SOIL CO_2 EMISSION UNDER DIFFERENT TILLAGE PRACTICES IN REDLOAM/ LATERITE, CLAY AND COASTAL SANDY SOILS OF KERALA

by

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THESIS

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DECLARATION

I, Toufeeq, S. (2010 – 20 – 102) hereby declare that this thesis entitled **"Soil CO_2 emission under different tillage practices in Redloam / Laterite, Clay and Coastal sandy soils of Kerala"** 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.

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INTRODUCTION

1. INTRODUCTION

Global warming has often been described as one of the most serious environmental problems ever to confront humanity, as this problem is inextricably linked to the process of development and economic growth itself The global warming has resulted in the warming of the oceans, rising of the sea levels, melting of glaciers, and diminished snow cover in the Northern Hemisphere International efforts to address this problem have been ongoing for the last few decades, with the Earth Summit in Rio de Jeneiro in June 1992 This convention adopted the notion of common but differentiated responsibility, recognizing that the global climate was a common resource and responsibility, but that there were clear asymmetries between the developed and the developing countries in terms of both the past and present contributions to the problem as well as the resources to respond to it

India as a developing country does not have any commitments or responsibilities at present for reducing the emissions of greenhouse gases such as CO_2 But, international pressure is increasing on India and other large, rapidly developing countries to adopt a more pro-active role It is therefore important for us to develop a clear understanding of our emission inventory We also need to document and analyze our efforts in areas such as renewable energy, wasteland development and afforestation – all of which contribute towards either reducing CO_2 emissions or increasing CO_2 removal from the atmosphere

Climate change is a newcomer to the international political and environmental agenda, but scientists have been working on the subject for decades They have known since the 19th century that carbon dioxide (CO_2) in the atmosphere is a 'greenhouse gas' that is, its presence in the atmosphere helps to retain the incoming heat energy from the sun, thereby increasing the earth's surface temperature CO_2 (54 7%) is the most important greenhouse gas that is being affected by human activities among such other greenhouse gases in the atmosphere such as methane (30%), nitrous oxide (4 9%), fluorinated gases (0 6%) and other gases (9 8%) (IPCC, 2007) The atmospheric concentration of CO_2 has increased considerably in recent years as a result of human activities The major sources of CO_2 are Energy supply (25 9%), Industry (19 4%), Forestry (17 5%), Agriculture (13 5%), Transport (13 1%), Residential and commercial buildings (7 9%) and Waste and waste water (2 8%) Since agriculture is one of the major contributor of CO_2 to atmosphere, measuring soil CO_2 emission is crucial to accurately evaluate the effect of soil management practices on global warming and carbon cycling

Soil carbon dynamics can have an indirect effect on climate change through net absorption or release of CO_2 from the soil to the atmosphere in the natural Carbon cycle Soils are an important pool of active carbon and play a major role in the global carbon cycle and have contributed to the changes in concentration of Greenhouse gases in the atmosphere (Schlesinger, 1985, Houghton *et al* 1999) The exchange of greenhouse gases between croplands and atmosphere plays an important role in the global carbon cycle and the carbon concentration in the atmosphere CO_2 is emitted from soil by two different ways, one is through the respiration of microbes in soil and the other is through the direct oxidation of organic and inorganic carbon present in the soil Both the ways are enhanced by the disturbances happening in the soil Measurements of soil gas emissions for different tillage treatments and cropping systems are, therefore, important for identifying management practices that can positively impact carbon balance (Post *et al*, 1990, Reicosky *et al*, 1997) and greenhouse gas (GHG) emission

Tillage is the mechanical manipulation of soil and crop residue to prepare a seedbed where crop seeds are planted, sprout, take root, and grow into plants to produce grain Tillage increases water infiltration and increases the soil porosity, especially large pores, which allow greater movement of soil gases through the soil Diffusion allows movement of gases into or out of the soil from higher to lower concentrations Tillage affects soil microbial activity, organic matter decomposition, and soil carbon loss in agricultural systems Much of the carbon is lost as CO_2 which is the end product of microbial feeding on soil organic matter Tillage processes and mechanisms leading to carbon loss are directly linked to soil productivity, soil properties and environmental issues

The magnitude of CO_2 loss from the soil due to tillage practices is highly related to the frequency and intensity of soil disturbance caused by tillage The environmental and economic benefits of less intensive tillage demand consideration in the development of improved management practices for sustainable agricultural production The rate of soil CO_2 emission is normally controlled by several factors, such as CO_2 concentration gradient between the soil and the atmosphere, soil temperature, soil moisture, soil organic matter content, bulk density, soil pH, atmospheric temperature and relative humidity (Raich and Schlensinger, 1992)

In this juncture the present study was undertaken to quantify the CO_2 release from three major soils of Kerala under three different tillage systems followed by the farming community with the following objectives

1 To quantify the CO_2 emission from three major soils of Kerala under three different tillage practices
2 To assess the effect of different soil parameters (soil compaction, soil organic carbon, soil moisture and soil temperature) and atmospheric parameters (atmospheric temperature and relative humidity) on emission of CO_2 from the selected soils after specific tillage practices
3 To optimize the tillage practices for minimum soil CO_2 emission

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Global warming due to increasing greenhouse gas concentrations in the atmosphere has been recognized as the foremost environmental issue in the 21st century The exchange of greenhouse gases especially CO_2 between croplands and atmosphere plays an important role in the global carbon cycle and the carbon concentration in the atmosphere Tillage operations influence soil physical properties and crop growth and thus both directly and indirectly affect the cropland carbon dioxide exchange with the atmosphere

In this chapter a brief review of research works carried out in CO_2 emission from different soils under different tillage practices have been presented

2 1 GREENHOUSE GASES AND GLOBAL WARMING

The concentration of greenhouse gases (GHGs) in the atmosphere has been increased considerably in recent years due to human activities The most important anthropogenic greenhouse gas is carbon dioxide (CO_2) whose annual emissions increased by about 80 per cent in the last few decades Houghton *et al* (1992) found that the anthropogenic activities such as the burning of fossil fuels, the burning of forests and the loss of soil organic matter have been recognized as the main causes of that increase

Houghton *et al* (1983), Keeling and Whorf (1994), studied that the global rise in atmospheric CO_2 concentration is well documented Agro ecosystems have been viewed as CO_2 sources largely due to the impact of long term cultivation on reducing soil carbon content

According to Schlesinger (1985), Houghton *et al*, (1999) agriculture will cause some environmental problems, especially related to water contamination, soil erosion, and the greenhouse effect

Tubiello and Ewert (2002), Uri (2000), Ugalde *et al* (2007), Pandey (2002), Calfapietra *et al* (2010), studied about the effect of soil management practices on greenhouse gas emission and concluded that currently, several different soil management strategies have been considered with regard to their potential to reduce the release of GHG from agriculture like cover crops no-till practices and agroforestry

2 2 PRODUCTION OF CO_2 FROM SOIL

Rolston (1986) found that carbon dioxide efflux is a physical process defined as the flow of CO_2 from the soil toward the atmosphere, and it is measured at the soil surface The second largest component of the global carbon cycle is the emission of CO_2 from soil and is important in climatic variation Soil is a major source and sink for atmospheric CO_2

Jensen *et al* (1996), Reth *et al* (2005), Carlisle *et al*, (2006) studied about the soil respiration effect on the release of CO_2 from soil and observed that Soil CO_2 efflux or soil respiration is one of the most important components of the C budget of ecosystems, which consists of decomposition and mineralization of organic matter, root respiration and rhizosphere or faunal respiration

Raich and Schlensinger (1992) sound that the rate of soil CO_2 emission is normally controlled by several factors, such as CO_2 concentration gradient between the soil and the atmosphere, soil temperature, soil moisture, pore size, and wind speed

Ellert and Janzen (1999) concluded that tillage can result in an immediate short-term outburst of CO_2 due to decrease in partial pressure of CO_2 in soil air, followed by disturbance in soil aggregation and pores, and sudden release of CO_2 from the soil solution

Prior *et al* (2000) in a study to observe shot term gas loss from the sandy loam soil (Luxicferralsols) in Alabama as a result of tillage practices found that increased CO_2 and water vapor losses were directly related to increased soil disturbances and concluded that selecting planting equipment which minimizes soil disturbances will help to reduce the emission of these gases from the soil They also observed that the flux value of CO_2 in disturbed soil surface is 0 37 g CO_2 m^{2} h^{-1} which is slightly higher than from the undisturbed soil which has a value of 0 29 g CO_2 m^{2} h^{1}

In tillage operations there is a rapid increase in CO_2 flux and a steady decay in the CO_2 emission and also there is a rapid increase in CO_2 flux and a rapid return to the pre tilled value of CO_2 emission So that the continuous monitoring before, during, and after tillage will be important for proper interpretation of CO_2 flux data (Stewart *et al* 2003)

Jabro *et al* (2008) studied about the CO_2 flux affected by tillage and irrigation and observed that in a Lihen sandy loam soil (sandy, mixed, frigid Entic Haplustoll) in land converted from perennial forages to annual crops significant differences in CO_2 fluxes between land management practices (irrigation and tillage) Higher CO_2 fluxes were detected in conventional tillage plots than in no tillage plots Soil CO_2 fluxes increased with increasing soil moisture while an exponential relationship was found between CO_2 emission and temperature Also they concluded that less intensive tillage, such as no-till or strip tillage, along with careful irrigation management will reduce soil CO_2 evolution

Wang *et al* (2010) concluded that pH-increasing and N-fertilization significantly enhanced CO2 emissions and heterotrophic microbial respiration played a dominant role in CO2 emissions in the tested soil

2 3 TILLAGE AND CO_2 PRODUCTION

Cambardella and Elliott (1992) found that the decomposition of soil organic matter is increased by the physical disturbance caused by soil tillage, breaking down macro aggregates and exposing the carbon protected in their interiors to microbial processes

Reicosky and Lindstrom (1993) found that the Molboard Plow which caused the roughest soil surface during the tillage and the highest initial CO_2 flux and maintained the highest flux throughout the 19-day study The initial CO_2 fluxes were high because the disturbed soil depth was high which caused the formation of rougher surface and larger voids in the tilled soil Similarly lower CO_2 fluxes were caused by tillage associated with low soil disturbance and small voids with no till (NT) having the least amount of CO_2 loss during 19 days

Larney and Bullock (1994), concluded that different tillage implements vary in the intensity of soil disturbance At one end of the spectrum are the rototillers, which have powered blades that disrupt aggregates intensely, whereas non powered disk mechanisms may be effective at inverting the soil profile but cause less aggregate breakdown

Calderon *et al* (2000) concluded that there is a decrease in the soil microbial respiration after tillage and thereby there will be a decrease in the CO_2 flux from the soil after the tillage

Tufekcioglu *et al* (2001) in a study for quantifying the rates of soil respiration among sites within an agricultural landscape in central Iowa, USA found that soil temperature and soil moisture together accounted for 69% of the seasonal variability in soil respiration and also observed that annual soil respiration rates ranged from 740g C m^{-2} to 1140 g C m^{-2} in different soil and vegetation conditions

Calderon and Jackson (2002) studied about the effect of roto tillage and disc tillage on CO_2 flux in the Yolo silt loam (Mollic Xerofluvent) soil with a no tilled control and observed that rototillage and disking increased the CO_2 efflux of the soil within 24 h of the tillage The increase was higher in the disked soil, which was more than three times the CO_2 efflux of the control soil at 0 25 hour after tillage They also observed that the irrigation enhanced the CO_2 release from the soil

Knoepp and Vose (2002) in a study of comparison of different soil CO_2 flux estimation methods observed that at different concentrations, NaOH collected between 40 and 47 percent of CO_2 entering the closed system used for trapping CO_2 flux from soil

Rastogi *et al* (2002) studied about the emission of CO_2 from the soil and found that CO_2 emission from a tilled soil is more than that from an undisturbed soil (no tillage), because tillage produces a favorable micro environment for accelerated microbial decomposition of plant and animal residues and also that tillage breaks down soil aggregates, helps in mixing soil and organic particles, improves infiltration and water-holding capacity and thereby increases CO_2 production residues

Logan *et al* (1991), Angers *et al* (1993), Hao *et al*, (2001) and Al- Kaisi and Yin (2005) studied about the effect of tillage on various soil parameters and found that tillage loosens the soil, increases the exposure of soil organic matter and speeds up organic matter oxidation, intensifying CO_2 emission from the soil to the atmosphere Tillage accelerates soil CO_2 emission by improving soil aeration, disaggregating soil, increasing the contact between soil and crop residue, and speeding organic C decomposition

Dao (1998), Rastogi *et al* (2002), La Scala *et al* (2006), Teixeira (2011) in different studies found that the amount of carbon lost in the form of CO_2 from the soils due to different tillage practices has high correlation with the intensity of the disruption and the volume of soil disturbed by the tillage implements used

Omanode *et al* (2007) found that the CO_2 emission from long term tillage systems in corn systems in a fine, silty, mixed, super active, Mesic Typic Endoaquoll soil is affected by tillage The CO_2 emissions in different tillage practices are for chisel plow it is 6 2 Mg CO_2-C ha ^{1} y ^{1}, for mold board plow it is 5 9 Mg CO_2-C ha ^{1} y ^{1} and for no tillage 5 7 Mg CO_2-C ha ^{1} y ^{1} respectively They also reported that CO_2 emissions were greater immediately after tillage (at 0 h) but declined sharply within hours after tillage operations and CO_2 emissions at 0, 1 and 2 h were significantly greater than for the 24–168 h following tillage

Sainju *et al* (2006) studied about soil carbon dioxide emission as influenced by irrigation, tillage, cropping system, and nitrogen fertilization found that the CO_2 flux was linearly related with soil temperature and daily average air temperature at the time of CO_2 measurement Tillage followed by heavy rain or irrigation during the crop growing season drastically increased CO_2 flux in the coarse-textured soil They also concluded that tillage increased CO_2 flux by 62 to 118% compared with no-tillage and also the flux was 1 5- to 2 5-fold greater with tilled than with non-tilled treatments

Vyn *et al* (2006) studied about the soil carbon sequestration and greenhouse gas emissions from corn soya bean rotations and from their study they found that the maximum greenhouse gas emission occurred from chisel plough followed by moldboard plough and the least from no-till

Jonard *et al* (2007) in a study about the soil CO_2 efflux from the oak and beech of Europe found that the annual CO_2 emission from the European beech forest soils ranges from 489 – 620 g C m^{-2} y^{-1}

Bilgili *et al* (2013) studied about the soil CO_2 emission from the apple orchard in Turkey using soda lime technology and observed that the weekly soil CO_2 emissions ranged from 87 8 kg week^{1} ha^{1} to 1087 kg week^{1} ha^{1}

Reicosky and Archer (2007) studied about the moldboard plow tillage and related CO_2 release with it and found that the relative cumulative tillage-induced CO_2 losses were directly related to depth of plowing The impact of moldboard plow tillage depth on the CO_2 release was largest at the maximum tillage depth and declined as tillage depth decreased Intensive tillage breaks up soil aggregates and CO_2 exchange is accelerated and this process is accelerated with respect to the increase in tillage

