IMPORTÂNCIA DO PÓS-PROCESSAMENTO DOS DADOS DE FLUXO DE CO_2 OBTIDOS PELO MÉTODO EDDY COVARIANCE

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RESUMO: O estudo das interações dos fluxos de massa e energia com o ambiente é de extrema importância, visto os cenários modelados de mudanças climáticas e o impacto das atividades humanas no ambiente. O estudo do comportamento da água e dos gases de efeito estufa no ambiente é crucial para modelagem de cenários futuros e prospecção de sustentabilidade. Este trabalho tem como objetivo verificar a influência de diferentes coberturas de solo e configurações do pós-processamento de dados dos fluxos obtidos pelo método Eddy Covariance. Para isso, foram utilizados dados de fluxos de CO_2 medidos em área agrícola, passando por diferentes simulações de configurações para tratamento dos dados. As médias de fluxo líquido de CO_2 diferiram dentro de cada manejo de cobertura do solo (“palha”, “solo exposto” e “soja”) e de acordo com o método de partição de fluxos, chegando a uma diferença de 25% no fluxo acumulado de CO_2 em um cultivo de soja.

PALAVRAS-CHAVE: soja, dióxido de carbono, cobertura do solo.

IMPORTANCE OF THE POST PROCESSING OF CO_2 FLUX DATA OBTAINED BY THE EDDY COVARIANCE METHOD

ABSTRACT: The study of the interactions of mass and energy fluxes with the environment is extremely important, given the modeled scenarios of climate change and the impact of human activities on the environment. Studying the behavior of water and greenhouse gases in the environment is crucial for future scenarios modeling and sustainability prospecting. The objective of this study is to verify the influence of different soil coverings and flux data post-

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configurations obtained by the Eddy Covariance method. For this, we used data of net ecosystem exchange for CO_2 fluxes measured in agricultural area, through different simulations of configurations for data treatment. The net CO_2 fluxes averages differed within each soil cover management (“straw”, “bare soil” and “soybean”) and according to the flux partition method, reaching a 25% difference in the cumulative flux of CO_2 in a soybean crop.

KEYWORDS: soybean, carbon dioxide, soil cover.

INTRODUCTION

The Eddy Covariance technique (EC) (AUBINET et al., 2012) is used to measure mass and energy exchanges between the surface and the atmosphere. The EC method enables the integration between direct measurements of high frequency turbulent fluxes such as latent (water state change) and sensitive heat fluxes (air heating), CO_2 flux, and low frequency measurements of meteorological and soil elements. It is a complex methodology that uses a combination of sonic instruments, with the possibility of flux data acquisition that can represent large areas of study continuously, allowing to observe fluctuations and changes in very small time scales.

Agriculture faces major challenges in relation to climate change, given the growing demands of the world's population each year. Carbon dioxide (CO_2) is a greenhouse gas with a tendency to increase its emissions in all productive sectors linked to human activity worldwide (FAO, 2016). Soil cover influences the alteration of CO2 fluxes in the environment, with the potential to boost its emission or capture it from the atmosphere through its absorption for plant photosynthesis.

Every year in the Brazilian sugarcane fields, on average, 10% of the areas are under renewal (CONAB, 2018). The renewal is a period after the last harvest of a sugarcane field where the plants are removed from the area and for approximately one year is not cultivated, so that next year a new sugarcane field will be implemented.

During this transition period between the end of the sugarcane's production cycle and the beginning of another sugarcane plantation in the area, soil management and a short-cycle cultivation in the area can greatly modify the CO2 balance (MOITINHO, et al. 2013; LA SCALA JR, 2006)

The net CO_2 flux balance obtained by the EC method is extremely important in the source or sink studies of this greenhouse gas. This methodology permit the acquisition of high frequency flux measurements, resulting in a difficult data processing, because the volume of information collected is very large. One of the biggest difficulties of the EC technique, is the need for post processing and corrections of the data obtained, these are subject to atmospheric variations in time scale that can reach 20 Hz. There are several methods available on different data processing platforms that can be used in data corrections and, consequently, influence the final result of the fluxes (MAMMARELLA et al., 2016).

The objective of this work is to compare and analyze different soil coverings and data post-processing configurations of carbon dioxide flux obtained by the Eddy Covariance method.

