Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 9 (12): 2307-2312, 2009
ISSN 1812-5654

Evaluating Carbonic Greenhouse Gasses Emission and Organic Carbon Balance from Soils under Current Agricultural Land Used

R. Zalaghi and A. Landi
Department of Soil Science, Faculty of Agriculture, Shahid Chamran University, Ahwaz, Iran

Abstract: This study have been conducted for evaluating agricultural practices and crop type effects on greenhouse gasses (GHG) emissions and soil carbon balance. Due to increase of GHGes in recent decades and their affect on Global warming, study of their emission from agricultural regions, seems to be necessary. The most important GHGes are carbon dioxide and methane. Carbon dioxide is increasing at the rate of 5% a year. Burning fuel and changing land use are two major human activities that result in this increase. Methane has a greenhouse effect as 21 times greater as CO_2. At this study carbonic GHGes emissions from 3 fields were measured at Khuzestan Province in Iran. Experiment was conducted at 3 fields including rice-follow rotation (F_1), follow-wheat rotation (F_2) and melon-wheat rotation (F_3); with 8 time sampling and with 3 repeats in completely randomized block design. Chamber method and gas chromatograph technique were used to measure CH_4 and CO_2 emission. Results showed that the highest amount of emission is related to CO_2 and total emission is greatest for F_1. This might be due to remaining crop residuals in this field and release of this gas during residuals decomposition. Average of methane emission was greatest for F_1 (2.222 mg C m^{-2} day^{-1}) and greatest emission was measured at near the rice harvest time on October, while the field 2 was a sink for atmospheric methane with mean of -0.106 (mg C m^{-2} day^{-1}) and it was not significant difference with field 3 (zero). Methane emission from soils is depending on long paddy conditions at soil and these conditions are performing in rice cultivation.

Key words: Greenhouse gasses, agricultural regions, rotation, emission, sink

INTRODUCTION

Soils with higher Organic Matter (OM) have higher exchange capacity and buffering ability (Stevenson and Cole, 1999). Organic matter is the main source of greenhouse gas (GHG) emissions from the soil (Post and Kwon, 2000).

Carbon is being transformed in organic and inorganic forms continually at carbon cycle. Therefore, mineralization and organization are two basic processes at carbon cycle. So, atmospheric carbon and soil-plant carbon are important. Carbon interring to plant-soil system is known as carbon fixation and its exiting is known as carbon loss (Rees *et al*., 2005). Most carbon loss occurs during respiration where soil Organic Carbon (OC) and plant absorbed carbon (by photosynthesis) release into atmosphere in the form of CO_2 (Stevenson and Cole, 1999). Usually soil organic matter loss is caused by converting natural lands to agriculture farms; soil respiration includes plant root and microorganisms respiration (Stevenson and Cole, 1999). Soil management plays an important role in carbon loss through respiration (Rees *et al*., 2005).

Organic carbon loss process is influenced by environmental factors such as ground water (Sanchez *et al*., 2003), soil temperature and moisture (Parashar *et al*., 1993; Rochette *et al*., 2000; Von *et al*., 2005), soil texture and structure, tillage, Dissolved Organic Carbon (DOC) (Rochette *et al*., 2000), microbial biomass, nitrogen mineralization (Kaiser *et al*., 2005), physical properties (Kimble *et al*., 1998), sun radiation, precipitation (Mattila *et al*., 2003), plant type (Maljanen *et al*., 2004), root respiration, discharge (Vose *et al*., 1995), mineral fertilizers (Rees *et al*., 2005) and the addition of organic residuals (Khalil *et al*., 2005).

Smith *et al*. (2000) had estimated the agriculture lands as the greatest bio-source of carbon loss in Europe.

Lou *et al*. (2004) used static chamber for measuring CO_2 emission in China's agriculture lands. They found that it had the greatest correlation with soil temperature and then with soil moisture, microbial biomass and DOC.

Schimel and Clein (1991) and Raich and Schlesinger (1992) found that soil moisture and temperature are two important factors that have direct effects on plant roots and soil microbial activity and have indirect effects on soil physical and chemical properties.