Lopez-Garrido *et al* (2009) in a study about carbon losses by tillage concluded that tillage caused a sharp increase in soil CO_2 emissions immediately after tillage implementation, with a maximum value of 6 24 g CO_2 m^{2} h^{1} under long-term traditional tillage treatment They also found that the yearly losses of carbon through CO_2 emission were higher (905 and 801 g C m^{2} y^{1}) in traditional tillage than for the conservation systems (764 and 718 g C m^{2} y^{1}) like reduced tillage and no tillage According to them the soil organic carbon accumulation in soil surface for conservation tillage systems is 1 17 to 1 24 times greater than the traditional tillage systems

Moussadek *et al* (2011) studied about the CO_2 fluxes from Mediterranian vertisols and they observed that the conventional method of tillage showed highest CO_2 flux (4 9 g m^{2} h^{1}) immediately after tillage than reduced tillage (2 1 g m^{2} h^{1}) and no tillage (0 7 g m^{2} h^{1})

Quintero and Comerford (2013) studied about impact of reduced tillage in potato-based rotations in the Colombian Andes (Andisols) They estimated that the reduced tillage operation in potato-based crop rotations increased the soil carbon concentration and average carbon content in the whole profile (≈117 cm depth) by 50 and 33% (1636 t C ha^{-1} v/s 1224 t C ha^{-1}), respectively, as compared to conventional farming practices

Silva-Olaya *et al* (2013) studied about carbon dioxide emissions under different soil tillage systems found that the CO_2 emissions results indicated a significant interaction between tillage method and time after tillage The amounts of CO_2 released under different tillage practices were 350 09 g m^{2} of CO_2 in conventional tillage, and 51 7 and 5 5 g m^{2} of CO_2 in roto tiller and moldboard tillage respectively

2 4 FACTORS AFFECTING CO_2 RELEASE FROM SOIL

Buyanowski and Wagner (1983) m a study arrived in following conclusions viz, the temperature of a soil greatly affects the physical, biological and chemical processes occurring in that soil In cold soils, chemical and biological rates are slow Biological decomposition can come to a near standstill thereby limiting the rate at which nutrients such as Nitrogen, Phosphorous, Sulphur and Calcium are made available Soil temperature is thus an important factor in controlling major processes in the C cycle, it exhibits large amplitude in its effects on CO_2 emission rates from soil surface under field conditions Soil moisture content affects soil respiration, higher moisture content provides better conditions for microbial habitat activities, increasing microbial oxygen consumption and CO_2 production and emission from the soil

According to Valerie, *et al* (1983), increasing soil moisture would increase CO_2 evolution up to an optimum level, above which it would reduce CO_2 evolution Periodic drying and wetting of soil has a pronounced influence on CO_2 evolution When the soil is rewetted the activity of the microbes, which were in a latent state in the dry soil, increases accompanied by release of air trapped in the soil pores contributing to an increase in CO_2 evolution But the relationship between soil CO_2 emission and soil moisture content is not yet clearly understood The rate of soil respiration increase with rise in water content

Johnson *et al* (1994) found that relative humidity has influence on removal of soil moisture Soil moisture affects soil respiration and hence CO_2 evolution In general, increasing relative humidity would increase CO_2 evolution up to an optimum level, above which it would reduce CO_2 evolution

According to Boone *et al* (1998), Davidson *et al* (1998), soil temperature is an important factor in controlling major processes in the carbon cycle, it exhibits large amplitude in its effects on CO_2 emission rates from the soil surface under field conditions As soil temperature increases the processes such as organic matter decomposition, oxidation, microbial and root activity, and carbon mineralization accelerates This will lead to the increase in CO_2 emission from the soil, which in turn causes a depletion of C storage Both root and microbial sources of CO_2 show an exponential increase in activity as a function of temperature

Schjonning and Rasmussen (2000) concluded that Minimum and zero-tillage practices initially lead to a decline in macro-pore volume in soil, which ultimately reduces diffusion of air into soil in comparison to conventional tillage

Rastogi *et al* (2002) observed that atmospheric temperature has a marked effect on CO_2 evolution from the soil since it directly influence the soil temperature At higher atmospheric temperature, the reaction of oxygen with soil carbon get accelerated However at higher atmospheric temperatures, soil temperature also increases and the partial inhibition of microbial respiration occurs, which is attributed to inactivation of biological oxidation systems

West and Marland (2002) estimated based on US average crop inputs, no-till emitted less CO_2 from agricultural operations than did conventional tillage, with 137 and 168 kg C ha^{-1} per year, respectively They also concluded that on average, changing from Conventional tillage to No tillage does not causes an increase in CO_2 emissions, and in most cases contributes to a decrease

Strong *et al*, (2004) found that soil structure is an important factor in determining the sequestration or decomposition of organic matter as it governs the physical space available for micro-organisms, aiding their actions in terms of aeration, moisture supply and mobility

The study conducted by Al-Kaisi and Yin (2005) to evaluate tillage effects on soil carbon storage and CO_2 emission in Clarion–Nicollet–Webster soil association in a corn – soybean rotation observed that no tillage with residue and strip-tillage significantly increased total soil organic carbon and mineral fraction carbon at the 0 to 5 and 5 to 10 cm soil depths compared with chisel plough after 3 year of tillage practices Soil CO_2 emission was lower for less intensive tillage treatments compared with moldboard plow, with the greatest differences occurring immediately after tillage operations Cumulative soil CO_2 emission was 19 to 41% lower for less intensive tillage treatments than moldboard plow Estimated soil mineralizable C pool was reduced by 22 to 66% with less intensive tillage treatments compared with moldboard plough

Omanode *et al* (2007) found that increase in CO_2 emission with temperature is a matter of concern, as the possible global warming would increase CO_2 evolution from the soil that would accelerate the depletion of soil carbon and soil fertility The CO_2 emission from long term tillage systems in corn systems in a fine, silty, mixed, super active, Mesic Typic Endoaquoll soil is affected by tillage and also the soil moisture and temperature in the surface 10 cm were significantly related to the CO_2 emissions

Sey *et al* (2008) concluded that increased CO_2 emissions have been reported from micro aggregates (<0 25 mm) compared with macro aggregate (>0 25 mm) fractions

Marland *et al* (2004), Beare *et al* (2009), studied about the relationship between the soil aggregation and the movement of gases in soils and found that soil aggregation is directly related to storage of soil organic carbon and affects movement of gases and water in soil by influencing both biological processes in soil and pore characteristics which regulate the flow of water and gases

Blagodatsky and Smith (2012) concluded that soil aggregate composition determines intra and inter aggregate porosity and largely controls gaseous composition and transport in soil

According to Zhang *et al* (2012) the decomposition of soil organic matter can vary in soils between different aggregate size classes Aggregates play a vital role in deciding the aerobic or anaerobic status of soil

Sainju *et al* (2012) studied about the tillage effects on soil carbon fraction and observed that surface residue C was 36% greater in no tillage than in Conventional Tillage in the regular practice and at 5 to 20 cm, Soil Organic Carbon was 14% greater in No Tillage Particulate Organic Carbon and Particulate Carbon Mineralization at 0 to 20 cm were 23% to 54% greater in no tillage than the regular practice of Conventional Tillage Similarly, microbial biomass Carbon at 10 to 20 cm was 70% greater with the regular practice in no tillage than the conventional tillage practices

Mangsalassery *et al* (2013), Bilgili *et al* (2013), studied about the influence of soil texture and aggregate size on CO_2 emission from soil and concluded that both texture and aggregate size of soils significantly influence CO_2 emission The average CO_2 emission was greater from clay loam (<0 5 mm aggregate fraction) soils (704 ng g^{1} h^{1}) compared to sandy loam (2 – 4 mm aggregate fraction) soil (624 ng g^{1} h^{1}) and soil CO_2 emissions were mostly impacted by soil and air temperature

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Tillage is assumed to have a major influence on soil CO_2 emissions Soil CO_2 emission due to different tillage systems need to be evaluated to encourage the adoption of conservation practices to sustain soil productivity and protect the environment This study hypothesize that soil CO_2 emission respond to three common tillage practices adopted by the farming community in three major soils of Kerala This chapter explains the details of experimental methodologies adopted for the study both in laboratory and in the experimental plots

3 1 LOCATION, SOIL AND CLIMATE

The study was conducted at the Instructional Farm, College of Agriculture, Vellayani, Kerala Agricultural University and farmer's field at Kovalam The analysis was done at the laboratory, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani The geographical coordinates of Instructional farm Vellayani is Latitude 8°35" N, Longitude 76°59" E at 25 m above MSL and that of farmer's field at Kovalam is 8° 39 ' N 77° 0034' E at 26 m above MSL

The farm is characterized by undulated topography with different types of soil types viz, red loam (*Typic Rhodustult*) and paddy field soil (*Typic Fluvaquent*) The field identified at Kovalam was characterized with coastal sandy soil (*Typic Ustipsamments*) The red loam soil was under vegetable cultivation The paddy field soil selected was under summer fallow vegetable cultivation The field of coastal sandy soil was under coconut based vegetable cultivation

The annual precipitation of the study area was 1850 mm, maximum temperature is 34°C and minimum temperature is 21°C The study was undertaken from February to May 2015 The mean precipitation, maximum temperature and minimum temperature during the study period was 400 mm, 32 1°C and 23°C respectively Daily temperature and precipitation during the study were observed from the observatory of the College of Agriculture, Vellayani, Kerala Agricultural University

3 2 EXPERIMENT LAYOUT AND TREATMENTS

The treatment combinations

T_1 – Red loam + Conventional tillage

T_2 – Red loam + Tillage with cultivator

T_3 – Red loam + Tillage with rotovator

T_4 – Coastal sandy + Conventional tillage

T_5 – Coastal sandy + Tillage with cultivator

T_6 – Coastal sandy + Tillage with rotovator

T_7 – Paddy field soil + Conventional tillage

T_8 – Paddy field soil + Tillage with cultivator

T_9 – Paddy field soil + Tillage with rotovator

3 3 SELECTION OF SOIL

Three soils were selected mainly based on their textural difference and predominance in southern Kerala, where the study was undertaken

3.3.1 Soil Texture

Soil texture affects the spread of microbial propagules and the growth of bacteria and fungi through the supply of air and moisture, and thus affects formation of CO_2 Water infiltration and gas diffusion rates are also greatly influenced by soil texture and thereby CO_2 formation and emission The selection of soils for the study was done based on the textural classification as shown in figure 1 The selected soils viz clay or paddy field soil, red loam and coastal sandy which differ significantly with each other in their properties and so that the categorization was definite

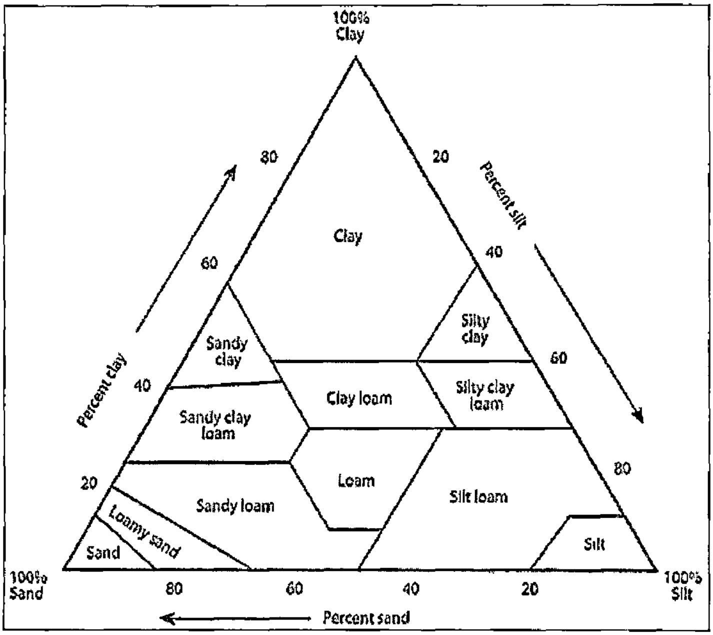

Figure 1. Soil textural triangle (Source - USDA)

3.3.1.1 Red loam (*Typic Rhodustult*)

These soils are localized in occurrence and are found mostly in the southern parts of Thiruvananthapuram district of Kerala These soils are identified in undulating plains of lowland with a general slope of 3 to 10 per cent These colluvial deposits are mostly very deep and homogenous in nature The texture of the soil generally ranges from sandy clay loam to clay loam with red to dark red colour Gravels are rarely noticed in this soils A variety of crops such as coconut, banana, yams, pineapple, vegetables, fruit trees etc can be grown under proper management

3.3.1.2 Coastal sandy soils (*Typic Ustipsamments*)

The coastal sandy soils are very deep, well drained, sands on very gently sloping subdued coastal sand dunes The colour is yellowish brown to brown or grey The disaggregated particles with apparently no coherent structure are often described as single grain The soil reaction is strongly acidic Moderately shallow water table is observed at places The sands with very low cation exchange capacity are deficient in basic cations like calcium, magnesium and potassium These soils have very low water and plant nutrient retention capacity The lack of soil development and sandy texture lead to the classification of these soils as mixed, isohyperthermic, *Typic Ustipsamments*, according to soil taxonomy (Soil survey staff, 2003)

3.3.1.3 Clay or paddy field soil (*Typic Fluvaquent*)

These soils are very deep, imperfectly drained, highly gleyed, very dark grey soils developed from lacustrine deposits of recent origin with ill-defined horizons The water table is very high and flooding is a common feature during rainy season During summer, vegetables are being cultivated The summer fallows were selected for the study since the CO_2 emission happens only from dry soil, while emission from wetland is methane (CH_4) due to the anaerobic decomposition of plant residue

3 4 METHOD OF TILLAGE

Tillage accelerates soil CO_2 emission by improving soil aeration, disaggregating soil, increasing the contact between soil and crop residue, and speeding organic carbon decomposition Tillage often increases short-term CO_2 emission from the soil due to a rapid physical release of CO_2 trapped in the soil air spaces The amount of CO_2 released into the atmosphere differed with different tillage systems and the amount lost was related to the amount of soil disturbance

3.4.1 Conventional method of tillage

The conventional method of tillage adopted and followed in South Kerala is soil manipulation with spade In this system all the operations from initial ploughing to seed bed preparation is being done with spades of different shapes The soil is being pulverized with spade alone to form seed bed and the operation is under the complete control of man who performs it Generally, the ploughing depth varies from 10 to 15 cm with considerable degree of pulverization

The manual ploughing with spade was carried out in the fields at a maximum depth of 15 cm by a trained labour

3.4 2 Tillage with cultivator

A cultivator is a secondary tillage farm implement, but in Kerala it is being used for initial land development as well as seed bed preparation The cultivator is being operated as an attachment to tractor, hence its use is restricted to medium or large farms But the method is very common in paddy fields during summer fallow vegetable cultivation The depth of ploughing varies from 10 to 15 cm with considerable degree of pulverization The soil breaks up is linear in pattern since it drags and break the soil

An eleven tine cultivator was operated as attached to a 45 hp tractor in the fields The operating depth was set by means of three point hitch system to a maximum depth of 15 cm

3.4.3 Tillage with rotavator

Implements that use rotary motion from Power Take Off (PTO) of tractor through chain and sprocket transmission system to operate L' shaped tynes or blades at a constant and predetermined operational speed It stirs and pulverise the soil at higher degree The soil tilth formed will be smooth and results in a loose seedbed The depth of operation varies from 10 to 15 cm

A rotovator was operated as attached to the PTO of a 45 hp tractor in the fields The PTO speed was set to 540 ± 10 rpm The operating depth was set by means of three point hitch system to a maximum depth of 15 cm

