SOIL CO2 EFFLUX IN FOUR DIFFERENT LAND USE SYSTEMS IN RIO POMBA, MINAS GERAIS/BRAZIL[1]

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ABSTRACT – Functioning and sustainability of agricultural systems depend directly on the soil biological activity. Soil respiration, or CO_2 efflux, is a sensible indicator of biological activity, revealing fast and accurately whether changes in environment affect soil community. In this context, soil respiration can be used to evaluate soil organisms behavior after an environmental change revealing the capacity of a soil in it normal functioning after a disturb event. The objective of this work was to study seasonal variation in soil CO_2 efflux in Rio Pomba/MG and its relation with typical land uses of Zona da Mata region of Minas Gerais. Fluctuation on soil CO_2 efflux was observed in all areas throughout the period of the study, from September 2010 to August 2011, as a result of climatic variation. We have also reported specific patterns on CO_2 efflux that can be associated with land use. It was observed that the area under annual crops presented the highest amplitude of changes in respiratory rates, while forest and guava plantation presented the lowest. The principal component analysis revealed that the area cultivated with guava presented pattern of CO_2 efflux similar to forest, and the area intensively cultivated with annual crops showed behavior opposite to the forest. We conclude that variation in soil respiration rates is higher in intensive cropped areas. Additionally, total soil respiration can be used as a methodology to assess the interference of cropping on soil biota.

Keywords: soil organisms, soil quality indicators, soil total respiration.

EFLUXO DE CO2 EM QUATRO DIFERENTES SISTEMAS DE USO DO SOLO EM RIO POMBA, MINAS GERAIS/BRASIL

RESUMO – O funcionamento e a sustentabilidade dos sistemas agrícolas dependem diretamente da atividade biológica do solo. A respiração, ou efluxo de CO_2, é um indicador sensível da atividade biológica do solo, revelando com rapidez e acurácia se mudanças ambientais afetam a comunidade do solo. Assim, pode-se utilizar a respiração do solo para avaliar o comportamento dos organismos em resposta a alterações ambientais, revelando a capacidade do solo em manter seu funcionamento após um distúrbio. O objetivo deste trabalho foi estudar a variação sazonal no efluxo de CO_2 do solo em Rio Pomba/MG e sua relação com usos típicos do solo na Zona da Mata de Minas Gerais. Observou-se flutuação no efluxo de CO_2 em todas as áreas estudadas ao longo do período do experimento, de setembro de 2010 a agosto de 2011, como resultado da variação na precipitação e na temperatura atmosférica. Verificaram-se padrões específicos no efluxo de CO_2 que podem ser associados ao uso do solo. A área de culturas anuais apresentou as maiores variações nas taxas respiratórias, enquanto a área de mata e do goiabal apresentaram as menores. A análise de componentes principais revelou que o padrão de respiração do goiabal foi o mais próximo do apresentado pela mata, já a área de culturas anuais apresentou comportamento oposto ao da mata. Conclui-se que a variação nas taxas respiratórias é maior em solos que apresentam cultivo intensivo. Adicionalmente, a respiração total do solo pode ser utilizada para avaliar a interferência das práticas de cultivo na biota do solo.

Palavras chave: biota do solo, indicadores de qualidade do solo, respiração total do solo.

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1. INTRODUCTION

Functioning and sustainability of agricultural production systems depends directly on the soil biological activity (Higa & Parr, 1994). In this context, evaluation of soil biological fraction is important to verify the effect of land use and climatic changes in soil community (Raich & Tufekcioglu, 2000). Effect of land use in soil organisms is poorly reported in Zona da Mata of Minas Gerais, and it comprehension may be helpful to define agricultural practices that contributes to maintain or increase soil biological quality.

Soil organisms are responsible to many processes linked to productivity and sustainability in agriculture. Nutrient cycling is one of these process, revealing the capability of a system in reduce nutrient losses by using efficiently environmental resources (Buerkert *et al.,* 2011). Also, the activity of microorganisms on the carbon cycle is central to maintain or increase levels of soil organic matter (SOM), which is a challenge for modern tropical agriculture (De-Polli *et al.,* 2005). In tropical soils, organic matter is a fundamental component for crop production and sustainability once it increases cationic exchange capacity, reducing nutrient lixiviation and adsorption to clay (De-Polli *et al.,* 2005). Increasing SOM is also environmentally important, once carbon fixation in soil may help to mitigate high levels of atmospheric CO_2 (Silveira & Freitas, 2007).

