Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi 13 (1):89-94, 2018
ISSN 1304-9984, *Araştırma Makalesi*

The Influence of Soil and Air Temperature on Soil Carbon Dioxide Emission in Farmland

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Geliş tarihi: 15.03.2018, Yayına kabul tarihi: 10.04.2018

Abstract: The aim of this study is to determine the effect of soil and air temperature on soil carbon dioxide emission. The air temperature in Isparta province of Turkey was measured about 20°C during the day and 10°C at night in the last week of September 2014. Temperature difference measured for soil and air during day and night will be given in the paper. An automated CFX-2 soil carbon dioxide flux system (PP Systems, Hitchin, UK) was used to record soil CO_2 emission for during 24 hours at 15 minutes intervals. Additionally, concomitantly soil/air temperature and soil evaporation were recorded. The soil and air temperature as min, max, and average were recorded during the trials as 13.6, 16.3, 14.9 and 2.1, 28.9, 14.1ºC the for mentioned period, respectively. Besides, soil CO_2 emission as min, max and average was recorded as 0.014, 0.22, 0.07 g CO_2 $m^{-2}h^{-1}$ respectively. Results showed that the soil temperature did not affect soil CO_2 emission (*R=0.05*). However, air temperature affected soil CO_2 emission (*R=0.58*).

Key words: Soil CO_2 emission, Soil temperature, Air temperature, greenhouse gas emission

Toprak ve Hava Sıcaklığının Toprak Karbondioksit Emisyonu Üzerine Etkisi

Özet: Bu çalışmanın amacı toprak ve hava sıcaklığının toprak karbondioksit emisyonu üzerine etkisini belirlemektir. Eylül 2014 'ün son haftasında Isparta'daki yaklaşık gece sıcaklığı 10 ºC, gündüz sıcaklığı ise 20 ºC olarak ölçülmüştür. Gece ve gündüz sıcaklık değişimleri makale içinde verilmiştir. 24 saat süresince 15 dakika aralıklarla otomatik olarak toprak karbondioksit emisyonları "CFX-2 soil measurement system" kullanılarak (PP Systems, Hitchin, UK) ölçülmüştür. Buna paralel olarak topraktan buharlaşma ve hava/toprak sıcaklığı da belirlenmiştir. Toprak ve hava sıcaklığı minimum, maksimum ve ortalama değerleri sırasıyla, 13.6, 16.3, 14.9 ve 2.1, 28.9, 14.1ºC olarak belirlenmiştir. Toprak karbondioksit emisyonu, minimum, maksimum ve ortalama değerleri sırasıyla 0.014, 0.22, 0.07 g CO_2 $m^{-2}h^{-1}$ olarak belirlenmiştir.
Sonuçlara göre, toprak sıcaklığı toprak karbondioksit emisyonunu etkilememiştir *(R=0.05).* Fakat hava sıcaklığı toprak karbondioksit emisyonunu etkilemiştir *(R=0.58).*

Anahtar sözcükler: Toprak CO_2 emisyonu, toprak sıcaklığı, hava sıcaklığı, sera gazı emisyonu

Introduction

Agricultural activities play a significant role in the emission of greenhouse gases and global climate change. Soil carbon dioxide (CO_2) emission varies depending on soil water content, soil organic carbon, soil temperature, tillage practices, and climatic conditions (Davidson et al.,1998; Jhonson et al.,2007; Shresta and Penrose, 2009; Senyigit and Akbolat, 2010; Akbolat et al., 2009). Jabro et al. (2008) reported that exponential relationships were found between soil surface CO_2 emission and soil temperature for no tillage, conventional, and undisturbed soil grass-alfalfa treatments. Verville et al. (1998) reported that on a local scale, vegetation composition had a greater effect on CH_4 and CO_2 emissions than direct manipulation of air and soil temperature. Schindlbacher and Zechmeister-Boltenstern

(2004) stated that the combination of soil temperature and soil moisture could explain a better part of variations in NO (up to 74%) and N_2O (up to 86%) emissions for individual soils, but average emissions differed significantly between various forest soils. The fluctuation in soil temperatures was related to variations in maximum and minimum air temperatures and incoming solar radiation (Rathore et al.,1998).

Nakadai et al. (2002) reported that the soil CO_2 flux was significantly related to the temperature at 5 cm above ground and 0 cm, but not related to that below the depth of 10 cm. They also reported that the ambient CO_2 levels generally increased from sunset and decreased gradually after sunrise. Kim et al. (2005) stated that warmer temperatures (12 and 22°C) considerably increased the CO_2 production from peat soils and peatland ground litter. Almagro et al., (2009) reported that soil moisture content rather influences than soil temperature on soil CO_2 emission.

