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Spatial variability of soil respiration in Archaeological Dark Earth areas in the Amazon

José Maurício da Cunha[a,*], Milton César Costa Campos[a], Denilton Carlos Gaio[b], Zigomar Menezes de Souza[c], Marcelo Dayron Rodrigues Soares[a], Douglas Marcelo Pinheiro da Silva[a], Emily Lira Simões[a]

[a] *Federal University of Amazonas, Institute of Education, Agriculture and Environment, Humaitá, Amazonas, Brazil*
[b] *Federal University of Mato Grosso, Institute of Physics, Cuiabá, Mato Grosso, Brazil*
[c] *Campinas State University, Department of Soil and Water, Campinas, São Paulo, Brazil*

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ABSTRACT

In natural ecosystems, soil respiration is one of the important components of carbon emission into the atmosphere – CO_2 efflux. Soil CO_2 efflux has both temporal (due to temperature and moisture changes) and spatial variability, which can be explained by different types of soil, soil use and management, as well as the influence of vegetation on CO_2 efflux. The aim of this study was to measure the spatial variability of soil CO_2 efflux, soil temperature and soil moisture in areas of archaeological dark earth cultivated with the guandu bean (GB) and pasture (PT), compared to soil use in natural forests (NF) in Amazonas state, Brazil. To that end, regular meshes were marked out in areas of forest (6 × 6 m spacing), guandu bean (4 × 5 m spacing) and pasture (8 × 8 m spacing) measuring 2500 m^2, 1700 m^2 and 4800 m^2, respectively, with 88 sample points georeferenced in each area. Soil CO_2 efflux (FCO_2) and soil temperature (ST) were measured at the intersection points of the meshes, and soil samples were collected at a depth of 0.00–0.10 m to determine soil moisture (SM) in the laboratory. FCO_2 measurements were taken using LI-6400 systems. Soil temperature (ST) was measured at 0.00–0.10 m, using a portable thermistor thermometer, and soil moisture (SM) using soil samples collected at 0.00–0.10 m. FCO_2 and ST were lower in the forest area, with higher SM content, no difference between FCO_2 and ST in GB and PT, but with lower SM content in PT. The models of the experimental semivariogram were predominantly spherical, except for FCO_2 in the NF and GB areas, and SM in the PT area, which were fit to the exponential model. The maps of spatial distribution patterns indicate a trend in concentration, with a positive correlation between FCO_2 and SM and negative correlation between FCO_2 and ST in natural forest. Positive correlations were observed between FCO_2 and ST and SM in GB, but in PT, FCO_2 correlations were restricted to SM.

1. Introduction

In natural ecosystems, soil respiration (CO_2 efflux) is one of the most important components of greenhouse gas emissions into the atmosphere. Net ecosystem CO_2 efflux, usually partitioned into gross primary productivity and total ecosystem CO_2 efflux, is measured worldwide using the eddy covariance technique to quantify terrestrial carbon sequestration and improve our understanding of ecosystem functioning and its response to climate change (Baldocchi, 2008). However, these measures lead to extrapolation between days and nights, with empirical relationships between temperature and soil water content (Desai et al., 2008), whose shortcomings are recurrent because they do not distinguish between these measures (Van Gorsel et al., 2009). This is because during relatively stable atmospheric nights, CO_2 efflux can be transported by advection with no transfer through the canopy (Aubinet et al., 2005). In this context, quantifying and understanding the spatial variability of soil CO_2 efflux may help elucidate the dynamics of abiotic and biotic effects on the main components of soil CO_2 efflux.

Several factors control CO_2 efflux from the soil surface to the atmosphere, including moisture, soil temperature, primary ecosystem biomass production, substrate quality, use and management, and the diversity and populations of soil organisms (Reichstein et al., 2003). However, Zhang et al. (2015) state that soil temperature and moisture content are highly sensitive to changes, because they are widely used as the measures that most interfere with the dynamics of CO_2 efflux.

Phillips et al. (2011) suggest that there are two important aspects to

* Corresponding author.
E-mail addresses: maujmc@ufam.edu.br (J.M. da Cunha), dcgaio@ufmt.br (D.C. Gaio), zigomarms@feagri.unicamp.br (Z.M. de Souza).