3 5 MEASUREMENT OF CO_2 RELEASE

The cumulative CO_2 emission from the tilled and undisturbed soil surfaces were measured using portable chamber system (Reicosky and Lindstom, 1993) Measurements were typically made by measuring the rise in CO_2 concentrations inside the chamber by the base trap method using NaOH as base

3.5.1 Collection chamber

A moulded transparent plastic box with height 20 cm, width 30 cm, and length 34 cm (Plate 1) was used as the collection chamber to trap and collect the CO_2 release from soil The area of release was then standardized to 1 m^2 by multiplying the data observed with a factor 9 8 The chamber was placed in the tilled soil up to a depth of 5 cm (Moussacdek *et al*, 2011) and the outer side walls were covered with soil, till the soil surface to prevent escape of CO_2 from the chamber and flow of atmospheric air into the chamber so as to make it a closed system A glass beaker of 30 ml capacity was used for keeping the NaOH base trap solution inside the chamber

3.5.2 Measurement of CO_2 release from the soil using base trap method

The base trap method is a static measurement method for CO_2, where NaOH was used as base When the solution get exposed to CO_2 emitted from the soil, it reacts to form Na_2CO_3 The quantity of CO_2 absorbed was measured through titration of Na_2CO_3 against HCl (0 1 N)

NaOH (1N) solution was prepared in the laboratory and 15 ml of the solution was pipetted out to low form glass beaker (Plate 2) The beaker with solution was placed above the soil surface and closed with collection chamber (Plate 3) The NaOH

Plate 1. Collection chamber and soil thermometer

Plate 2. NaOH solution in glass beaker

Plate 3. Collection chamber and NaOH solution

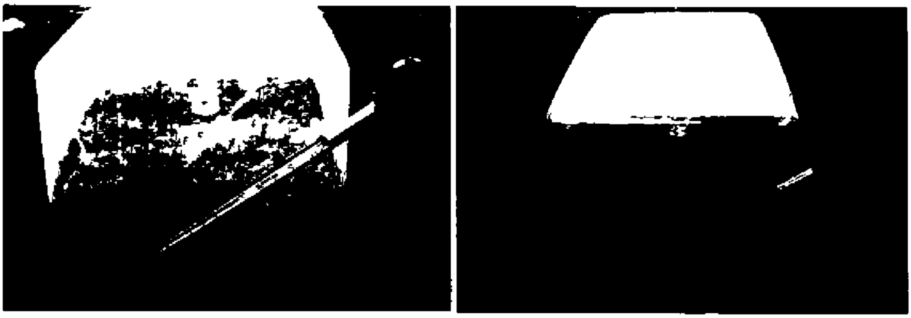

Plate 1 Collection chamber and soil thermometer

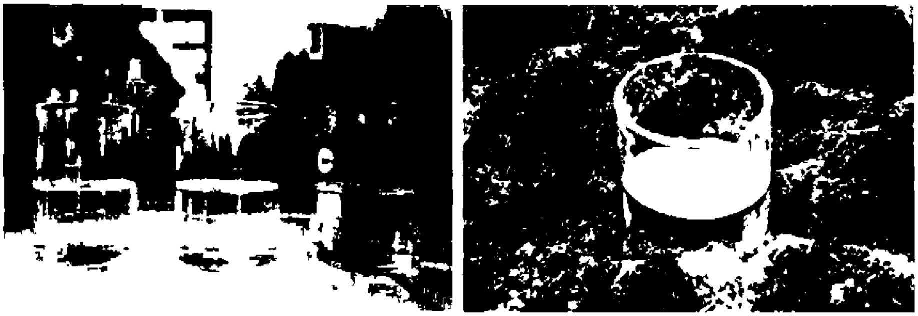

Plate 2 NaOH solution in glass beaker

Plate 3 Collection chamber and NaOH solution

reacted with the CO_2 available inside the chamber which is the sum of atmospheric CO_2, CO_2 released due to the oxidation of carbon present in the soil and CO_2 released due to microbial activity in presence of atmospheric oxygen and moisture from soil to form Na_2CO_3 The sample was shifted to the lab without further contact with air (Plate 4) The cumulative hourly release of CO_2 from the selected area due to the said reasons were calculated by titration of Na_2CO_3 with 0 1 N Hydrochloric acid (HCl) with phenolphthalein as indicator (Plate 5) After adding the indicator the solution turned to pink in colour The endpoint was disappearance of this pink colour (Plate 6) The volume of HCl used for the titration could be related to the amount of CO_2 absorbed by NaOH, ultimately the cumulative amount of CO_2 released from the soil

The reaction equations are

$$2\,NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

Calculation

Amount of CO_2 released, mg $= V \times N \times 22$

Where,

V = Volume of HCl used

N = Normality of HCl

22 is a constant

3.5 3 Standardization of data

The result from the titration procedure was in mg of CO_2, which is the amount of CO_2 released from the chamber area of 0 102 m^2 This was converted to quantity of CO_2 released from m^2, the unit area by multiplying with the factor 9 8 Since the result represent the cumulative quantum of CO_2 released in an hour, from a unit area, the data could be represented in standard form viz g m^{2} h^{1} for further analysis

Plate 4 Sample collected for analysis

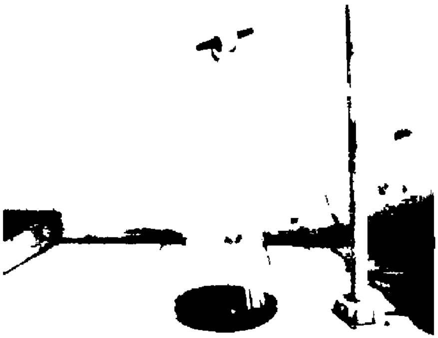

Plate 5 Sample prepared with phenolphthalein indicator

Plate 6 Endpoint – disappearance of pink colour

3 6 OTHER PARAMETERS INFLUENCING CO_2 EMISSION FROM SOIL

Studies have shown that factors such as soil temperature, soil moisture content, presence of organic matter in the field (Moore and Dalva, 1993), soil pH (Jabro, *et al*, 2008), bulk density (Moussadek, *et al*, 2011), atmospheric temperature and relative humidity (Kirschbaum, 1995) also influence the CO_2 release from the soil surface to atmosphere

3.6.1 Bulk density

Bulk density is an indicator of soil compaction and it has a negative correlation with organic matter content in the soil The quantum of CO_2 release from soil is being positively correlated to the amount of organic matter content of soil, it can be inferred that the bulk density has an indirect negative correlation with the process CO_2 release from the soil

For the estimation of the bulk density of the soil, volumetric method was used and the bulk density of soil measured was expressed in $g\ cm^{-3}$ or $Mg\ m^{-3}$

$$\text{Bulk Density} = \frac{\text{Weight of soil}}{\text{Volume of soil in field condition}}$$

Procedure followed

- The sampler was driven into a vertical soil surface slightly enough to fill the sampler but avoiding the compression of the soil in the confined space of sampler
- Sampler was dug out without disturbing the natural position of soil within the sampler
- The two cylinders of the sampler were separated retaining the soil mass undisturbed in the sample holder (inner core)

- The soil extending beyond each end of sampler was trimmed with the help of the sharp knife, so that the volume of the sample holder is equal to the volume of the soil
- The entire soil from sample holder was transferred to a previously weighed moisture box and the total weight was taken
- The soil mass was oven dried at 105°C until a constant weight is reached (10 to 15 hours)
- The moisture box was then cooled and its content at room temperature and again the weight was noted
- The length and inner diameter of the sampler was measured with the help of vernier caliper

Calculation

Weight of aluminium box, g $= W_1$

Weight of aluminium box + field soil, g $= W_2$

Weight of aluminium box + oven dry soil, g $= W_3$

Weight of water in the soil, g $= (W_2 - W_3) = Z$

Weight of dry soil $= (W_3 - W_1) = Y$

Thus water content of soil, P (%) $= \frac{Z}{Y} \times 100$

Bulk Density of soil (g cc-^{1}) $= \frac{Y}{\pi/4\, d^2\, h}$

Where,

d - Diameter of the sampler, cm

h - Height of the sampler, cm

3.6.2 Soil pH

Soil pH generally refers to the degree of soil acidity or alkalinity Chemically, it is defined as the negative $\log_{10}$ hydrogen ions (H^+) in the soil solution Hydrogen ion activity (pH) of soil has a marked effect on the growth and proliferation of soil microbes It is attributed to adverse effect of low pH on soil microbial activity, which contributes to lower respiration rate and consequently lower CO_2 evolution

Soil pH was measured using the pH meter with the following specifications by observing the standard procedure

Make	Eutech Instruments
Model	PC 510
pH range	0 to 14
Resolution	0 01 pH
Calibration	up to 5 points with auto buffer recognition

Procedure followed

- The pH meter was calibrated over the appropriate range using the standard buffers
- 10 g of sieved, air-dried soil was scooped into a paper cup
- 25 ml of distilled water was poured into the sample
- The solution was stirred vigorously for 15 seconds and kept undisturbed for 30 minutes
- The electrodes were placed in the suspension, swirled carefully and the pH was recorded immediately

3.6.3 Soil temperature

Soil temperature has a marked effect on CO_2 evolution from the soil At higher soil temperatures partial inhibition of microbial respiration occurs, which is attributed to inactivation of biological oxidation systems

It was measured using soil thermometer by inserting it into the soil to a depth of 10 cm (Plate 1) The display part of the soil thermometer shown the current soil temperature in °C

3.6.4 Soil moisture

Soil moisture content affects soil respiration, higher moisture content provides better conditions for microbial habitat activities, increasing microbial oxygen consumption and CO_2 production and emission from soil The soil respiration could be represented as a function of soil matric potential which has a negative correlation with CO_2 emission increase from soil surface

For the estimation of the soil moisture of each soil, gravimetric method is used Traditionally water content in soil is expressed as the ratio of the weight of water present in the soil to the weight of dry soil This ratio was multiplied by 100, to get the percentage of water in the soil sample on dry weight basis

Procedure followed

- 10 to 100 g soil sample was dug out with the help of the soil augur out from a depth from 10 to 15 cm and immediately transferred into a previously weighed aluminium box with tight fitting lid to avoid any evaporation loss
- The box with wet soil sample was weighed and recorded
- The aluminium box was dried in the oven with lid off and at a temperature of 105°C for 24 hours
- After drying the aluminium box was removed from the oven along with its lid was kept in desiccator and cooled to room temperature
- The weight of aluminium box and its lid with dry soil was measured and recorded
- The results were expressed in percentage

Calculation

Weight of empty aluminium box with its lid	= X g
Weight of aluminium box with its lid + wet soil sample	= Y g
Weight of aluminium box with its lid + dry soil sample	= Z g

Percentage moisture of soil $= \frac{Y-Z}{Z-X} \times 100$

3 6.5 Organic carbon content

Soluble organic carbon in the soil is an immediate source of Carbon for soil microorganisms, which in turn emit CO_2 Large quantities of organic manure that are added to agricultural soils every year for supplying nutrients to crops may contribute significantly to CO_2 emission

For the estimation of the organic matter content of each soil, Modified Walkley and Black's titration method was used A known weight of manure sample is digested with a mixture of 1 N Potassium dichromate ($K_2Cr_2O_7$) and concentrated H_2SO_4 The mixture produces a strong oxidizing agent chromic acid The carbon in the organic matter is oxidized to CO_2 which itself is reduced to chromium sulphate The reaction is,

$$2\,K_2Cr_2O_7 + 8\,H_2SO_4 + 3C \longrightarrow 2K_2SO_4 + 2Cr_2\,(SO_4)_2 + 8H_2O + 3CO_2$$

1 ml of 1 N $K_2Cr_2O_7$ = 0 003 g of organic carbon

Procedure followed

- Weighed exactly 0 2 g of soil into a 500 ml Erlenmeyer flask
- 20 ml $K_2Cr_2O_7$ solution was pipetted into the flask Gently swirled and added 20 ml concentrated H_2SO_4 mix by gentle rotation
- The flask was left undisturbed for 30 minutes and then added 200 ml distilled water to stop the reaction

- Then 10 ml of orthophosphoric acid and 1 ml of diphenyl amine indictor was added to the solution
- Titration was carried out against standard ferrous ammonium sulphate until a green colour appears
- A blank was also run simultaneously without the sample

Calculation

Weight of soil sample = W g

Volume of Ferrous ammonium sulphate used for blank titration = B ml

Normality of Ferrous sulphate = 1 N

Ammonium sulphate used for titration of the sample = T

1 ml of 1 N $K_2Cr_2O_7$ = 0 003 g of carbon

$$\text{Percent of organic carbon} = \frac{(B-T) \times N \times 0\ 003 \times 100}{Weight\ of\ soil} \%$$

Percent of organic matter = Per cent of organic carbon × 1 724

3.6 6. Atmospheric temperature

Atmospheric temperature has a marked effect on CO_2 evolution from the soil since it directly influences the soil temperature At higher atmospheric temperatures, soil temperature also increases and the partial inhibition of microbial respiration occurs, which is attributed to inactivation of biological oxidation systems

The atmospheric temperature recorded from the Stevenson screen available in the observatory of College of Agriculture, Vellayani was used for the study The Stevenson screen consisted of dry bulb thermometer, wet bulb thermometer, maximum thermometer and minimum thermometer

3.6.7. Relative humidity

Relative humidity has influence on removal of soil moisture Soil moisture affects soil respiration and hence CO_2 evolution In general, increasing relative humidity would increase CO_2 evolution up to an optimum level, above which it would reduce CO_2 evolution

The relative humidity recorded from the Stevenson screen available in the observatory of College of Agriculture, Vellayani was used for the study Observations from dry bulb thermometer and wet bulb thermometer, the Relative Humidity of the atmosphere is found out using the hygrograph Relative Humidity (H) is the ratio of the vapor pressure (e) of the moist air to its saturation vapor pressure (es) at its temperature, which is expressed in per cent

3.6 8. Analysis of data

The Completely Randomized Design with Single Factor ANOVA was done to evaluate whether the difference between the treatments were significant Correlation between CO_2 emission and various parameters viz , soil temperature, atmospheric temperature, relative humidity and soil moisture was computed Total 9 treatments (3 types of soils × 3 methods of tillage) with 3 replications were conducted in the field The samples collected were analyzed in the laboratory for quantifying the CO_2 emission from soil

RESULTS

4. RESULTS

4 1 EFFECT OF TILLAGE ON CO_2 EMISSION FROM SOILS

The CO_2 emission rates before soil manipulation of the three types of soils showed that CO_2 emission rate was the highest (4 27 to 4 33 g m^{2} h^{1}) in paddy field soil (treatments T_7, T_8 and T_9) and the lowest was recorded in the coastal sandy soil (1 18 to 1 35 g m^{2} h^{1}) (T_4, T_5 and T_6) The CO_2 emission rate of redloam soil (treatments T_1, T_2 and T_3) was intermediate (2 12 to 2 54 g m^{2} h^{1}) between paddy field soil and coastal sandy soil Irrespective of soil type tillage resulted in a sudden increase in CO_2 emission Paddy field soil showed the maximum emission in all the tillage practices and the lowest was recorded in coastal sandy soil The maximum value of CO_2 emission was observed in the treatment T_7 which is the application of conventional tillage in the paddy field soil and the least value of CO_2 emission was observed in the treatment T_6 which is the application of rotovator in the coastal sandy soil

