IMPACTS OF METEOROLOGICAL VARIABLES ON NET ECOSYSTEM EXCHANGE OF WINTER WHEAT

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ABSTRACT
Understanding the characterization of net ecosystem exchange (NEE) with atmospheric variables is crucial. Measured NEE of CO_2 between the atmosphere and different ecosystems helps to understand the CO_2 balance and its component (gross primary production (GPP) and ecosystem respiration (R_{eco}). In order to measure long-term CO_2 and H_2O fluxes over a winter wheat field in the Northwestern part of Turkey, an Eddy Covariance (EC) measurement system was established and used for investigating the impacts of biophysical and atmospheric factors on NEE. It is aimed to determine the relationships between NEE, GPP and R_{eco} and meteorological variables such as soil temperature and global radiation. Results showed that the best relationship occurred between NEE and Photosynthetic Photon Flux Density (PPFD) (r^2=0.47), which is affected by clear and cloudy sky conditions. GPP and R_{eco} are mostly affected by PPFD and soil temperature, respectively. More attention is to be paid to include also their influences within the process to enhance our insight into the CO_2 flux perspectives.

Keywords: Net Ecosystem Exchange, winter wheat, meteorological variables, Kırklareli/Turkey.

INTRODUCTION
Increasing global mean temperatures revealed the need of evaluations on greenhouse gases concentrations and the associated emission amounts. Therefore, determination of carbon dioxide released to and captured from the atmosphere as major components of global carbon cycle have been searched by scientists. In this connection, measurements on CO_2 concentrations have begun at the Hawaii Island in 1950's. Researches especially over water and forest surfaces allow us to understand the variations in CO_2 and H_2O fluxes. Determining the CO_2, H_2O and energy balance components over agricultural areas is crucial because these areas capture carbon dioxide from the atmosphere and release it back to the atmosphere again.
Evaluation of CO_2 and H_2O fluxes over agricultural areas became more important for the studies on global carbon budget and climate change. That is why some flux networks are established to measure carbon dioxide, water vapor and energy fluxes between different terrestrial ecosystems (forests, croplands, grasslands etc.) and the atmosphere. Most of the related micrometeorological systems are installed firstly in forests rather than in

croplands. Concordantly, amount of the micrometeorological tower sites is increasing in order to measure the needed mass and energy fluxes above vegetation. Researches over different plants show that continuous measurements involving whole of the vegetation-growing period; are necessary. Although many studies about greenhouse gases over different vegetations exist since 1990's, researches about same issues have been only scanty in Turkey until now [1].

Variations in carbon dioxide fluxes during two successive growing periods of winter wheat were measured and determined to fulfill this lack for the Thrace region using a well-accepted micrometeorological method; called the Eddy Covariance. As a globally accepted scientific approximation, the eddy-covariance technique has been widely used during the past 20 years to measure exchange fluxes of mass and energy between ecosystems and the atmosphere over vegetation surfaces directly [2].

The aim of this study is to determine the impact of meteorological variables on CO_2 flux over winter wheat crop, which is an important nutritional source for Turkey. In this context, relationship between net ecosystem exchange of winter wheat and meteorological factors was determined on wide areas to analyze the vegetation dynamics better.

MATERIALS and METHODS

Figure 1 shows the location of this study, which was conducted at the experiment field of the Atatürk Soil Water and Agricultural Meteorology Research Station Directorate in the Kırklareli city of Turkey (41°41'53" N, 27°12'37" E).

Figure 1. Atatürk Soil Water and Agricultural Meteorology Research Station Directorate

After data collection, quality control was applied on all of the flux and meteorological data. Net ecosystem exchange (NEE) was calculated from the sum of half-hourly CO_2 flux (F_c) and CO_2 storage (F_s) over the canopy. F_c represents the sum of EC-measured flux and F_s is the flux associated with the change in storage in CO_2 in the layer below the level of CO_2 flux measurement and F_s values were obtained by integrating the change in CO_2 concentration through the air layer up to the heights of measurement.

