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EFFECT OF TEMPERATURE AND HUMIDITY IN SOIL CARBON DIOXIDE EMISSION

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ABSTRACT

Carbon dioxide (CO_2) emissions from terrestrial ecosystems have a global impact, and one of the most important of these is the greenhouse effect. Results demonstrated that the highest CO_2 emissions were observed in apple cultivated fields, the least were found in cultivated land. The soil CO_2 emission was measured as 54.47 g CO_2 m^{-2} $week^{-1}$ when the soil temperature was maximum (39.54°C) and the soil moisture was minimum (1.46%) and when the soil temperature was minimum (5.20 ° C) and soil moisture was maximum (18.77%) soil CO_2 emissions was measured 49.89 g CO_2 m^{-2} $week^{-1}$. Soil CO_2 emission was 36.98 g CO_2 m^{-2} $week^{-1}$ at the point where the soil moisture was maximum (29.93 %) and the soil temperature was 9.47 °C. Soil CO_2 emission was at its maximum (74.04 g CO_2 m^{-2} $week^{-1}$) where soil temperature was 31.95 °C and soil moisture was 6.10 %.

Keywords: PVC container, CO_2 emissions, soil respiration, greenhouse effect.

INTRODUCTION

Soil respiration is the most important component of terrestrial carbon cycle that occurs in terrestrial ecosystems. A large part of terrestrial ecosystems, soil respiration is among the main processes of carbon (CO_2) transfer from terrestrial ecosystems into the atmosphere (Bond-Lamberty and Thomson, 2010; Fiedler *et al*., 2015). Carbon dioxide released from the soil that exists in all ecosystems has a global effect, and the most significant character of this effect is that it causes greenhouse effect. Greenhouse effect is a natural characteristic of our atmosphere and prevents the transfer of the heat created by greenhouse gasses to the outer space, causing the atmosphere to get warmer. Human activities since the industrial revolution resulted in a rapid increase of greenhouse gasses in the atmosphere. Probably, this rapid increase is the cause of several environmental outcomes to occur gradually such as global warming, elevation of the sea level, change in precipitation regimes and severe storms (IPCC, 2014).

Most of the carbon released to the atmosphere is originated through agricultural activities. Based on 2011 data, 37.8% of all land available on earth is used for agricultural purposes (FAOSTAT, 2011). As a result, a large portion of global soil respiration is created by agricultural land utilization (5.2 Mg C ha^{-1} yr^{-1}) (Chen *et al*., 2010; Zahra *et al*., 2016). There are three sources of soil respiration. These are (i) soil organic matter (SOM), (ii) dead vegetation residue, and (iii) organisms living in soil. The activities of these sources change throughout the year (Atarashi-Andoh *et al*., 2012) and generally depends on the soil moisture and temperature (Xu and Luo., 2012). Soil moisture and temperature also affect microbial activity (Kim *et al*., 2012). Strong relationships between soil moisture and temperature and soil CO_2 respiration rates have been identified (Rey *et al*., 2011; Sugihara *et al*., 2012; Forrester *et al*., 2012). Furthermore, soil respiration changes based on vegetation type, management applications, environmental conditions and land utilization types (Giardina *et al.*, 2014; Angert *et al*., 2015; Wagan *et al*., 2016).

Increasing significance of soil respiration resulted in several studies that focus on the subject matter. Several studies were conducted to model soil CO_2 emissions and the parameters that affect these emissions. Exponential functions were used in modeling soil CO_2 emissions and the relationship between soil temperatures and CO_2 was defined using the same model (Lloyd and Taylor, 1994). This type of modeling is only valid for soil CO_2 emissions. The temperature model should be calibrated for the unique conditions of the field of study. The process includes daily maximum and minimum soil and ambient temperatures. It was developed using the methods that were utilized to measure soil CO_2 emissions. Today, the measurements are generally conducted using chamber-based methods. After the measurements were conducted, CO_2 is predicted for the period between the measurement dates using the fundamental models. Until now, certain basic approaches were proposed to measure the effect of cultivation on CO_2 flow in soil. In these models, a correlation of breaking up of organic carbon in the soil and soil respiration was assumed and first degree kinetic approaches were used in both models. However, parameters required for these models are specific to the soil and the land and not suitable for unknown factors (Fiedler *et al.,* 2015).