MATERIALS AND METHODS

The work was carried out in a commercial area of sugarcane production in the municipality of Piracicaba, São Paulo at latitude -22°46'9.04 " S and longitude -47°34'47.10" W. The experiments were conducted between June, 29 of 2017 to March, 23 of 2018 and were collected at the local weather station the data of solar radiation, air temperature, air humidity and precipitation.

The data period was divided according to the soil cover management, comprising in the first moment the soil covered with sugarcane residual straw, called “straw”, followed by a post-soil period in which the straw was incorporated in-depth and the soil was left without cover, called "bare soil" and a period with soybean cultivation, called "soybean". The periods occurred successively and lasted 64, 84 and 120 days, respectively.

The “straw” and “bare soil” periods were divided into dry and wet, as they have distinct periods separated by rainy days and dry days. For soybean, precipitation distribution was uniform throughout the period, without distinction of dry phase.

The determination of the CO_2 fluxes was performed in the *datalogger* by programming inserted according to the calculation methodologies proposed by Aubinet et al. (2012). The fluxes were integrated for 30 minutes and stored with raw data from high frequency measurements. The flux data obtained by the Eddy Covariance method requires a series of quality control processes, eliminating spurious data, according to the guidelines presented by Mauder & Foken (2006) and Foken et al. (2012). After data quality control, a *footprint* filtering was performed. *Footprint* is a mathematical relationship that associates the spatial distribution of flux sources and their degree of intensity, and is essentially an estimate of the area of origin corresponding to each measured flux.

After data quality control and footprint filtering, 2.11% of all data (30-minute scale) were discarded due to initial failures (prior to treatment), 11.89% of data was outside the maximum and minimum (unrealistic data), 5.18% of data in rainy periods and 19.04% of data outside the *footprint* were discarded, totaling 38.22% of the data.

Flux data discarding is within the range as normal, according Papale et al. (2006) this percentage can reach 60%. The largest source of data discarding is *footprint* filtering because the data likely to come from outside the study area is discarded, not representing the site evaluated.

Figure 1 shows a 30-minute scale data showing that under all ground cover conditions there was a difference in CO_2 data discard in dry or humid environment and night data was more discarded than in daytime data.

At night there was more data discarding, increasing in wet periods during the day. This is predominantly due to *footprint* filtering. During rainy periods, data are discarded due to measurement failures and unreliability of flux data, increasing the occurrence of data outside the actual measurement limits. With a balanced distribution of data discards at each filtering stage due to the more favorable conditions for obtaining the fluxes (higher atmospheric instability, frequent short rainfall and data within the measurement area), the soybean cultivation period did not reach longer variations between data discard throughout the day.

After quality control and data filtering, the CO_2 flux measurements went through a data post-processing tool for new filtering, gap filling and, for soybean, NEE partitioning on Ecosystem Respiration (ER) and Gross Primary Production (GPP).

Through the “*REddyProcWeb online tool*” (WUTZLER et al., 2018), the CO_2 fluxes were filtered by the friction velocity (u*, or *Ustar*) and the missing data gaps was filled with Reichstein et al. (2005) methodology and was applied a partitioning algorithm for the fluxes. The *Ustar* threshold is estimated by the Moving Point Test according to Papale et al. (2006), and filtration is performed due to more stable conditions at night, where less turbulence occurs, resulting in an underestimation of the night flow, therefore the need for correction.

This tool allows configuration of input data for *Ustar* estimation and subsequent filtering. In order to verify the influence of the input parameters chosen to fill in the faults, four simulations of initial configurations of the online tool were performed, varying according to the *Ustar* estimation method, called “standard”, “test 1”, “test 2 ”and“ test 3 ”.

The simulations were performed considering data filtering by *Ustar*, which can be performed using different methods of temporal data separation, segregating data within each year (standard), temporal data continuity (test 1), temporal data separation specified by the user (test 2) which, in this case, was separated according to the soil cover. Data filtering by *Ustar* may not be performed either (test 3).Each simulation was performed within a CO_2 flux partition method provided by the tool. The first, proposed by Reichstein et al. (2005), consists of the estimation of ecosystem respiration by night and extrapolated to daytime, which in this work was called "night". In this method, the NEE value filled by the algorithm does not change, being divided into GPP and ER. The second method, by Lasslaop et al. (2010) estimates the respiration of the ecosystem by adjusting the light response curve (linked to solar radiation), called "day". In this method, the sum of GPP and ER results in a new NEE value.