Frequency response corrections, WPL (Webb-Pearman-Leuning) correction [3] and coordinate rotation (tilt correction) have been applied on 10 Hz time series of eddy covariance data after spike removal, high pass, low filtering effects and linear detrending [4]. As known, heavy precipitation and low turbulent exchange conditions affect the eddy covariance measurements, so the produced EC data need correction. Hence, the corresponding data gaps caused by the above conditions must be filled. To achieve this, international standard procedures have been followed. Finally, flux partitioning was applied to data set with gaps.
To compute daily to annual sums of fluxes, NEE gaps were filled in all dataset. An algorithm described in [5] and [6] was used for gap filling.
Once the gap filling was completed, the NEE was partitioned into gross ecosystem production (GPP) and ecosystem respiration (R_{eco}) components (Eq 1).

$$NEE = R_{eco} - GPP \tag{1}$$

In Equation 2, R_{eco} was calculated using the regression model [7].

$$R_{eco} = R_{eco,ref} \cdot e^{E_0\left(\frac{1}{T_{ref}-T_0} - \frac{1}{T-T_0}\right)} \tag{2}$$

While the regression parameter T_0 is kept constant at -46.02°C [7], the activation-energy kind of parameter (E_0); which essentially determines the temperature sensitivity, was allowed to vary. The reference temperature (T_{ref}) was set to 10°C as in the original model. Finally, GPP is calculated as the difference between calculated NEE and R_{eco}.
The clearness index (k_t) is used to describe sky conditions and the degree of impact of cloudiness [8]. It can be calculated by Equations 3, 4 and 5.

$$k_t = \frac{S}{S_e} \tag{3}$$

$$S_e = S_{sc}[1 + 0.033 \cos(\frac{360 t_d}{365})] \sin\beta \tag{4}$$

$$\sin\beta = \sin\emptyset \sin\delta + \cos\emptyset \cos\delta \cos\omega \tag{5}$$

Where; S, is global solar radiation; S_e, the extraterrestrial radiation; S_{sc}, the solar constant (1367 W m^{-2});t_d the day of year; β, the solar elevation angle; ϕ, the local latitude; δ, the declination of the sun and ω, hour angle.
The clearness index (k_t) varies between 0 and 1. The ratio indicates that dense cloud cover less than or equal to 0.33, also clear sky greater than or equal to 0.60 [9].

RESULTS

Figure 2 presents the time series of NEE, GPP, and R_{eco} during the 2012 – 2013 growing period of winter wheat. Their cumulated values during the growing period were -383.94, 1222.17, and 838.23 gC/m^2, respectively. Daily means of total NEE, GPP and R_{eco} for the whole growth period were -1.59, 5.05, and 3.46 gC/m^2, successively [10].

