

Soil CO₂ Emission under Different Tillage Practices in Major Soils of Kerala

**S. Toufeeq¹, D. Dhalin^{2*}, Seena R. Subhagan³, Dipak S. Khatawkar⁴,
B. Aparna⁵ and M. Ameena⁶**

¹ACCER, Kerala Agricultural University, India.

²FPM, CoA, Kerala Agricultural University, India.

³RARS, Ambalavayal, Kerala Agricultural University, India.

⁴Department of FPME, KCAET, Kerala Agricultural University, India.

⁵SS&AC, CoA, Kerala Agricultural University, India.

⁶AgonomyC, CoA, Kerala Agricultural University, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors ST and DD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SRS and DSK managed the analyses of the study. Authors BA and MA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i1130639

Editor(s):

(1) Dr. Teresa De Pilli, University of Foggia, Italy.

Reviewers:

(1) Antoninho Valentini, Brazil.

(2) Juvy G. Mojares, Batangas State University, Philippines.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/57245>

Original Research Article

Received 07 March 2020

Accepted 12 May 2020

Published 24 May 2020

ABSTRACT

International responsibility is increasing in 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 Carbon dioxide (CO₂) emissions. Soils are an important pool of active carbon and tillage can lead to carbon emission from agricultural soils. This study assess the quantity of CO₂ release from three major soils (red loam, coastal sandy and paddy field soil) of Kerala under different tillage practices (conventional, with cultivator and with rotovator) and to optimize the tillage practices with minimum CO₂ emission. The CO₂ emission from soil surfaces was measured using base trap method with Sodium hydroxide (NaOH) as base. The influence of soil temperature, soil moisture content, organic matter in soil, soil pH, bulk density, atmospheric temperature and relative humidity on CO₂ emission was assessed. The conventional tillage resulted in the maximum CO₂ emission

*Corresponding author: E-mail: dhalin.d@kau.in, dhalindharan@gmail.com;

followed by the tillage with cultivator and the least value was observed when tilled with rotovator. The maximum CO₂ emission was observed in the paddy field soil followed by red loam and the least value was observed from the coastal sandy. The major quantity of CO₂ 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 CO₂ emission from the red loam soil in all the tillage practices. No significant correlation was obtained between relative humidity and soil moisture with CO₂ emission. Tillage with rotovator contributed the minimum CO₂ to atmosphere and significantly affects the concentration of CO₂ in the atmosphere, ultimately contribute in mitigation of global warming.

Keywords: Global warming; tillage; CO₂ emission; cultivator; rotovator.

1. INTRODUCTION

Climate change due to rapid increase of carbon dioxide is a newcomer to the international political and environmental agenda, but scientists have been working on the subject for decades [1,2]. 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 [3]. International pressure is increasing on India and other large, rapidly developing countries to adopt a more proactive role. It is, therefore, important to develop a clear understanding of emission inventory [4,5]. Measuring soil CO₂ emission is crucial to accurately evaluate the effect of soil management practices on global warming and carbon cycling, since agriculture is one of the major contributors of CO₂ to atmosphere [6,7, 8,9,10].

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 [11,12]. Soil carbon dynamics can have an indirect effect on climate change through net absorption or release of CO₂ from the soil to the atmosphere in the natural carbon cycle [13,14,15]. CO₂ 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 [16]. 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 [1,17]. Tillage is the mechanical manipulation of soil, affects soil microbial activity,

organic matter decomposition, and soil carbon loss in agricultural systems [18,19,20,21]. Tillage processes and mechanisms leading to carbon loss are directly linked to soil productivity, soil properties and environmental issues [22,23,24]. The magnitude of CO₂ loss from the soil due to tillage practices is highly related to the frequency and intensity of soil disturbance caused by tillage [25,26,27].

The environmental and economic benefits of less intensive tillage demand consideration in the development of improved management practices for sustainable agricultural production [25,28]. The rate of soil CO₂ emission is normally controlled by several factors, such as CO₂ 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 [29,30,31,32,33,34,23,26,35,36,37].

The present study was undertaken to quantify the CO₂ release from three major soils of Kerala under three different tillage systems (conventional tillage, tillage with cultivator and tillage with rotovator) and to optimize the tillage practices for minimum soil CO₂ emission.

2. 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 Mean Sea Level (MSL). The farm was characterized by undulated topography with soil type red loam (*Typic Rhodustult*), paddy field soil (*Typic Fluvaquent*) and coastal sandy soil (*Typic Ustipsammets*). The annual precipitation of the study area was

1850 mm, maximum temperature is 34°C and minimum temperature is 21°C.