Generally, soil CO_2 flux amount was measured in such studies. In this study, the effect of internal temperature of PVC container was investigated on the amount of CO_2 flux from the soil. Because, in this studies, the area to be measured was closed with the PVC container during the incubation period.

In the present study, the effect of internal temperature and moisture of PVC containers used in studies conducted on soil carbon emissions, which are measured with traditional methods such as soda-lime and similar methods.

MATERIALS AND METHODS

Materials: The present study was conducted in GAP Agricultural Research Institute Directorate test fields between the 36° 53' 38" N latitude and 36° 55' 16" E longitude at Harran plain. Carbon dioxide was measured in fields with different cultivation conditions (apple, pomegranate, vineyard, cultivated and uncultivated) (Figure 1) during 2014-2016 years for 24 months. Elevation of the test field is 379 m above the sea level. The region where the study was conducted has arid and semi-arid climate with temperate winters and arid and hot summers. According to long-term climate data (1954 – 2013), the highest temperature was observed in July (46.8°C), and the lowest was observed in February with -9.6 °C. Mean temperature (59 years) demonstrate that the highest mean temperatures were observed in the month of July (31.9°C), whereas the lowest mean temperatures were in January (5.6°C). Annual net evapotranspiration in Harran plain is approximately 2.221 mm (DMİ, 2014).

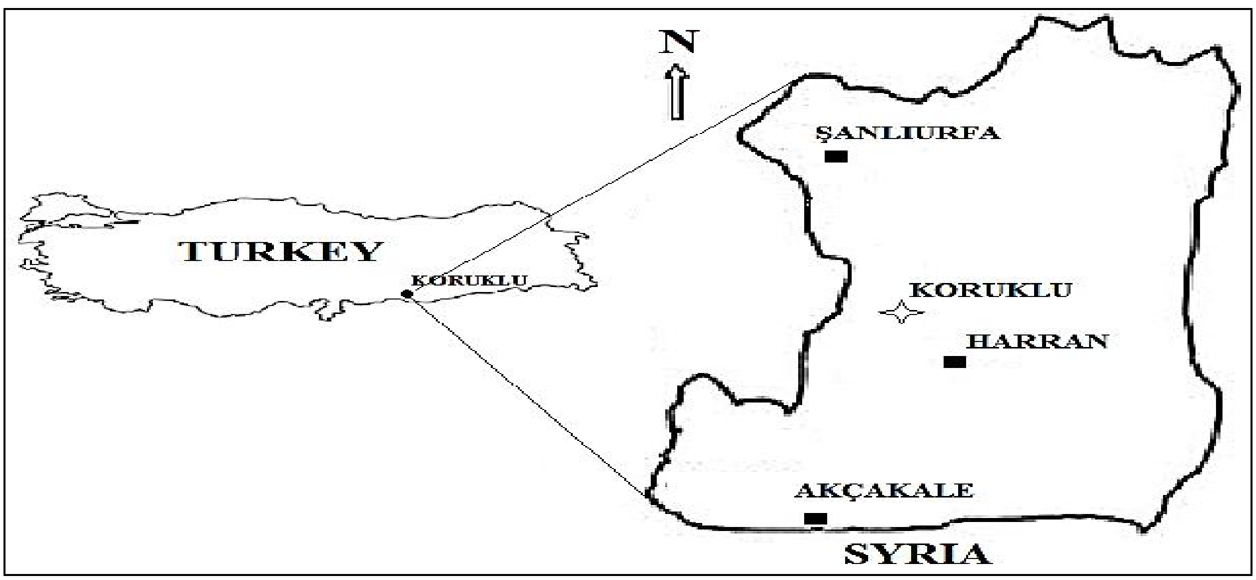

Figure 1. Location of the study site

METHODS

Laboratory analyses: To determine certain physical and chemical characteristics of the soil, soil samples were obtained from 0-5 depths air-dried and sieved through a 2 mm. Soil particle size distribution (texture) was determined with a hydrometer (Bouyoucus, 1962), calcareous content with a Scheibler calcimeter (Allison and Moodie, 1965), organic carbon content with Walkley-Black method (Nelson and Sommers, 1982), soil reaction (pH) with a pH-meter in a 1:2.5 soil/water suspension (Horneck *et al*., 1989), electrical conductivity (EC) with a conductivity-meter in a soil extraction (1:5 soil/water) (Horneck *et al*., 1989), and BD with Black (1965) methodology. Study field soil is clayed, calcareous, with high organic carbon content and slightly alkali and has no salinity problem (Table 1).