In the first hour after tillage the least CO_2 emission was observed in the treatment T_6 (tillage with rotovator in the Coastal sandy soil) followed by T_5 (tillage with cultivator in coastal sandy soil) The highest CO_2 emission was found in the treatment T_7 (conventional tillage in paddy field soil) followed by T_8 (tillage with cultivator in paddy field soil) and T_9 (tillage with rotovator in paddy field soil) In the case of redloam soil it is observed that in T_1 (conventional tillage in redloam) has the highest CO_2 emission followed by T_3 (tillage with cultivator in the redloam) and the minimum CO_2 emission was observed in T_3 (tillage with rotovator) Here the percentage increase of soil CO_2 emission ranges between 86 to 95 per cent The highest percentage of increase in the initial CO_2 emission was observed in T_4 (application of conventional tillage in coastal sandy soil) and the least in T_3 (application of rotovator in redloam soil) In all the soil types the highest percentage of increase in CO_2 emission was observed in the application of conventional tillage (T_1, T_4, and T_7)

Among the soil types the maximum CO_2 emission was observed in the Paddy field soil and within the paddy field soil, the conventional tillage resulted in the maximum CO_2 emission followed by the tillage with cultivator The least CO_2 emission in the paddy filed soil was observed when it was tilled with rotovator The highest CO_2 emission was observed in the conventional tillage practice in all the soils (T_1, T_4, and T_7) At the same time the least CO_2 emission was observed in all the soils when it was tilled with rotovator (T_3, T_6, and T_9) The CO_2 emission in tillage with cultivator ranged between the other two tillage practices in all the soils (T_2, T_5, and T_8) When the comparison is done between the soils the least value of CO_2 emission was observed from the coastal sandy soil (T_6) and the highest value from the paddy field soil (T_7)

In second hour of tillage the CO_2 emission declined drastically irrespective of soil types and tillage mechanisms But in the case of paddy field soil the CO_2 emission was considerably higher than that of undisturbed soils unlike the other soils responded When the percentage of decrease of CO_2 emission was considered, in the case of redloam and Coastal sandy soils, it ranges from (-)92 to (-)95 per cent But in the case of paddy field soil it ranges from 79 to 86 per cent That is the percentage of decrease of CO_2 emission was lowest in the case of paddy field soil Here also the maximum value of CO_2 emission was observed in the conventional tillage practice in all the soils except in the case of Coastal sandy soil in which the T_4 (Conventional tillage) and T_6 (Tillage with rotovator) showed the same value of CO_2 emission

After the second hour of tillage the CO_2 emission recorded the values lower than that of undisturbed soil conditions This trend was continued with minor fluctuations corresponding to the changes in soil temperature and soil moisture Among all the tillage practices, conventional tillage (tillage with spade) resulted in significantly higher CO_2 emission whereas the CO_2 emission rate was significantly lower in the tillage with cultivator and rotovator The least CO_2 emission rate was recorded in the tillage with rotovator which was significantly lower than the other two tillage practices

Table.1. CO_2 emission (in g m^{-2} h^{-1}) from three different soils under three different tillage practices (Values in bracket are the percentage difference from the previous values)

Treatments	Initial hour	1st hour	2nd hour	3rd hour	4th hour	5th hour	6th hour	7th hour	48th hour	72nd hour	96th hour	120th hour	144th hour	168th hour
T_1	2 12	36 28 (94 15)	1 11 (-96 14)	0 35 (-68 46)	0 66 (88 57)	0 22 (66 67)	0 61 (177)	0 61 (0)	2 11 (245)	1 98 (-6 16)	2 04 (3 03)	1 98 (2 94)	2 05 (3 41)	2 01 (-1 95)
T_2	2 54	33 11 (92 32)	1 17 (96 46)	0 37 (-68 37)	0 51 (37 83)	0 34 (-33 33)	0 42 (23 52)	0 42 (0)	1 96 (366)	1 98 (1 02)	1 54 (22 22)	1 91 (24 02)	1 44 (-24 60)	1 95 (35 41)
T_3	2 52	19 28 (86 92)	1 21 (-95 38)	0 35 (-71 07)	0 51 (45 71)	0 22 (-56 86)	0 31 (40 9)	0 31 (0)	1 74 (461)	1 64 (5 74)	1 48 (-9 75)	1 64 (10 81)	1 54 (-6 09)	1 42 (7 79)
T_4	1 18	21 21 (94 43)	0 98 (-95 38)	0 65 (33 67)	0 55 (-15 38)	0 64 (16 36)	0 42 (-34 37)	0 42 (0)	1 28 (204 76)	1 01 (-21 09)	1 41 (39 60)	1 10 (-21 98)	1 01 (8 18)	1 35 (33 66)
T_5	1 33	18 56 (92 83)	0 97 (-94 77)	0 75 (-22 68)	0 62 (-20 96)	0 61 (-1 61)	0 51 (-16 39)	0 51 (0)	1 24 (73 21)	1 32 (6 45)	1 01 (-23 48)	1 22 (20 79)	1 10 (-9 83)	1 01 (-8 18)
T_6	1 35	12 55 (89 24)	0 98 (92 19)	0 67 (-31 63)	0 55 (17 91)	0 45 (-18 18)	0 41 (-8 89)	0 41 (0)	1 19 (190 32)	1 11 (-6 72)	1 29 (16 21)	1 02 (-20 93)	1 21 (18 62)	1 01 (-16 52)
T_7	4 33	55 25 (92 16)	10 11 (-81 7)	4 15 (58 95)	1 12 (-73 01)	0 61 (-45 53)	0 71 (16 39)	0 71 (0)	3 48 (390 21)	2 92 (-16 09)	3 62 (23 97)	2 23 (-38 39)	3 32 (48 87)	2 98 (10 24)
T_8	4 32	48 14 (91 02)	8 14 (83 09)	3 21 (-60 56)	1 04 (67 60)	0 65 (-37 5)	0 51 (-21 53)	0 51 (0)	2 25 (341 17)	2 02 (-10 22)	2 77 (37 12)	2 13 (23 1)	2 11 (-0 93)	2 44 (15 63)
T_9	4 27	42 17 (89 87)	8 53 (-79 77)	2 24 (73 73)	0 84 (-62 5)	0 75 (10 71)	0 51 (-0 32)	0 51 (0)	2 34 (358 82)	2 13 (-8 97)	2 45 (15 02)	2 14 (-12 65)	2 65 (23 83)	2 25 (-15 09)
CD (0 05)	0 06	0 14	0 01	0 08	0 07	0 01	0 01	0 13	0 02	0 02	0 02	0 02	0 00	0 02
SE	0 02	0 04	0 03	0 02	0 02	0 006	0 004	0 004	0 028	0 005	0 005	0 005	0 005	0 005

4 2 EFFECT OF SOIL TEMPERATURE ON CO_2 EMISSION

Table 2. Soil temperature (°C) observed in treatments

Treatments	Time in hours					
	48th hour	72nd hour	96th hour	120th hour	144th hour	168th hour
T_1	31 2	29 5	30 0	29 1	31 0	29 9
T_2	31 0	31 2	29 6	31 2	29 5	31 0
T_3	31 0	28 5	28 3	30 1	29 6	29 1
T_4	30 5	29 6	30 8	29 5	29 1	29 9
T_5	29 5	30 5	28 4	29 3	28 8	28 3
T_6	30 5	29 6	30 9	28 5	30 5	28 3
T_7	31 0	29 5	31 0	28 6	31 0	29 9
T_8	30 4	28 2	31 2	28 9	28 7	30 5
T_9	31 2	28 6	31 7	28 6	32 0	29 2

Table 3. Correlation coefficient between Soil temperature and CO_2 emission from soils under different tillage practices

	Correlation coefficient		
	Conventional tillage	Tillage with cultivator	Tillage with rotovator
Redloam soil	0 883*	0 984**	0 679
Coastal sandy soil	0 899*	0 973**	0 990**
Paddy field soil	0 964**	0 859*	0 952**

* Significant at 5% **Significant at 1%

In all the soil types the soil temperature and the CO_2 release are positively correlated in all the tillage practices except in the case of tillage with rotovator in the redloam soil From these it was clear that the soil temperature and the CO_2 emission from the soil were related to each other in a way such that as the soil temperature increases the CO_2 emission also increases

4 3 EFFECT OF ATMOSPHERIC TEMPERATURE ON CO_2 EMISSION

Table 4. Atmospheric temperature (°C) observed in treatments

Treatments	Time in hours					
	48th hour	72nd hour	96th hour	120th hour	144th hour	168th hour
T_1	32 3	30 9	31 3	30 4	32 0	31 0
T_2	32 0	31 0	31 0	32 0	31 0	32 1
T_3	32 1	29 8	29 6	31 0	30 1	30 8
T_4	30 8	30 5	31 5	30 8	30 1	31 2
T_5	30 5	31 4	29 6	30 6	29 8	29 5
T_6	31 0	30 2	31 5	29 6	30 6	29 6
T_7	32 0	31 2	32 0	29 6	32 0	31 1
T_8	31 6	29 6	32 1	29 6	29 8	31 5
T_9	32 3	30 5	32 6	29 8	32 8	30 6

Table 5. Correlation coefficient between Atmospheric temperature and CO_2 emission from soils under different tillage practices

	Correlation coefficient		
	Conventional tillage	Tillage with cultivator	Tillage with rotovator
Redloam soil	0 897*	0 985**	0 591
Coastal sandy soil	0 954**	0 988**	0 980**
Paddy field soil	0 964**	0 918**	0 931**

* Significant at 5% **Significant at 1%

In all the soil types the temperature and the CO_2 release were positively correlated in all the tillage practices except in the case of tillage with rotovator in the redloam soil From these it was evident that the temperature and the CO_2 emission from the soil were related to each other in a way such that as the temperature increases the CO_2 emission also increases

4 4 EFFECT OF RELATIVE HUMIDITY ON CO_2 EMISSION

Table 6. Relative Humidity (%) observed in treatments

Treatments	Time in hours					
	48th hour	72nd hour	96th hour	120th hour	144th hour	168th hour
T_1	52 10	52 40	52 70	52 10	53 00	52 70
T_2	51 40	52 50	52 50	52 40	52 10	53 40
T_3	54 50	53 00	53 20	54 10	54 10	53 70
T_4	55 80	55 10	55 30	55 80	55 10	55 00
T_5	54 95	54 22	54 12	55 21	55 32	55 64
T_6	54 25	54 36	54 25	54 69	55 21	55 10
T_7	54 10	53 20	53 50	53 60	53 40	53 70
T_8	55 31	54 32	54 10	53 90	53 50	53 79
T_9	55 10	55 30	55 00	54 70	54 90	55 20

Table 7. Correlation coefficient between Relative humidity and CO_2 emission in different soils under various tillage practices

	Correlation coefficient		
	Conventional tillage	Tillage with cultivator	Tillage with rotovator
Redloam soil	-0 113	-0 078	0 543
Coastal sandy soil	0 184	-0 284	-0 417
Paddy field soil	0 305	-0 234	-0 211

In all the soil types the relative humidity and the CO_2 release were not correlated in all the tillage practices From these it was evident that the relative humidity and the CO_2 emission from the soil has not any significant relationship between them

4 4 EFFECT OF SOIL MOISTURE ON CO_2 EMISSION

Table 8. Soil moisture (%) observed in treatments

Treatments	Time in hours					
	48th hour	72nd hour	96th hour	120th hour	144th hour	168th hour
T_1	7 50	7 42	7 52	7 47	7 58	7 32
T_2	7 50	7 49	7 40	7 43	7 45	7 46
T_3	7 50	7 49	7 40	7 43	7 45	7 46
T_4	6 31	6 21	6 22	6 10	6 10	6 10
T_5	6 24	6 31	6 41	6 31	6 35	6 10
T_6	6 21	6 21	6 20	6 30	6 12	6 20
T_7	8 67	8 65	8 63	8 64	8 65	8 66
T_8	8 42	8 31	8 35	8 41	8 35	8 39
T_9	8 65	8 63	8 64	8 65	8 57	8 65

Table 9. Correlation coefficient between Soil moisture and CO_2 emission from soils under different tillage practices

	Correlation coefficient		
	Conventional tillage	Tillage with cultivator	Tillage with rotovator
Redloam soil	0 389	0 606	0 596
Coastal sandy soil	0 435	0 129	-0 547
Paddy field soil	0 162	0 116	-0 689

In all the soil types the soil moisture and the CO_2 release were not correlated in all the tillage practices From these it was evident that the soil moisture and the CO_2 emission from the soil has not any significant relationship between them

DISCUSSION

5. DISCUSSION

Among greenhouse gases, CO_2 is one of the most significant contributors to regional and global warming as well as climate change Tillage is a principal cause of CO_2 emission from croplands leading to the depletion of soil organic matter This study hypothesized CO_2 emission from three major soils of Kerala in respond to three common tillage practices adopted by the farming community In this chapter the observations and results obtained from field and laboratory were analysed and discussed

The study was undertaken during between February to May 2015 The mean precipitation, maximum temperature and minimum temperature during the study period was 400 mm, 32 1°C and 23°C respectively Three soils were selected based on their textural difference and predominance in southern Kerala, were Red Loam (*Typic Haplustult*), Paddy field soil (*Typic Fluvaquent*) and Coastal sandy soil (*Typic Ustipsamments*) Three different mode of tillage selected were conventional method of tillage, tillage with cultivator and tillage with Rotovator The cumulative hourly and daily CO_2 emission from the tilled and undisturbed soil surfaces were measured using portable chamber system The CO_2 released from the soil and trapped in the chamber was quantified using base trap method with NaOH as base through titration against HCl The results were standardized and represented in g m^{2} h^{1} The study was conducted under the statistical frame work, Completely Randomized Design – Single Factor ANOVA

5.1 Effect of tillage on release of CO_2 from Redloam soil

5 1.1 Hourly interval

The data observed on hourly basis were standardized to g m^{2} h^{1} of CO_2 released and represented graphically as shown in Fig 2, Fig 3 and Fig 4 The trend of plotted