2.1 Soil

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

2.2 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.

2.3 Clay or Paddy Field Soil (Typic Fluvaquent)

These soils are very deep, imperfectly drained, highly clayed, 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 CO₂ emission happens only from dry soil, while emission from wetland is methane (CH₄) due to the anaerobic decomposition of plant residue.

2.4 Coastal Sandy Soils (Typic Ustipsamments)

The coastal sandy soils are very deep, well drained, sands on very gently sloping subdued coastal sand dunes. 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.

2.5 Method of Tillage

The amount of CO₂ released into the atmosphere differed with different tillage systems and the

amount lost was related to the amount of soil disturbance.

2.6 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.

2.7 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.

2.8 Tillage with Rotovator

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.

2.9 Measurement of CO₂ Release

The cumulative CO₂ emission from the tilled and undisturbed soil surfaces were measured using

portable chamber system [38]. Measurements were typically made by measuring the rise in CO₂ concentrations inside the chamber by the base trap method using NaOH as base.

2.9 Collection Chamber

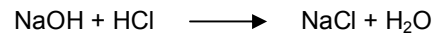
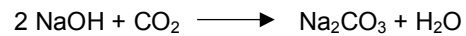
A moulded transparent plastic box with height 20 cm, width 30 cm, and length 34 cm (Fig. 1) was used as the collection chamber to trap and collect the CO₂ release from soil. The area of release was then standardized to 1 m² by multiplying the data observed with a factor 9.8. The chamber was placed in the tilled soil up to a depth of 5 cm [39] and the outer side walls were covered with soil, till the soil surface to prevent escape of CO₂ 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.

2.10 Measurement of CO₂ Release from the Soil Using Base Trap Method

The base trap method is a static measurement method for CO₂, where NaOH was used as base [40,41]. When the solution gets exposed to CO₂ emitted from the soil, it reacts to form Sodium carbonate (Na₂CO₃). The quantity of CO₂ absorbed was measured through titration of Na₂CO₃ against Hydrochloric acid (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 CO₂ available inside the chamber which is the sum of atmospheric CO₂, CO₂ released due to the oxidation of carbon present in the soil and CO₂ released due to microbial activity in presence of atmospheric oxygen and moisture from soil to form Na₂CO₃. The sample was shifted to the lab without further contact with air. The cumulative hourly release of CO₂ from the selected area due to the said reasons was calculated by titration of Na₂CO₃ with 0.1 N 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 CO₂ absorbed by NaOH, ultimately the cumulative amount of CO₂ released from the soil.

The reaction equations are:



2.11 Standardization of Data

The result from the titration procedure was in mg of CO₂, which is the amount of CO₂ released from the chamber area of 0.102 m². This was converted to quantity of CO₂ released from m², the unit area by multiplying with the factor 9.8. Since the result represent the cumulative quantum of CO₂ 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.



Fig. 1. Collection chamber with NaOH solution



Fig. 2. Endpoint – disappearance of pink colour

2.12 Other Parameters Influencing CO₂ Emission from Soil

Studies have shown that factors such as soil temperature, soil moisture content, presence of organic matter in the field [42], soil pH [43], bulk density [39], atmospheric temperature and relative humidity [44] also influence the CO₂ release from the soil surface to atmosphere.

2.13 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 CO₂ emission and various parameters viz., soil temperature, atmospheric temperature, relative humidity and soil moisture was computed.

3. RESULTS AND DISCUSSION

3.1 Effect of Tillage on CO₂ Emission

The data observed on hourly basis were standardized to g m⁻² h⁻¹ of CO₂ released and represented graphically as shown in Fig. 3 to Fig. 11. The trend of plotted data as shown in figures evident that, major quantity of CO₂ was released just after the breakage of soil in all kind of tillage methods. The maximum value of CO₂ emission was observed in the application of conventional tillage in paddy field soil (55.25 g m⁻² h⁻¹), red loam soil (36.28 g m⁻² h⁻¹) and coastal sandy soil (21.215 g m⁻² h⁻¹). The minimum value of CO₂ emission was observed in the application of rotovator in coastal sandy soil (12.55 g m⁻² h⁻¹), redloam soil (19.28 g m⁻² h⁻¹) and paddy field soil (42.17 g m⁻² h⁻¹).

