, B., and Thomson, A. 2010. Temperature-associated increases in the global soil respiration record. *Nature*. 464: 579-582.

Boyer, J. N., and Groffman, P. M. 1996. Bioavailability of water extractable organic carbon fractions in forest and agricultural soil profiles. *Soil Biol. Biochem.* 28(6):783–790.

Bremner, E. and Van Kissel, C. 1992. Plant-available nitrogen from lentil and wheat residues during a subsequent growing season. *Soil Sci. Soc. Am. J.* 56: 1155–1160.

Burke, I. C., Yonker, C. M., Parton, W. J., Cole, C. V., Flach, K., and Schimel, D. S. 1989. Texture, climate, and cultivation effects on soil organic matter content in US grassland soils. *Soil sci. soc. Am. J.* 53(3): 800-805.

Caravaca, F., Lax, A., and Albaladejo, J. 1999. Organic matter, nutrient contents and cation exchange capacity in fine fractions from semiarid calcareous soils. *Geoderma*. 93(3-4) :161-176.

Carter, M. R. 1986. Microbial biomass and mineralizable nitrogen in solonetzic soils: Influence of gypsum and lime amendments. *Soil Biol. Biochem.* 18(5): 531-537.

Cassida, L. E., Klein, D. A., and Santaro, T. 1964. Soil dehydrogenase activity. *Soil Sci.* 98: 371–376.

Chan, K. Y., Bowman, A., and Oates, A. 2001. Oxidizible organic carbon fractions and soil quality changes in an oxic paleustalf under different pasture leys. *Soil Sci.*166(1): 61-67.

Chandrika, V. 1996. Incidence of antagonistic Bacillus spp.- an eco-friendly aquatic probiotic from aquaculture ponds. In: The fourth Indian fisheries forum proceedings, 24-28 November 1996, Kochi. School of Marine Science, Cochin University of Science and Technology, pp. 147-150.

Chantigny, M. H. 2003. Dissolved and water-extractable organic matter in soils: a review on the influence of land use and management practices. *Geoderma*, 113(3-4): 357-380.

Chen, X., Chen, H. Y., Chen, X., Wang, J., Chen, B., Wang, D., and Guan, Q. 2016. Soil labile organic carbon and carbon-cycle enzyme activities under different thinning intensities in Chinese fir plantations. *Applied soil ecol.*, 107: 162-169.

Chendrayan, K., Anhya, T. K., and Sethunathan, M. 1980. Dehydrogenase and invertase activities of flooded soils. *Soil Biol. Biochem.* 12: 271-273.

Choi, Y., and Wang, Y. 2004. Dynamics of carbon sequestration in a coastal wetland using radiocarbon measurements. *Glob. Biogeochem. Cycles*. 18: 1-12.

Chorom, M., and Rengasamy, P. 1997. Carbonate chemistry, pH, and physical properties of an alkaline sodic soil as affected by various amendments. *Soil Res.* 35(1): 149-162.

Christ, M. J. and David, M. B. 1996. Temperature and moisture effects on the production of dissolved organic carbon in a Spodosol. *Soil Biol. Biochem*. 28(9): 1191–1199.

Chung, H., Ngo, K.J., Plante, A., and Six, J. 2010. Evidence for carbon saturation in a highly structured and organic-matter-rich soil. *Soil Sci. Soc. Am. J.* 74(1): 130-138.

Conant, R.T., Drijber, R. A., Haddix, M. L., Parton, W. J., Paul, E. A., Plante, A. F., Six, J. and Steinweg, J. M. 2008. Sensitivity of organic matter decomposition to warming varies with its quality. *Glob. Chang. Biol*. 14: 868-877.

Curtis, D., Campbell, C. A., and Jalil, A. 1998. Effect of acidity on mineralization: pH-dependence of organic matter mineralization in weakly acidic soils. *Soil Biol. Biochem*. 30(1): 57-64.

Dakshinamurti, C. and Gupta, R. P. 1968. Practicals in Soil Physics, Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi, 67p.

Dalal, R. C. 1998. Soil microbial biomass - what do the numbers really mean? *Aust. J. Exp. Agric.* 38: 649-665.

Datta, A., Basak, N., Chaudhari, S. K., and Sharma, D. K. 2015. Effect of horticultural land uses on soil properties and organic carbon distribution in a reclaimed sodic soil. *J. Indian Soc. Soil Sci.* 63(3): 294- 303.

Datta, A., Jat, H. S., Yadav, A. K., Choudhary, M., Sharma, P. C., Rai, M., Singh, L. K., Majumder, S. P., Choudhary, V., and Jat, M. L. 2019. Carbon mineralization in soil as influenced by crop residue type and placement in an *Alfisols* of Northwest India. *Carbon Manag.* 10(1): 37-50.

Davidson, E. A. and Janssens, I. A. 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature*, 440(7081): 165-173.

Deepa, K. M. 2014. Seasonal variation in Avifauna with respect to habitat changes in *Pokkali* field of Ernakulam district Kerala. PhD thesis, Mahatma Gandhi University, Kottayam. 105p.

Dendooven, L., Alcantara-Hernandez, R. J., Valenzuela-Encinas, C., Luna-Guido, M., Perez-Guevara, F., and Marsch, R. 2010. Dynamics of carbon and nitrogen in an extreme alkaline saline soil: A review. *Soil Biol. Biochem.* 42: 865-877.

Dent, D. 1986. Acid sulphate soils: a baseline for research and development. ILRI Publications 39, Wageningen, The Netherlands. 204p.

Dhanya, K. R. 2017. Assessment of soil carbon pools in acid sulphate soils of Kuttanad. MSc. (Ag) Thesis, Kerala Agricultural University, Thrissur, 117p.

Diya, P. V. and Sreelatha, A. K. 2018. Effect of calcium salts application on soil properties of *Pokkali* soils. *J. Trop. Agric.* 56(2): 183-186.

Dominic, V. J. and Jithin, T. 2012. Effect of NaCl and boron toxicity on proline biosynthesis of Oryza sativa (*Pokkali* VTL-4). *Int. J. Life Sci. Biotechnology Pharma Res.* 1(3): 73-83.

Don, A., Schumacher, J., Scherer-Lorenzen, M., Scholten, T., and Schulze E, D. 2007. Spatial and vertical variation of soil carbon at two grassland sites—implications for measuring soil carbon stocks. *Geoderma*, 141: 272–282.

Farshad, N. and Ahmad, R. S. H. 2006. A kinetic approach to evaluate salinity effects on carbon mineralisation in a plant residue amended soil. *J. Zhejiang Univ. Sci.*, 7: 788-793.

Fontaine, S., Barot, S., Barre, P., Bdioui, N., Mary, B., and Rumpel, C. 2007. Stability of organic carbon in deep soil layers controlled by fresh carbon supply. *Nature*, 450: 277–281.

Gajri, P. R. and Majumdar, S. P. 2002. Tillage. In: G. S. Shekhon *et al.* (ed), *Fundamentals of Soil Science*. ISSS. pp. 125–132.