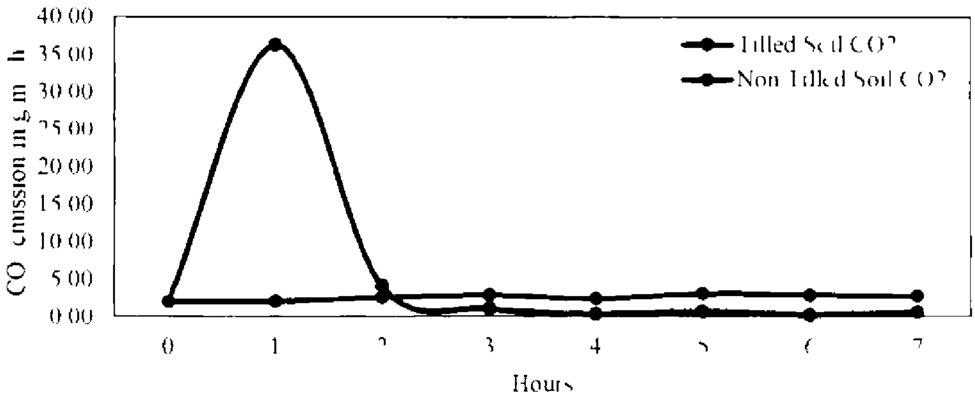

Fig 2 CO_2 emission from red loam soil under conventional tillage

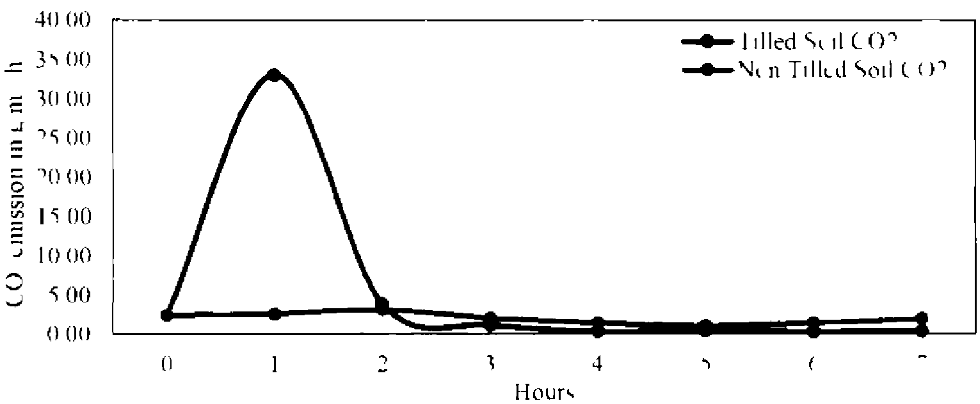

Fig 3 CO_2 emission from red loam soil under tillage with cultivator

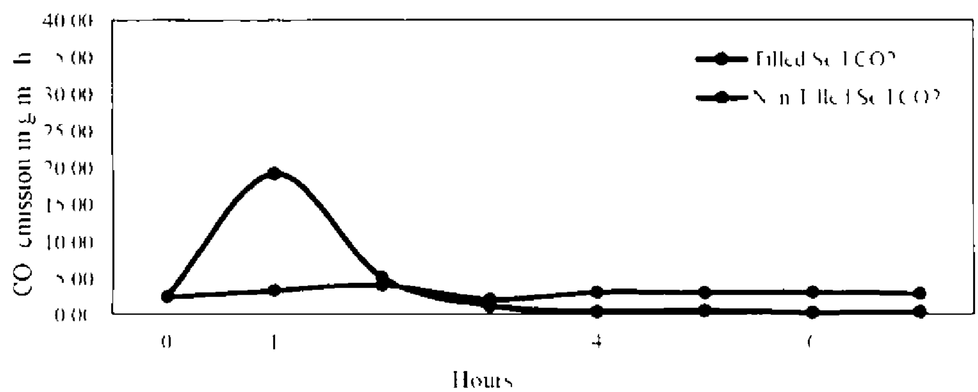

Fig 4 CO_2 emission from red loam soil under tillage with rotovator

data as shown in figures evident that, major quantity of CO_2 was released just after the breakage of soil in all kind of tillage methods The release of CO_2 from the soil was almost equal to the undisturbed condition after two hours of ploughing Immediate release of CO_2 from organic matter content due to the microbial activities in presence of atmospheric oxygen (microbial respiration) also observed within two hours after tillage Ellert and Janzen (1999) reported that enhanced release of CO_2 immediately after tillage was associated with the release of CO_2 stored m soil pores and from stimulated biological production Calderon *et al*, (2000) concluded that there was a decrease in the soil microbial respiration after tillage hence a decrease in the CO_2 flux from the soil after the tillage Lopez-Garrido *et al*, (2009) reported that tillage caused a sharp increase m soil CO_2 emissions immediately after tillage implementation

After 2 to 3 hours of tillage, the emission of CO_2 was lesser than that of undisturbed soil condition Moussadek *et al*, (2011) reported that the release of CO_2 from all the available sources in soil has taken place immediately after tillage and after two hours it was almost equal or lesser than the undisturbed condition when the soil get dried and release of CO_2 from exposed area was completed Mahdi and Xinhua found that the maximum CO_2 emission from all tilled treatments (strip-tillage, deep rip, chisel plow, and moldboard plow) was observed immediately after tillage operation However, CO_2 emission from these tilled treatments decreases sharply by 52 to 68% within the first 2 hours following tillage operations

It was evident from observations that, the CO_2 released was higher in rate under the conventional tillage practices (Fig 2) with the maximum value of 36 28 g m^{-2} h^{-1} while that under tillage with cultivator (Fig 3) and the same with rotovator (Fig 4) were 33 11 g m^{-2} h^{-1} and 19 28 g m^{-2} h^{-1} respectively In conventional method of tillage the degree of pulverization is comparatively lesser with the other two methods This resulted in left over of bigger soil clods with maximum surface area exposure to the atmospheric oxygen, hence the formation of CO_2 (36 28 g m ^{2} h ^{1}) both from soil carbon and carbon from organic matter get accelerated

According to Reicosky and Lindstrom (1993) the Molboard Plow resulted in the highest initial CO_2 flux and maintained the highest CO_2 flux because the disturbed soil depth was high which caused the formation of rougher surface and larger voids in the tilled soil Similarly lower CO_2 fluxes were caused by tillage associated with low soil disturbance and small voids According to Calderon and Jackson (2002) the CO_2 emission was three times higher in the disked soil, than the CO_2 emission from the undisturbed soil Moussadek *et al* (2011) reported that the CO_2 fluxes from the soil was higher in the conventional tillage immediately after tillage than reduced tillage and no tillage

Under the tillage with cultivator, the degree of soil pulverization is higher than that of conventional method, and the exposed area of soil is slightly lesser than that of conventional method, hence release of CO_2 also reduced (33 11 g m ^{2} h ^{1}) (Fig 3) As seen in conventional method the release of CO_2 from all the sources was taken place immediately after tillage and after two hours it was almost equal or lesser than the undisturbed condition when the soil get dried and release of CO_2 from exposed area was completed Dao (1998), Rastogi *et al*, (2002), La Scala *et al*, (2006), Moussadek *et al*, (2011), Teixeira (2011) were reported that the amount of carbon lost in the form of CO_2 from the soils due to different tillage practices has high correlation with the intensity of the disruption and the volume of soil disturbed by the tillage implements used

When the tillage is performed with rotovator, the degree of pulverization was higher and the exposed area to atmospheric oxygen was lesser and hence release of CO_2 also reduced (19 28 g m ^{2} h ^{1}) (Fig 4) Under rototilled condition the soil clod formation was significantly less in comparison with the other two methods The soil was powdered after tillage and the fine particles of soil formed a sealed layer over the seed bed This layer restrict the free exposure of soil carbon and organic matter content to the atmospheric oxygen considerably As seen in other two methods of tillage, the amount of CO_2 released from all the sources was taken place immediately after tillage and after two hours it was almost equal or slightly lesser than undisturbed condition when the soil get dried and release of CO_2 from exposed area was completed The CO_2 flux soon after soil disturbance has been related to the depth of tillage and the degree of soil disturbance (Alvaro-Fuentes *et al*, 2007, Calderon and Jackson, 2002) In contrast, the two no-tillage treatments have only 12 to 33% reduction during the same period (2 hours after tillage operations)

5.1.2 Daily interval

The CO_2 emission from redloam soil under different methods of tillage on daily basis was collected and measured in the laboratory as per the procedure explained in section 3 3 2 The observations of CO_2 emission during initial 3 hours were omitted for the analysis of data on daily basis, since it was recorded as the maximum and very high values comparatively The data observed on daily basis were standardized to $g\ m^{-2}\ h^{-1}$ of CO_2 emitted and represented graphically as shown in Fig 5, Fig 6 and Fig 7

From the graph it was evident that, CO_2 emission from the plowed land was lesser than that from undisturbed soil The observations were taken after three hours of ploughing for this analysis since the maximum release of CO_2 both from oxidation of soil carbon and microbial respiration were recorded in two to three hours after ploughing The emission of CO_2 from ploughed soil, irrespective of method of tillage, was lesser or more or less equal with the undisturbed soil The CO_2 emission due to microbial respiration was observed minimum in tilled soil and hence the reduction in release The fluctuations occurred were explained due to the effect of parameters like, soil temperature, soil moisture or so (Buyanowski and Wagner, 1983, Boone *et al*, 1998, Davidson *et al*, 1998) Omonode *et al* (2007) reported that CO_2 emissions were greater immediately after tillage (at 0^{th} hour) but declined sharply within two to three

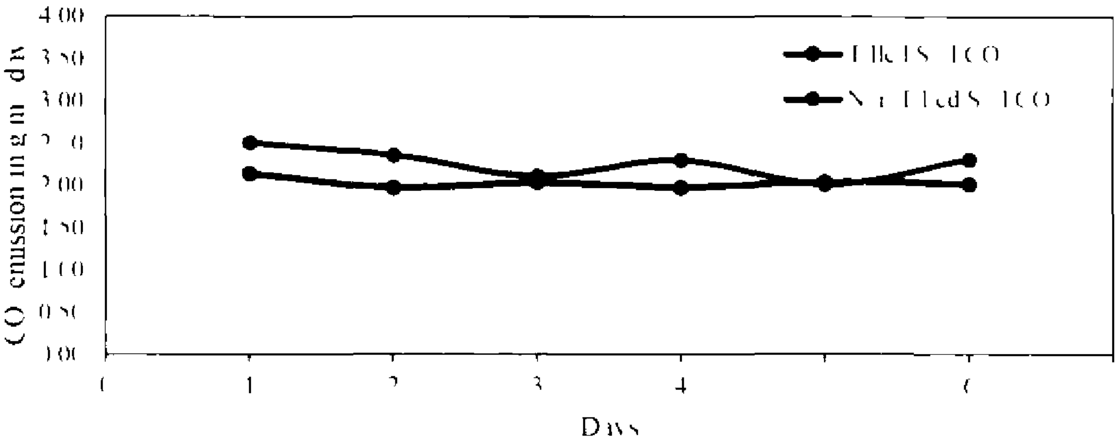

Fig 5 CO_2 emission from red loam soil under conventional tillage

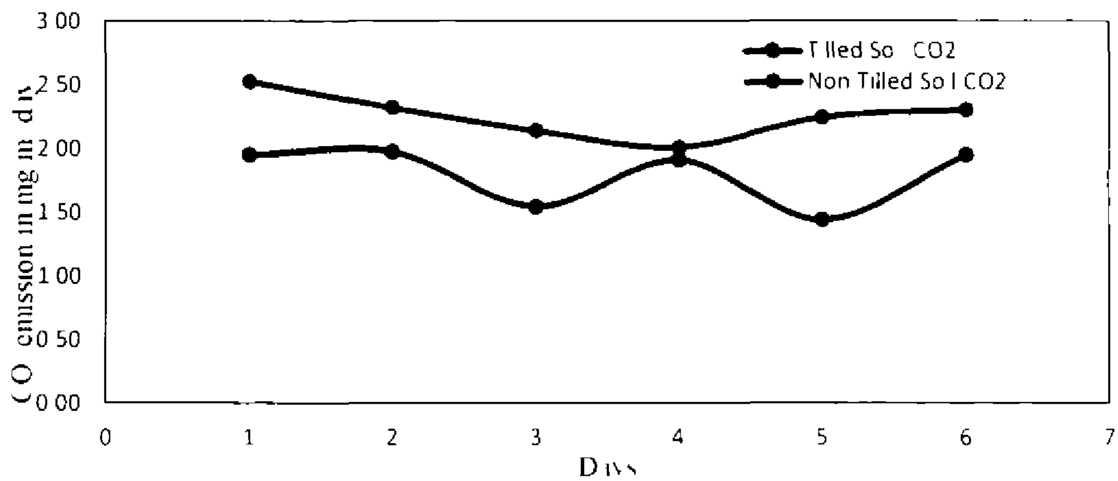

Fig 6. CO_2 emission from red loam soil under tillage with cultivator

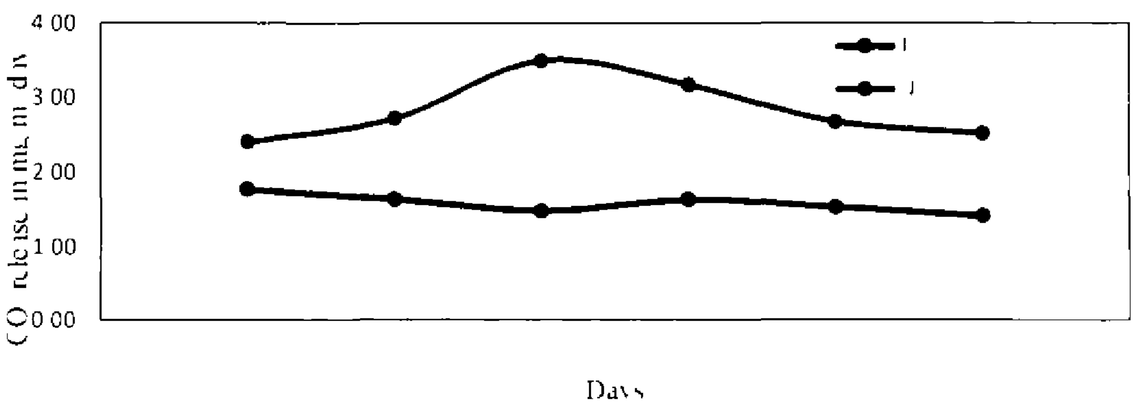

Fig 7 CO_2 emission from red loam soil under tillage with rotovator

hours after tillage operations and CO_2 emissions at 0, 1 and 2 h were significantly greater than for the 24 to 168 h following tillage

5.2 Effect of tillage on release of CO_2 from costal sandy soil

5.2.1 Hourly interval

The data observed on hourly basis were standardized to g m^{-2} h^{-1} of CO_2 released and represented graphically as shown in Fig 8, Fig 9 and Fig 10 The definite trend of graphically represented data clears that, a chief amount of CO_2 was emitted immediately after the soil breakage of in all methods of ploughing Then after two hours of ploughing the emission of CO_2 from soil was reduced drastically to almost equal as in undisturbed condition This tendency may be due to the immediate emission of CO_2 when the soil carbon get exposed to the atmospheric oxygen Instantaneous emission of CO_2 from organic matter content due to the microbial activities in presence of atmospheric oxygen (microbial respiration) also observed within two hours after tillage After 3 hours of ploughing, the emission of CO_2 was reduced to that of undisturbed soil condition These observations could be justified with the conclusions made by Ellert and Janzen (1999), Calderon *et al*, (2000), Lopez-Garrido *et al*, (2009), Moussadek *et al*, (2011)

In the case of coastal sandy soil the CO_2 emitted was higher in rate under the conventional tillage practices with the maximum value of 21 21 g m^{-2} h^{-1} (Fig 8) while that under tillage with cultivator (Fig 9) and rotovator (Fig 10) were 18 56 g m^{-2} h^{-1} and 12 55 g m^{-2} h^{-1} respectively When compared with other two types of soils, the amount of CO_2 emitted was minimum from the coastal sandy soil This may be due to the presence of larger soil aggregates, which allows the free movement of atmospheric air through the soil even in undisturbed condition The regular formation of CO_2 due to oxidation and microbial respiration was higher since more area was exposed to