Meteorological data: Meteorological data were measured every 30 minutes using a Decagon data logger (5TE, EM50 Data Logger) setup at the test field. Measurements were taken at 5 cm soil depth, representing the area covered by the PVC containers, by determining the internal temperature and moisture of PVC containers. Collected data were assessed weekly and compared to the carbon emission values obtained during the same period. Obtained data were related to weekly CO_2 emission values.

Table 1. Basic soil physical and chemical properties of the study site.

	Depth (0-5 cm)				
	Uncultivated	Cultivated	Apple Cultivation	Pomegranate Cultivation	Vineyard Cultivation
Soil Reaction; pH (1:2.5)	7.55	7.50	7.51	7.51	7.50
Electrical Conductivity; EC (1:5)	0.91	1.10	1.23	1.23	1.10
Soil Organic Carbon; SOC (%)	2.01	0.85	1.30	1.29	0.85
Bulk Density; HA (Mg M^{-3})	1.36	1.25	1.20	1.20	1.25
Calcareous content (%)	25.11	26.01	25.03	25.03	26.01
Clay (%)	52.56	53.33	50.90	50.90	53.33
Sand (%)	26.42	25.12	23.10	23.10	25.12
Silt (%)	21.02	21.55	26.00	26.00	21.55

Figure 2. PVC containers in the sampling field

Carbon dioxide (CO_2) emission measurements: In the present study, soda lime method, which was preferred by several researchers in the world for its easy and inexpensive nature (Keith and Wong, 2006), was used to determine CO_2 emissions from uncultivated land at Harran plain (Grogan, 1998). In this method, CO_2 is chemically adsorbed by soda-lime (Edwards, 1982). Soda-lime is a granular CaOH + NaOH (calcium and sodium hydro oxides) mixture, with a granular size that varies about 2 and 5 mm. Alkali soda-lime adsorbs CO_2.

Although the amount of soda-lime used varies based on ecological conditions, generally 50 – 100 g soda-lime is used. For the present study, 50 g soda-lime was utilized. Statistical analyses were performed using the SPSS 21.0 packet program and the emissions calculations were conducted with the following equation:

$$E_{CO_2} = \frac{(SL_{ad} - SL_{ini}) \cdot WC}{(A \cdot t)}$$

Where;

E_{CO_2} is the total amount emitted during the incubation period (g CO_2 m^{-2} day^{-1});
SL_{ad} is CO_2 adsorbed soda-lime amount (g);
SL_{ini} is the initial soda-lime amount (g);
A is the area of measurement (m^2);
t is the incubation time (the time past in the field) (day) and;
WC is water correction factor was taken as 1.69.

RESULTS AND DISCUSSION

Results: Soil carbon emissions were measured in the land under five (5) different cultivation conditions of cultivated and uncultivated soil where pomegranate, vineyard and apple cultivation were implemented between 2014 and 2016 in the study fields. The mean carbon emission values obtained under different cultivation conditions varied between 46.05, 58.07, 55.60, 42.67, and 61.99 g CO_2 m^{-2} $week^{-1}$, respectively (Table 2). The highest carbon emission rate was observed in apple-cultivated soil and the lowest was observed in vine-cultivated soil. It was estimated that the high carbon emissions in apple orchards were due to the fallen leaves and twigs and infusion of rotten grass and unpicked fruits into the soil among the trees, and the shade areas created by the trees and the low soil temperatures as a result of irrigation. On the other hand, in vine-cultured fields, wide placement of vines and the sunny nature of areas in between and the low organic waste input could result in a decrease in soil carbon emissions.

Table 2. Descriptive statistical of weekly CO_2 emissions and climatic parameters.