Garcia, C. and Hernandez, T. 1996. Influence of salinity on the biological and biochemical activity of a calciorthird soil. *Plant Soil.* 178: 255-263.

García-Orenes, F., Roldán, A., Morugán-Coronado, A., Linares, C., Cerdà, A., Caravaca, F. 2016. Organic fertilization in traditional Mediterranean grapevine orchards mediates changes in soil microbial community structure and enhances soil fertility. *Land Degrad. Dev.* 27(6): 1622- 1628.

George, B. S., Ashique T. K., and Binitha, N. K. 2017. Assessment of microbial properties of *Pokkali* soil in Kerala, India. *Int. J. Curr. Microbiol. App. Sci.* 6(12): 1964-1967. Available: https://doi.org/10.20546/ijcmas.2017.612.224

Ghani, A., Dexter, M., and Perrott, K. W. 2003. Hot water extractable carbon in soils: A sensitive measurement for determining impacts of fertilisation, grazing and cultivation. *Soil Biol. Biochem.* 35(9): 1231-1243.

Ghollarata, M. and Raiesi, F., 2007. The adverse effects of soil salinization on the growth of Trifolium alexandrinum L. and associated microbial and biochemical properties in a soil from Iran. *Soil Biol. Biochem.* 39: 1699-1702.

Ghosh, S., Wilson, B. R., Mandal, B., Ghoshal, S. K., and Growns, I. 2010. Changes in soil organic carbon pool in three long-term fertility experiments with different cropping systems and inorganic and organic soil amendments in the eastern cereal belt of India. *Soil Res.* 48(5): 413-420.

Giardina, C. P., Ryan, M. G., Hubbard, R. M., and Binkley, D. 2001. Tree species and soil textural controls on carbon and nitrogen mineralization rates.

Gladis, R., Aparna, B., Joseph, B. 2019. Carbon dynamics in major soils of south Kerala. *J. Pharmacognosy Phytochem.* 2: 15-17.

Gladis, R., Dhanya, K. R., Joseph, B., Aparna, B., and Rehana, M. R. 2020. Soil carbon stock and pools in acid sulphate soils of Kerala. *Curr. J. Appl. Sci. Tech.* 39(21): 135-147.

Goldin, A. 1987. Reassessing the use of loss-on-ignition for estimating organic matter content in noncalcareous soils. *Commun. in Soil Sci. Plant Anal.* 18: 1111-1116.

Gong, W., Yan, X. Y., Wang, J. Y., Hu, T. X., and Gong, Y. B. 2009. Long-term manuring and fertilization effects on soil organic carbon pools under a wheat maize cropping system in North China. *Plant Soil.* 314: 67-76.

Gonzalez-Pereza, J. A., Gonzalez-Vila, F. J., Gonzalo, A., and Heike, K. 2004. The effect of fire on soil organic matter-a review. *Environ.* Int. 30: 855– 870.

Guo, L. B. and Gifford, R. M. 2002. Soil carbon stocks and land use change: a meta-analysis. *Glob. Chang. Biol.* 8: 345–360

Hansen, V. and Nestlerode, J. 2014. Carbon sequestration in wetland soils of the northern Gulf of Mexico coastal region. *Wetlands Ecol. Manag.*

Harriman, R., Anderson, H., and Miller, J. D. 1995. The role of sea-salts in enhancing and mitigating surface water acidity. *Water Air Soil pollut.* 85(2): 553-558.

Haynes, R. and Naidu, R. 1998. Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: a review. *Nutrient Cycling in Agroecosystems,* 51**:** 123–137.

Hendershot, W. H. and Duquette, M. 1986. A simple barium chloride method for determining cation exchange capacity and exchangeable cations. *Soil Sci. Soc. Am. J.* 50(3): 605-608.

Hindar, A., Henriksen, A., and Tørseth, K. 1994. Acid water and fish death. *Nature.* 372: 327–328. Available: https://doi.org/10.1038/372327b0

Howe, A. J., Rodriguez, J. F., and Saco, P. M. 2009. Surface evolution and carbon sequestration in disturbed and undisturbed wetland soils of the Hunter estuary, Southeast Australia. *Estuar, Coastal shelf Sci.* 84: 75-83.

Hu, S., Coleman, D. C., Carroll, C. R., Hendrix, P. F., and Beare, M.H. 1997. Labile soil carbon pools in subtropical forest and agricultural ecosystems as influenced by management practices and vegetation types. *Agric. Ecosyst. Environ.* 65(1): 69-78.

Huang, X., Kurata, N., Wang, Z. X., Wang, A., Zhao, Q., Zhao, Y., Liu, K., Lu, H., Li, W., Guo, Y., and Lu, Y. 2012. A map of rice genome variation reveals the origin of cultivated rice. *Nature*. 490(7421): 497-501.

Indraratna, B., Glamore, W. C., and Tularam, G. A. 2002. The effects of tidal buffering on acid sulphate soil environments in coastal areas of New South Wales. *Geotechnical Geol. Eng. 20*(3): 181-199.

Inglett, K. S., Inglett, P. W., Reddy, K. R., and Osborne, T. Z. 2012.Temperature sensitivity of greenhouse gas production in wetland soils of different vegetation. *Biogeochem.* 108: 77-90.

Inglett, P. W., Reddy, K. R., and Corstanje, R. 2005. Anaerobic soils. In: Hillel, D. (ed.) Encyclopedia of Soils in the Environment. Elsevier, Oxford, pp.71-78.

IPCC. 2000. Special report on land use, land use change and forestry. Cambridge University Press, Cambridge, UK.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Houghton, J.T., Ding, D. J., Griggs, M., Noguer, P. J., van der Linden, X., Dai, K., Maskell, and Johnson C. A (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, USA, pp.881.

IPCC. 2007. Climate Change 2007: Mitigation of Climate Change. Cambridge University Press, Cambridge. Available at: http://www.ipcc.ch/publications_and_data/ar4 /wg3 /en/ contents.html.

Jackson, M. L. 1958. Soil Chemical Analysis. Prentice Hall of India Private Ltd., New Delhi, 498p.

Jandl, R. and Sollins, P. 1996. Water-extractable soil carbon in relation to the belowground carbon cycle. *Biol. Fertil. Soils* 25**:** 196–201

Jastrow, J. D., Amonette, J. E., and Bailey, V. L., 2007. Mechanisms controlling soil carbon turnover and their potential application for enhancing carbon sequestration. *Climatic Change*. 80(1): 5-23.

Jayan, P. R. and Sathyanathan, N. 2010. Overview of farming practices in the water-logged areas of Kerala, India. *Int. J. Agric. Biol. Eng.*, 3: 28-43.

Jenkinson, D. S. and Pawlson, D. S. 1976. The effect of biocidal treatments on metabolism in soil. *Soil Biol. Biochem.* 8: 209-213.

