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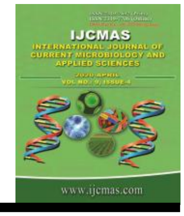

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Effect of Tillage Methods on CO_2 Emission from Red Loam Soil of Kerala

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A B S T R A C T

Soils are an important pool of active carbon and tillage can lead to carbon emission from agricultural soils. This study aimed in assessment of quantity of CO_2 release from red loam, the major soil of Kerala 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 were assessed. 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. The major quantity of CO_2 was released just after the breakage of soil in all kind of tillage methods and became 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 the red loam soil in all the tillage practices. No significant correlation was obtained between relative humidity and soil moisture with CO_2 emission. Tillage with rotovator contributes the minimum CO_2 to atmosphere and significantly affects the concentration of CO_2 in the atmosphere, ultimately contribute in mitigation of global warming.

Introduction

Global warming has often been described as one of the most serious environmental problems ever to confront humanity, as it is inextricably linked to the process of development and economic growth itself. 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 (Houghton *et al.*, 1983; Keeling and Whorf, 1994).

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. 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 (Pandey, 2002; Tubiello and Ewert, 2002; Uri, 2000; Ugalde *et al*., 2007; Calfapietra *et al*., 2010).

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 (Jensen *et al*., 1996; Reth *et al*., 2005; Carlisle *et al*., 2006). 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). 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*., 2007).

Tillage is the mechanical manipulation of soil, affects soil microbial activity, organic matter decomposition, and soil carbon loss in agricultural systems (Logan *et al*., 1991; Angers *et al*., 1993; Hao *et al.*, 2001a; Al-Kaisi and Yin, 2005). Tillage processes and mechanisms leading to carbon loss are directly linked to soil productivity, soil properties and environmental issues (Rastogi *et al*., 2002; La Scala *et al*., 2006; Teixeira, 2011).

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 (Silva-Olaya *et al.*, 2013; Farhate *et al*., 2018; Rosa *et al*., 2019). The environmental and economic benefits of less intensive tillage demand consideration in the development of improved management practices for sustainable agricultural production (Ray, *et al*., 2015). 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 (Valerie, *et. al*., 1983; Raich and Schlensinger, 1992; Johnson *et al.*, 1994; Davidson *et al*., 1998; Rastogi *et al*., 2002; Strong *et al*., 2004; Omanode *et al.*, 2007; Beare *et al*., 2009; Zhang *et al*., 2012; Bilgili *et al*., 2013).

The present study was undertaken to quantify the CO_2 release from Redloam soil of Kerala under three different tillage systems with the objectives.

- To quantify the CO_2 emission from Redloam soil of Kerala under three different tillage practices.
- To assess the effect of different soil parameters and atmospheric parameters on emission of CO_2 from the selected soil after specific tillage practices.
- To optimize the tillage practices for minimum soil CO_2 emission.

Materials and Methods

The study was conducted at the Instructional Farm, College of Agriculture, Vellayani, Kerala Agricultural University and farmer's field nearby. The geographical coordinates of Instructional farm Vellayani is Latitude 8°35" N, Longitude 76°59" E at 25 m above MSL.

The farm was characterized by undulated topography with soil type red loam (*Typic Rhodustult*), under vegetable cultivation. The annual precipitation of the study area was 1850 mm, maximum temperature is 34°C and minimum temperature is 21°C.

Soil: 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 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 soil. A variety of crops such as coconut, banana, yams, pineapple, vegetables, fruit trees etc. can be grown under proper management.

Method of tillage

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.

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 for the study.

Tillage with cultivator

A cultivator, though a secondary tillage farm implement, 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. 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. For the study, 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.

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. For the study, 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.

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.

Collection chamber

A moulded transparent plastic box with height 20 cm, width 30 cm, and length 34 cm (Fig. 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.

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 gets 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. The beaker with solution was placed above the soil surface and closed with collection chamber. The NaOH 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.

The cumulative hourly releases of CO2 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. After adding the indicator the solution turned to pink in colour. The endpoint was disappearance of this pink colour (Fig. 2). 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:

$$2\,NaOH + CO_2 \qquad Na_2CO_3 + H_2O$$
$$NaOH + HCl \qquad NaCl + H_2O$$

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.

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.

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.

Results and Discussion

Effect of tillage on CO_2 emission

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. 3, 4 and 5. The trend of plotted 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.

Enhanced release of CO_2 immediately after tillage associated with the release of CO_2 stored in soil pores (Ellert and Janzen, 1999; Lopez-Garrido *et al.*, 2009). Then 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 (Calderon *et al.*, 2000). After 2 to 3 hours of tillage, the emission of CO_2 was lesser than that of undisturbed soil condition (Moussadek *et al.*, 2011) when the soil gets dried and release of CO_2 from exposed area was completed.