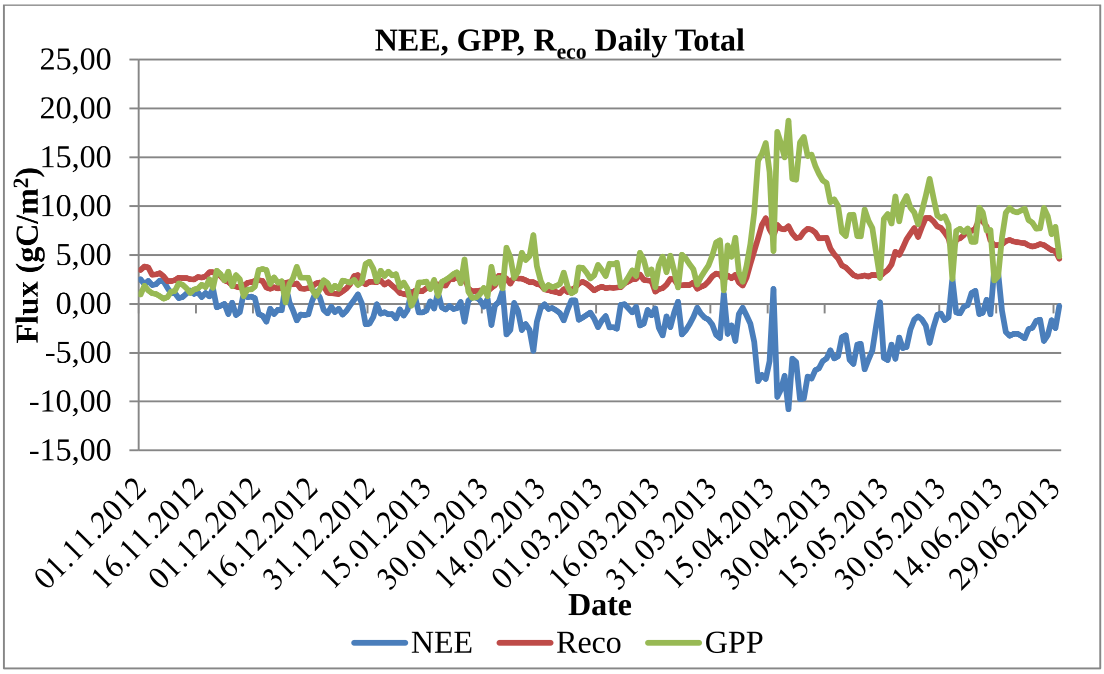

Figure 2. Daily NEE, GPP, R_{eco} of 2012-2013 growing season for winter wheat

Figure 3, 4 and 5 show the relationships between NEE, GPP, R_{eco} and meteorological variables (PPFD, soil temperature, air temperature). Relationships between NEE~PPFD, GPP~PPFD, and R_{eco}~Soil Temperature have high determination coefficients as 0.47, 0.69, 0.64; respectively ($P<0.05$).