Soil quality can be defined as *¨The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation"* (Doran & Parkin, 1994). In order to function as previously described, the role of microorganisms cannot be excluded, once they promote plant growth with increasing supply of water (Augé, 2001), nutrients (Ingham & Trofymow, 1985), and protecting plants against pathogenic organisms (Bezemer & Dam, 2005). This way, evaluation of the soil biological activity can be used as predictive tool to verify the effect of agricultural practices in soil biological processes.

Soil organisms are sensible to changes caused by management practices and high quality soils have intense biological activity with balanced populations (Tótola & Chaer, 2002). Diversely from chemical and physical indicators of soil quality, establishment of soil biological quality parameters is very complex (Arshad & Martin, 2002). Nevertheless, soil respiration is among the indicators that can be used in order to study soil biological quality (USDA-ARS 1998) because it presents high correlation with many production and sustainable parameters (Arshad & Martin, 2002).

Soil respiration, or soil CO_2 efflux, is the sum of autotrophic (roots, algae, and cianobacteria) and heterotrophic (micro-, meso-, and macrofauna) respiration and, to less extend, chemical oxidation of carbon-containing materials (Raich & Schlesinger, 1992; Hanson *et al.,* 2000). Soil respiration is an indicator of biological activity, which reveals fast and accurately whether changes in environment affect soil community (Hanson *et al.,* 1993). However, interpretation of respiration data requires attention because a raise in respiration rates can be triggered either by an increase in the productivity or by the stress arising from an environmental disturb (Islam & Weil, 2000).

In this context, soil respiration can be used to evaluate the effect of land uses on soil organisms behavior after an environmental change revealing soil resistance. Soil resistance can be defined as the capacity of a soil in maintaining the functioning after a disturbance event (Seybold *et al.,* 1999). Thus, the use of soil respiration to access soil resistance is a convenient manner to the comprehension of ecosystem stability (Tilman & Downing, 1994). The objective of this work was to study seasonal variation in soil CO_2 efflux in Rio Pomba/MG and its relation with typical land uses of Zona da Mata region of Minas Gerais.

2. MATERIAL AND METHODS

Experiment location

This study was conducted at the Laboratory of Soil Microbiology/Department of Agriculture and Environment of Instituto Federal de Educação, Ciência e Tecnologia do Sudeste de Minas Gerais (IF Sudeste MG). Areas under investigation are located in Rio Pomba/ MG, Brazil, in a Red-Yellow Latosol.

Edafo-climatic characterization of the areas

Soil respiration analyses were performed from September 14^{th}, 2010 to August 25^{th}, 2011, as indicated in Figure 1. Meteorological data were obtained at "Sistema de Meteorologia e Recursos Hídricos do Estado de Minas Gerais" (Figura 1).