It was evident from observations that, the CO_2 released was higher in rate under the conventional tillage practices (Fig. 3) with the maximum value of 36.28 g m^{-2} h^{-1} while that under tillage with cultivator (Fig. 4) and the same with rotovator (Fig. 5) 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.

The primary tillage 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. The CO_2 emission was three times higher in the disked soil, than the CO_2 emission from the undisturbed soil. Also observed that the CO_2 fluxes from the soil was higher in the conventional tillage immediately after tillage than reduced tillage and no tillage (Calderon and Jackson, 2002; Moussadek *et al.*, (2011).

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. 4). 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. 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 (Rastogi *et al*., 2002; Teixeira, 2011).

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. 5). 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 (Álvaro-Fuentes *et al.*, 2007). In contrast, the two no-tillage treatments have only 12 to 33% reduction during the same period (2 hours after tillage operations).

Effect of tillage on CO_2 emission in relation to bulk density

Estimation of the bulk density of the selected soil was done with volumetric method and expressed in g cm^{-3} or Mg m^{-3}. The 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 (Fig. 6).

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). Bulk density was negatively correlated in all the tillage practices.

Effect of tillage on CO_2 emission in relation to organic matter content (OMC)

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 (Fig. 6). It was observed that CO_2 emission 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}in conventional tillage, 33.11 g m^{-2} h^{-1} in tillage with cultivator and 19.28 g m^{-2} h^{-1} in tillage with rotavator. Organic matter content in the soil was positively correlated in all the tillage practices

The soil temperature and the CO_2 release are positively correlated in all the tillage practices except in the case of tillage with rotovator. 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. The temperature and the CO_2 release were positively correlated in all the tillage practices except in the case of tillage with rotovator. 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.