The release of CO₂ from the soil was almost equal to the undisturbed condition after two

hours of ploughing. In second hour of tillage the CO₂ emission declined drastically irrespective of soil types and tillage mechanisms. The percentage of decrease of CO₂ emission was reduced from ⁽⁻⁾92 to ⁽⁻⁾95 per cent for red loam and coastal sandy soils. But that of paddy field soil it ranges from 79 to 86 per cent. After the second hour of tillage the CO₂ 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. Immediate release of CO₂ from organic matter content due to the microbial activities in presence of atmospheric oxygen (microbial respiration) also observed within two hours after tillage [45]. Enhanced release of CO₂ immediately after tillage associated with the release of CO₂ stored in soil pores. Then there was a decrease in the soil microbial respiration after tillage hence a decrease in the CO₂ flux from the soil after the tillage. After 2 to 3 hours of tillage, the emission of CO₂ was lesser than that of undisturbed soil condition when the soil get dried and release of CO₂ from exposed area was completed [40,41].

It was evident from observations that, the CO₂ released was higher in rate under the conventional tillage practices (Fig. 3, Fig. 6 and Fig. 9). 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 CO₂ both from soil carbon and carbon from organic matter get accelerated. The conventional method of tillage resulted in the highest initial CO₂ flux and its maintenance may because of disturbed soil depth was high which caused the formation of rougher surface and larger voids in the tilled soil. Similarly lower CO₂

fluxes were caused by tillage associated with low soil disturbance and small voids.

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 CO₂ also reduced (Fig. 4, Fig. 7 and Fig. 10). As seen in conventional method the release of CO₂ 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 CO₂ from exposed area was completed. The amount of carbon lost in the form of CO₂ 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.