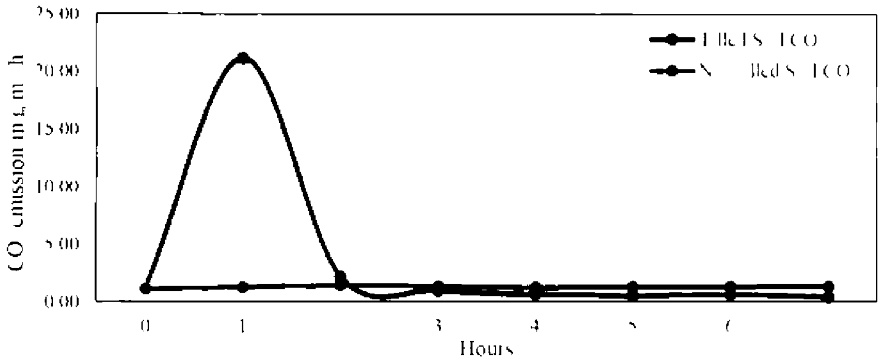

Fig 8 CO_2 emission from coastal sandy soil under conventional tillage

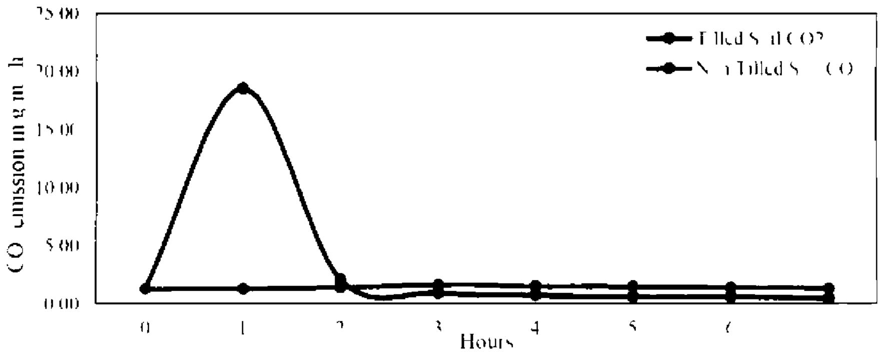

Fig 9 CO_2 emission from coastal sandy soil under tillage with cultivator

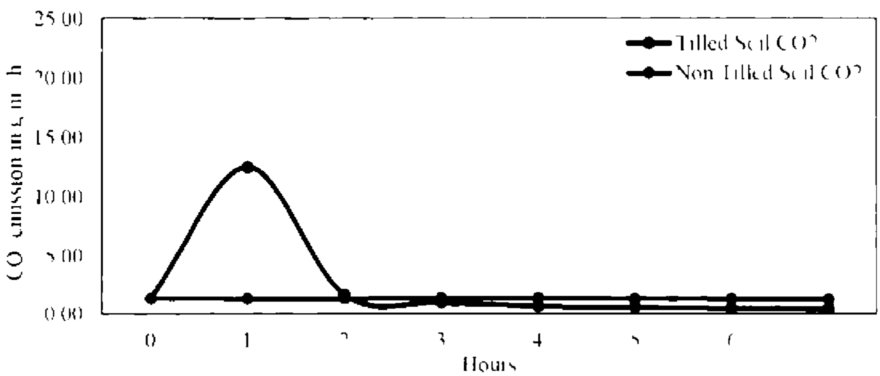

Fig 10 CO_2 emission from coastal sandy soil under tillage with rotovator

oxygen in normal situation Due to the same reason the status of soil carbon and organic carbon content were lower than that of other two soils

During conventional method of tillage the degree of pulverization is comparatively lesser than that of other two methods and hence resulted in left over of bigger soil clods with maximum surface area exposure to the atmospheric oxygen Hence the formation of CO_2 (21 21 g m^{2} h^{1}) both from soil carbon and carbon from organic matter get accelerated The emission of CO_2 from all the sources of soil was taken place straightaway after tillage After 2 hours the emission was almost equal or lesser than that from undisturbed condition, since the soil get dried and formation of CO_2 due to oxidation from exposed area was completed These observations were supported by Reicosky and Lindstrom (1993), Moussadek *et al* (2011)

During the treatment combination, tillage with cultivator, the degree of soil pulverization is higher than that of conventional method, and the exposed area of soil is slightly lesser than that of conventional method, hence release of CO_2 also reduced (18 56 g m^{2} h^{1}) (Fig 9) The emission of CO_2 from all the sources was taken place immediately after tillage as observed in conventional method The CO_2 emission was almost equal or lesser than the undisturbed condition and after two hours of ploughing, as the soil get dried and emision of CO_2 from exposed area was completed Dao (1998), Rastogi *et al* , (2002), La Scala *et al* , (2006), Teixeira (2011) were also reported the similar observations

Under the treatment, tillage is performed with rotovator, the degree of pulverization was higher than that of other two methods, hence the emission of CO_2 was reduced (12 55 g m^{2} h^{1}) (Fig 10) since the exposed area of soil to atmospheric oxygen was lesser comparatively Under rototilled condition the soil clod formation was significantly less in comparison with the other two methods The soil was powdered after tillage and the fine particles of soil formed a sealed layer over the seed bed This layer restrict the free exposure of soil carbon and organic matter content to the atmospheric oxygen considerably As seen in other two methods of tillage, the amount of CO_2 emitted from all the sources was taken place immediately after tillage and after two hours it was almost equal or slightly lesser than undisturbed condition when the soil get dried and emission of CO_2 from exposed area was completed Alvaro-Fuentes *et al* , (2007), Calderon and Jackson, (2002) also reported similar findings

5.2.2 Daily interval

The amount of CO_2 emitted from costal sandy soil after disturbed with different methods of tillage was collected and measured in the laboratory on daily basis as per the procedure explained in section 3 3 2 The observed emission of CO_2 during initial 3 hours were exempted for the analysis of data on daily basis, since it was recorded as the maximum and very high values comparatively The data observed during the treatment were standardized to g m^{2} h^{1} of CO_2 released and represented graphically as shown in Fig 11, Fig 12 and Fig 13

From the graph it was evident that, CO_2 release from the plowed land was lesser than that from undisturbed soil The observations were taken after three hours of ploughing onwards for this analysis since the maximum release of CO_2 both from oxidation of soil carbon and microbial respiration were recorded in 2 to 3 hours after ploughing The emission of CO_2 from plowed soil, irrespective of method of tillage, was lesser or more or less equal with the undisturbed soil The CO_2 release due to microbial respiration observed was minimum in tilled soil and hence the reduction in release The fluctuations in CO_2 release occurred could be explained with the effect of parameters like, soil temperature, soil moisture or so Buyanowski and Wagner, (1983), Boone *et al* , (1998), Davidson *et al* , (1998), Omonode *et al* , (2007) also reported similar observations

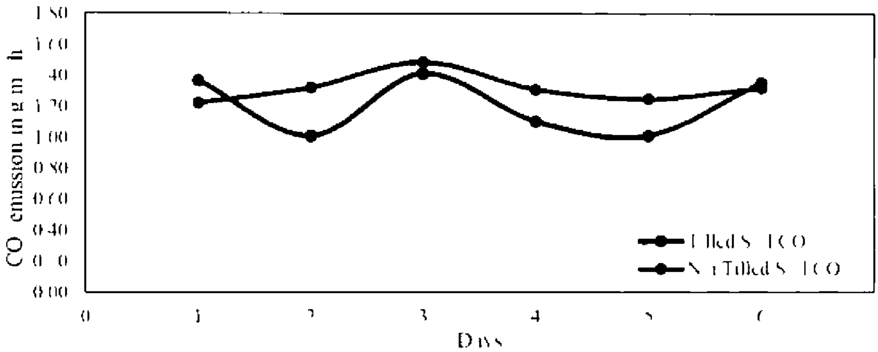

Fig 11 CO_2 emission from coastal sandy soil under conventional tillage

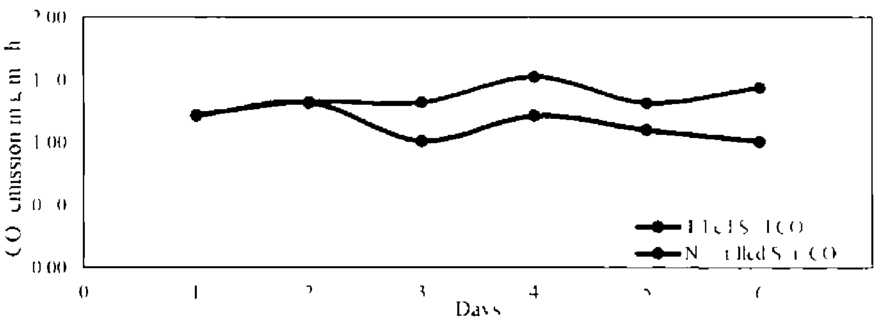

Fig 12 CO_2 emission from coastal sandy soil under tillage with cultivator

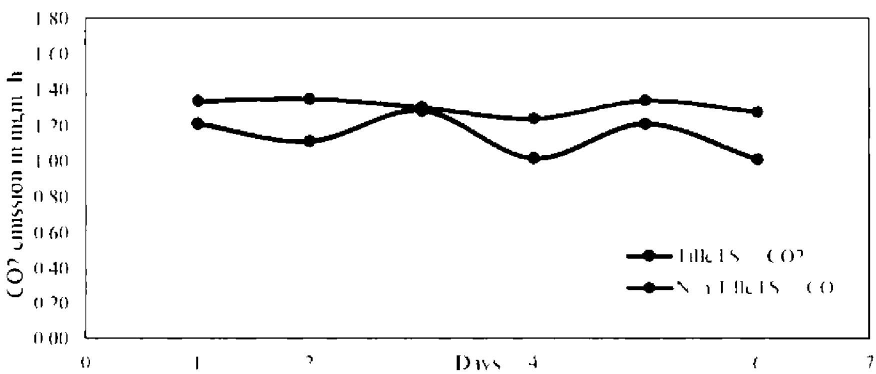

Fig 13 CO_2 emission from coastal sandy soil under tillage with rotovator

5.3 Effect of tillage on release of CO_2 from clay (paddy field soil)

5.3.1 Hourly interval

The quantum of CO_2 emitted from clay (paddy field soil) soil under different tillage practices was collected from field and measured in the laboratory as per the procedure explained in section 3 3 2 The data observed on hourly basis were standardized to g m^{-2} h^{-1} of CO_2 emitted and represented graphically as shown in Fig 14, Fig 15 and Fig 16

It was clear from the plotted data that, major quantity of CO_2 was emitted just after the breakage of soil in all the ploughing treatments The emission of CO_2 from the soil was almost equal to the undisturbed condition after two hours of ploughing This trend of graph could be due to the formation of CO_2 immediately after the soil carbon get exposed to the atmospheric oxygen Speedy emission of CO_2 from organic matter content by the microbial activities in presence of atmospheric oxygen (microbial respiration) also observed within the initial two hours after tillage After 2 to 3 hours of ploughing, the emission of CO_2 was less than that of undisturbed soil condition These observations could be justified with the conclusions made by Ellert and Janzen (1999), Calderon *et al*, (2000), Lopez-Garrido *et al*, (2009), Moussadek *et al*, (2011)

The CO_2 released was higher in rate under the conventional tillage practices with the maximum value of 55 25 g m^{-2} h^{-1} (Fig 14) while that under tillage with cultivator and rotovator were 48 14 g m^{-2} h^{-1} (Fig 15) and 42 17 g m^{-2} h^{-1} (Fig 16) respectively In conventional method of tillage, the degree of pulverization was comparatively lesser than that of the other two methods This resulted in left over of bigger soil clods with maximum surface area exposure to the atmospheric oxygen, hence the formation of CO_2 (55 25 g m^{-2} h^{-1}) (Fig 14) both from soil carbon and carbon from organic matter get accelerated The release of CO_2 from all the sources have taken place immediately after tillage and after two hours it was almost equal or lesser than

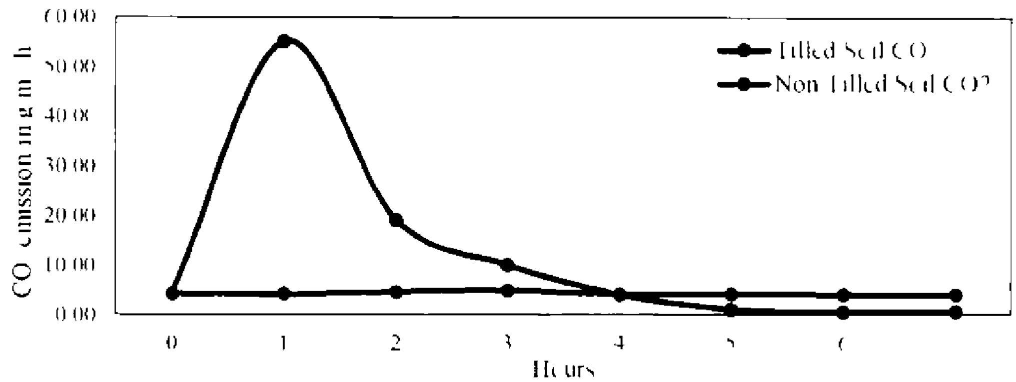

Fig 14 CO_2 emission from paddy field soil under conventional tillage

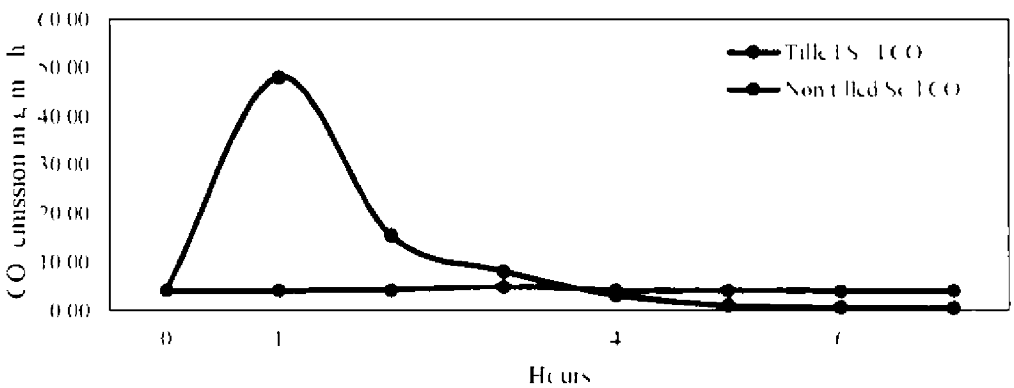

Fig 15 CO_2 emission from paddy field soil under tillage with cultivator

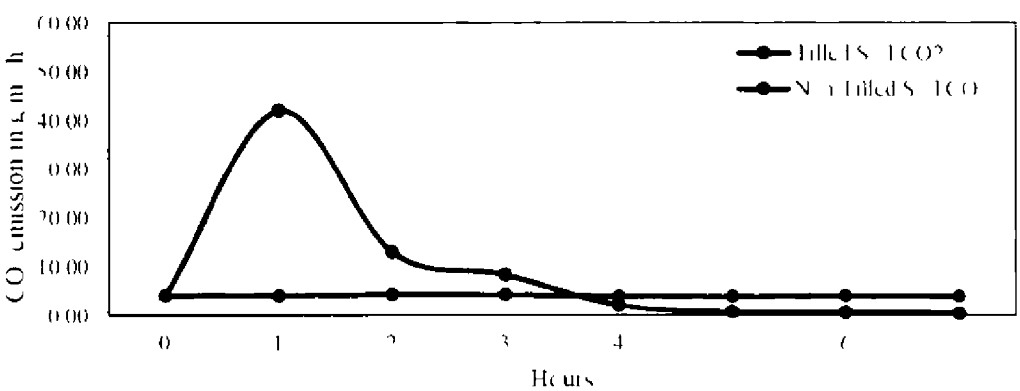

Fig 16 CO_2 emission from paddy field soil under tillage with rotovator

the undisturbed condition when the soil get dried and release of CO_2 from exposed area was completed