The aim of this study is to determine the effect of soil and air temperature on soil carbon dioxide emission.

Material and methods

Study Site

The experiment was carried out at the Agricultural Research Station of the Faculty of agriculture of Suleyman Demirel University in Isparta (37.75º N, 30.55º E). The experimental field is located in the semi-arid Mediterranean climate and has mean monthly minimum and maximum temperatures of -10ºC in January and 35ºC in July. A mean annual temperature is 12ºC and, a mean annual precipitation is 525 mm. A mean annual potential pan evaporation is 1290 mm, and an elevation is 1035 m above mean sea level. The main soil properties of the experimental site for the depth of 0-30 cm were as follows: 33.9% sand, 22.3% clay, 1.7% soil organic matter, and pH 7.87 (Karatepe, 2000). Bulk density was 1.25 g cm^{-3}; porosity 52.9%; soil water content at the trial time was 16.6% by weight. Gravimetric soil moisture was determined by Walkley-Black (1934).

Soil Carbon Dioxide Emission Measurement

In-situ soil respiration was measured using an automated CFX-2 soil CO_2 flux system (PP Systems, Hitchin, UK) consisting of the integral CO_2 analyzer and H_2O sensor, soil respiration chamber, and soil temperature probe (Akbolat et al., 2009). Measurements of soil net CO_2 efflux in g CO_2 m^{-2} h^{-1} are based on concentration differences between air entering and leaving the chamber and the flow rate under normal soil atmosphere exchanges, with an accuracy of better than 1% and 2% for CO_2 and H_2O concentrations, respectively.

A soil CO_2 flux chamber of 21 cm in diameter and 12 cm in height was installed 1.5 cm deep into the soil, and thus was isolated from the outer atmosphere. The measurements were made 24 hours per 15-minute interval as automatic. In addition, soil (H_2O emission) evaporation, soil temperature in the 20 cm soil, and air temperature above the 20 cm soil surface were concomitantly measured.

K type thermocouples connected to PC were used to measure air and soil temperature.

Statistical Analyzing

Statistical calculations were performed with statistics tools provided by Minitab version 1.6 (Minitab Inc. State College, PA). In this study, Pearson's correlation coefficient was calculated for discussing to the presence of a linear relationship among all variables. Multiple regression analysis was performed considering soil CO_2 emission dependent variable. Then, soil CO_2 emission was estimated using independent characteristics of soil temperature (T_{soil}), air temperature (T_{air}) and soil evaporation. Best subsets regression method, which is one of the variable elimination methods, was used. The best subset regression equation with precision (R^2) were presented together. All data after the standardization (Xi-meanXi) / (StandevXi), distribution of data-based CO_2 emission was given the same graph.

Results and Discussion

Research started at 14:00 pm on October 1, 2014, and data was recorded every 15 minutes during the day. Soil CO_2 emission, T_{soil}, T_{air}, soil evaporation were recorded every 15 minutes. The data obtained in the research are given in Table 1. Additionally, soil moisture was measured at every 8 hours. Gravimetric soil moisture content in 8^{th}, 16^{th}, and 24^{th} hours were determined as 17.3%, 16.9%, and 16.0%.

Table 1. Descriptive Statistics: T_{soil}, T_{air}, soil CO_2, and soil evaporation.

Tablo 1. Tanımlayıcı istatistikler: T_{toprak}, T_{hava}, toprak CO_2 emisyonu ve toprak buharlaşması

Variables Değişkenler	The number of measurements Kayıt sayısı	Mean Ortalama	Standard Deviation St. sapma	Minimum En az	Maximum En fazla
T_{soil} (ºC) T_{toprak}	96	14.95	0.79	13.60	16.30
T_{air} (ºC) T_{hava}	96	14.10	8.95	2.10	28.90
Soil CO_2 emission ($g\ m^{-2}h^{-1}$) Toprak CO_2 emisyonu ($g\ m^{-2}h^{-1}$)	96	0.07	0.05	0.014	0.22
Soil evaporation ($g\ m^{-2}h^{-1}$) Toprak buharlaşması ($g\ m^{-2}h^{-1}$)	96	7.57	7.16	0.38	24.94

Soil CO_2 emission, T_{soil}, T_{air}, and soil evaporation changing with time are given in Figure 1. Although no significant changes in T_{soil} for 24 hours, the air temperature varied significantly throughout the day. There is a linear correlation between soil CO_2 emission and T_{air}. Besides, there is a linear relation between soil CO_2 emission and soil evaporation (Figure 1).