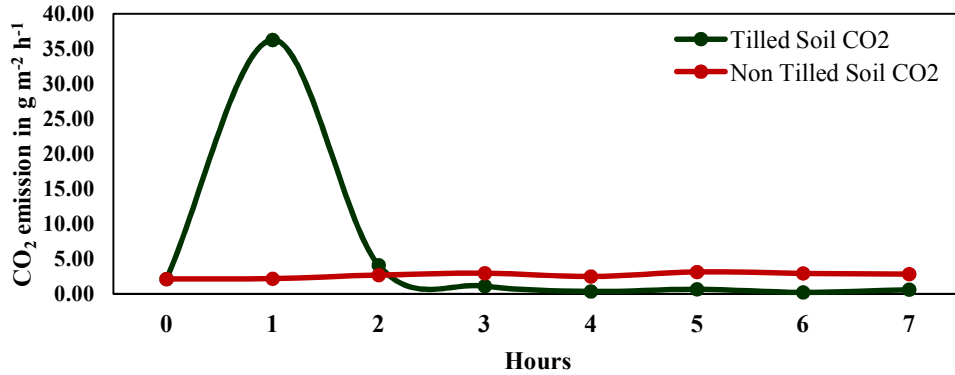


Fig. 3. CO₂ emission from red loam soil under conventional tillage

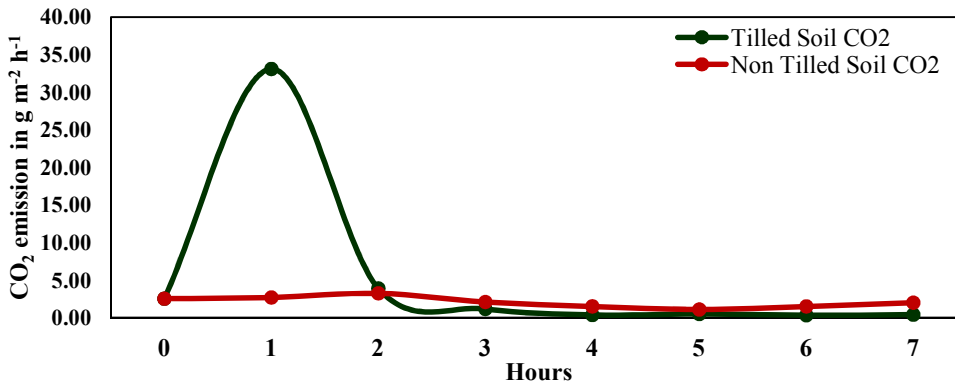


Fig. 4. CO₂ emission from red loam soil under tillage with cultivator

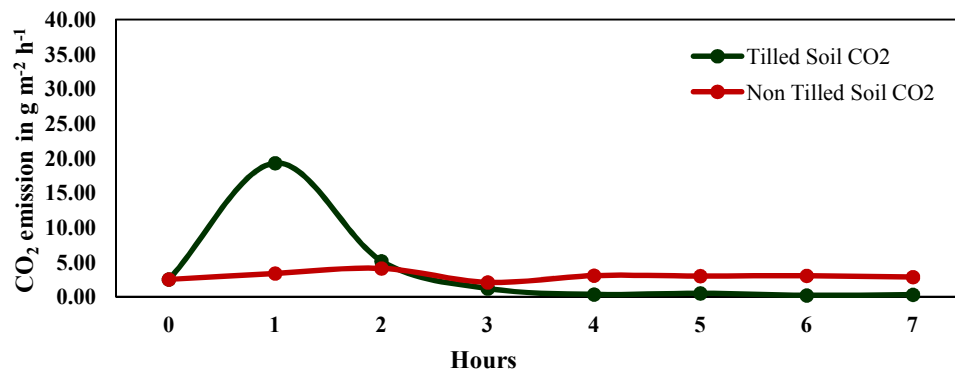


Fig. 5. CO₂ emission from red loam soil under tillage with rotovator

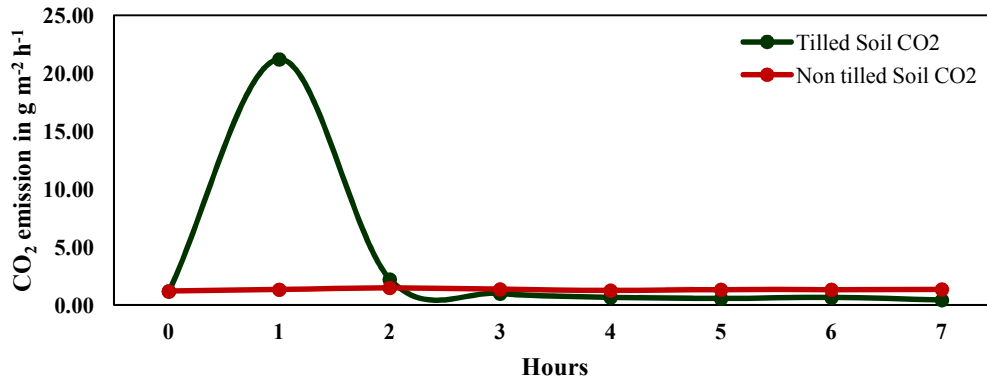


Fig. 6. CO₂ emission from coastal sandy soil under conventional tillage

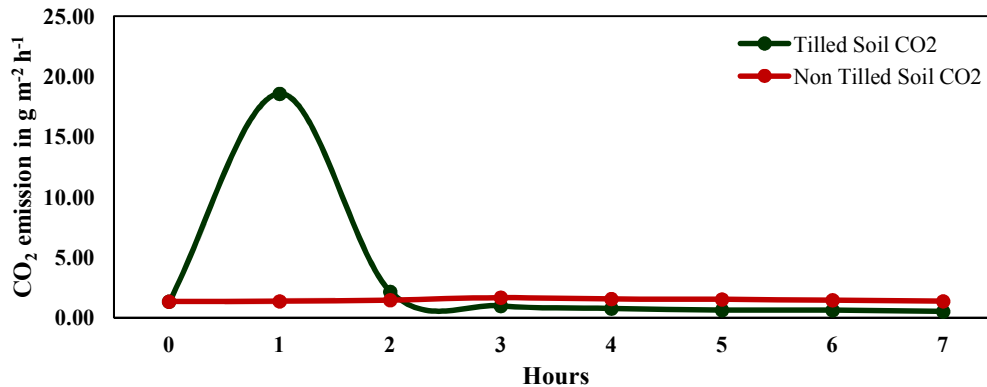


Fig. 7. CO₂ emission from coastal sandy soil under tillage with cultivator

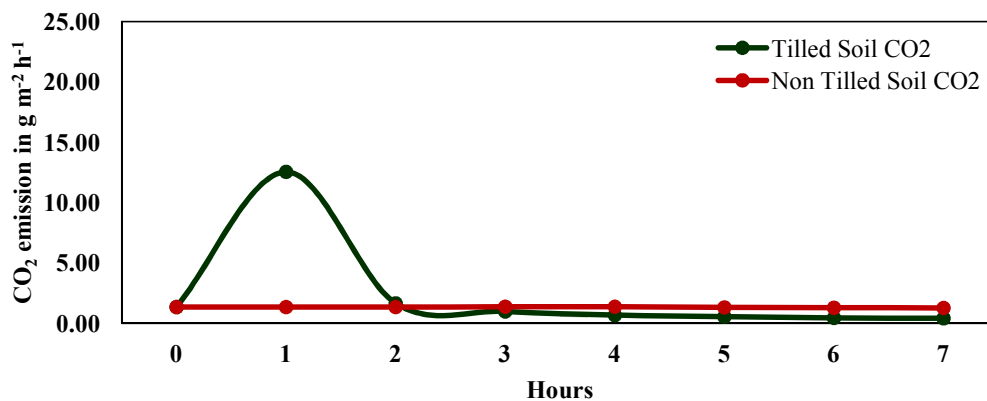


Fig. 8. CO₂ emission from coastal sandy soil under tillage with rotovator

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 CO₂ also reduced (Fig. 5, Fig. 8 and Fig. 11). 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 restricts 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 CO₂ 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 CO₂ from exposed area was completed [38]. The CO₂ flux soon after soil disturbance has been related to the depth of tillage and the degree of soil disturbance [46,22,39,24].

The paddy field soil with the lower bulk density (1.14 g cm⁻³) performed the maximum CO₂ emission under all the three methods of tillage adopted followed by red loam with bulk density 1.41 g cm⁻³ and finally costal sandy soil with bulk density 1.58 g cm⁻³. 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 [47]. This reduces the rate of emission of CO₂ due to tillage operations [29, 48].

3.2 The Tillage Practices for Minimum Soil CO₂ Emission

From these observations and analysis it could be concluded that tillage with rotovator in any type of soil contribute the minimum CO₂ to atmosphere. Whereas conventional method of tillage (especially with primary tillage implements) gives the maximum CO₂ emission [22,24] and that of tillage with cultivator resulted as intermediate emission [22,23,24]. The reduction in emission of CO₂ 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 CO₂ when it considered globally. Hence this reduction significantly affect the concentration of CO₂, the major greenhouse gas in the