Corresponding Author: Roya Zalaghi, Department of Soil Science, Faculty of Agriculture, Shahid Chamran University, Ahwaz, Iran

Because of high potential for agriculture and two crops in a year in Khuzestan, farmers usually burn crop residuals of the first planting and immediately till the soil and plant the second crop. This causes high amount of CO_2 emissions during the burning.

Carbonic GHGes includes CO_2 and CH_4 that have communication with soil sources and agriculture practices.

Lal and Kimbel (1995) stated that atmospheric CO_2 is increasing at the rate of 5% a year. They said a significant increase is started from 1850 and believe burning fuel and changing land use are two major human activities that result in this increase.

Methane is one of the most important greenhouse gasses with a 10 year life time and with 21 times as much greenhouse effect as CO_2 in 100 years (Neue *et al*., 1995). It is the most abundant carbonic gas at atmosphere after CO_2. Methane concentration at troposphere is 1.6 to 1.8 ppmv and it is increasing with the rate of 0.8 to 1% a year (Khalil *et al*., 2005).

Different greenhouse gas emissions had been differentially affected by soil moisture and among them, major methane emissions is from paddy and logged lands.

Rice is grown in different agriculture ecosystems, but the biggest distribution (55% of fields) is in the form of paddy fields and the most yields (75% rice world yield) are from these fields (Olszyka *et al*., 1999). These fields are logged for most of growth period, so, anaerobic conditions emerge at these fields that result in CH_4 production and emission (Neue, 1993; Olszyka *et al*., 1999).

It seems to be a positive correlation between increasing the rice fields and atmospheric CH_4 concentration in recent years. There are about 145 million ha of rice agricultural field all over the world. Khuzestan Province with 50 to 60×10^3 ha of rice field is one of important rice producing areas in Iran. Most rice fields are in Ahvaz with straight plantation.

The amount of CH_4 emission from rice fields depends on plant growth and availability of carbonic material in soil that is affected by plant conditions, irrigation regime, fertilizers type and amount, crop organic material returning to soil and seasonal climate. It is significantly changed by rice type, fertilizers, irrigation time and extra factors depicting the role of management in the emission of CH_4 (Neue, 1993; Neue *et al*., 1996).

Transmission of CH_4 from soil to atmosphere is mostly through rice plant. CH_4 diffuses from rice rhizosphere to rice stem and moves through rice shoot tube and then go away to atmosphere through leave pores (Olszyka *et al*., 1999).

At this study for evaluating the effect of crop type and season on carbonic GHGes emissions and carbon balance, the CO_2 and CH_4 emissions from rice-follow, follow-wheat and melon-wheat rotations have been measured and carbon balance of these fields calculated during one year. So, it is possible to resulting that which fields are source of GHG emissions and which fields are sink for them.

MATERIALS AND METHODS

Study site: This study was conducted in 3 fields 12 km away from Ahvaz around 48° 27' 50" West to 48° 28' 59" East and from 31° 13' 45" South to 31° 14' 1" North.

Field 1 (F_1) with 100 ha rice- follow rotation, field 2 (F_2) with 100 ha follow-wheat rotation and field 3 (F_3) with 100 ha wheat rotation were selected and 15 ha from each field were studied.

Layout and experiment design: These fields were saline and alkaline lands in the past and were bare or covered by halophyte plants. Plant covers in non-agricultural spaces are Acacia SP, Atriplex SP, Chenopodiaceae family, Alhage SP and ext.

These fields have been planted since 5 to 12 years ago.

F_1 was planted from 5 years ago and was used for wheat crop for the first three years and for rice- fallow for two recent years. Rice variety is Red Anbory (local variety).

The 250 to 300 kg ha^{-1} nitrogen fertilizer (in the form of urea), 50 kg ha^{-1} triple super phosphate and 100 to 150 kg ha^{-1} potassium sulfate were used for rice field.

Nitrogen fertilizer was used as 100 kg N ha^{-1} at planting time and rest at two times during the plant growth. During rice growth period field was continually soaked. Rice residuals were remained at the field and added to the soil with spring tillage. Rice planting at this area starts at the beginning of summer and harvest time is at the middle fall (with 110 to 125 days growth period).