Parameters	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Cultivated (g m^{-2} day^{-1})	21.94	73.16	46.05	0.94	9.71
Uncultivated (g m^{-2} day^{-1})	21.63	96.25	58.07	1.43	14.79
Pomegranate cultivation (g m^{-2} day^{-1})	25.60	97.19	55.60	1.42	14.68
Vineyard cultivation (g m^{-2} day^{-1})	16.82	76.92	42.67	1.25	12.90
Apple cultivation (g m^{-2} day^{-1})	33.21	111.52	61.99	1.89	19.51
Internal humidity of PVC container (5 cm of soil depth) (%)	1.46	29.93	11.84	0.70	7.21
Internal temperature of PVC container (5 cm of soil depth) (°C)	5.20	39.54	22.54	1.09	11.26

The relationship between soil carbon emission and internal container temperature and moisture is displayed in Figures 3 and 4. Thus, as the temperature increased, soil carbon emission volume increased as well. Or, in other words, increasing carbon emissions resulted in an increase in temperature (Figure 3). On the other hand, when all other factors remained constant, as soil moisture content increases, soil carbon emissions decrease (Figure 4). Soil carbon emission was 54.47 g CO_2 m^{-2} $week^{-1}$ at the point where the soil temperature was maximum (39.54 °C) and the soil moisture was minimum (1.46 %). Soil carbon emission was 49.89 g CO_2 m^{-2} $week^{-1}$, where soil temperature was minimum (5.20 °C) and soil moisture was 18.77%. Soil carbon emission was 36.98 g CO_2 m^{-2} $week^{-1}$ at the point where the soil moisture was maximum (29.93 %) and the soil temperature was 9.47 °C. Soil carbon emission was at its maximum (74.04 g CO_2 m^{-2} $week^{-1}$) where soil temperature was 31.95 °C and soil moisture was 6.10 %.

Soil carbon emissions were reduced when soil water content went below or above 6.10% and 31.95°C, respectively. When soil water content increased from 1.46% to 1.86% (an increase of 0.4%), and soil temperature decreased from 39.54°C to 38.54 °C (a decrease of 1°C), soil carbon emissions increased from 54.47 g CO_2 m_{-2} $week^{-1}$ to 60.53 g CO_2 m^{-2} $week^{-1}$ (a 6 g increase). These facts demonstrated the effect of soil temperature and moisture on carbon emissions. It was considered that carbon emissions were reduced due to the lack of disintegration and decay, soil microorganism and plant root activities when the soil lacks moisture. When Figures 3 and 4 are examined, it seems like as the carbon emissions, one of the greenhouse gases, increase, global warming increases as well. In fact, the opposite could also be stated. Perhaps, as the global warming is prevalent, soil greenhouse gas emissions could increase as a result.