In condition where the tillage with cultivator, the degree of soil pulverization is higher than that of conventional method, and the exposed area of soil was slightly lesser than that of conventional method, hence release of CO_2 also reduced (48 14 g m^{-2} h^{-1}) (Fig 15) As seen in conventional method the release of CO_2 from all the sources have taken place immediately after tillage and after two hours it was almost equal or lesser than the undisturbed condition when the soil get dried and release of CO_2 from exposed area was completed Dao (1998), Rastogi *et al* , (2002), La Scala *et al* , (2006), Teixeira (2011) were also reported the similar observations

During the experimental combination where tillage is performed with rotovator, the degree of pulverization was higher and the exposed area to atmospheric oxygen was lesser and hence release of CO_2 also reduced (42 17 28 g m^{-2} h^{-1}) (Fig 16) Under rototilled condition the soil clod formation was significantly less in comparison with the other two methods The soil was powdered after tillage and the fine particles of soil formed a sealed layer over the seed bed This layer restrict the free exposure of soil carbon and organic matter content to the atmospheric oxygen considerably As seen in other two methods of tillage, the amount of CO_2 released from all the sources was taken place immediately after tillage and after two hours it was almost equal or slightly lesser than undisturbed condition when the soil get dried and release of CO_2 from exposed area was completed Alvaro-Fuentes *et al* , (2007), Calderon and Jackson, (2002) were also reported the similar findings

5.3.2 Daily interval

The release of CO_2 from paddy field soil under different methods of tillage was collected and measured in the laboratory on daily interval basis as per the procedure explained in section 3 3 2 The observations after initial 3 hours were taken for the analysis of data on daily basis, since it was recorded as the maximum and very high values comparatively The data observed were standardized to g m ^{2} h ^{1} of CO_2 released and represented graphically as shown in Figures 17, 18 and 19

From the graph it was obvious that, CO_2 release from the plowed land was lesser than that from undisturbed soil The observations were taken after three hours of ploughing for this analysis since the maximum release of CO_2 both from oxidation of soil carbon and microbial respiration were recorded in 2 to 3 hours after ploughing The release of CO_2 from ploughed soil, irrespective of method of tillage, was lesser or more or less equal with the undisturbed soil The CO_2 release due to microbial respiration was observed minimum in tilled soil and hence the reduction in release The fluctuations occurred were explained with the effect of parameters like, soil temperature, soil moisture or so Boone *et al*, (1998), Davidson *et al*, (1998), Omonode *et al*, (2007) also reported similar observations

5 4 INFLUENCE OF SOIL AND ATMOSPHERIC PARAMETERS ON CO_2 EMISSION FROM SOIL

The influence of factors such as soil temperature, soil moisture content, organic matter in soil, soil pH, bulk density, atmospheric temperature and relative humidity were also analyzed as per the procedure explained in chapter 3 6

5.4.1 Effect bulk density on CO_2 emission

Estimation of the bulk density of the selected soil was measured with volumetric method and expressed in g cm ^{3} or Mg m ^{3} The bulk density has significant influence on CO_2 release in the initial hours after tillage It was observed that CO_2 emission showed an increasing trend when bulk density decreases as evident from Fig 20, Fig 21 and Fig 22

The clay or paddy field soil with the lower bulk density (1 14 g cm ^{3}) performed the maximum CO_2 emission under all the three methods of tillage adopted viz

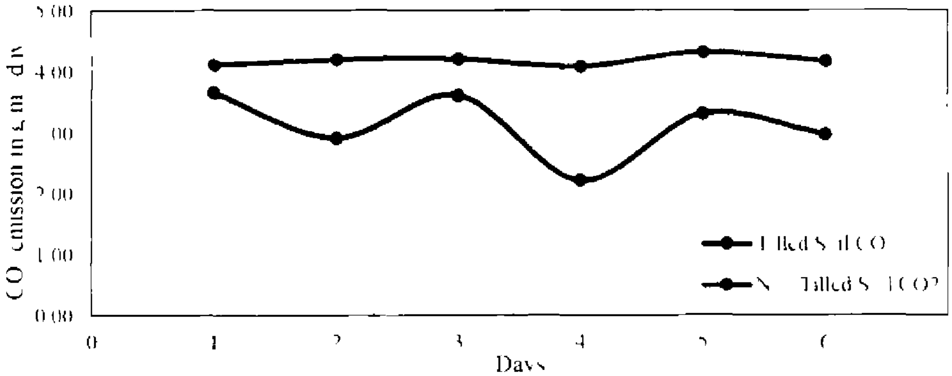

Fig 17 CO_2 emission from paddy field soil under conventional tillage

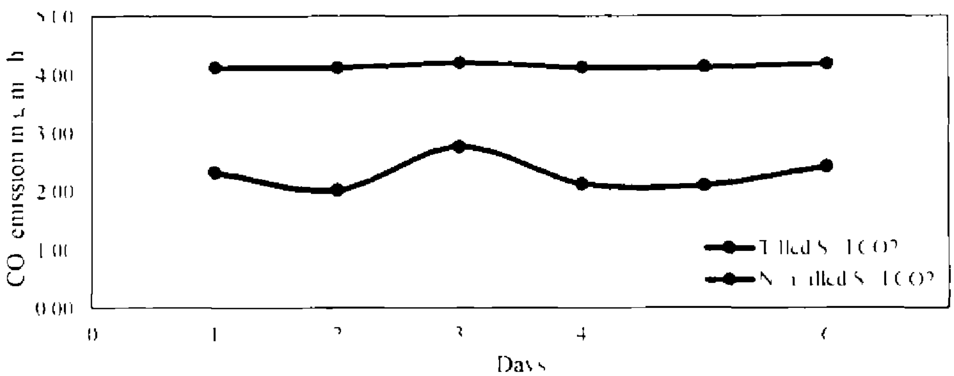

Fig 18 CO_2 emission from paddy field soil under tillage with cultivator

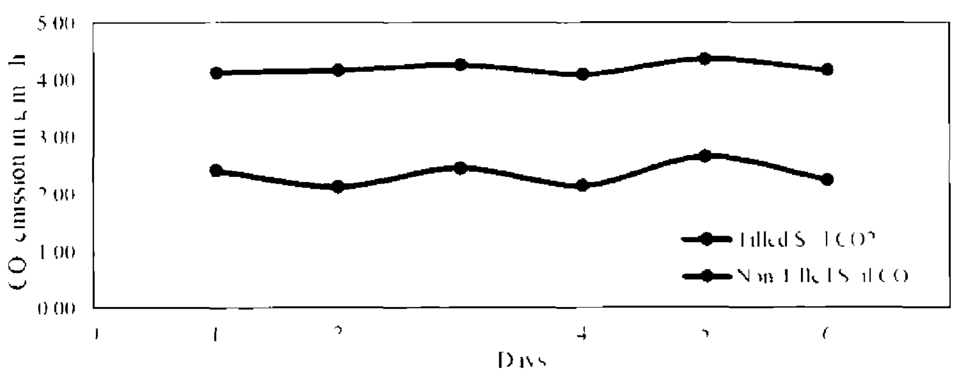

Fig 19 CO_2 emission from paddy field soil under tillage with rotovator

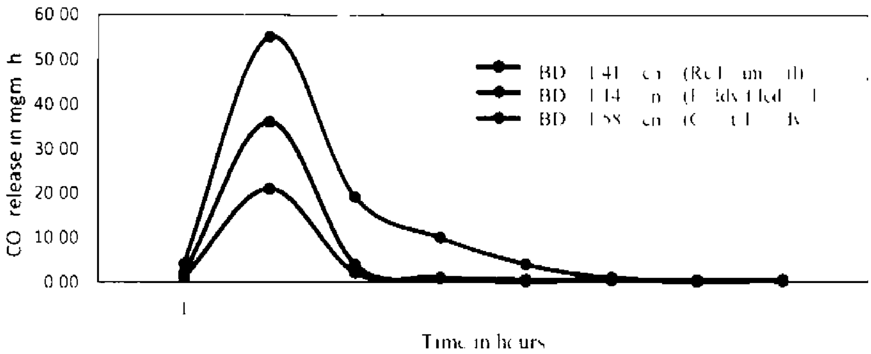

Fig 20 Effect of bulk density on soil CO_2 emission - conventional tillage

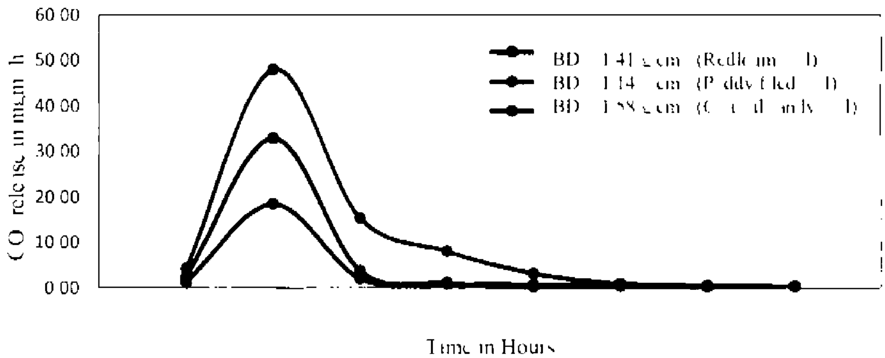

Fig 21 Effect of bulk density on soil CO_2 emission - tillage with cultivator

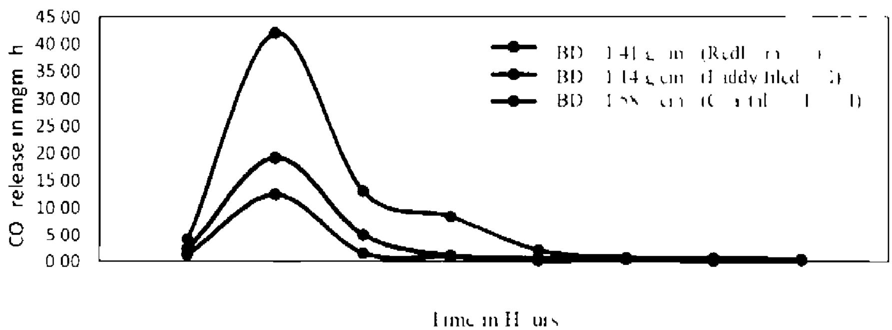

Fig 22 Effect of bulk density on soil CO_2 emission - tillage with rotovato

conventional tillage (55 25 $g\ m^{2}\ h^{1}$), tillage with cultivator (48 14 $g\ m^{2}\ h^{1}$) and tillage with rotovator (42 17 $g\ m^{2}\ h^{1}$) Followed by red loam with bulk density 1 41 $g\ cm^{3}$ and CO_2 emission of three tillage methods were 36 28 $g\ m^{2}\ h^{1}$, 33 11 $g\ m^{2}\ h^{1}$ and 19 28 $g\ m^{2}\ h^{1}$ respectively The corresponding observations of costal sandy soil with bulk density 1 58 $g\ cm^{3}$ were 21 21 $g\ m^{2}\ h^{1}$, 18 56 $g\ m^{2}\ h^{1}$ and 12 55 $g\ m^{2}\ h^{1}$ respectively

Mangalassery *et al*, (2013) reported that the texture, bulk density and aggregate size affects the CO_2 emission from the soils, in a way such that the CO_2 emission in clay loam soil was larger than that of the sandy loam soil Sey *et al*, (2008) reported that Increased CO_2 emissions was observed from micro aggregates (<0 25 mm) compared with macro aggregate (>0 25 mm) fractions Both soil greenhouse gas emission and soil carbon storage are linked to soil pore and aggregate structure The soil aggregation directly affects the storage of soil organic carbon and movement of gases and water in soil by influencing both biological processes in soil and pore characteristics which regulate the flow of water and gases (Marland *et al*, 2004, Beare *et al*, 2009)

The larger the soil aggregates higher will be the oxidation rate of soil carbon and soil microbial respiration This implies, the unexposed carbon in the soil towards atmospheric oxygen will be lesser when bulk density is low This will reduce the rate of emission of CO_2 due to tillage operations

5.4.2 Effect of organic matter content on CO_2 emission

The organic matter content of soil has significant influence on CO_2 release in the initial hours after tillage But the effect was observed as a combined result of both bulk density and organic matter content of soil It was observed that CO_2 emission was high at higher organic matter content as evident from Fig 23, Fig 24 and Fig 25 The clay or paddy field soil with the higher organic matter content (2 086 per cent)

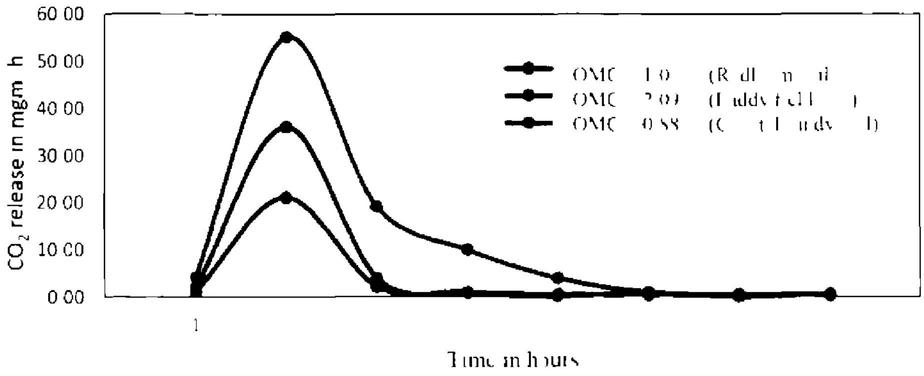

Fig 23 Effect of organic matter on soil CO_2 emission - conventional tillage

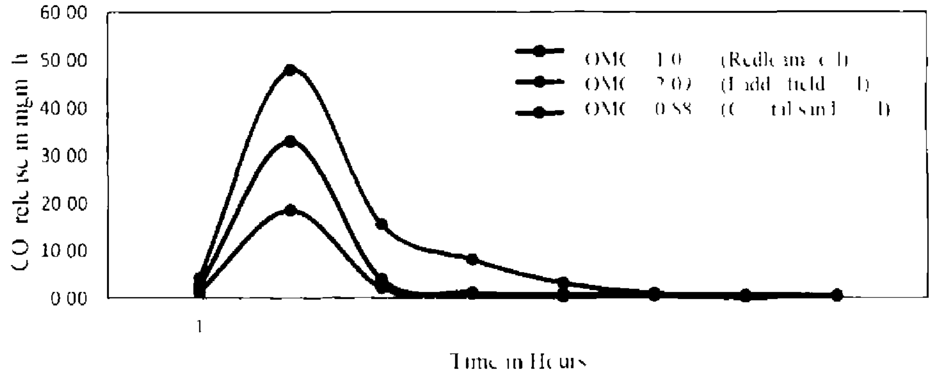

Fig 24 Effect of organic matter on soil CO_2 emission - tillage with cultivator

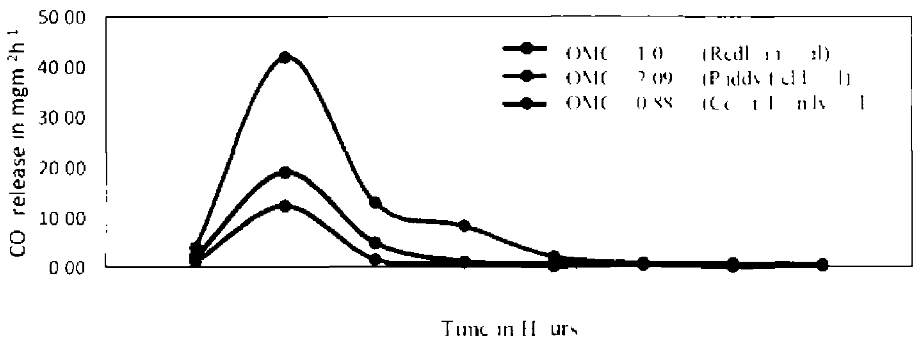

Fig 25 Effect of organic matter on soil CO_2 emission - tillage with rotovator

performed the maximum CO_2 emission under all the three methods of tillage adopted viz conventional tillage (55 25 g m^{2} h^{1}), tillage with cultivator (48 14 g m^{2} h^{1}) and tillage with rotovator (42 17 g m^{2} h^{1}) Followed by red loam with organic matter content 1 068 per cent and CO_2 emission from selected three tillage methods were 36 28 g m^{2} h^{1}, 33 11 g m^{2} h^{1} and 19 28 g m^{2} h^{1} respectively The corresponding observations for the costal sandy soil with organic matter content 0 879 per cent were 21 21 g m^{2} h^{1}, 18 56 g m^{2} h^{1} and 12 55 g m^{2} h^{1} respectively The larger the soil aggregates higher will be the oxidation rate of soil carbon and soil microbial respiration and hence the lower orgamc content in the soil (Mangalassery *et al* 2013) This will reduce the rate of emission of CO_2 due to tillage operations