F_2 has been planted from 8 years ago and has dominantly been used to planting wheat in the fall and has been fallowed in the summer (at least in 5 recent years). Fertilizers used in this field include 250 kg ha^{-1} N fertilizer (in 3 periods), 100 kg ha^{-1} triple super phosphate and 150 kg ha^{-1} potassium sulfate yearly. This field was irrigated 4 times during wheat growth period and crop residuals were burned before tillage in the middle of fall.

F_3 has been planted from 7 years ago and during the past 5 years; it was used for two crops a year. First plantings at this field usually contained melon, water melon, cucumber and grains in summer and second planting was usually wheat in the fall. This field was

Table 1: Soil analysis of the fields

Field	Texture	Gypsum (meq/100 g)	Lime (%)	CEC (cmol kg^{-1})	pH	EC (dS m^{-1})	SP (%)	P_b (g cm^{-3})
F_1	SCL	2.7-4.2	46.0-47.0	19.2-19.4	7.7-7.8	8.3-8.4	57-58	1.35-1.37
F_2	SCL	2.6-6.5	48.5-48.7	18.1-18.4	7.9-8.1	7.5-8.5	53-54	1.32-1.38
F_3	SCL	2.5-3.8	47.5-47.7	16.0-16.2	7.2-7.3	5.4-5.6	53-55	1.38-1.40

Table 2: Average OC loss in the form of GHG (ton/ha/year)

Field	CH_4-C	CO_2-C	Total C
F_1	8.11×10^{-3}	3.65	3.66
F_2	0.39×10^{-3}	1.86	1.86
F_3	0.00×10^{-3}	2.68	2.68

irrigated by Karoon River 10 to 13 times during summer and 4 to 5 times during fall and crop residuals were burned before fall tillage. Fertilizers used on this field contained 200 kg h^{-1} N fertilizer and 100 kg h^{-1} triple super phosphate during the first planting and 200 kg h^{-1} N fertilizer (3 times during plant growth), 100 kg h^{-1} triple super phosphate and 100 kg h^{-1} potassium sulfate during the second planting.

The experiment was a split-plot design with randomized complete block design. Crop type (F_1, F_2 and F_3) were the main plot, time sampling (8 times) were the sub-plots and all treatments were replicated trice.

Soil sampling: Soil sampling was carried out for 30 cm of soil surface in the summer of 2006 and 3 mixed samples for each field were provided. Soil samples air dried and passed through 2 mm sieve and were analyzed for soil texture, Electrical Conductivity (EC), soil saturation percentage, soil saturation acidity (pH), soil lime using contrary titration, Cation Exchange Capacity (CEC) with sodium acetate method, bulk density with core method, gypsum percentage by titration (Table 1).

Furthermore, soil sampling from 5 different depths to 110 cm was carried out using auger 8 times during the year (two times for each season) and organic carbon was determined by walkey black method. Then the average for each season was calculated (Table 2).

Plant sampling: Plant samplings from rice, wheat and melon were performed with a 20×30 cm plot, 8 times along with the soil and air samplings. Plant samples were dried and scaled to determine the field's biomass.

Air sampling: Nine static chambers were built to collect the gasses. Chambers framework was built from poly-ethylene tube with 1 cm thickness and 20 cm diameter. One side of tubes was locked with transparent polyethylene with 1 cm thickness and two orifices were shebanged for a specific pipe (for air sampling) and a thermometer in the middle of framework.