Fig.1 Collection chamber with NaOH solution

Fig.2 Endpoint – disappearance of pink colour

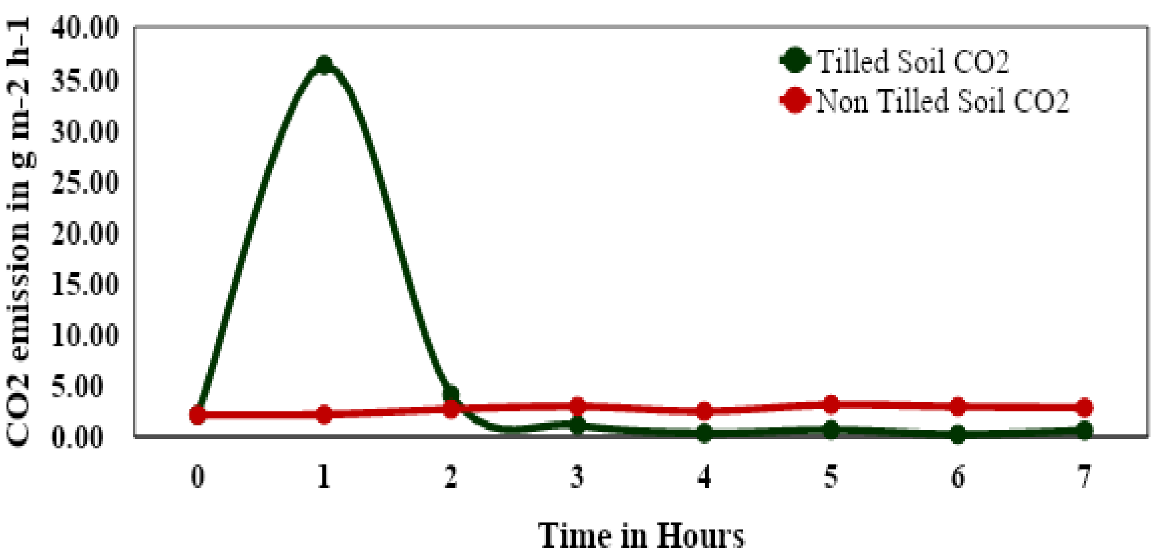

Fig.3 Hourly CO_2 emission under conventional tillage

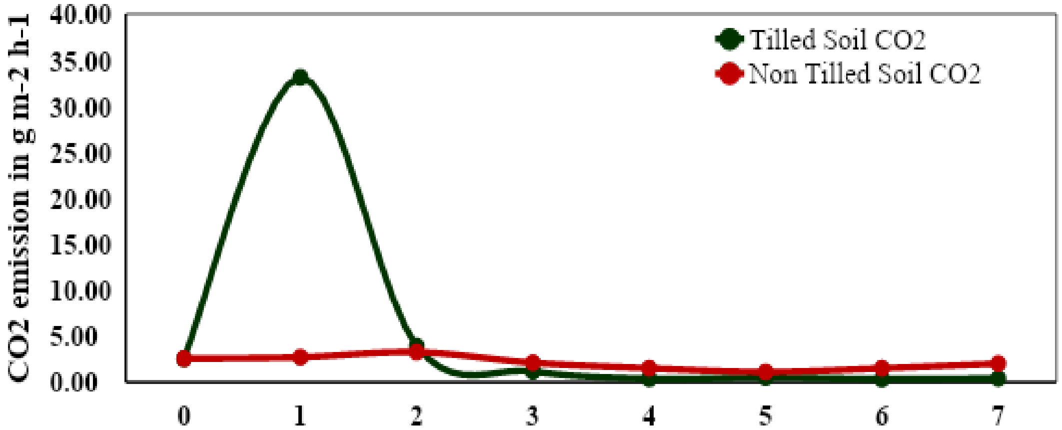

Fig.4 Hourly CO_2 emission under tillage with cultivator

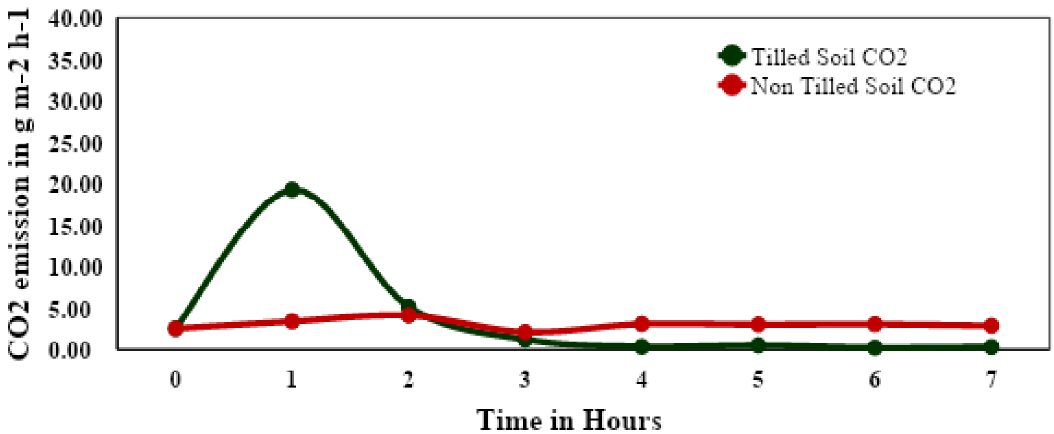

Fig.5 Hourly CO_2 emission under tillage with rotovator

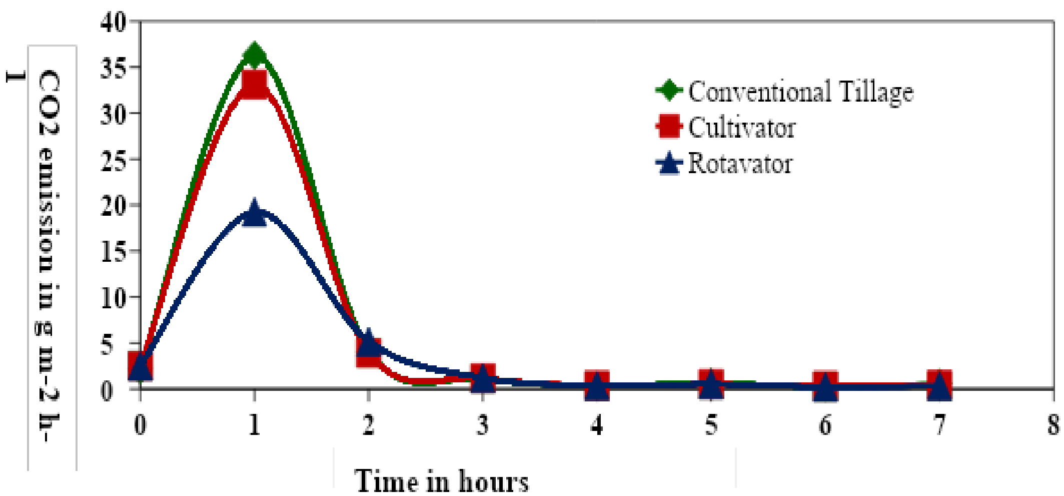

Fig.6 Effect of Tillage on CO_2 emission at 1.07 % OMC

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.

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.

World soils are an important pool of active carbon and tillage can lead to carbon emission because of the exposure and subsequent oxidation of previously protected organic matter. The 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. In second hour of tillage the CO_2 emission declined drastically irrespective of 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.

Tillage with rotovator in redloam 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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