atmosphere, ultimately contribute in mitigation of global warming.

It was also observed that CO₂ emission was high at higher organic matter content. The clay or paddy field soil with the higher organic matter content (2.086 per cent) performed the maximum CO₂ emission under all the three methods of tillage adopted followed by red loam with organic matter content 1.068 per cent and finally the costal sandy soil with organic matter content 0.879 per cent. The larger the soil aggregates higher will be the oxidation rate of soil carbon and soil microbial respiration and hence the lower organic content in the soil [47]. This will reduce the rate of emission of CO₂ due to tillage operations. Tillage accelerates soil CO₂ emission by improving soil aeration, disaggregating soil, increasing the contact between soil and crop residue, and speeding organic carbon decomposition [18,19].

The soil temperature and the CO₂ release are positively correlated in all the tillage practices except in the case of tillage with rotovator [49,31]. The temperature and the CO₂ 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 CO₂ emission from the soil were related to each other in a way such that as the temperature increases the CO₂ emission also increases. The relative humidity and the CO₂ release were not correlated in all the tillage practices. From these it was evident that the relative humidity and the CO₂ emission from the soil has not any significant relationship between them. The soil moisture and the CO₂ release were not correlated in all the tillage practices. From these it was evident that the soil moisture and the CO₂ emission from the soil have not any significant relationship between them.