Chambers with 1 m height were considered for rice field. Although rice plant do not produce methane, but because of air tube; it is a major way for methane to escape from soil to atmosphere (about 50 to 80% of total methane emission). It is necessary that plant place in chamber. On the other hand, to measure net soil carbonic gas emission, a few chambers with 40 cm heights were put at spaces without plant with waterlogged soil to measure CO_2 and CO in F_1. Chambers with 40 cm heights for F_2 and F_3 were put in the soil near the plants. To collect soil air, chambers placed at fields and 5-7 cm inserted into soil and packed with mud, then after 4 h air sampling done with a 60 mL syringe and thermometer was read. Air sampling has been done 8 times during this study. One hour after sampling air samples were translocated to the laboratory and were read by a Gas Chromatograph (GC) system with FID (Flame Ionization Detector) and TCD (Thermal Conductivity Detector) detectors. To calculate the initial gas in chamber, air sampling from 2 m free air was also done for the blank. To get net emission blank readings was subtracted from samples readings, so; some what that gas absorbed through soil emission is negative. Reading data then revised for standard temperature and calculated on the base of carbon emission mass from surface at time unit. Calculations were done with Excel software and results analyzed with SPSS (version 13) software.

RESULTS AND DISCUSSION

Gasses emission amounts are near as reported by Jrecki and Lal (2006) (Table 2). Results show that average carbon losses in the form of CO_2 and CH_4 are significantly different among the fields. Total emission is greatest for F_1 and the highest amount of emission is related to CO_2. This might be due to decomposition of remaining crop residuals in this field. But in two other fields, residuals were burned and large amounts of CO_2 were released to atmosphere. In F_3, because of two crops in a year, more residuals added to soil and more CO_2 emission was observed compared to F_2 (Fig. 1, 2).

Increase in CO_2 emission after October in F_1 is because of rice harvest at the end of October and start of aerobic condition which increase residuals degradation that produce CO_2. In F_2 and F_3 because of soil plow and wheat plant at November CO_2 emission increase. Carbon

Table 3: OC % process during time

Depth (cm)	1988	Field	Summer	Fall	Winter	Spring	2006 average	Yearly increase
0-10	0.39	1	0.61	0.83	0.66	0.57	0.67	0.016
		2	0.46	0.53	0.67	0.55	0.55	0.009
		3	0.55	0.60	0.59	0.57	0.58	0.011
10-20	0.29	1	0.48	0.66	0.59	0.54	0.57	0.016
		2	0.32	0.40	0.60	0.53	0.46	0.009
		3	0.46	0.53	0.55	0.51	0.51	0.012
20-40	0.22	1	0.37	0.53	0.48	0.43	0.45	0.013
		2	0.26	0.34	0.45	0.40	0.36	0.008
		3	0.38	0.45	0.44	0.42	0.42	0.011
40-60	0.18	1	0.20	0.25	0.21	0.20	0.22	0.002
		2	0.25	0.30	0.36	0.30	0.30	0.007
		3	0.26	0.40	0.42	0.41	0.37	0.010
60-110	0.16	1	0.17	0.18	0.18	0.17	0.18	0.001
		2	0.17	0.17	0.17	0.17	0.17	0.001
		3	0.17	0.18	0.18	0.18	0.18	0.001

Table 4: OC balance at 30 cm surface soil of fields (ton/ha/year)

			Exit amount	
Field	Yearly increase	Entrance amount (crop residuals)	Biomass burning	Gas emission
F_1	0.662	3.7-4.7	0.0	3.66
F_2	0.375	3.5-4.2	1.9-2.3	1.86
F_3	0.400	5.5-6.0	3-3.3.0	2.68

dioxide emission is greater for F_1 and F_3 rather than F_2, probably because of higher OC in F_1 and F_3. Organic carbon changes with time are shown in Table 3.

Methane emission in F_1 is greatest too and emission is highest in October. This time is end of rice growth and start of harvest, so highest reduction condition and highest CH_4 emission have been exist. Due to aerobic condition in F_2 and F_3, CH_4 emission is very low and zero, respectively.

Organic carbon amount changes: Many parameters such as soil formation factors including parent material, climate, topography, plant cover and time affect OC amount. Organic carbon changes is very small, but some factors such as land use type, land management, soil humidity condition and irrigation and specific plant covering existence can strongly change it. Due to same soil series and same soil properties in the selected fields (Table 1), OC changes is related to environmental factors.