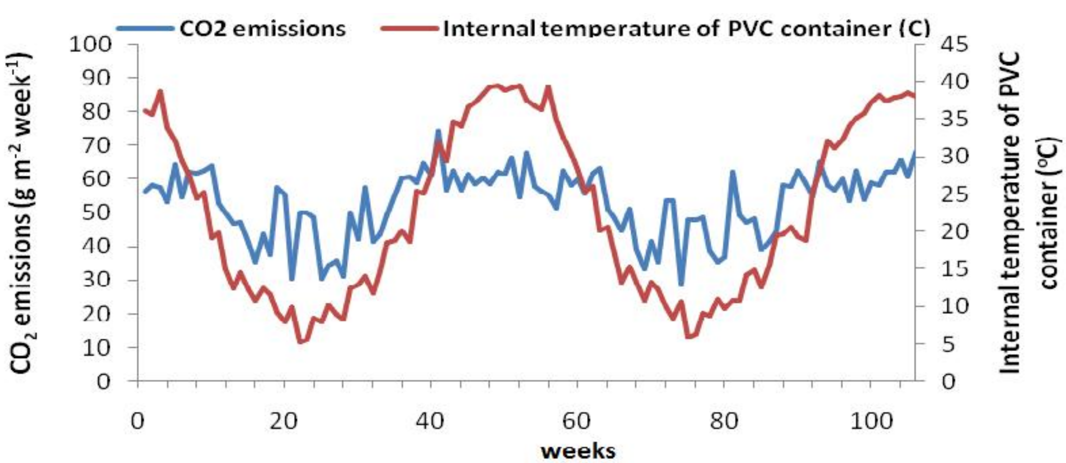

Figure 3. Relationship between CO_2 emissions with internal PVC temperature

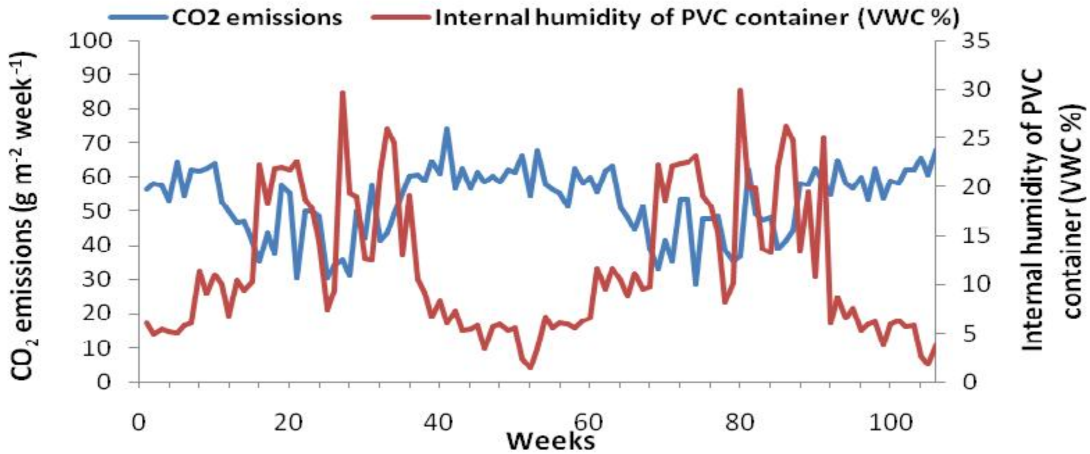

Figure 4. Relationship between CO_2 emissions with internal PVC humidity

The correlation between soil carbon emission and soil moisture was statistically significant in cultivated fields ($r = -0.229$, $p < 0.05$), and was very significant in uncultivated ($r = -0.494$, $p < 0.01$), pomegranate ($r = -0.444$, $p < 0.01$), vine ($r = -0.478$, $p < 0.01$) and apple ($r = -0.367$, $p < 0.01$) cultured fields (Table 3). The correlation between soil carbon emission and soil temperature was statistically very significant in cultivated ($r = 0.265$, $p < 0.01$), uncultivated ($r = 0.527$, $p < 0.01$), pomegranate ($r = 0.510$, $p < 0.01$), vine ($r = 0.539$, $p < 0.01$) and apple ($r = 0.504$, $p < 0.01$) fields. The correlation between soil moisture and temperature was very significant in all test groups ($r = -0.776$, $p < 0.01$)

Table 3. Correlation between CO_2 emissions and meteorological parameters at different sites.

Parameters	Cultivated	Uncultivated	Pomegranate cul.	Vineyard cul.	Apple cul.	Internal humidity of PVC container (5 cm of soil depth)
Uncultivated	0.477**					
	0.000					
Pomegranate cultivate	0.151	0.204*				
	0.123	0.036				
Vineyard cultivate	0.427**	0.448**	0.356**			
	0.000	0.000	0.000			
Apple cultivate	0.190	0.446**	0.362**	0.331**		
	0.050	0.000	0.000	0.001		
Internal humidity of PVC container (5 cm of soil depth)	-0.229*	-0.494**	-0.444**	-0.478**	-0.367**	
	0.018	0.000	0.000	0.000	0.000	
Internal temperature of PVC container (5 cm of soil depth)	0.265**	0.527**	0.510**	0.539**	0.504**	-0.776**
	0.006	0.000	0.000	0.000	0.000	0.000

**p<0.01; *p<0.05.

DISCUSSION

Almagro *et al*. (2009) reported that soil respiration increased with an increase in soil temperature, however, when soil water content dropped below 10%, soil respiration decreased, and emission peaked during the precipitations after a period of draught and then it decreased back. Furthermore, they stated that, if soil moisture content is above 10%, there was a positive relationship between soil respiration and temperature ($p<0.01$). In another study, it was determined that soil water content prevented soil CO_2 diffusion and inhibited microbial activity and root respiration (Curiel Yuste *et al.,* 2003). Soil carbon emission was minimum when soil temperature dropped below 6°C, and soil water content went above 20%. It was at maximum when soil temperature reached 40°C and soil water content touched 6% (Sakin, 2016). In the current study, soil respiration decreased when soil water content dropped below 6.10%. The carbon emissions reached a maximum at that level of soil water content and when the temperature was 31.94°C in this study.