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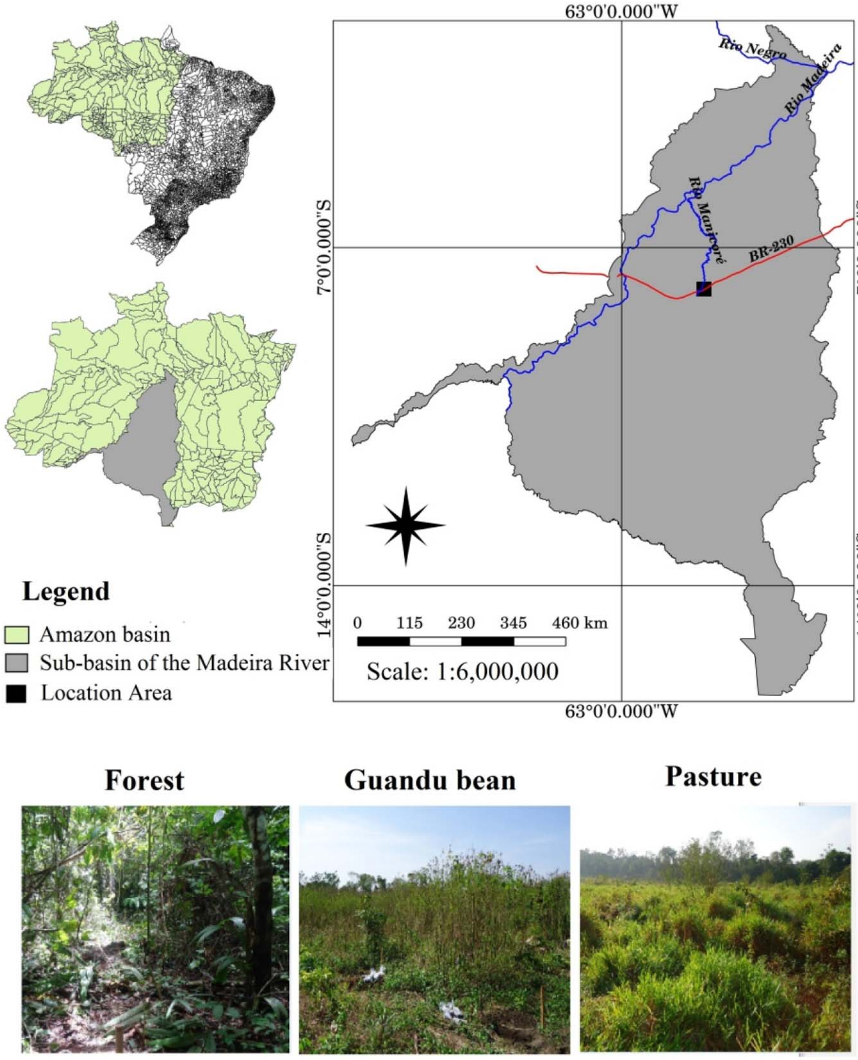

Fig. 1. Location of the study areas in the municipality of Novo Aripuanã, state of Amazonas, Brazil, along the Trans-Amazon Highway (BR-230).

Table 1
Physical properties and organic carbon in Archaeological Dark Earth areas in the region of Novo Aripuanã, state of Amazonas.

Statistics	BD	MaP	MiP	OM	CS	Sand	Silt	Clay
	$mg\ m^{-3}$	$m^3\ m^{-3}$		$g\ kg^{-3}$	$t\ ha^{-1}$	$g\ kg^{-1}$		
Natural forest								
Average	1.32 a	24.65 a	29.51 b	39.01 b	147.97 b	701.34 c	195.89 a	102.77 a
SD	0.08	2.66	2.37	8.46	28.14	39.64	36.31	14.71
CV	6.06	10.79	8.03	21.69	19.02	5.65	18.54	14.31
Guandu bean								
Average	1.35 a	22.93 b	31.18 a	43.99 a	166.99 a	768.73 a	145.22 c	86.07 b
SD	0.1	3.84	3.32	10.29	34.84	39.39	40.39	25.2
CV	7.41	16.75	10.65	23.39	20.86	5.12	27.81	29.28
Pasture								
Average	1.32 a	21.51 c	32.14 a	38.8 b	148.54 b	745.19 b	173.70 b	81.11 b
SD	0.08	4.9	3.25	7.67	29.1	27.42	31.5	17.05
CV	6.06	22.78	10.11	19.77	19.59	3.68	18.13	21.02

BD = bulk density; MaP = macroporosity; MiP = microporosity; OM = organic matter; CS = carbon stock; CV = coefficient of variation (%); SD = standard deviation. The averages followed by the same lower-case letter in the column do not differ from each other in Tukey's test ($p < 0.05$).

understand the influence of temperature on CO_2 efflux. The first is based on biological factors, especially CO_2 production in the soil through the decomposition of organic waste by microbial activity and the respiration process in organisms (including plant root systems). The second is related to physical factors, since CO_2 efflux involves transporting the gas from the upper soil layers to the surface, and is calculated using the diffusion equation. In other words, the rate at which CO_2 is released from the soil to the atmosphere is controlled by the CO_2 concentration gradient between the soil and the atmosphere (Panosso et al., 2009).

Suseela et al. (2012) underscore the effect of soil organic substrate quality on CO_2 efflux, suggesting that materials with more molecularly