Organic matter measurement from different depths of these lands was carried out 18 years ago. This has been done 8 times during the year (two times a season) for the purpose of this study. Average amounts for each season appear in Table 3. Significant increase in OC amounts because of agricultural operation was observed and this increase is greatest in F_1. Results show carbon balance is positive and soil OC has increased during the time. Despite high temperature in the summer time, rice cultivation brings humidity and temperature to that level which microbial activity could take place and decomposition of residuals goes on due to this process and increased at the end of dry season.

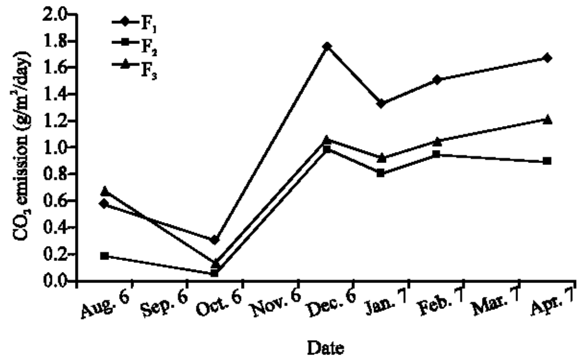

Fig. 1: CO_2 emission from fields

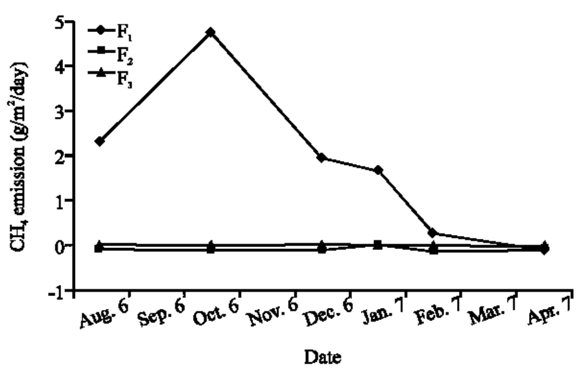

Fig. 2: CH_4 emission from fields

Soil carbon balance: Carbon balance is calculated from the differences between carbon entrance and losses in the year (Table 4).

Major part of OC entrance is from crop residuals and carbon losses include erosion, residual burning and gas emission. Organic materials were not added to these fields due to the field's history, so OC entrance is only from crop residuals. Organic carbon loss by surface erosion is zero or very little because of very low gradient, so OC exit is due to residuals burning and gas emission. With regard to soil bulk density, yearly OC increasing amounts calculate for ton at hectare at year scale. It is possible to calculate additional OC to soil with measuring the dry residuals biomass, considering that 35% of residuals dry weight is OC approximately. Burned biomass regarding that the upper biomass after harvest is 50 to 60% of total biomass (upper plus inner biomass) was calculated. Gas emission amounts were measured during this study. Biomass burning was not performed in F_1, so major amount of additional residuals loss is in gas form. In F_3, two plantings was done during the year and more crop residuals added to soil but major amount of this lost with burning, so remained OC and also gas emission is less than F_1. F_2 with one planting a year and burning the biomass has minor OC yearly increase as well as gas emission.

REFERENCES

Jrecki, M.K. and R. Lal, 2006. Compost and mulch effects on gaseous flux from an alfisol in Ohio. J. Soil Sci., 171: 249-260.

Kaiser, C., H. Meyer, C. Biasi, O. Rusalimova, P. Barsukov and A. Richter, 2005. Storage and mineralization of carbon and nitrogen in soils of a frost-boil tundra ecosystem in Siberia. J. Applied Soil Ecol., 29: 173-183.

Khalil, M.I., M.B. Hossain and U. Schmidhalter, 2005. Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. J. Soil Biol. Biochem., 37: 1507-1518.

Kimble, J.M., R.F. Follett and C.V. Cole, 1998. The Potential of US Cropland to Sequester Carbon and Mitigate the Greenhouse Effect. 1st Edn., Ann Arbor Press, Chelsea, MI, USA., 157504112X, pp: 128.

Lal, R. and J. Kimble, 1995. Soils and Globle Change In: Advances in Soil Science. 1st Edn., CRC Press, Boca Raton FL, USA., 156670118X, pp: 1-2.