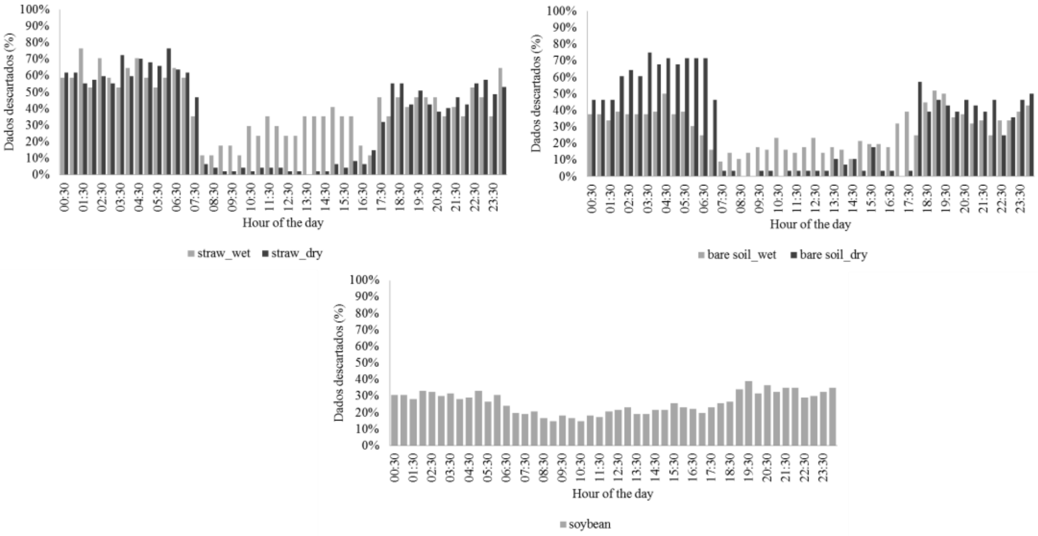

Figure 1. Data discard every 30 minutes throughout the data series.

RESULTS AND DISCUSSION

The total rainfall in the "straw" and "bare soil" periods was 49.5 and 164.8 mm, respectively. For soybean, the total accumulated rainfall was 582.4 mm. The average air temperature for "straw", "bare soil" and "soybean" was 18.6, 22.9 and 23.6 ºC. The average air temperature and accumulated precipitation over the days of the study period can be observed in Figure 2, which shows the transition between winter, spring and summer for the three soil coverings.