Jha, P. Biswas, A. K. Lakaria, B. L. Saha, R. Singh, M., and Rao, A. S. 2014. Predicting total organic carbon content of soils from Walkley and Black analysis. *Commun. Soil Sci. Plant Anal*. Available at: 10.1080/00103624.2013.874023

Jha, P., Rashmi, L., Patel, N. S., Lakaria, B. L., Biswas, A. K., Singh, M., and Rao, A. S. 2012. Effect of Ca salts on mineralisation of organic residue in soil. *Agrochimica*. 3: 129-138.

Jimenez, J. J., Lal, R., Leblanc, H. A., and Russo, R. O. 2007. Soil organic carbon pool under native tree plantations in the Caribbean lowlands of Costa Rica. *Forest Ecol. Manage.* 241(1-3):134-144.

Jinbo, Z., Changchun, S., and Wenyan, Y. 2006. Land use effects on the distribution of labile organic carbon fractions through soil profiles. *Soil Sci. Soc. Am. J.* 70(2): 660-667.

Johnston, S. G., Bush, R. T., Sullivan, L. A, Burton, E. D., Smith, D., Martin, M. A., Mc Elnea, A. E., Ahem, C. R., Powell, B., Stephen, L. P., Wilbraham, S. T., and Van Heel, S. 2009. Changes in water quality following tidal inundation of coastal low land acid sulphate landscapes. *Estuar. Coast. Shelf. Sci*. 81: 257-266.

Joseph, C. 2014. Assessment of soil quality of acid saline *Pokkali* soils under different land uses. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur. 101p.

Kaiser, K., Guggenberger, G., and Zech, W. 1996. Sorption of DOM and DOM fractions to forest soils. *Geoderma*, 74(3-4): 281-303.

Kennedy, S., Saravanan, A., Natarajan, S. K., Veerabadran, V., and Mani, S. 2005. Microbial population and enzymatic activity as influenced by organic farming. *J. Agric. Biol. Sci.* 1(1): 85-88.

Keren, R. 1996. Reclamation of sodic-affected soils. *Soil erosion, conserve. rehabil.* 1996: 353-374.

Killham, K. and Firestone, M. K. 1984. Salt stress control of intracellular solutes in streptomycetes indigenous to saline soils. Appl. Environ. Microbiol. 47: 301–306. doi: 10.1128/AEM.47.2.301-306.1984

Klose, S., Wernecke, K. D., and Makeschin, F. 2004. Microbial activities in forest soils exposed to chronic depositions from a lignite power plant. *Soil Biol. Biochem*. 36(12): 1913-1923.

Kong, X., Dao, T.H., Qin, J., Qin, H., Li, C., and Zhang, F. 2009. Effects of soil texture and land use interactions on organic carbon in soils in North China cities' urban fringe. *Geoderma*. 154(1-2): 86-92.

Krishnani, K. K., Gupta, B. P., Muralidhar, M., Saraswathy, R., Pillai, S. M., Ponnusamy, K., and Nagavel, A. 2011. Soil and water characteristics of traditional paddy and shrimp fields of Kerala. *Indian J. Fish.* 58(4): 71-77.

Kuruvila, V. O. 1974. Chemistry of low productive acid sulphate soils of Kerala and amelioration for growing rice. PhD thesis, Utkal University, Bhubaneswar, 156p.

Ladd, J. N., Foster, R. C., Nannipieri, P. and Oades, J. M., 1996. Soil structure and biological activity. *Soil Biochem.* 9: 23-78.

Lal, R. 2002. Soil carbon sequestration in China through agricultural intensification, and restoration of degraded and desertified ecosystems. *Land Degrad. Dev.*13: 469–478.

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Sci*. 304(5677): 1623-1627.

Lal, R. 2009. Sequestering atmospheric carbon dioxide. *Critical Rev. Plant Sci*. 28: 90-96.

Lal, R., 2008. Sequestration of atmospheric CO2 in global carbon pools. *Energy Environ. Sci*., 1: 86-100.

Lal, R., Follett, R. F., Kimble, J., and Cole, C.V. 1999. Managing US cropland to sequester carbon in soil. *J. Water Conserv. 54*(1): 374-381.

Larson, W. E. and Pierce, F. J. 1991. Conservation and enhancement of soil quality. In: evaluation for sustainable land management in the developing world. Proceeding of the international workshop, 20-25 October 1991. *International board for soil Resilience and Management*, Bangkok, Thailand, pp.175-203.

Laura, R. D. 1974. Effects of neutral salts on carbon and nitrogen mineralization of organic matter in soil. *Plant and Soil*. 41: 113-127.

Laura, R. D. 1977. Salinity and nitrogen mineralisation in soil. *Soil Biol. Biochem.* 9: 333-336.

Li, X. G., Li, F. M., Ma, Q. F., and Cui, Z. J. 2006. Interactions of NaCl and Na_2SO_4 on soil organic C mineralization after addition of maize straws. *Soil biol. Biochem*. 38(8): 2328-2335.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J. O., Thies, J., Luizão, F. J., Petersen, J., and Neves, E. G. 2006. Black carbon increases cation exchange capacity in soils. *Soil Sci. Soc. Am. J.* 70(5): 1719-1730. https://doi.org/10.2136/sssaj2005.0383

Liang, Y., Si, J., Nikolic, M., Peng, Y., Chen, W., and Jiang, Y., 2005. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. *Soil biol. Biochem.* 37(6): 1185-1195.

Liu, Y., Yu, Z., Chen, J., Zhang, F., Doluschitz, R., and Axmacher, J. C. 2006. Changes of soil organic carbon in an intensively cultivated agricultural region: A denitrification decomposition (DNDC) modelling approach. *Sci. Total Envi*. 372: 203–214.

Malik, K.A. and Haider, K., 1977. Decomposition of carbon-14-labelled plant material in saline-sodic soils. *Soil organic matter studies*.

Mandal, B., Majumder, B., Adhya, T.K., Bandyopadhyay, P.K., Gangopadhyay, A., Sarkar, D., Kundu, M.C., Choudhury, S.G., Hazra, G.C., Kundu, S., and Samantaray, R.N., 2008. Potential of double-cropped rice ecology to conserve organic carbon under subtropical climate. *Glob. change biol.*, 14(9): 2139-2151.

McCarty, G. W. and Ritchie, J. C. 2002. Impact of soil movement on carbon sequestration in agricultural ecosystems. Environ. Pollut. 116: 423–430.

McGill, W.B., Hunt, H.W., Woodmansee, R. G., and Reuss, J. O. 1981. PHOENIX, Amodel of dynamics of carbon and nitrogen in grassland soils. *Ecol. Bulletins,* : 49-115.

McCormick, R. W. and Wolf, D. C. 1980. Effect of sodium chloride on CO_2 evolution, ammonification, and nitrification in a Sassafras sandy loam. *Soil Biol. Biochem.* 12:153-157.

McLauchlan, K. K. and Hobbie, S. E. 2004. Comparison of labile soil organic matter fractionation techniques. *Soil Biol. Biochem.* 26:821–831.