Results showed that mean carbon emission based on the temperature and moisture rate was 5.46 g CO_2 m^{-2} day^{-1} (±0.075). There was a positive relationship between soil CO_2 emission and soil temperature, and a negative relationship between soil CO_2 emission and soil moisture. An increase in soil temperature resulted in increases in microorganism activities, disintegration and decay. In the present study, CO_2-C emission was determined as 2.071 g CO_2-C m^{-2} day^{-1} based on soil moisture (mean:12.13 % VWC) and soil temperature (mean: 22.61°C) in the same region, with the same soil conditions, at the same depth and using the same methodology at different times. Although there seems to be differences between the findings of the two studies, when compensated for the differences in soil temperature, it was determined that there were no actual differences between the results. Since it was found that 0.091 g C is emitted for each 1°C increase in soil temperature, the results of the studies were in fact similar (Sakin and Sakin 2015).

The effect of soil moisture and temperature on soil CO_2 emission is complex and not only dependent on these two factors, but others as well (carbon influx, agricultural techniques, etc.). In the current study, determined CO_2 emission amounts could be ranked in a decreasing order as apple, uncultivated, pomegranate, and vine fields. Apple orchards are usually shady fields with a thick surface cover. In uncultivated fields, there are usually herbaceous and woody plants, balancing the carbon emissions and influx. In vineyards, the soil between the vineyards are open and they have been cultivated for many years and weeded regularly. Thus, carbon influx was minimal in these fields, thus, the total carbon emissions remained low. Pan *et al*. (2011) investigated microbial biomass (MB) and temperature-moisture (TM) parameters to determine soil CO_2 emissions at Skukuza Camp located at Kruger National Park region in African Savannah ecosystems 28% covered with trees and with a 600 cm soil depth and average yearly precipitation of 550 mm (November – April). They have determined that average annual CO_2 flow was related to soil air CO_2 concentration and vegetation. Comparison of CO_2 emissions in shady (forest) and penumbral areas showed that 30% of the annual soil emissions were originated in shady areas (forests) when compared to half-shady (penumbral) areas ($F = 11.62$, $p < 0.006$). It was determined that mean CO_2 emission in shady (forest) and penumbral areas were 0.99 g CO_2 m^{-2} h^{-1} (±0.07 SE) and 0.77 g CO_2 m^{-2} h^{-1} (±0.06 SE), respectively.

In the current study, the highest CO_2 emissions were observed in apple orchards. Organic waste input into the soil is very high in these fields having extensive cultivation processes (tilling, etc.). Thus, carbon emission increased in these type of fields. It was determined that, in Timonha region, high CO_2 emissions were not dependent on high soil carbon content, but mostly on extreme anthropogenic factors (Silva and Souza, 2006; Nobrega *et al*. 2016). Another disadvantage due to these anthropogenic activities is the reduction of soil carbon influx (Nobrega *et al*., 2016). Initially, the real anthropogenic effects (e.g. deforestation, etc.) have a great effect on CO_2 emission, but these effects decline in time (Langart *et al*., 2014).

Soil carbon emission is not only dependent on soil temperature and moisture, but affected by other factors (drought, cultivation, organisms, etc.) as well. In a study conducted in arid and semi-arid regions on uncultivated land, it was determined that carbon emissions were at a maximum in late July and early August and at a minimum in mid-February. Furthermore, it was reported that, due to the disintegration and decay that occur in soil under long term radiation, soil carbon emissions could be observed (Sakin, 2016). Since our field of study was also arid, hence there is possibility that these factors would have affected our results as well.