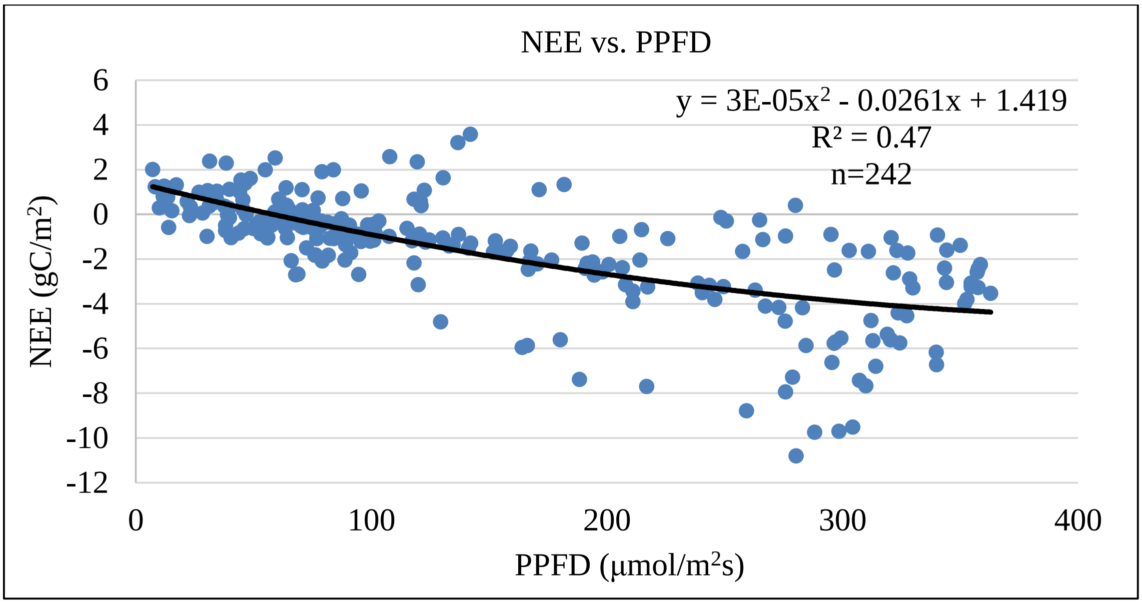

Figure 3. Relationship between NEE and PPFD

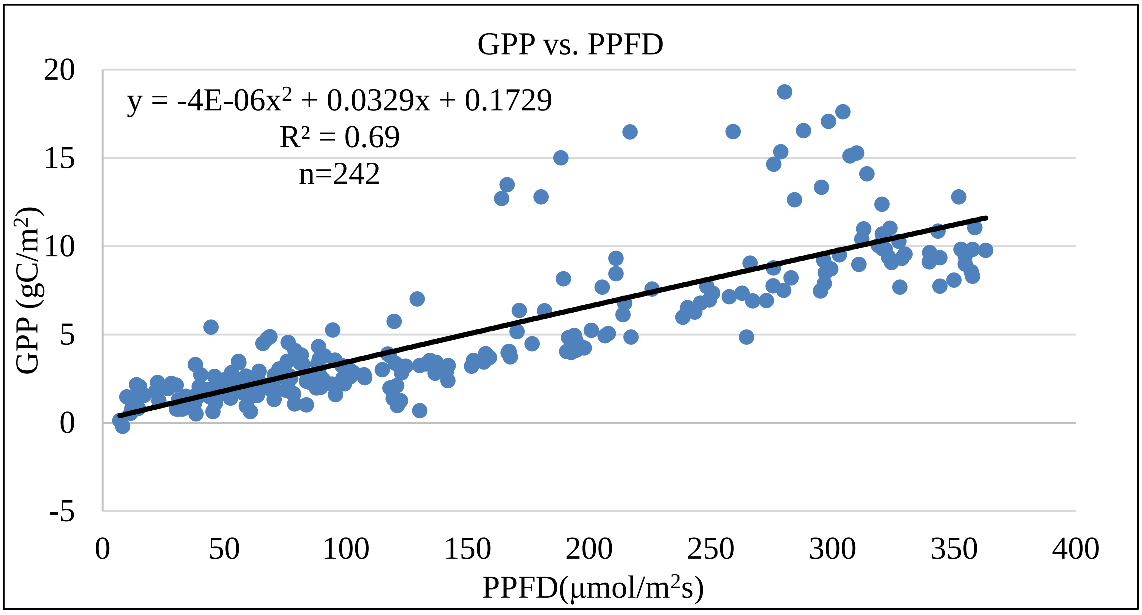

Figure 4. Relationship between GPP and PPFD

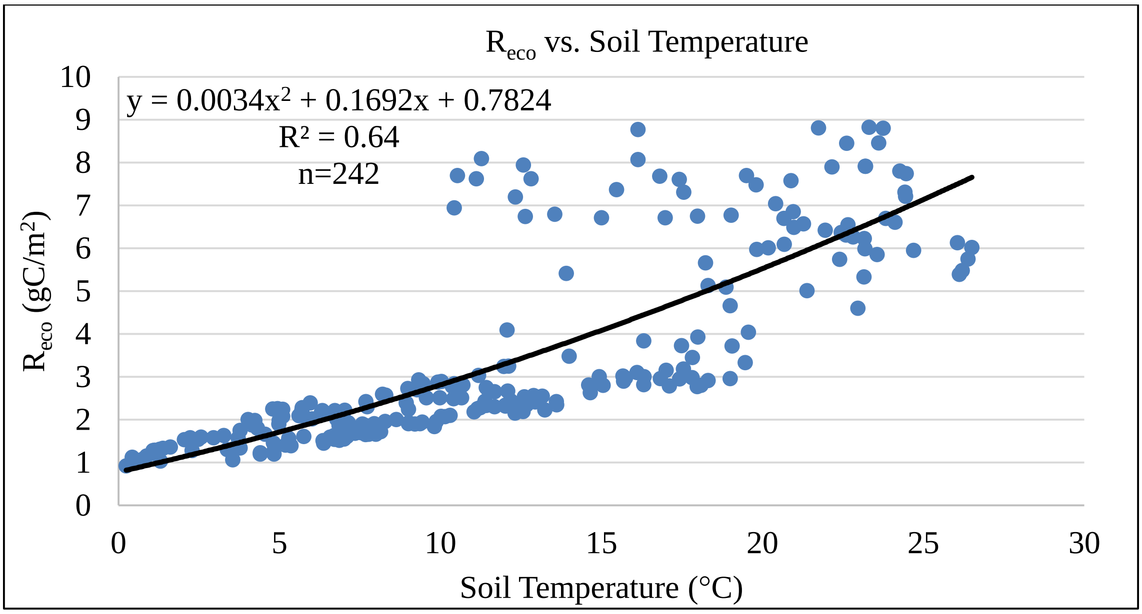

Figure 5. Relationship between R_{eco} and Soil Temperature

Scatterplots of relationships between k_t and NEE, GPP, R_{eco} is showed in Figures 6, 7, and 8. Figure 6 indicates that NEE is positive when dense cloud cover is occurred, which indicates carbon uptake from ecosystem to atmosphere and also that the GPP values are relatively small. NEE values become negative when the clearness index increases, namely under less cloudy or clear sky conditions.