Mfilinge PL, Atta N, Tsuchiya M. 2002. Nutrient dynamics and leaf litter decomposition in a subtropical mangrove forest at Oura Bay, Okinawa, Japan. *Trees.* 16:172–180

Mitra, S., Wassmann, R., and Vlek P. L. G. 2005. An appraisal of global wetland area and its organic carbon stock. *Curr. Sci.* 88: 25–35.

Mitsch W. J., Bernal, B., Nahlik, A. M., Mander, U., Zhang, L., Anderson, C. J., Jorgersen, S. E., and Brix, H. 2013. Wetlands, carbon, and climate change. *Lands Ecol.* 28: 583–597.

Mitsch, W. J. and Gosselink, J. G. 2007. *Wetlands*. (4th Ed.). Chichester: Wiley and Sons.

Mohan, A. 2016. Ion interactions and rice nutrition in acid saline *Pokkali* soils. MSc. (Ag) Thesis, Kerala Agricultural University, Thrissur, 171p.

Mohanty, S., Nayak, A. K, Kumar, A., Tripathi, R., Shahid, M., Bhattacharyya, P., Raja, R., and Panda, B. B. 2013. Carbon and nitrogen mineralization kinetics in soil of rice-rice system under long term application of chemical fertilizers and farmyard manure. *Eur. J. Soil Biol.* 58: 113–121.

Moore, J. M., Klose, S., and Tabatabai, M. A. 2000. Soil microbial biomass carbon and nitrogen as affected by cropping systems. *Biol. Fertil. Soils*. 31(3): 200-210.

Nair, P. G. and Money, N. S. 1968. Studies on some chemical and mechanical properties of salt affected rice soils of Kerala. *Agric. Res. J. Kerala.* 10(1): 51-53

Nambiar, G. R. and Raveendran, K. 2009. Exploration of Untapped Potentiality of Coastal Paddy Fields of Kerala, India, A Case Study. *Middle-E. J. Sci. Res.* 4(1): 44-47.

Nath, A. J., Bhattacharyya, T., Deka, J., Das, A. K., and Ray, S. K., 2016. Management effect on soil organic carbon pools in lowland rain-fed paddy growing soil. *J. Tropic. Agric.*, *53*(2): 131-138.

Needelman, B. A., Wander, M. M., Bollero, G. A., Boast, C. W., Sims, G. K. and Bullock, D. G., 1999. Interaction of tillage and soil texture biologically active soil organic matter in Illinois. *Soil Sci. Soc. Am. J. 63*(5): 1326-1334.

Nelson, P. N. and Oades, J. M. 1998. Organic matter, sodicity, and soil structure. In: Sumner, M. E. and Naidu, R. (eds), *Sodic Soils*. Oxford University Press, New York. pp. 51–75.

Nelson, P. N., Ladd, J. N., and Oades, J. M. 1996. Decomposition of ^{14}C-labelled plant material in a salt affected soil. *Soil Biol. Biochem.* 28: 433-441.

Nichols, J. D. 1984. Relation of organic carbon to soil properties and climate in the southern Great Plains. *Soil Sci. Soc. Am. J.* 48(6): 1382-1384.

Nidheesh, P. 2019. Taxonomy and organic carbon nutrient interactions in selected wetland soils of Kerala. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 290p.

NOAA. 2020. National Centers for Environmental Information, State of the Climate: *National Climate Report for Annual* 2020.

Oades, J. M. 1988. The retention of organic matter in soils. *Biogeochem.* 5**:** 35–70.

Okur, N., Altindisli, A., Cengel, M., Gocmez, S., and Kayikcioglu, H. H. 2009. Microbial biomass and enzyme activity in vineyard soils under organic and conventional farming systems. *Turk. J. Agric. For.* 33: 413– 423.

Padmaja, P., Geethakumari, V. L., Harikrishnana, N. K., Chinnamma, N. P., Sasidharan, N. K., and Rajan, K. C. 1994. *A glimpse to problem soils of Kerala.* Kerala Agricultural University, Thrissur. pp.76-89.

Page, A. L., Miller, R. H., and Keeney, D. R. 1982. Methods of soil analysis, part 2 (2nd Ed.). ASA and SSSA, Wisconsin, USA, 1159p.

Pan, G., Zhou, P., Li, Z., Smith, P., Li, L., Qiu, D., and Chen, X. 2009. Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake region, China. *Agric. Ecosyst. Environ.*131(3-4): 274-280.

Papini, R., Valboa, G., Favilli, F. and L'abate, G., 2011. Influence of land use on organic carbon pool and chemical properties of Vertic Cambisols in central and southern Italy *Agric. Ecosyst. Environ*, 140(1-2): 68-79.

Parfitt, R. L., Giltrap, D. J., and Whitton, J. S. 1995. Contribution of organic matter and clay minerals to the cation exchange capacity of soils. *Commun. Soil Sci. Plant Anal.* 26 (9–10): 1343–55.

Pathak, H. and Rao, D. L. N. 1998. Carbon and nitrogen mineralisation from added organic matter in saline and alkali soils. *Soil Biol. Biochem.* 30: 695-702.

Pathak, H., Prasad, S., Bhatia, A., Singh, S., Kumar, S., Singh, J., and Jain, M. C. 2003. Methane emission from rice–wheat cropping system in the Indo-Gangetic plain in relation to irrigation, farmyard manure and dicyandiamide application. *Agric. Ecosyst. Environ*. 97: 309–316.

Piper. C. S. 1966. Soil and Plant Analysis. Hans Publisher, Bombay

Ponnamperuma, F. N. 1972. The chemistry of submerged soils. *Adv. Agron*. 24: 29–96.

Post, W. M. and Kwon, K. C. 2000. Soil carbon sequestration and land-use changes: Processes and potential. *Glob. Change Biol*. 6: 317–327.

Post, W. M., Emmanuel, W. R., Zinke, P. J., Stangenberger, A. G., 1982. Soil carbon pools and world life zones. *Nature*. 298: 156±159.

Prabha, S. V., Renuka, R., Sreekanth, N. P., Padmakumar, B., and Thomas, A. P. 2013. A study of the fertility and carbon sequestration potential of rice soil with respect to the application of biochar and selected amendments. *Ann Environ Sci*. 7: 17-30.

Pramila, S. and Chandrika, V. 2001. Studies on the oxidative positive gram-negative rods in the perennial and *Pokkali* fields around Cochin. In: Menon, N. G. and Pillai, P. P. (eds), *Perspectives in Mariculture*. The Marine Biological Association of India, Cochin, pp. 139-148.

Purdy, R. and Macrory, R. 2003. Geological carbon sequestration: critical legal issues. Tyndall Centre Working Paper No. 45. University College London. London WC1H 0EG. Available at: http://www.tyndall.ac.uk/sites/default/files/wp45.pdf.