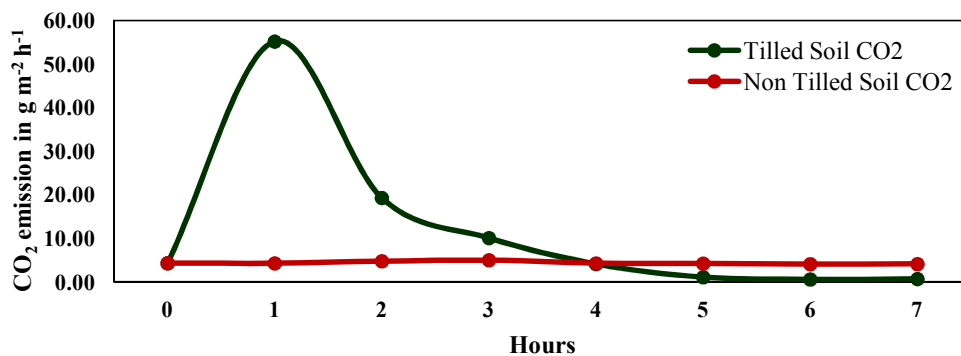


Fig. 9. CO₂ emission from paddy field soil under conventional tillage

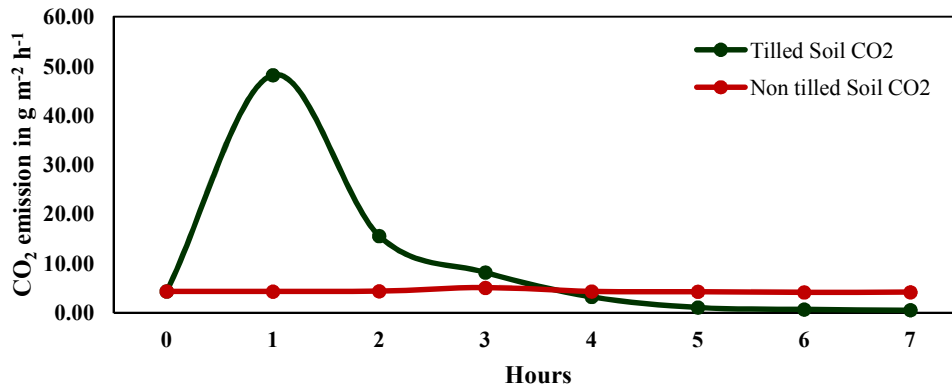


Fig. 10. CO₂ emission from paddy field soil under tillage with cultivator

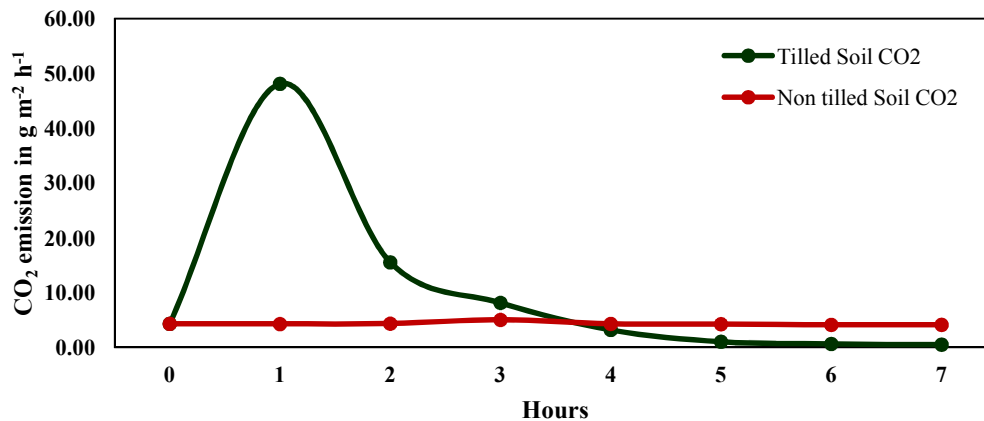


Fig. 11. CO₂ emission from paddy field soil under tillage with rotovator

4. CONCLUSION

The major quantity of CO₂ was released just after the breakage of soil in all kind of tillage methods. The release of CO₂ from the soil was almost equal to the undisturbed condition after two hours of ploughing. In second hour of tillage the CO₂ emission declined drastically irrespective of tillage mechanisms. After the second hour of tillage the CO₂ 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 conventional tillage resulted in the maximum CO₂ emission followed by the tillage with cultivator and the least value was observed when tilled with rotovator in all the soil types studied. The tillage with rotovator in any type of soil contributes the minimum CO₂ to atmosphere. The reduction in emission of CO₂ from soil when tilled with rotovator in comparison

with cultivator and conventional tillage was 4% and 6% respectively. This contributes a significant reduction in emission of CO₂ when it considered globally. This reduction significantly affects the concentration of CO₂, ultimately contribute in mitigation of global warming.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Post WM, Peng TH, Emmanuel WR, King AW, Dale VH, De Angelis DL. The global carbon cycle. *Am. Sci.* 1990;78:310-326.
2. Wood FP. Monitoring global climate change: The case of greenhouse warming. *Am Metereol Soc.* 1990;71(1):42-52.