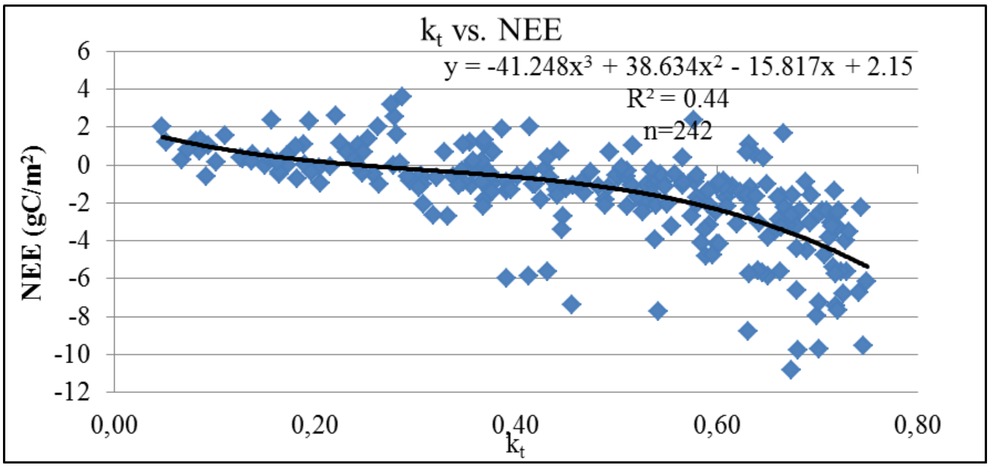

Figure 6. Relationship between k_t and NEE

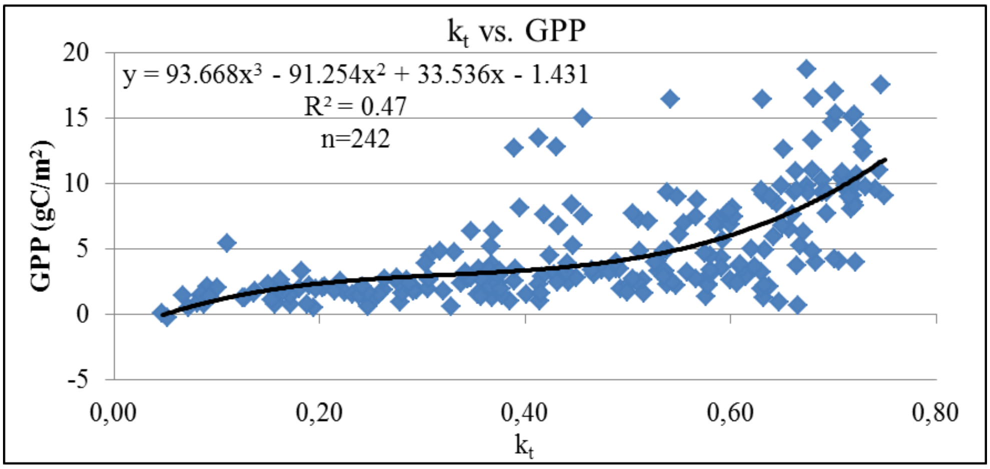

Figure 7. Relationship between k_t and NEE

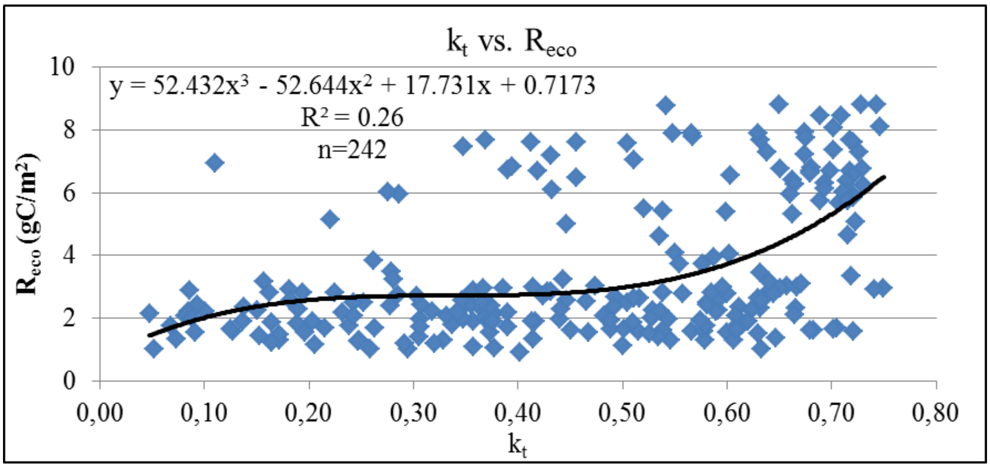

Figure 8. Relationship between k_t and NEE

CONCLUSION

Number of measurements on greenhouse gases from agricultural activities and above agricultural crops should be increased throughout the world in order to estimate the carbon exchange between ecosystem and atmosphere better. This study is one of the first researches about CO_2 fluxes of winter wheat in Turkey. Further studies on modeling the CO_2 exchange between the atmosphere and biosphere are necessary in order to extend the results from micro scale to meso and macro scales. In order to gather the relationships between the vegetative surface and atmosphere, actual (measured) data are necessary to be collected with high sustainability.

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