Purushan, K. S. 2002. Wetland eco-system development and management in relation to *Pokkali* areas. In: Kokkal, K., Premachandran, P. N., and Bijukumar, A. (eds), *Wetland Conservation and Management in Kerala*. State Committee on Science, Technology and Environment, Thiruvananthapuram, Kerala, pp. 46–55.

Raich, J. W. and Potter, C. S. 1995. Global Patterns of Carbon Dioxide Emissions from Soils. Glob. Biogeochem. Cycles. 9: 23-36.

Raman, K. and Menon, M. K. 1969. A preliminary note on an experiment in paddy field prawn fishing, *Indian J. fisheries*. 10A (1): 33-39.

Ranga, M. R. 2006. Transformation of coastal wetland agriculture and livelihood in India, M.Sc. thesis. National Resource Institute, University of Manitoba, Canada.

Rao, D. L. N. and Pathak, H. 1996. Ameliorative influence of organic matter on biological activity of salt-affected soils. *Arid Land Res. Manage*. 10(4): 311-319.

Ratcliffe, R. G. 2003. Rengel, Z. (ed.) Handbook of plant growth. pH as the master variable. *Annals of Botany*. 92(1): 165–166. https://doi.org/10.1093/aob/mcg112

Ray, R. C., 1984. Effect of liming on dehydrogenase and rhodanese activity of flooded and nonflooded acid sulfate soils. *Fertil. Res*. 6(3): 193-197.

Reddy, N. and Crohn, D. M. 2014. Effects of salinity and carbon availability from organic amendments on nitrous oxide emissions. *Geoderma*. 235: 363-371.

Reichardt, W., Mascarina, G., Padre, B., Doll, J. 1997 Microbial communities of continuously cropped irrigated rice fields. *Appl. Environ. Microbiol.* 63:233-238.

Reichstein, M., Bahn, M., Ciais, P., Frank, D., Mahecha, M. D., Seneviratne, S. I., Zscheischler, J., Beer, C., Buchmann, N., Frank, *et al*. 2013. Climate extremes and the carbon cycle. *Nature*: *12350.*

Rengel, Z. 2002. Role of pH in availability of ions in soil. In: *Handbook of Plant Growth pH as the Master Variable*. CRC Press, pp. 317-342.

Rey, A., Petsikos, C., Jarvis, P. G., Grace, J. 2005. Effect of temperature and moisture on rates of carbon mineralization in a Mediterranean oak forest soil under controlled and field conditions. *Eur. J. Soil. Sci.* 56: 589–599.

SAC. 2011. National wetland atlas. SAC/EPSA/ABHG/NWIA/ATLAS/34/2011.

Saffigna, P.G., Powlson, D. S., Brookes, P. C., and Thomas, G. A. 1989. Influence of sorghum residues and tillage on soil organic matter and soil microbial biomass in an Australian Vertisol. *Soil Biol. Biochem.* 21(6): 759-765.

Samikutty, V. 1977. Investigations on the salinity problems of *Pokkali* soils and *Kaipad* areas of Kerala state. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur,109p.

Santhosh, C. 2013. Chemistry and transformation of boron in soils of Kerala. PhD thesis, Kerala Agricultural University, Thrissur, 187p.

Sardinha, M., Muller, T., Schmeisky, H., and Joergensen, R. G. 2003. Microbial performance in soils along a salinity gradient under acidic conditions. *Applied Soil Ecol*. 23: 237-244.

Sarig, S. and Steinberg, Y. 1994. Microbial biomass response to seasonal fluctuation in soil salinity under the canopy of desert halophytes. *Soil Biol. Biochem.* 26: 1405-1408.

Sarma, B., Farooq, M., Gogoi, N., Borkotoki, B., Kataki, R., and Garg, A. 2018. Soil organic carbon dynamics in wheat - green gram crop rotation amended with Vermicompost and Biochar in combination with inorganic fertilizers: A comparative study. *J. Clean. Prod.* 201: 471–480.

Sasidharan, N. K. 2004. Enhancing the productivity of the rice – fish/ prawn farming system in *Pokkali* lands. PhD thesis, Kerala Agricultural University, Thrissur, 190p.

Saviozzi, A., Vanni, G., and Cardelli, R. 2014. Carbon mineralization kinetics in soils under urban environment. *Appl. Soil Ecol.* 73: 64-69.

Schimel, J. P., Scott, W. J., and Killham, K. 1989. Changes in cytoplasmic carbon and nitrogen pools in a soil bacterium and a fungus in response to salt stress. *Appl. Environ. Microbiol.* 55: 1635–1637.

Schmatz, R., Recous, S., Aita, C., Tahir, M. M., Schu, A. L., Chaves, B., and Giacomini, S. J. 2017. Crop residue quality and soil type influence the priming effect but not the fate of crop residue C. *Plant Soil*, 414: 229-245.

Sekhon, B. S. and Bajwa, M. S. 1993. Effect of organic matter and gypsum in controlling soil sodicity in rice-wheat-maize system irrigated with sodic waters. *Agric. water manage.* 24(1): 15-25.

Shao, X., Yang, W., and Wu, M. 2015. Seasonal dynamics of soil labile organic carbon and enzyme activities in relation to vegetation types in Hangzhou Bay tidal flat wetland. PLoS ONE, 10(11): 1–15.

Sharma, K. L. and Mandal, B. 2009. Soil quality and its relevance in sustainable agriculture. *J. Ind. Soc. Soil Sci.* 57 (4): 572-586.

Sharma, V., Hussain, S., Sharma, K. R., and Arya, V. M. 2014. Labile carbon pools and soil organic carbon stocks in the foothill Himalayas under different land use systems. *Geoderma,* 232: 81-87.

Shiny, R. and Byju, G. 2020. Kinetics of Soil Carbon Mineralization Under Continuous Site-Specific Nutrient Management in Ultisols Under Cassava. *Commun. Soil Sci. Plant Anal.* 52(1): 1-11. Available at: https://doi.org/10.1080/00103624.2020.1836209

Shrestha, B. M., Sitaula, B. K., Singh, B. R., and Bajracharya, R. M. 2004. Soil organic carbon stocks in soil aggregates under different land use systems in Nepal. *Nutr. cycling in Agroecosyst.* 70(2): 201-213.

Shylaraj, K. S., Sreekumaran, V., and Annie, K. 2013. *Five Decades of Glorious Research at the Rice Research Station Vytilla (1958-2013).* Directorate of extension, Kerala Agricultural University, Thrissur, 80p.

Silpa, P. S., Sankar, J., and Sureshkumar, P. 2021. Spatial and Temporal Variation of Chemical Properties in Different Land Uses of Acid Saline *Pokkali* Soils. *Kerala. Res. J. Agric. Sci.* 12 (3): 948–954.

Smith, J. L. and Doran, J. W. 1996. Measurement and Use of pH and Electrical Conductivity for Soil Quality Analysis. In: Doran, J. W and Jones, A. J. (eds), *Methods For assessing Soil Quality*. Soil Science Society of America, Madison, pp. 49.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C. *et al*. 2008. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society. *Biol. Sci.* 363: 789–813.