Logan *et al*, (1991) and Hao *et al*, (2001) reported that continuous tillage causes soil deterioration accompanied by reduction of soil orgamc carbon levels due to increased aeration Angers *et al*, (1993) and Al- Kaisi and Yin, (2005) concluded that tillage accelerates soil CO_2 emission by improving soil aeration, disaggregating soil, increasing the contact between soil and crop residue, and speeding organic carbon decomposition

5.4.3 Effect of soil pH on CO_2 emission

Soil pH generally refers the $\log_{10}$ hydrogen ions (H^+) in the soil solution which has effect on the growth and proliferation of soil microbes Since it is a long term process, no significant influence of pH on CO_2 emission was observed in this study Soil pH in a large extent alters the rates of microbial carbon turnover, and thus can regulate CO_2 emissions Wang *et al*, (2010) reported that soil acidification decreases the CO_2 emission All the researchers had measured soil CO_2 emission due to change in pH in laboratory The significant observations could be made only when the study is being conducted under controlled conditions for a long period of time

5.4.4 Effect of soil temperature on CO_2 emission

The effect of soil temperature on CO_2 emission was significant only after 2 to 3 hours of tillage The data was observed at an interval of 24 hours for 6 days from the date of tillage A corresponding increase in CO_2 emission was observed with increase in soil temperature in all the treatments except in T_3 (red loam + rotovator) as shown in Fig 26, Fig 27 and Fig 28 Boone *et al*, (1998) Davidson *et al*, (1998) reported that due to increase in soil temperature the processes like organic matter decomposition, oxidation, microbial and root activity, and carbon mineralization get accelerated which resulted in increased CO_2 emission

5.4.5 Effect of soil moisture on CO_2 emission

The effect of soil moisture on CO_2 emission was significant only after 2 to 3 hours of tillage The data was observed at an interval of 24 hours for 7 days from the date of tillage A corresponding increase in CO_2 emission was observed with increase in soil moisture in all the treatments as shown in Fig 29, Fig 30 and Fig 31 Soil moisture content affects soil respiration, higher moisture content provides better conditions for microbial habitat activities, increasing microbial oxygen consumption and CO_2 production and emission from soil (Buyanowski and Wagner, 1983) All the studies undertaken in this subject area were done in a long term manner such that the comparison is done between the data of different years or seasons (Omonode *et al*, 2007, Sainju *et al*, 2006) and most of the studies revealed that there is a significant correlation between the soil moisture and the CO_2 emission from the soil

5.4.6 Effect of atmospheric temperature on CO_2 emission

Atmospheric temperature indirectly influences the CO_2 release since the soil temperature and soil moisture content are significantly depended on it The effect of atmospheric temperature could be distinguished only from a long term observation Hence the study could not conclude any significant correlation between atmospheric temperature and CO_2 emission, even though it was present Boone *et al*, (1998)

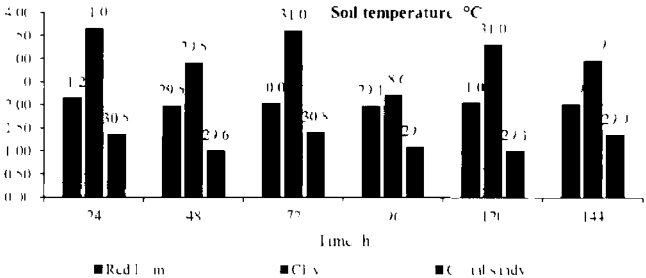

Fig 26 Effect of soil temperature on soil CO_2 emission – conventional tillage

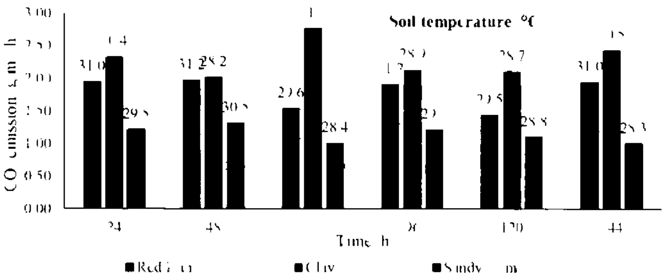

Fig 27 Effect of soil temperature on soil CO_2 emission tillage with cultivator

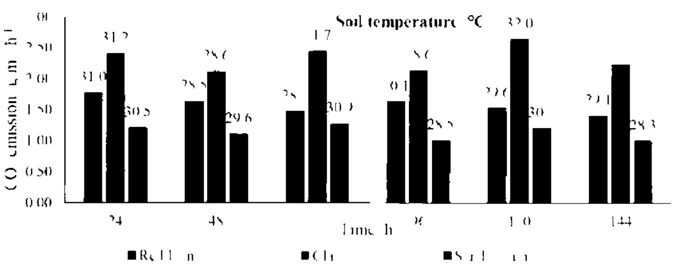

Fig 28 Effect of soil temperature on soil CO_2 emission – tillage with rotovator

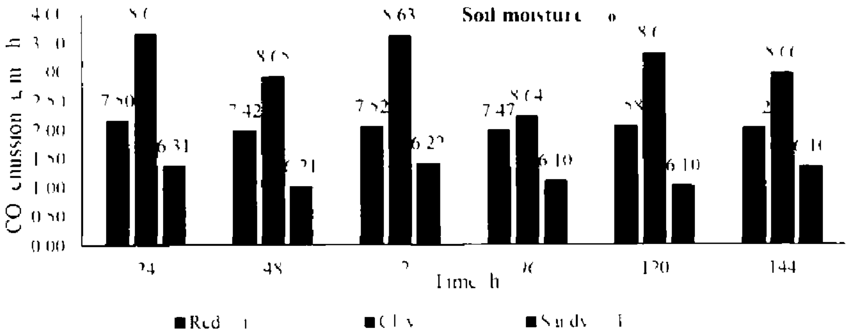

Fig 29 Effect of soil moisture on soil CO_2 emission – conventional tillage

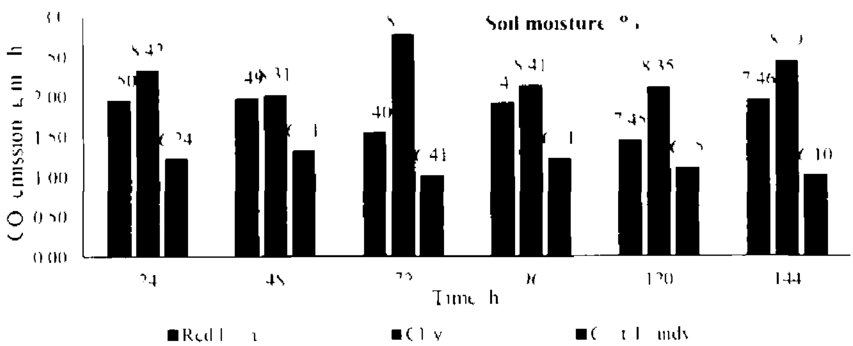

Fig 30 Effect of soil moisture on soil CO_2 emission – tillage with cultivator

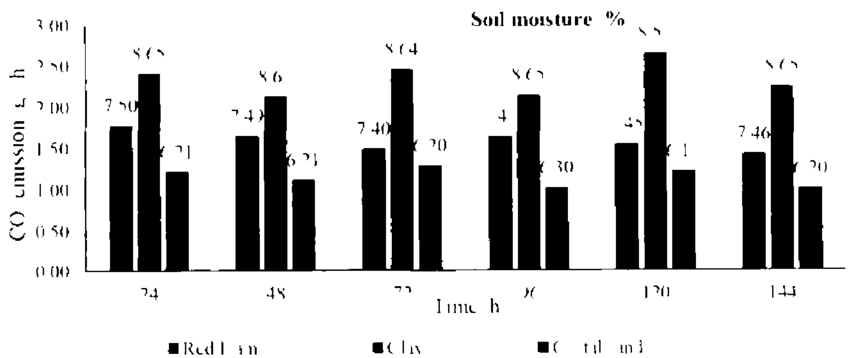

Fig 31 Effect of soil moisture on soil CO_2 emission – tillage with rotovator

Davidson *et al*, (1998) reported that the increase in atmospheric temperature increases the soil temperature and ultimately accelerated CO_2 emission The effect of atmospheric temperature could be distinguished only from a long term observation

5.4.7 Effect of relative humidity on CO_2 emission

Relative humidity indirectly influences the CO_2 release since the soil temperature and soil moisture content are significantly depended on it The effect of relative humidity could be distinguished only from long term observations Hence the study could not conclude and any significant correlation between relative humidity and CO_2 emission, even though it was present

SUMMARY

6. SUMMARY

World soils are an important pool of active carbon and play a major role in the global carbon cycle and have contributed to the changes in concentration of greenhouse gases in the atmosphere Tillage can lead to carbon emission from agricultural soils because of the exposure and subsequent oxidation of previously protected organic matter The study entitled 'Soil CO_2 emission under different tillage practices in red loam/ laterite, clay and coastal sandy soils of Kerala' was carried out at College of Agriculture, Vellayani during October 2014 to August 2015 The objectives of the study included assessment of quantity of CO_2 release from three major soils under different tillage practices and to optimize the tillage practices with minimum CO_2 emission

The study was undertaken during between February to May 2015 The mean precipitation, maximum temperature and minimum temperature during the study period was 400 mm, 32 1°C and 23°C respectively Three soils were selected based on their textural difference and predominance in southern Kerala, were Red Loam (*Typic Haplustult*), Paddy field soil (*Typic Fluvaquent*) and Coastal sandy soil (*Typic Ustipsamments*) Three different mode of tillage selected were conventional method of tillage, tillage with cultivator and tillage with Rotovator The cumulative hourly and daily CO_2 emission from the tilled and undisturbed soil surfaces were measured using portable chamber system

The CO_2 released from the soil and trapped in the chamber was quantified using base trap method with NaOH as base through titration against HCl The results were standardized and represented in $g\ m^{2}\ h^{1}$ The influence of factors such as soil temperature, soil moisture content, organic matter in soil, soil pH, bulk density, atmospheric temperature and relative humidity were also assessed along with the quantification of CO_2 emitted from soil The study was conducted under the statistical frame work, Completely Randomized Design – Single Factor ANOVA

The following findings were obtained from the study

- The maximum CO_2 emission was observed in the Paddy field soil followed by red loam and the least value was observed from the coastal sandy soil
- The conventional tillage resulted in the maximum CO_2 emission followed by the tillage with cultivator and the least value was observed when tilled with rotovator in all the soil types studied
- The major quantity of CO_2 was released just after the breakage of soil in all kind of tillage methods and soil types The release of CO_2 from the soil was almost equal to the undisturbed condition after two hours of ploughing
- In second hour of tillage the CO_2 emission declined drastically irrespective of soil types and tillage mechanisms
- After the second hour of tillage the CO_2 emission recorded the values lower than that of undisturbed soil conditions This trend continued with minor fluctuations corresponding to the changes in soil temperature and soil moisture
- The bulk density of soil and CO_2 emission from soils were negatively correlated in all the tillage practices
- The organic matter content of soil and CO_2 emission from soils were positively correlated in all the tillage practices
- The soil temperature and CO_2 emission from soils were positively correlated in all the tillage practices

- The atmospheric temperature and CO_2 emission from soils were positively correlated in all the tillage practices

- There was no significant correlation obtained between relative humidity and CO_2 emission

- There was no significant correlation obtained between soil moisture and CO_2 emission

From these observations and analysis it could be concluded that tillage with rotovator in any type of soil contribute the minimum CO_2 to atmosphere Whereas conventional method of tillage gives the maximum CO_2 emission and that of tillage with cultivator resulted as intermediate emission

The reduction in emission of CO_2 from soil when tilled with rotovator in comparison with cultivator and conventional tillage was 4% and 6% respectively This contribute a significant reduction in emission of CO_2 when it considered globally Hence this reduction significantly affect the concentration of CO_2 the major greenhouse gas in the atmosphere, ultimately contribute in mitigation of global warming

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7. REFERENCES

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SOIL CO_2 EMISSION UNDER DIFFERENT TILLAGE PRACTICES IN REDLOAM/ LATERITE, CLAY AND COASTAL SANDY SOILS OF KERALA

by

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ABSTRACT OF THESIS

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ABSTRACT

International pressure is increasing on India to adopt a more pro-active role in greenhouse gas emission Hence it is important to develop a clear understanding of our emission inventory towards reducing CO_2 emissions Soils are an important pool of active carbon and tillage can lead to carbon emission from agricultural soils This study aims in assessment of quantity of CO_2 release from three major soils of Kerala (red loam, coastal sandy and paddy field soil) under different tillage practices (conventional, with cultivator and with rotovator) and to optimize the tillage practices with minimum CO_2 emission The CO_2 emission from soil surfaces were measured using base trap method with NaOH as base The influence soil temperature, soil moisture content, organic matter in soil, soil pH, bulk density, atmospheric temperature and relative humidity on CO_2 emission was also assessed The maximum CO_2 emission was observed in the Paddy filed soil followed by red loam and the least value was observed from the coastal sandy The conventional tillage resulted in the maximum CO_2 emission followed by the tillage with cultivator and the least value was observed when tilled with rotovator in all the soil types studied The major quantity of CO_2 was released just after the breakage of soil in all kind of tillage methods and soil types The release of CO_2 from the soil was almost equal to the undisturbed condition after two hours of ploughing The bulk density of soil was negatively correlated, organic carbon content was positively correlated, soil temperature was positively correlated and atmospheric temperature was positively correlated with CO_2 emission from soils in all the tillage practices No significant correlation was obtained between relative humidity and soil moisture with CO_2 emission It could be concluded that tillage with rotovator in any type of soil contribute the minimum CO_2 to atmosphere This contribute a significant reduction in emission of CO_2 when it considered globally This reduction significantly affect the concentration of CO_2 the major greenhouse gas in the atmosphere, ultimately contribute in mitigation of global warming