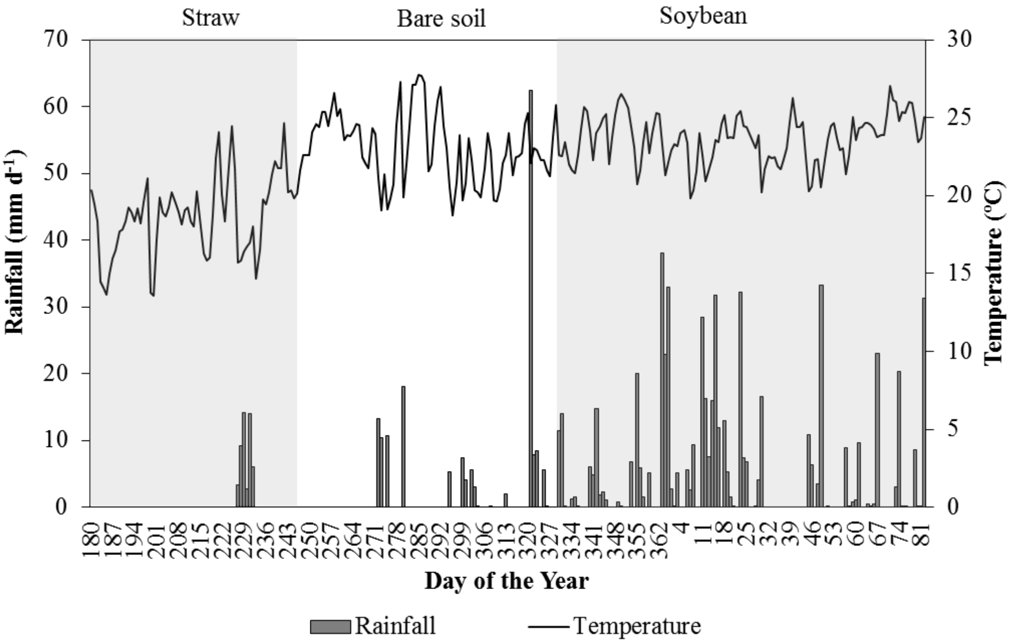

Figure 2. Average air temperature and accumulated precipitation over the study period. The areas in gray separate the period of soil covered with “straw” (left), period of “bare soil” and period of “soybean” (right).

The average Net Ecosystem Exchange of CO_2 differed significantly ($p < 0.05$) within each cover (“straw”, “bare soil” and “soybean”). Considering the simulations performed, there was a significant difference in NEE for the period with bare soil and straw cover. In these conditions where there is no crop covering the soil, the flux is more prone to the occurrence of less turbulence due to the lower surface roughness (Table 1).

Table 1. Results of simulatons in the series data with different soil cover.

Soil cover	Simulations							
	Day				Night			
	Standard	Test_1	Test_2	Test_3	Standard	Test_1	Test_2	Test_3
Straw	80.3ab	75.9b	72.3b	72.3b	95.3ab	95.3ab	104.8ab	83.4ab
Bare soil	101.7ab	99.4ab	93ab	102.7ab	118ab	117.8ab	129.9a	104.6ab
Soybean	-72.3c	-74c	-74.3c	-70.3c	-55.8c	-58.3c	-50.9c	-77.9c

Note: Lower case letters represent significant difference at 5% by Tukey test. Equal letters do not represent significant difference.

The simulations of configurations by the “day” and “night” method are shown in Figures 3-A and 3-B, respectively. The negative data represent the CO_2 consumption by the plants by photosynthesis and the positive values represent the CO_2 emission by the ecosystem.

The means were compared by the “day” and “night” methods of flux partition (Table 2), with significant difference between the methods, being obtained for the first method lower averages compared to the second for "straw" and "bare soil".

Table 2. Net CO2 flux averages (NEE) considering the day and night partition methods for the study period in each soil cover.

Partitioning method	Soil cover		
	Straw	Bare Soil	Soybean
	NEE (kg ha^{-1} d^{-1})		
Day	75.21c	99.21ab	-72.74d
Night	94.67bc	117.57a	-60.73d

Note: Lower case letters represent significant difference at 5% by Tukey test. Equal letters do not represent significant difference.

The mean found to the soybean CO_2 flux by the “night” method was closer to what presents Lewczuk et al. (2017), that was -51.32 kg ha^{-1} day^{-1} for 2011 crop and -52.46 kg ha^{-1} day^{-1} for 2012 crop of soybean in Argentina with EC technique, in this work a different post-processing methodology was presented by Posse et al. (2014). In the work presented by Wagle et al. (2017), was performed the treatment of NEE data by the EC method equivalent to the simulation “Test_2”, with partition of the fluxes by the “night” method and obtained an average for no irrigated soybean of -78.69 kg CO_2 ha^{-1} day^{-1} in Oklahoma, USA and -165.75 kg CO_2 ha^{-1} day^{-1} for irrigated soybean in Mississippi, USA.