Souza, W. and Melo, W. 2003. Soil organic matter in an oxisol under different corn production systems. *Revista Brasileira de Ciencia do Solo*. 27: 1113-1122.

Sparling, G. 1992. Ratio of microbial biomass carbon to soil organic carbon as a sensitive indicator of changes in soil organic matter. *Aust. J. Soil Res*. 30(2): 1-14.

Sreelatha, A. K. and Shylaraj, K. S. 2017. *Pokkali* rice cultivation in India: A technique for multi-stress management. In: Gupta, S. K. and Goyal, M. R. (eds), *Soil Salinity*

Management in Agriculture: Technological Advances and Applications, Apple Academic Press Inc, Waretown, New Jersey, pp. 317-335.

Steenwerth, K. L. 2003. *Links between soil microbial communities and transformations of soil carbon and nitrogen along a gradient in land-use history and soil disturbance*. University of California, Davis.

Stern, N. 2006. The price of change: Economics of climate change. *IAEA bulletin,* 480: 25-28.

Stoecio, M., Francisco, X., Teogenes, O., Eduardo, M., and Joao, F. 2007. Organic carbon pools in a Luvisol under agroforestry and conventional farming systems in the semi-arid region of Cear, Brazil. *Agrofor*. Syst. 71: 127-138.

Sudhan, C., Mogalekar, H. S., Ranjithkumar, K., and Sureshbhai, P. D. 2016. Paddy cum prawn farming (*Pokkali* fields) of Kerala. *Int. J. Innovative Res. Multidisciplinary Field.* 2(7): 42-46.

Sun, H., Zhou, S., Fu, Z., Chen, G., Zou, G., and Song, X. 2016. A two-year field measurement of methane and nitrous oxide fluxes from rice paddies under contrasting climate conditions. Sci. Rep. 6: 1–11.

Tacon, A. G. J. 1987. *The Nutrition and Feeding of Farmed Fish and Shrimp - a Training Manual* [e- book]. Food and Agriculture Organisation of the United Nations, Rome. Available: http://www.fao.org/3/ab468e/AB468E00.htm [11 March 2020].

Tejada, M., Garcia, C., Gonzalez, J. L. and Hernandez, M. T. 2006. Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. *Soil Biol. Biochem*. 38: 1413–1421.

Telles, E. D. C. C., de Camargo, P. B., Martinelli, L. A., Trumbore, S. E., da Costa, E. S., Santos, J., Higuchi, N. and Oliveira Jr, R. C. 2003. Influence of soil texture on carbon dynamics and storage potential in tropical forest soils of Amazonia. *Glob. Biogeochem. Cycles*. *17*(2).

Thampy, D. M. 2002. Development of fisheries in the wetland ecosystem of Kerala. In: Kokkal, K., Premachandran, P. N., and Bijukumar, A. (eds), *Wetland*

Conservation and Management in Kerala, State Committee on Science, Technology and Environment, Thiruvananthapuram, Kerala, pp. 141–145.

Tisdall, J. M., Oades, J. M. 1982. Organic matter and water-stable aggregates in soils. *J. Soil Sci.* 33: 141–163.

Tomy, P. J. 1981. *Pokkali* cultivation of Kerala. In: *Problems and Management of Coastal Saline Soil*. Proceeding second conference, CSSRI, Research station, West Bengal, pp. 337-340.

Tripathi, S., Kumari, S., Chakraborthy, A., Gupta, A., Chakrabarthy, K. and Bandyapadhyay, B. K. 2006. Microbial biomass and its activities in salt- affected coastal soils. *Boil. Fert. Soils.* 42:273-277.

Trumbore, S. E., Vogel, J. S., and Southon, J. R., 1989. AMS 14C measurements of fractionated soil organic matter: an approach to deciphering the soil carbon cycle. *Radiocarbon*, 31(3): 644-654.

Unni, N. 2020. Assessment of soil quality in the post flood scenario of AEU 5 and AEU 9 of Ernakulam District of Kerala and mapping using GIS techniques. MSc. (Ag) Thesis, Kerala Agricultural University, Thrissur, 120p.

Valzano, F. P., Greene, R. S. B., Murphy, B. W., Rengasamy, P., and Jarwal, S. D. 2001. Effects of gypsum and stubble retention on the chemical and physical properties of a sodic grey Vertosol in western Victoria. *Soil Res.* 39(6): 1333-1347.

Vanaja, T. 2013. KAIPAD–a unique, naturally organic, saline prone rice ecosystem of Kerala, India. *Am. J. Environ. Prot.* 2(2): 42-46.

Vance, W. H., Tisdall, J. M., and McKenzie, B. M., 1998. Residual effects of surface applications of organic matter and calcium salts on the subsoil of a red-brown earth. *Aust. J. Exp. Agric.* 38(6): 595-600.

Varghese, T., Thampi, P. S., and Money, N. S. 1970. Some preliminary studies on the *Pokkali* saline soils of Kerala. *J. Indian Soc. Sci.* 18: 65-69.

Von Lützow, M., Leifeld, J., Kainz, M., Kögel-Knabner, I., and Munch, J. C. 2002. Indications for soil organic matter quality in soils under different management, *Geoderma*, 105(3–4): 243-258.

Voroney, R. P. and Paul, E. A. 1984. Determination of kC and kN in situ for calibration of the chloroform fumigation-incubation method. *Soil Biol. Biochem.*16(1): 9-14.

Walkley, A. J. and Black, I. A. 1934. Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.* 31: 29-38.

Walpola, B. and Arunakumar, K. 2010. Effect of salt stress on decomposition of organic matter and nitrogen mineralisation in animal manure amended soils. *J. Agri. Sci.* 5: 9-18.

Wang, W. J., Dalal, R. C., Moody, P. W., Smith, C. J., 2003. Relationships of soil respiration to microbial biomass, substrate availability and clay content. *Soil Biol. Biochem.* 35: 273-284.

Weller, S., Janz, B., Jorg, L., Kraus, D., Racela, H. S. U., Wassmann, R. Butterbach-Bahl, K., and Kiese, R. 2016. Greenhouse gas emissions and global warming potential of traditional and diversified tropical rice rotation systems. *Glob. Chang. Biol.* 22: 432-448.

West, T. O. and Post, W. M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. *Soil Sci. Society Am. J.* 66: 1930–1946.

Weston, N. B., Vile, A. M., Neubauer, S. C., and Velinsky, D. J. 2010. Accelerated microbial organic matter mineralization following salt-water intrusion into tidal freshwater marsh soils. *Biogeochem.* 102: 135–151.

Weston, N. B., Vile, M.A., Neubauer, S. C., and Velinsky, D. J. 2011. Accelerated microbial organic matter mineralization following salt-water intrusion into tidal freshwater marsh soils. *Biogeochem.* 102(1–3): 135–151.