Conclusion: The present study investigated soil carbon emission measurements with soda-lime method and internal temperature and moisture of the PVC container, one of the factors that affect carbon emissions. In the current study, the highest CO_2 emissions were observed in apple orchards while the lowest emissions were in cultivated lands. Soil carbon emission was at its maximum where soil temperature was 31.95 °C and soil moisture was 6.10 %. Soil carbon emission was 54.47 g CO_2 m^{-2} $week^{-1}$ at the point where the soil temperature was maximum (39.54 °C) and the soil moisture was minimum (1.46 %). Soil carbon emission was 49.89 g CO_2 m^{-2} $week^{-1}$, where soil temperature was minimum (5.20 °C) and soil moisture was 18.77%. Soil carbon emission was 36.98 g CO_2 m^{-2} $week^{-1}$ at the point where the soil moisture was maximum (29.93 %) and the soil temperature was 9.47 °C. Soil carbon emissions do not only depend on a few parameters, thus, all factors that affect the emission should be considered when conducting these types of studies. Only then the results would be conclusive. Otherwise, certain aspects of the study would be missing.

REFERENCES

Allison, L. E. and C. D. Moodie (1965). "Carbonate." Methods of Soils Analysis. Part 2. Chemical and microbiological properties, (methodsofsoilanb), Wisconsin (U.S.A.), Am. Soc. of Argon., Inc., Madison. pp. 1379 – 1400.

Almagro, M., J. Lopez, J.I Querejeta and M. Martinez-Mena (2009). Temperature dependence of soil CO_2 efflux is strongly modulated by seasonal patterns of moisture availability in a Mediterranean ecosystem. Soil Biol. Biochem. 41(3): 594–605.

Angert, A., D. Yakir, M. Rodeghiero, Y. Preisler, E.A. Davidson. and T. Weiner (2015). Using O_2 to study the relationships between soil CO_2 efflux and soil respiration. Biogeoscience. 12(7): 2089–2099.

Atarashi- Andoh, M., J. Koarashi, S. Ishizuka and K. Hirai (2012). Seasonal patterns and control factors of CO_2 effluxes from surface litter, soil organic carbon, and root-derived carbon estimated using radiocarbon signatures. Agr. Forest Meteorol. 152: 149–158.

Black, C.A. (1965). Methods of Soil Analysis, Part II, American Soci. of Agroninc. Pub. No: 9 Madison WI (USA).

Bond-Lamberty, B. and A. Thomson (2010). A global database of soil respiration data. Biogeosciences. 7(6): 1915–2010.

Bouyoucus, G.J. (1951). A Recalibration of the Hydrometer for Making Mechanical Analysis of Soils. Agron. J. 3: 434 – 438.

Chen, S.T., Huang, Y., Zou, J.W., Shen, Q.R., Hu, Z.H., Qin, Y.M., Chen, H.S. and Pan, G.X. (2010). Modeling interannual variability of global soil respiration from climate and soil properties. Agr. Forest Meteorol. 150 (4): 590–605.

Curiel Yuste, J., Baldocchi, D.D., Gershenson, A., Goldstein, A., Misson, L. and Wong, S. (2007). Microbial soil respiration and its dependency on carbon inputs, soil temperature, and moisture. Glob. Change Biol. 13: 2018–2035.

DMİ (Devlet Meteoroloji İşleri) (2014). Şanlıurfa ili iklim verileri, Ankara, Türkiye.

Edwards, N.T .(1982). The Use of Soda-Lime Measuring Respiration Rates in Terrestrial Systems. Pedobiologia. 23: 321-330

FAOSTAT. (2011). Dataset land resources. Food and Agriculture Organization of The Unıted Nations Statistics Division., http://faostate3.fao.org.

Fiedler, S.R., Buczko, U., Jurasinski, G. and Glatzel, S. (2015). Soil respiration after tillage under different fertilizer treatments–implications for modeling and balancing. Soil Till. Res. 150: 30-42.

Forrester, J.A., J.D. Mladenoff, S.T. Gower, and J.L. Stoffel (2012). Interactions of temperature and moisture with respiration from coarse woody debris in experimental forest canopy gaps. Forest Ecol. Manag. 265:124–132.

Giardina, C.P., C.M. Litton, S.E. Crow and G.P. Asner (2014). Warming-related increases in soil CO_2 efflux are explained by increased below-ground carbon flux. Nat. Clim. Change. 4: 822–827.