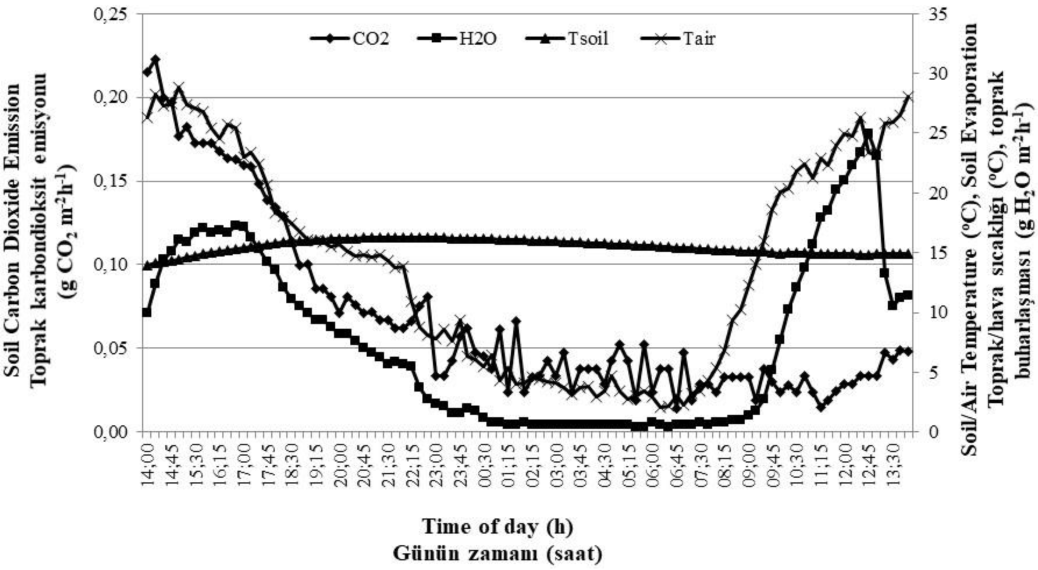

Figure 1. The change of soil CO_2 emission, T_{soil}, T_{air}, and soil evaporation as a function of time

Şekil 1.Zamanın bir fonksiyonu olarak T_{toprak}, T_{hava} ve topraktan buharlaşmaya bağlı toprak CO_2 emisyonu değişimi

Soil CO_2 emission was highly correlated with the decrease of time (R=-0.828). This correlation was found to be statistically significant (p <0.01) in Table 2. It means that one of the features increases, the other decreases. In other words, soil CO_2 emission decreased towards the evening. Soil CO_2 emission showed the similarity with the air temperature as a function of time. The correlation between the air temperature and the soil evaporation is relatively high (R=0.91). However, the soil CO_2 emission and air temperature are moderately correlated with the R of 0.58. Additionally, the correlation between soil temperature and soil CO_2 emission is very low (R= 0.053).

There were moderate correlations between the increase of the temperature (T_{air}) and the increase of soil CO_2 emission with R of 0.576. This correlation was statistically significant (p<0.01). This indicates that both the air temperature and soil CO_2 emission increase simultaneously (Table 2).

Table 2. Pearson correlation coefficients and P values
Tablo 2. Pearson korelasyon sabitleri ve P değerleri

Variables Değişkenler	Time Zaman	T_{air} T_{hava}	T_{soil} T_{toprak}	Soil CO_2 emission Toprak CO_2 emisyonu
T_{air} T_{hava}	-0.179 0.081			
T_{soil} T_{toprak}	-0.535 0.000	-0.359 0.000		
Soil CO_2 emission **Toprak CO_2 emisyonu**	**-0.828** **0.000**	**0.579** **0.000**	**0.053** **0.611**	
Soil evaporation Topraktan buharlaşma	-0.112 0.276	0.907 0.000	-0.327 0.001	0.473 0.000

The first value in each row indicates R, second value indicates P (P<0.01).
Her satırdaki ilk değer R 'yi, ikinci değer ise P (P<0.01) 'yi göstermektedir.

Application of the best subset regression method for the best combination for the prediction of soil CO_2 emission is as a function of time, T_{air} and T_{soil} are presented in Table 3. The results showed that the best combination of R and Mallows are 0.948 and 3.1 respectively. When the stand-alone time is included in model, R^2 decreased as 0.685 and mallows increased as 458.4. The increase of mallows values of the combination deteriorated the combination.