Wichern, F., Islam, R., Hemkemeyer, M., Watson, C., and Joergensen, R. G. 2020. Organic Amendments Alleviate Salinity Effects on Soil Microorganisms and

Mineralisation Processes in Aerobic and Anaerobic Paddy Rice Soils. *Front. Sustain. Food Syst.* 4(30): 1-13.

Wichern, J., Wichern, F., and Jeorgenson, R. G. 2006. Impact of salinity on soil microbial communities and the decomposition of maize in acidic soils. *Geoderma*, 137: 100-108.

Wiklander, L. 1975. The role of neutral salts in the ion exchange between acid precipitation and soil. *Geoderma*, 14(2): 93-105.

Wissing, L., Kolbl, A., Vogelsang, V., Fu, J., Cao, Z., and Kogel-Knabner, I. 2011. Organic carbon accumulation in a 2000-year chronosequence of paddy soil evolution. *Catena,* 87: 376–385.

Wong, V. N. L., Dalal, R. C., and Greene, R. S. B. 2008. Salinity and sodicity effects on respiration and microbial biomass of soil. *Biol. Fertil. Soils*, 44: 943–953.

Wong, V. N. L., Dalal, R. C., and Greene, R. S. B. 2009. Carbon dynamics of sodic and saline soils following gypsum and organic material additions: a laboratory incubation. *Appl. Soil Ecol.* 41: 29–40.

Wong, V. N. L., Greene, R. S. B., Dalal, R. C., and Murphy, B. W. 2010. Soil carbon dynamics in saline and sodic soils: a review. *Soil Use Manage.* 26: 2-11.

Wu, J. 2011. Carbon accumulation in paddy ecosystems in sub-tropical China: evidence from landscape studies. *Eur. J. Soil Sci*. 62: 29–34.

Xie, J., Li, Y., Zhai, C., and Lan, Z. 2009. CO_2 absorption by alkaline soils and its implication to the global carbon cycle. *Environ. Geology,* 56: 953-961.

Yadav, R. L., Dwivedi, B. S., Prasad, K., Tomar, O. K., Shurpali, N. J., and Pandey, P. S. 2000. Yield trends, and changes in soil organic-C and available NPK in a long-term rice–wheat system under integrated use of manures and fertilisers. *Field Crops Res.*68(3): 219-246.

Yang, Y., Guo, J., Chen, G., Yin, Y., Gao, R., and Lin, C. 2009. Effects of forest conversion on soil labile organic carbon fractions and aggregate stability in subtropical China. *Plant and soil*, 323(1): 153-162.

Yu, D. F. and Li, J. L. 1985. *Microbiology*. Science Press, Beijing

Yuan, B. C., Li, Z. Z., Liu, H., Gao, M., and Zhang, Y. Y. 2007. Microbial biomass and activity in salt affected soils under arid conditions. *Appl. Soil Ecol.* 35: 319-328.

Zhang, M. and He, Z. 2004. Long-term changes in organic carbon and nutrients of an Ultisol under rice cropping in southeast China. *Geoderma,* 118(3-4): 167–179.

Zhou, H., Fang, H., Mooney, S. J., and Peng, X. 2017. Effects of long-term inorganic and organic fertilization on the soil micro and macro structures of rice paddies. *Geoderma*, 266: 66–74.

Zsolnay, A. 1996. Dissolved humus in soil waters. In: *Humic substances in terrestrial ecosystems*. Elsevier Science BV. pp. 171-223.

APPENDIX I

a. Correlation analysis of rice-prawn(Kumbalangi) land use in *Pokkali* ecosystem

	pH	EC	BD	SOC	LC	SOC Stock	MBC	WSC	TOC	DHA
pH	1.000	0.559	0.672	-0.100	0.405	0.620	0.700	-0.159	-0.324	0.678
EC		1.000	0.900*	0.317	0.116	0.989*	-0.193	-0.300	-0.499	0.733
BD			1.000	-0.113	-0.124	0.948*	-0.002	0.062	-0.781	0.928
SOC				1.000	0.503	0.209	-0.307	-0.930	0.628	-0.392
LC					1.000	0.039	0.398	-0.558	0.505	-0.094
SOC Stock						1.000	-0.114	-0.229	-0.573	0.790
MBC							1.000	-0.028	0.122	0.112
WSC								1.000	-0.662	0.354
TOC									1.000	-0.887
DHA										1.000

*. Correlation is significant at the 0.05 level (2-tailed)

b. Correlation analysis of rice alone(RRS, Vyttila) land use in *Pokkali* ecosystem

	pH	EC	BD	SOC	LC	SOC Stock	MBC	WSC	TOC	DHA
pH	1.000	0.042	-0.405	-0.495	-0.449	-0.480	-0.036	0.626	-0.274	-0.967*
EC		1.000	0.780	-0.235	-0.396	0.533	-0.412	-0.477	-0.692	-0.052
BD			1.000	0.405	0.206	0.940*	-0.718	-0.660	-0.374	0.478
SOC				1.000	0.924	0.691	-0.655	-0.222	0.408	0.663
LC					1.000	0.493	-0.455	-0.310	0.713	0.644
SOC Stock						1.000	-0.829	-0.571	-0.172	0.599
MBC							1.000	0.136	0.233	-0.141
WSC								1.000	-0.225	-0.685
TOC									1.000	0.394
DHA										1.000

*. Correlation is significant at the 0.05 level (2-tailed)

c. Correlation analysis of prawn alone (Kadamakkudy) land use in *Pokkali* ecosystem

-	pH	EC	BD	SOC	LC	SOC Stock	MBC	WSC	TOC	DHA
pH	1.000	-0.152	-0.638	-0.694	-0.745	-0.770	-0.133	0.101	-0.013	-0.631
EC		1.000	-0.555	-0.409	-0.200	-0.461	0.930*	0.492	-0.608	0.501
BD			1.000	0.655	0.820	0.879*	-0.598	-0.215	0.430	-0.130
SOC				1.000	0.391	0.937	-0.205	-0.225	0.613	0.427
LC					1.000	0.633	-0.408	-0.417	-0.158	0.133
SOC Stock						1.000	-0.353	-0.202	0.571	0.244
MBC							1.000	0.592	-0.326	0.576
WSC								1.000	0.258	-0.189
TOC									1.000	-0.297
DHA										1.000

*. Correlation is significant at the 0.05 level (2-tailed)

APPENDIX II

a. Correlation analysis of rice-prawn(Kumbalangi) land use in *Pokkali* ecosystem

	Cumulative CO_2	pH (74)	EC (74)	WSC (74)	DHA (74)	TOC (74)
Cumulative CO_2	1.000	0.846*	0.375	0.616	0.678*	0.774*
pH (74)		1.000	0.465	0.792*	0.579	0.905*
EC (74)			1.000	0.515	0.693*	0.606
WSC (74)				1.000	0.453	0.596
DHA (74)					1.000	0.524
TOC (74)						1.000

b. Correlation analysis of rice alone (RRS, Vyttila) land use in *Pokkali* ecosystem