Lou, Y., Z. Li, T. Zhang and Y. Liang, 2004. CO_2 emissions from subtropical arable soils of China. J. Soil Biol. Biochem., 36: 1835-1842.

Maljanen, M., V.M. Komulainen, J.T. Hytonen, P.J. Martikainen and J. Laine, 2004. Carbon dioxide, nitrous oxide and methane dynamics in boreal organic agricultural soils with different soil characteristics. J. Soil Biol. Biochem., 36: 1801-1808.

Mattila, P.K., E. Joki-Tokola and R. Tanni, 2003. Effect of treatment and application technique of cattle slurry on its utilization by ley. Part II. Recovery of nitrogen and composition of herbage yield. Nutrient Cycling Agroecosyst., 65: 231-242.

Neue, H.U., 1993. Methane emission from rice fields: Wetland rice fields may make a major contribution to global warming. Biosci., 43: 466-474.

Neue, H.U., R. Wassmann and R.S. Lantin, 1995. Mitigation Options for Methane Emissions from Rice Fields. In: Climate Change and Rice, Peng S., K. Ingram, H.U. Neue and L. Ziska (Eds.). Springer-Verlag, Berlin, UK., 3540589066, pp: 136-144.

Neue, H.U., R.L. Lantin, M.C.R. Alberto, J.B. Aduna, M.A. Javellana and R. Wassmann, 1996. Factors affecting methane emission from rice fields. Atmos. Environ., 30: 1751-1754.

Olszyka, D.M., H.G.S. Centeno, L.H. Ziska, J.S. Kern and R.B. Matthews, 1999. Global climate change, rice productivity and methane emissions: Comparison of simulated and experimental results. J. Agric. For. Meteorol., 97: 87-101.

Parashar, D.C., K. Gupta, J. Rai, R.C. Sharma and N. Singh, 1993. Effect of soil temperature on methane emission from paddy fields. Chemosphere, 26: 247-250.

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

Raich, J.W. and W.H. Schlesinger, 1992. The global carbondioxide flux in soil respiration and its relationship to vegetation and climate. Tellus, 44: 81-99.

Rees, R.M., I.J. Bingham, J.A. Baddeley and C.A. Watson, 2005. The role of plants and land management in sequestering soil carbon in temperate arable and grassland ecosystems. Geoderma, 56: 125-132.

Rochette, P., D.A. Angers and D. Cote, 2000. Soil carbon and nitrogen dynamics following application of pig slurry for the 19th consecutive year: I. Carbon dioxide fluxes and microbial biomass carbon. Soil Sci. Soci. Am. J., 64: 1389-1395.

Sanchez, M.L., M.I. Ozores, M.J. Lopez, R. Colle, M.A. De Torre and G.I. Pérez, 2003. Soil CO_2 fluxes beneath barley on the central Spanish plateau. Agric. For. Meteorol., 118: 85-95.

Schimel, J.P. and J.S. Clein, 1991. Microbial response to freeze-thaw cycles in tundra and taiga soils. Soil Biol. Biochem., 28: 1061-1066.

Smith, P., D.S. Powlson, J.U. Smith, P.D. Falloon and K. Coleman, 2000. Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture. Global Change Biol., 6: 525-539.

Stevenson, F.J. and M.A. Cole, 1999. Cycles of Soil: Carbon, Nitrogen, Phosphorous, Sulfur and Micronutrients. 2nd Edn., Wiley and Sons Inc., Tronto, Canada, ISBN-10: 0471320714.

Von A.K., M. Nilsson, B. Hanell, P. Weslien and L. Klemedtsson, 2005. Fluxes of CO_2, CH_4 and N_2O from drained organic soils in deciduous forests. Soil Biol. Biochem., 37: 1059-1071.

Vose, J.M., K.J. Elliott and D.W. Johnson, 1995. Soil CO_2 Flux in Response to Elevated Atmospheric CO_2 and Nitrogen Fertilization: Patterns and Methods. In: Advances in Soil Science: Soils and Global Change, Lal, R., J. Kimble, E. Levine and B.A. Stewart (Eds.). CRC Press, USA., ISBN: 1-56670-118-X/95/.