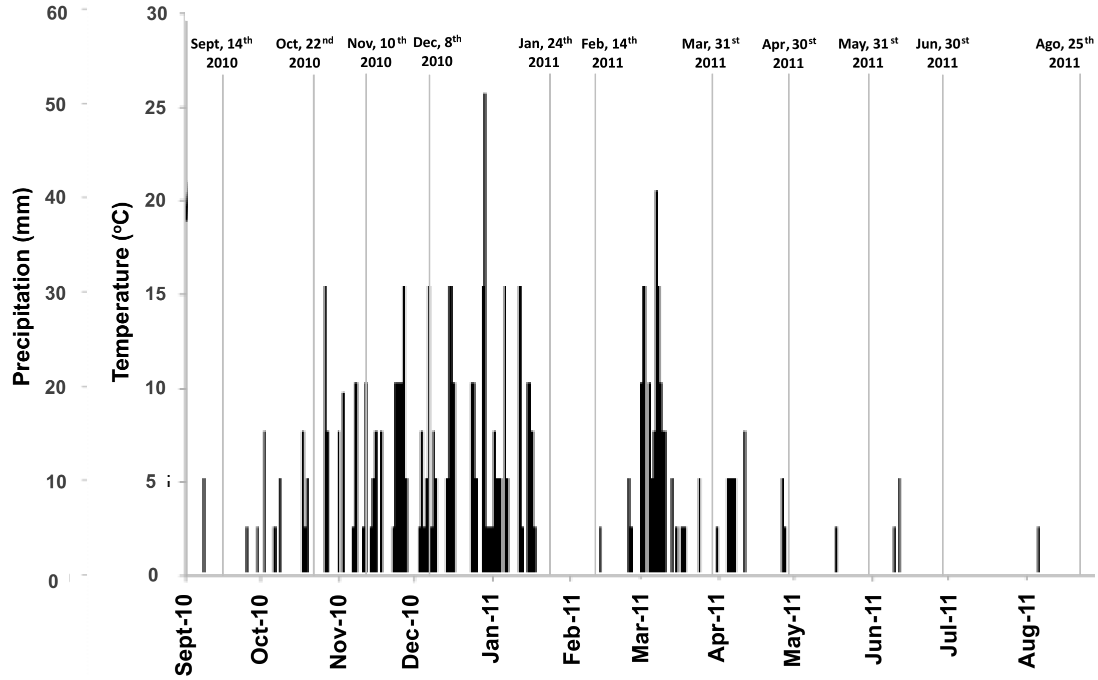

Figure 1 - Daily precipitation (columns - mm) and mean temperature (line - °C) in Rio Pomba/MG from September 2010 to August 2011. Data was obtained at "Sistema de Meteorologia e Recursos Hídricos do Estado de Minas Gerais" (SIMGE – http://ricardonun.Dominiotemporario.com/monitoramento/chuva_diaria.html#). Vertical lines indicate dates of respiration measurements.

Analysis were realized in four areas which represents the main land uses at Zona da Mata of Minas Gerais: 1. Forest Area – (21°14'30" S; 43°09'17" O; alt. 449 m) formerly a cattle pasture, today it presents Atlantic secondary forest vegetation originated from natural regeneration with sixty years old; 2. Coffee area – (21°14'47" S; 43°09'19" O; alt. 453 m) *Coffea arabica* var. *Oeiras* cultivated in organic system intercroped with the legume tree *Gliricidia sepium*, both with five years old receiving amendments with organic composts from animals and plants; 3. Guava cultivation area – (21°14'41" S; 43°09'57" O, alt. 490 m) *Psidium guajava* var. *Paluma* with eight years old. Nowadays this area is in transition from conventional to organic agriculture; 4. Annual crops area – (21°15'57" S; 43°09'93" O, alt. 442 m) area intensively and conventionally cultivated with maize, *Zea mays* variety Ag 10-15, and common bean *Phaseolus vulgaris*. Over the last 30 years, annual crops area received 8-28-16 fertilizer, insecticide, and pre-emergence herbicide. Soil chemical analysis for each of these areas was performed by the Laboratory of Soil Chemical Analysis/ IF Sudeste MG – *Campus* Rio Pomba (Table 1).

Evaluation of soil respiration

Soil Respiration was evaluated using chambers covering 11 cm^2 using a flask containing 10 ml 0.5 mol L^{-1} NaOH as CO_2 trap. Four chambers were installed randomly in each area described above. After 24 hours, flasks containing alkali were hermetically closed and transported to the Laboratory of Soil Microbiology. Finally, quantification of CO_2 evolved by soil organisms respiration was realized by titration with HCl 0.25 mol L^{-1}, as described by Carvalho *et al.* (2008).

Statistical analysis

The experiment was conducted in a completely randomized design with four repetitions, in a factorial 4 (areas) x 11 (months) arrangement. Data were submitted to variance analyses and the means were grouped using Scott-Knott at 5% of probability. Finally, a Principal Component Analysis was performed to compare the

Table 1 - Chemical analysis of soil sampled in September 2010 in the areas studied in this work

Item	Forest	Coffee plantation	Guava plantation	Annual crops area
pH (H_2O) \1	5.7	6.6	6.2	6.0
P (mg dm^{-3})	4.6	2.2	54.8	39.6
K (mg dm^{-3})	100	158	132	166
Ca^{2+} ($cmol_c$ dm^{-3})	1.5	2.9	3	1.8
Mg^{2+} ($cmol_c$ dm^{-3})	0.5	2.0	0.7	0.8
Al^{3+} ($cmol_c$ dm^{-3})	0.0	0.0	0.0	0.0
H + Al^{3+} ($cmol_c$ dm^{-3})	5.4	2.1	1.32	2.7
SB ($cmol_c$ dm^{-3})	2.3	5.3	3.7	3.0
CTC (t) ($cmol_c$ dm^{-3})	2.3	5.3	3.7	3.0
CTC (T) ($cmol_c$ dm^{-3})	7.7	7.4	5.0	5.7
V (%)	29.5	71.6	74	52.8
MO (dag/kg)	3.87	0.56	1.8	3.46

\1Chemical analysis was performed in the Laboratory of Soil Chemical Analysis/IF Sudeste MG - *Campus* Rio Pomba using standard methods described by Empresa Brasileira de Pesquisa Agropecuária - Embrapa (1997).

behavior of CO_2 efflux of from each area throughout the time.