Grogan, P. (1998). CO_2 flux measurement using soda lime: correction for water formed during CO_2 adsorption. Ecology. 79: 1467-1468.

Horneck, D.A., J. M. Hart, K. Topper and B. Koepsell (1989). Methods of soil analysis used in the soil testing laboratory at Oregon State University. 1-21, State of Oregon, University Publication USA.

IPCC, (2014): Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva (Switzerland). p.151

Kim, D.G., R. Vargas, B. Bond-Lamberty and M. Turetsky (2012). Effects of soil rewetting and thawing on soil gas fluxes: a review of current literature and suggestions for future research. Biogeosciences. 9 (7): 2459–2483.

Keith, H. and S.C. Wong (2006). Measurement of soil CO_2 efflux using soda lime absorption: both quantitative and reliable. Soil Biol. Biochem. 38: 1121–1131.

Lang'at, J.K.S., J.G. Kairo, M. Mencuccini, S. Bouillon, M.W. Skov, S. Waldron and M. Huxham (2014). Rapid losses of surface elevation following tree girdling and cutting in tropical mangroves. PLoS One. 9 (9): e107868.

Lloyd, J. and J.A. Taylor (1994). On the temperature dependence of soil respiration. Funct. Ecol. 8(3): 315–323.

Nelson, D. and W.L.E. Sommers (1982). Total carbon, organic carbon, and organic matter. Methods of soil analysis. Part 2. Chemical and microbiological properties. pp 539-579.

Nobrega, G.N., T.O. Ferreira, M.S. Neto, H.M. M. Queiroz, A.G. Artur, De S. Eduardo, E.D.S. Mendonça, E.D.O. Silva, and X.L Oterof (2016). Edaphic factors controlling summer (rainy season) greenhouse gas emissions (CO_2 and CH_4) from semiarid mangrove soils (NE-Brazil). Sci. Total Environ. 542: 685–693.

Pan, Y., R.A. Birdsey, J. Fang, R. Houghton, P.E. Kauppi, W.A. Kurz, O.L. Phillips, A. Shvidenko, S.L. Lewis, J.G. Canadell, P. Ciais, R.B. Jackson, S.W. Pacala, A.D. McGuire, S. Piao, A. Rautiainen, S. Sitch and D. Hayes (2011). A large and persistent carbon sink in the world's forests. Science. 333: 988–993.

Rey, A., E. Pegoraro, C. Oyonatre, A. Were, P. Escribano and J. Raimundo (2011). Impact of land degradation on soil respiration in a steppe (Stipa tenacissima L.) semiarid ecosystem in the SE of Spain. Soil Biol. Biochem. 43:393-403.

Sakin, E. and E.D. Sakin (2015). Harran Ovasının Killi Topraklarında Karbon Emisyonun Ölçülmesi. GAP VII. Tarım Kongresi. Şanlıurfa (Türkiye): 208-214.

Sakin, E. (2016). Seasonal Variations of Carbon Emissions in Uncultivated Soils. Oxid. Commun. 39(2):1374-1384.

Silva, E.V.D., Souza, M.M.A.(2006). Principais formas de uso e ocupação dos manguezais do estado do Ceará. Cad. Cult. Ciênc. 1: 12–20.

Sugihara, S., Funakawa, S., Kılasara, M., Kosakı, T. (2012). Effects of land management on CO_2 flux and soil C stock in two Tanzanian croplands with contrasting soil texture. Soil Biol. Biochem. 46: 1-9.

Wagan, B., Zhanyu, Z., Baoping, F., Memon, S., and Han, S. (2016). An evaluation of meteorological variations and drought effects ın China over the period 1980-2010. The J. Anim. Plant Sci, 26 (1): 217-224.

Xu, X., Luo, X. (2012). Effect of wetting intensity on soil GHG fluxes and microbial biomass under a temperate forest floor during dry season. Geoderma 170: 118–126.

Zahra, S. I., F. Abbas, W. Ishaq, M. Ibrahim, H. M. Hammad, B. Akram and M. R. Salik (2016). Carbon sequestration potential of soils under maize production ın ırrigated agriculture of The Punjab province of Pakistan. The J. Anim. Plant Sci,, 26 (3): 706-715.