3. Rolston DE. Gas flux. In: A. Klute (ed.) Methods of soil analysis. Part 1. Physical and mineralogical methods. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI. 1986;1103-1119.
4. Houghton RJ, Hobbie, Melillo JM. Changes in the carbon content of terrestrial biota between 1860-1980: A net release of CO₂ to the atmosphere. Ecological Monograph. 1983;53:235-262.
5. Keeling CD, Whorf TP. Atmospheric CO₂ records from sites in the SIO air sampling network. In: Boden, T.A., Kaiser, D.P., Sepanski, R.J., Stoss, F.W. (Ed.), Trends 1993: A Compendium of Data on Global Change. CDIC, ORNL, Oak Ridge, TN. 1994;16–26.
6. Calfapietra C, Gielen B, Karnosky D, Ceulemans R, Mugnozza SG. Response and potential of agroforestry crops under global change. J. Env Pollution. 2010;158: 1095–1104.
7. Pandey DN. Carbon sequestration in agro forestry systems. Climate Policy. 2002;2: 367-377.
8. Tubiello FN, Ewert F. Simulating the effects of elevated CO₂ on crops: Approaches and applications for climate change. European J. Agron. 2002;18:57-74.
9. Ugalde D, Brungs A, Kaebnick M, McGregor A, Slattery B. Implications of climate change for tillage practice in Australia. Soil and Tillage Research. 2007; 97:318-330.
10. Uri ND. Conservation practices in US agriculture and their implication for global climate change. Science of the Total Environment. 2000;256:23-38.
11. Houghton RA, Hackler JL, Lawrence KT. The U.S. carbon budget: Contributions from land-use change. Science. 1999;285: 574-577.
12. Schlesinger WH. Changes in soil carbon storage and associated properties with disturbance and recovery. In: Tralhalha JR, Reichle DE. (ed.) The Changing Carbon Cycle: A Global Analysis. Springer–Verlag, New York. 1985;194-220.
13. Carlisle EA, Steenwerth KL, Smart DR. Effects of land use on soil respiration: Conversion of oak woodlands to vineyards. J. Envl. Qual. 2006;35:1396–1404.
14. Jensen LS, Mueller T, Tate RK, Ross DJ, Magid J, Nelson NE. Soil surface CO₂ flux as an index of soil respiration *in situ*: A comparison of two chamber methods. Soil Biol. and Biochem. 1996;28:1297-1306.
15. Reth S, Reichstein M, Falge E. The effect of soil water content, soil temperature, soil pH-value and the root mass on soil CO₂ efflux - a modified model. Plant and Soil. 2005;268:21-33.
16. Krauss M, Ruser R, Muller T, Hansen S, Mader P, Gattinger A. Impact of reduced tillage on greenhouse gas emissions and soil carbon stocks in an organic grass-clover ley - winter wheat cropping sequence. Agriculture, Ecosystems & Environment. 2017;239(15):324-333.
17. Reicosky DC, Archer DW. Moldboard plow tillage depth and short-term carbon dioxide releases. Soil and Tillage Res. 2007;94: 109-121.
18. Al-Kaisi MM, Yin X. Tillage and crop residue effects on soil carbon and carbon dioxide emission in corn–soybean rotations. J. Envl. Qual. 2005;34:437–445.
19. Angers DA, N'dayegamiye A, Cote D. Tillage induced difference in organic matter of particle-size fractions and microbial biomass. Soil Sci. Soc. Am. J. 1993;57: 512–516.
20. Hao X, Chang C, Lindwall CW. Tillage and crop sequence effects on organic carbon and total nitrogen content in an irrigated Alberta soil. Soil and Till. Res. 2001;62: 167-169.
21. Logan TJ, Lal R, Dick WA. Tillage systems and soil properties in North America. Soil Tillage Res. 1991;20:241-270.
22. La Scala N, Bolonhezi D, Pereira GT. Short-term soil CO₂ emission after conventional and reduced tillage of a no-till sugar cane area in southern Brazil. Soil Tillage Res. 2006;91:244-248.
23. Rastogi M, Singh S, Pathak H. Emission of carbon dioxide from soil. Current Science. 2002;82:510-517.
24. Teixeira LG, Fukuda A, Panosso AR, Lopes A, La Scala N. Soil CO₂ emission as related to the sugarcane crop residues incorporation and aggregates break after rotary tillage Eng. Agric. 2011;31:1075-84.
25. Farhate CVV, Souza ZM, La Scala N, Sousa ACM, Santos APG, Carvalho JLN. Soil tillage and cover crop on soil emissions from sugarcane fields. Soil Use Manag. 2018;35:273–282.