3. RESULTS AND DISCUSSION

We analyzed *in situ* soil CO_2 efflux in forest, coffee plantation, guava plantation and annual crops area in Rio Pomba/MG. The results showed that CO_2 efflux patterns throughout the year could be associated to the land use and cropping practices (Figure 2).

Despite of the land use effects in soil CO_2 efflux, we observed reduction on soil CO_2 efflux beginning in October 2010 and in May 2011 for all analyzed areas. In the beginning of the raining season, October to December 2010, soil respiration initially decreased, returning to the average levels in January 2011 (Figure 2). Our results contrast with observations that indicate increase in respiration rates during raining period (Davidson, 2000). In this last experiment, the effect of water on soil respiration could be linked to increase in primary production. In our study, we can link reduced respiration with fulfillment of soil pores with water. This reduces the availability of O_2 for soil organisms metabolism, thus reducing soil respiration (Kaschuk *et al.,* 2010).

Decrease in soil CO_2 efflux was observed after temperature reduction in May and June 2011. In a global scale study, it was observed that temperature showed the highest correlation with soil respiration, considering a single environmental factor (Raich & Schlesinger, 1992). Additionally, increase in soil CO_2 efflux is reported to occur in high temperatures (Schlesinger & Andrews.

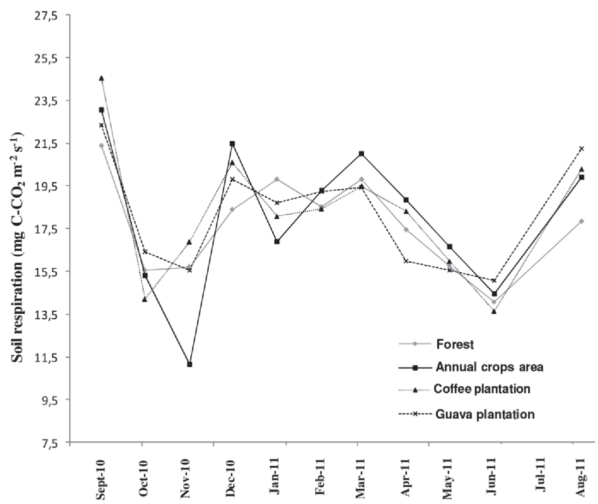

Figure 2 - Soil respiration (mg C-CO_2 m^{-2} s^{-1}) in forest, coffee plantation, guava plantation and annual crops area in Rio Pomba/MG from September 2010 to August 2011.

2000). Temperature effect on soil CO_2 efflux is probably related with the rate of enzymatic reactions (Tótola & Chaer, 2002). This way, the decrease on atmosphere temperature reduced the rates of biological reactions in soil, consequently soil respiration.

Comparison between areas with different land uses in a single period of the year is not informative about the effect of cropping in CO_2 efflux. In our experiment. when CO_2 efflux levels are compared for each individual month, they are equal in 6 of 11 months for analyzed areas (Table 1). In the five remaining months, no consistent behavior was observed (Table 1), showing that measurements of soil CO_2 efflux in only one period of the year are not informative and could give rise to contrasting conclusions.

However, we observed that long term analysis of CO_2 efflux is more suitable to evaluate the relationship between microbial activity and land use in our region. Over all, forest and guava plantation showed the lowest amplitude on CO_2 efflux (Amplitude = Biggest CO_2 efflux in the year - Shortest CO_2 efflux in the year) during the period of the study, respectively, 7.34 and 7.26 mg C-CO_2 m^{-2} h^{-1} (Table 1). Annual crops area and coffee plantation showed the highest amplitudes, respectively, 11.92 and 10.89 mg C-CO_2 m^{-2} h^{-1} (Table 1). It is well reported that land use can interfere on soil CO_2 efflux (Hanson *et al.,* 1993; Reeve *et al.,* 2010) and that intensive cropping practices, such as tillage, triggers an increased soil CO_2 efflux (Schlesinger & Andrews, 2000). Our results corroborate these observations, showing that soil respiration is affected by land use.

Soil CO_2 efflux can reveal soil microbial resistance after environmental changes. Resistance can be defined as the capacity of a soil microbial community in maintains biological function unaltered after a disturbance (Seybold *et al*., 1999). This concept can be associated with ecosystem stability (Tilman & Downing, 1994) and thus can be linked to the effects of agricultural practices on soil microbial communities.