	Cumulative CO_2	pH (74)	EC (74)	WSC (74)	DHA (74)	TOC (74)
Cumulative CO_2	1.000	0.869*	0.365	0.062	0.671*	0.869*
pH (74)		1.000	0.689*	0.481	0.849*	0.825*
EC (74)			1.000	0.520	0.793*	0.448
WSC (74)				1.000	0.427	0.106
DHA (74)					1.000	0.739*
TOC (74)						1.000

*. Correlation is significant at the 0.05 level (2-tailed)

c. Correlation analysis of prawn alone (Kadamakkudy) land use in *Pokkali* ecosystem

	Cumulative CO_2	pH (74)	EC (74)	WSC (74)	DHA (74)	TOC (74)
Cumulative CO_2	1.000	0.972*	0.434	0.275	0.897*	0.852*
pH (74)		1.000	0.570	0.194	0.862	0.735*
EC (74)			1.000	-0.028	0.559*	0.020
WSC (74)				1.000	0.353	0.400
DHA (74)					1.000	0.756*
TOC (74)						1.000

*. Correlation is significant at the 0.05 level (2-tailed)

APPENDIX III

Meteorologicaldata from Rice Research Station, Vyttila during 2020

Months	**Temperature (°C)**		**Relative humidity (%)**		**Rainfall (mm)**	**Evaporation (mm/day)**
	Maximum	Minimum	Maximum	Minimum		
January	32.3	22.6	77.0	61.0	NIL	2.9
February	32.4	23.6	82.0	61.0	37.5	2.6
March	31.8	25.3	89.0	65.0	NIL	3.02
April	32.7	26.1	89.0	66.0	20.5	3.1
May	32.3	25.1	91.3	68.2	164.5	3.2
June	30.1	23.9	87.1	76.5	383.5	2.3
July	29.6	23.8	92.5	74.1	535.0	2.5
August	29.3	24.3	89.9	76.2	256.1	2.5
September	30.1	24.0	91.1	65.4	519	2.5
October	30.6	24.1	84.5	71.2	139.4	2.6
November	31.2	23.9	86.8	69.2	83.3	2.1
December	31.0	22.4	89.5	60.1	15.4	2.6

EFFECT OF SALINITY ON CARBON MINERALISATION UNDER DIFFERENT LAND USES IN *POKKALI* ECOSYSTEM

By

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ABSTRACT OF THE THESIS

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Abstract

Soil forms the largest storehouse for terrestrial organic carbon, encompassing approximately two-thirds of the carbon in the ecosystem. This plays a pivotal role in reducing atmospheric CO_2 and combating global warming and related concerns. Differences in land use have a considerable effect on soil organic carbon pools and fluxes. Mineralisation of soil organic carbon enhances CO_2 emission into the atmosphere and salinity of soil can affect the rate of this process. In this context, an investigation was carried out with the objective to study the effect of salinity on carbon mineralisation under different land uses in *Pokkali* ecosystem.

The study was conducted by collecting georeferenced surface soil samples (0-20 cm) from three land uses of *Pokkali* ecosystem namely rice-prawn, rice alone and prawn alone from Kumbalangi, RRS, Vyttila and Kadamakkudy respectively. The samples were analyzed for different soil properties such as pH, electrical conductivity (EC), particle size, cation exchange capacity, bulk density and estimated soil organic carbon pools such as soil organic carbon, labile carbon, water soluble carbon and microbial biomass carbon. Soil organic carbon stocks and dehydrogenase activity were also estimated as per standard procedures. Carbon mineralisation was studied by a laboratory incubation experiment for 74 days where two sets of soil (with and without 1% paddy straw) was amended with different concentrations of $CaSO_4$ and Na_2SO_4 alone or both in combinations of 40 and 80 mmol per kg soil in order to get the desired change in electrical conductivity similar to field conditions.

The mean pH registered for rice-prawn, rice alone and prawn alone land uses were under neutral range and mean EC were less than 4 dS m^{-1}. Soil texture of rice-prawn and rice alone belonged to clay and prawn alone in sandy clay loam class. 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.

The results revealed that rice-prawn land use recorded the highest organic carbon pools and prawn alone land use recorded the lowest organic carbon pools. Rice-prawn land use recorded higher content of soil organic carbon, labile carbon, water soluble carbon, microbial biomass carbon and total carbon followed by rice alone land use due to abundance of organic matter in these soils. The maximum soil organic carbon stock was

recorded in rice alone (26.46 Mg ha $^{-1}$) and minimum in rice-prawn (22.53 Mg ha $^{-1}$) land use. The maximum dehydrogenase activity was recorded from rice alone (2959.697 µg TPF h^{-1} g^{-1}) and the lowest from prawn alone (2132.491 µg TPF h^{-1} g^{-1}) land uses.

Carbon mineralisation study revealed that CO_2 evolved from soil decreased with time. The maximum CO_2 was evolved on day 11 for rice-prawn and prawn alone land uses and day 17 for rice alone land use and declined steadily thereafter. The maximum cumulative CO_2 was recorded from the treatments other than control (without paddy straw and salts). The lowest mean cumulative CO_2 in the control was recorded from rice- prawn (7.2 mg 100 g^{-1}) land use and the highest recorded from prawn alone (26.48 mg 100 g^{-1}) followed by rice alone (25.15 mg 100 g^{-1}) land uses. A significant positive correlation was observed between pH, dehydrogenase activity and total organic carbon with cumulative CO_2 in all land uses.

After 74 days of incubation study, the pH of control was reduced and that of other treatments (with paddy straw and salts) was increased in all land uses. The EC of the treatments with salts amendments were more than 4 dS m^{-1} in all land uses before the start of incubation. After the incubation period, EC decreased in all salt amendments of different land uses and increased in treatments without salt amendments. Dehydrogenase activity and total carbon were found higher in the treatments with paddy straw and salts than in control. Relatively higher dehydrogenase activity was recorded in rice-prawn land use followed by prawn alone and rice alone land uses. The EC was positively correlated with dehydrogenase activity which stimulated carbon mineralisation in these soils. In these land uses, there was no discernible difference between paddy straw and salt amended treatments with respect to carbon mineralisation. Both the dehydrogenase activity and the total carbon content contributed to carbon mineralisation process.

In *Pokkali* ecosystems, rice-prawn land use recorded the highest soil organic carbon pools and the lowest carbon mineralisation, indicating the existence of an environment that is conducive for building organic carbon which is crucial for sequestering more carbon into these soils. As the salinity increased carbon mineralisation was also increased. The rice cultivation in the low saline phase reduces salinity by leaching out the accumulated salts, whereas prawn farming does not. Therefore, prawn alone land use remains saline throughout the year, resulting in increased carbon mineralisation and decreased carbon sequestration. This study emphasizes the importance of integrated rice-prawn farming systems in *Pokkali* lands to maintain soil quality and slow down the global warming through increased carbon sequestration.