26. Rosa CB, Oscar VG, Rafaela OF, Manuel MG, Gottlieb B, Amir K, Miguel ARRT, Emilio JGS. The effect of conservation agriculture and environmental factors on CO₂ emissions in a rain fed crop rotation. *Sustainability*. 2019;11:3955.
27. Silva-Olaya AM, Cerri CEP, La Scala N, Dias CTS, Cerri CC. Carbon dioxide emissions under different soil tillage systems in mechanically harvested sugarcane. - *Environ. Res. Lett. IOP Publishing*. 2013;8:015014
28. Ray D, Gerber JS, MacDonald GK, West PC. Climate variation explains a third of global crop yield variability. *Nat. Commun*. 2015;6:5989.
29. Beare MH, Gregorich EG, St-Georges P. Compaction effects on CO₂ and N₂O production during drying and rewetting of soil. *J. Soil Biol. and Biochem*. 2009;41: 611–621.
30. Bilgili AV, Yilmaz G, Ikinici A. Modeling temporal variability of soil CO₂ emissions from an apple orchard in the Harran Plain of southeastern Turkey. *Turkish J. Agri. and Forestry*. 2013;37:744-761.
31. Davidson EA, Belk E, Boone RD. Soil water content and temperature as independent or confounded factors controlling soil respiration in a temperate mixed hardwood forest. *Global Change Biol*. 1998;4:217–227.
32. Johnson D, Geisinger D, Walker R, Newman J, Vose J, Elliot K, Ball T. Soil CO₂, soil respiration, and root activity in CO₂-fumigated and nitrogen-fertilized ponderosa pine. *Plant Soil*. 1994;165:129-138.
33. Omonode RA, Vyn TJ, Smith DR Hegymegi P, Gal A. Soil carbon dioxide and methane fluxes from long-term tillage systems in continuous corn and corn - soybean rotations. *Soil and Tillage Res*. 2007;95:182-195.
34. Raich JW, Schlen Singer WH. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. *Tellus*. 1992;44B:81-99.
35. Strong DT, Dewever H, Merckx R, Recous S. Spatial location of carbonate composition in the soil pore system. *European Journal of Soil Science*. 2004; 55:739–750.
36. Valerie AO, Cook FJ. Relationship between soil respiration and soil moisture. *Soil Biol. Biochem*. 1983;15:447-453.
37. Zhang S, Li Q, Zhang X, Wei K, Chen L, Liang W. Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. *Soil and Tillage Res*. 2012;124:196–202.
38. Reicosky DC, Lindstrom MJ. Fall tillage methods: Effect on short-term carbon dioxide flux from soil. *Agron. J*. 1993;85(6): 1237-1243.
39. Moussadek R, Mrabet R, Dahan R, Douaik A, Verdoodt A, Ranst EV, Corbeels M. Effect of tillage practices on the soil carbon dioxide flux during fall and spring seasons in a Mediterranean Vertisol. *J. Soil Sci and Envl. Management*. 2011;2:362-369.
40. Ellert BH, Janzen HH. Short-term influence of tillage on CO₂ fluxes from a semi-arid soil on the Canadian Prairies. *Soil and Tillage Res*. 1999;50:21–32.
41. Lopez-Garrido R, Diaz-Espejo A, Madejon E, Murillo JM, Moreno F. Carbon losses by tillage under semi-arid Mediterranean rainfed agriculture (SW Spain). *Spanish J. Agri. Res*. 2009;7:706-716.
42. Moore TR, Dalva M. The influence of temperature and water table position on carbon dioxide and methane emissions from laboratory columns of peat land soils. *Journal of Soil Science*. 1993;44:651-664.
43. Jabro JD, Sainju UM, Stevens WB, Evans RG. Carbon dioxide flux as affected by tillage and irrigation in soil converted from perennial forages to annual crops. *J. Envl. Management*. 2008;88:1478-1484.
44. Kirschbaum MUF. The temperature dependence of soil organic matter decomposition and the effect of global warming on soil organic carbon storage *Soil Biol. Biochem*. 1995;27:753-760.
45. Calderon FJ, Jackson LE, Scow KM, Rolston DE. Microbial responses to simulated tillage in cultivated and uncultivated soils. *J. Soil Biol. Biochem*. 2000; 32:1547–1559
46. Dao TH. Tillage and crop residue effects on carbon dioxide evolution and carbon storage in a Paleustoll. *Soil Sci. Soc. Am. J*. 1998;62:250–256.
47. Mangalassery S, Sjoegersten S, Sparkes DL, Sturrock CJ, Mooney SJ. The effect of soil aggregate size on pore structure and its consequence on emission of greenhouse gases. *Soil and Tillage Res*. 2013; 132:39-46.

48. Marland G, Garten Jr. CT, Post WM, West TO. Studies on enhancing carbon sequestration in soils. *Energy*. 2004;29: 1643-1650.
49. Boone RD, Nadelhoffer KJ, Canary JD, Kaye JP. Root exerts a strong influence on the temperature sensitivity of soil respiration. *Nature*. 1998;396:570–572.

© 2020 Toufeeq et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/57245>