Analysis of soil respiration revealed high resistance of soil organisms in Forest and Guava plantation. Our results agree with other reports that indicate that soil respiration in native vegetation area is less variable than cropped areas (Davidson, 2000; Pinto-Júnior *et al.,* 2009). This way, soil respiration analysis can be used as tool to verify the ecosystem stability, helping to evaluate the effect of a land use to local soil biological quality (Tilman & Downing, 1994).

Comparing variation of respiration patterns of the annual crops area with results observed for Forest, we concluded that high floristic diversity was associated with high resistance of soil biological community (Figure 2). Also, we observed that amplitude on respiration rates at guava plantation were inferior to those reported in coffee plantation (Table 2). In this last comparison, both systems are organic, increasing vegetal diversity by the presence of weeds, which contributes to the increase on soil resistance (Borron, 2006). Nevertheless, specific characteristics of coffee plantation, such as the presence of *Gliricidia sepium,* a deciduous legume tree (Parrota, 1992), and the frequent use of organic manure, contributed to the higher variation in CO_2 efflux rates reported herein.

Principal Components Analysis (PCA) showed that CO_2 efflux patterns in guava plantation were similar to those observed in Forest (Figure 3). Also, it was revealed that the pattern of soil CO_2 efflux observed in annual crops area was the most dissimilar to those verified for forest (Figure 3). Considering that forest is the best reference condition for Rio Pomba, this analysis showed that intensive cropping practices triggered the most pronounced modifications on soil organisms metabolism.

Table 2 - Monthly comparison of soil respiration in forest, coffee plantation, guava plantation and annual cropping area in Rio Pomba/MG from September 2010 to August 2011

Month/Year	**Soil respiration (mg C-CO_2 m^{-2} s^{-1})**			
	Forest	**Annual crops area**	**Coffee plantation**	**Guava plantation**
September 2010	21.38 aB[\1]	23.04 aB	24.54 aA	22.33 aB
October 2010	15.54 cA	15.30 dA	14.20 eA	16.41 cA
November 2010	15.70 cA	11.12 eB	16.88 dA	15.54 cA
December 2010	18.38 bB	21.46 aA	20.59 bA	19.81 bA
January 2011	19.80 aA	16.88 cA	18.07 cA	18.70 bA
February 2011	18.50 bA	19.29 bA	18.42 cA	19.21 bA
March 2011	19.80 aA	20.99 aA	19.49 bA	19.41 bA
April 2011	17.44 bA	18.86 bA	18.30 cA	17.59 cA
May 2011	15.74 cA	16.65 cA	13.69 eB	16.33 cA
June 2011	14.04 cA	14.44 dA	13.65 eA	15.07 cA
August 2011	17.83 bB	19.90 bA	20.28 bA	21.23 aA

[\1]Means with the same letter indicates no difference by Scott-Knott test at 5% probability. Lowercase letters indicate comparisons between lines and capital letters comparisons between columns. Coefficient of variation (CV) = 7.90%.

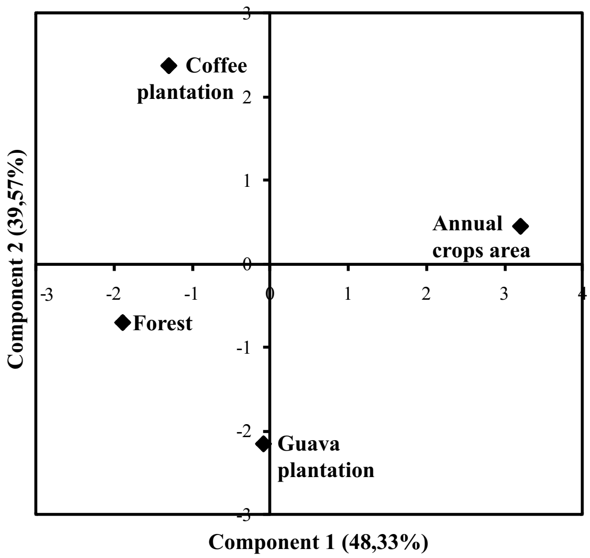

Figure 3 - Principal components analysis based on soil respiration data (mg C-CO_2 m^{-2} s^{-1}) in the different land use areas in Rio Pomba/MG. Annual crops area. Forest, coffee plantation and guava plantation from September 2010 to August 2011.

4. CONCLUSION

Interference of seasonal environment changes on soil respiration rates are affected by land use system. This variation was more pronounced in intensively cultivated soil with lower floristic diversity. This way, soil respiration can be used to evaluate the effect of agricultural practices on soil organisms, revealing soil microorganism's resistance and soil biological quality. However, this evaluation is only worthy if continuously performed to reveal the variation range on biological activity after seasonal changes of environmental conditions.

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