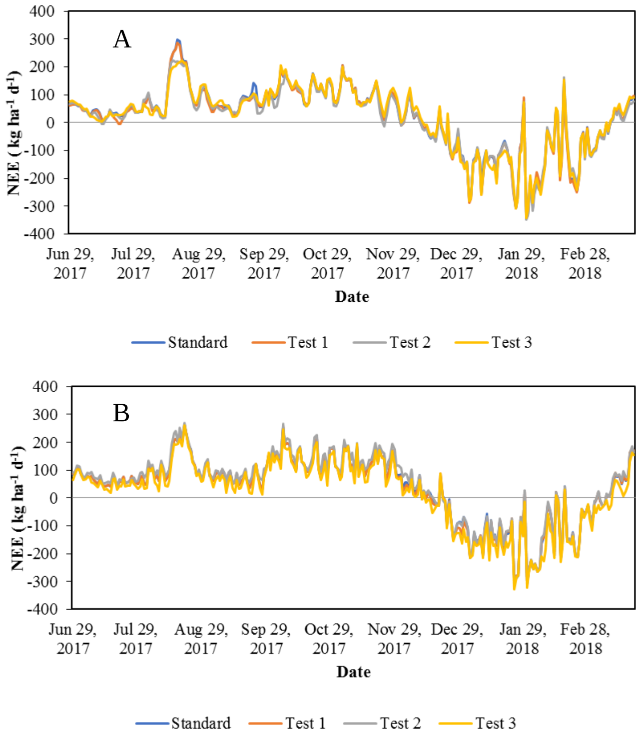

Figure 3. Daily averages of Net Ecosystem Exchange of CO_2 (NEE) for each input data simulation and by the “day” (A) and “night” (B) flux partition methods.

Considering the accumulated CO_2 flux for each simulation (Figure 4), the “Test_3” obtained less difference compared to the others when comparing the “day” and “night” methods of flux partition. For the “straw” and “bare soil” periods in the four simulations performed, on average, occurred 15 and 16% of the difference between the “day” and “night” method. In the soybean period, for the “Test_3” simulation, the difference was 10% between the methods, and for the other simulations, on average, the difference was 25%.

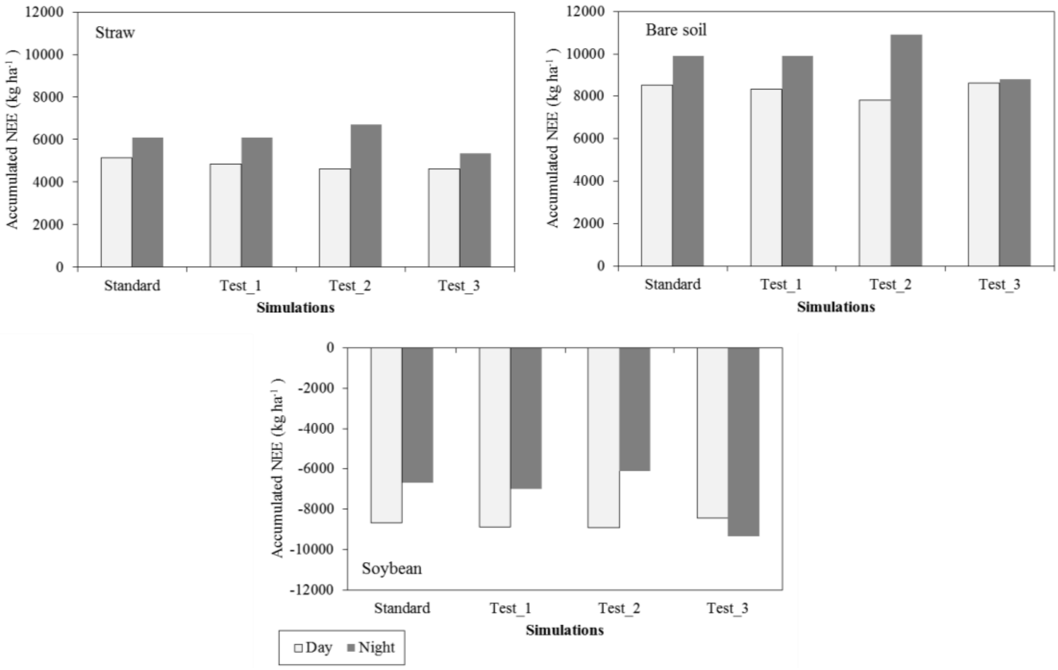

Figure 4. Accumulated CO_2 net flux exchange (NEE) for the different soil coverings ("straw", "bare soil" and "soybean") in each post-processing simulation in the "day" and "night" methods for flux partition.

CONCLUSIONS

The CO_2 flux varied according to soil cover. The “night” method of NEE partition presented higher averages for different soil coverings. Under conditions of lower atmospheric turbulence, the configuration used to determine *Ustar* influences the CO_2 fluxes.

Este trabalho mostrou que o pós-processamento é importante na obtenção do fluxo de CO2, no entanto, a metodologia escolhida para o tratamento de dados influencia diretamente no quantitativo do fluxo gerado.

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