Table 3. Best subsets regression: CO_2 versus time; T_{air}; T_{soil}; evaporation.
Tablo 3. En iyi alt kümeler regresyonu: CO_2 x Zaman; T_{hava} x T_{toprak} x Buharlaşma

No	Variables Değişkenler	R-sq R kare	Mallows Cp	Time Zaman	T_{air} T_{hava}	T_{soil} T_{toprak}	Soil evap. Buharlaşma
1	1	68.5	454.8	X			
2	1	33.5	1061.5		X		
3	2	89.9	85.9	X		X	
4	2	87.7	123.7	X	X		
5	**3**	**94.8**	**3.1**	**X**	**X**	**X**	
6	3	93.5	24.6	X		X	X
7	4	94.8	5.0	X	X	X	X

Regression analysis yielded the best equation which is given below;

$CO_2 = 0.525 - 0.000127 \cdot Time + 0.00163 \cdot T_{air} - 0.0258 \cdot T_{soil}$ and R^2 is 0.948.

The relationship between the soil CO_2 emission is as a function of time, T_{air} and T_{soil} were highly correlated with R^2 of are 0.948. However, mallows value (5.0) is higher than 3.1. Therefore, the importance of this combination has reduced. According to the research results, it was found that the air temperature is the most influential factors on soil CO_2 emissions. Correlation of temperature on soil CO_2 emissions alone was found to be R = 0.576. The relation between air temperature and soil CO_2 emission is given in Figure 2.

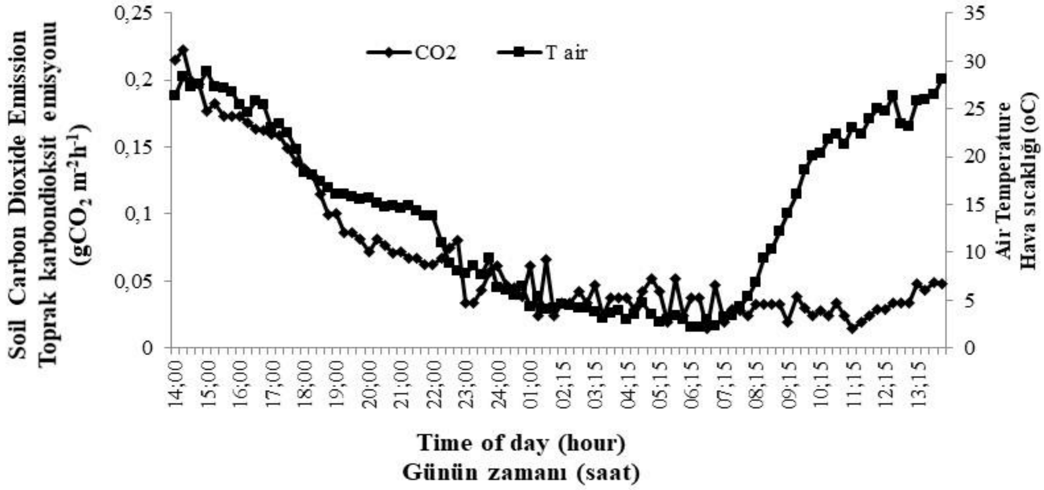

Figure 2. The relationship between carbon dioxide (CO_2) emission and air temperature (T_{air})
Şekil 2. Hava sıcaklığı (T_{hava}) ve karbondioksit emisyonu (CO_2) arasındaki ilişki

While soil CO_2 emission depending on the air temperature reached the highest value in an hour of the day (14:00pm), it decreased to the lowest value towards the evening (18:00 pm). Despite the increase in temperature to noon, soil CO_2 emission has not increased at the same rate. Nakadai et al. (2002) found that soil surface air temperature affected soil CO_2 emission. While the highest soil CO_2 emission was detected in May, at 11:00 am, the lowest emission was detected at 4:00 am o'clock in the same study. As for this study, soil CO_2 emission was affected by soil surface air temperature.

According to the research result, changes in air temperature throughout the day did not affect the soil temperature. Probably air temperature might affect to the microorganism density near the soil surface and CO_2 emissions could be increased in parallel with the air temperature. According to research result of Dilekoglu and Sakin (2017); air temperature has affected the soil CO_2 emission. Our results are consistent with their results. As a result, soil CO_2 emissions are more influenced by the air temperatures than the soil temperature.

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