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Effects of land-use changes on soil respiration

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ABSTRACT

In Brazil, soil use and occupation are largely responsible for greenhouse gas emissions, and one of the ways to monitor disturbances to ecosystems is through edaphic respiration, resulting in root respiration and microorganisms' activity presented in the soil layers. The study aimed to evaluate edaphic respiration in four land-use systems. The research was carried out in four soil use systems: Forest Remnant Area (F); Agroforestry System (AFS); Mandala (M) and Pasture (P), in the Bananeiras-PB countryside. Three soil samples of each system were collected, at 0-20 cm depth, for chemical and physical analysis to characterize them. The carbon dioxide was measured using a methodology described by Grisi and the captures of CO_2 were analyzed at night and daytime for eight months. A completely randomized design was used in a 4 x 2 factorial scheme. The lower temperatures, during the night, favored a higher CO_2 emission; the pasture system and the AFS showed higher CO_2 release in two evaluation shifts; the forest remnant area showed less carbon dioxide release. The pasture area, due to its low vegetation cover, and consequently high temperature and low humidity, presented greater carbon release, in contrast, the remaining forest area, due to its greater vegetation cover, and thus lower temperatures and high humidity, presented less CO_2 release.

Keywords: Agroforestry, caatinga, carbon dioxide.

Introduction

Since the industrial revolution began and the continuous process of industrialization, urbanization, and population growth the contribution led to an increase in consumption patterns and consequent increase in the use of natural resources (Zapparoli et al., 2018). The growing demand for worldwide food has been contributed to increasing deforestation for the expansion of production areas and, consequently, an increase in greenhouse gas (GHG) emissions as nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4), which only started to be discussed in the 90's (Pereira, 2018).

In Brazil, soil use and occupation for the expansion of agricultural and livestock areas are responsible for GHGs, with about 1.33 Gt of CO_2-eq emitted in 2018 (SEEG, 2020). In northeastern Brazil, the high-altitude swamps, which are humid enclaves with lower temperatures, Atlantic Forest vegetation, and occurrence within the semi-arid domain, have been suffering impacts from anthropic actions (Cordeiro et al., 2020).

In this sense, it is important to monitor these ecosystems, the disturbances caused to them and the effect of changes in land use, such as erosion, desertification, and inadequate agricultural techniques, and one of the ways to monitor them is through edaphic respiration, which is the result of root respiration and the process of organic matter degradation carried out by microorganisms (Araújo et al., 2016). It is necessary to understand the factors that are directly linked to the soil CO_2 production process, serving as a parameter in predicting the increase in CO_2 in the atmosphere and its contribution to climate change (Haugwitz et al., 2014).

The production of CO_2 in the soil occurs mainly through biological processes, decomposition of organic matter, and respiration of soil organisms and plant root systems (Gomes et al., 2021ab). Formiga et al. (2017) state that the entire CO_2 release process, through edaphic respiration, occurs at 10 cm deep in the soil, the site of concentration of microorganisms involved in this process fungi and nitrifying bacteria. In association with the mesofauna and edaphic macrofauna, the microorganisms present in the soil are mainly responsible for decomposing all organic matter present in the soil (Araújo et al., 2016). According to the same authors, the removal of the vegetation cover affects edaphic respiration because the superficial layer of the soil is the place of more significant occurrence of the activity of the microorganisms, which is influenced by temperature, humidity, and pH.

The maintenance of the quality of agricultural soils can be changed based on its management (Sousa et al., 2018), and it affects biodiversity and microbial activity, causing alterations in the release of CO_2 where it increases when there is an increase in organic material or vegetation suppression. Monitoring of edaphic respiration can be used to identify more impactful changes to environments and be helpful to the development of conservation practices (D'Andrea et al., 2010; Gomes et al., 2021a). This information can contribute to the development of practices aimed at ensuring more sustainable land use (Formiga et al., 2017). Given the above, the objective was to evaluate edaphic respiration in four land-use systems.

Material and Methods

The study was developed at the Centro de Ciências Humanas, Sociais e Agrárias (CCHSA), Campus – III, da Universidade Federal da Paraíba (UFPB), Bananeiras - PB. The municipality of Bananeiras is located in the Paraíba swamp; has acid soils with varied fertility, with the predominance of typical dystrophic Yellow Latosol (Embrapa, 2018); its climate is classified as Tropical Rainy, Hot, and Humid (Köppen & Geiger, 1930), with an average temperature of 28ºC and rains between autumn and winter (Medeiros et al., 2016). According to Silva et al. (2021), most of the Bananeiras vegetation is characteristic of "mountainous forest" or "altitude swamp", justified by the orography and local edaphoclimatic conditions.

Data collections were performed in four areas (Figure 1):

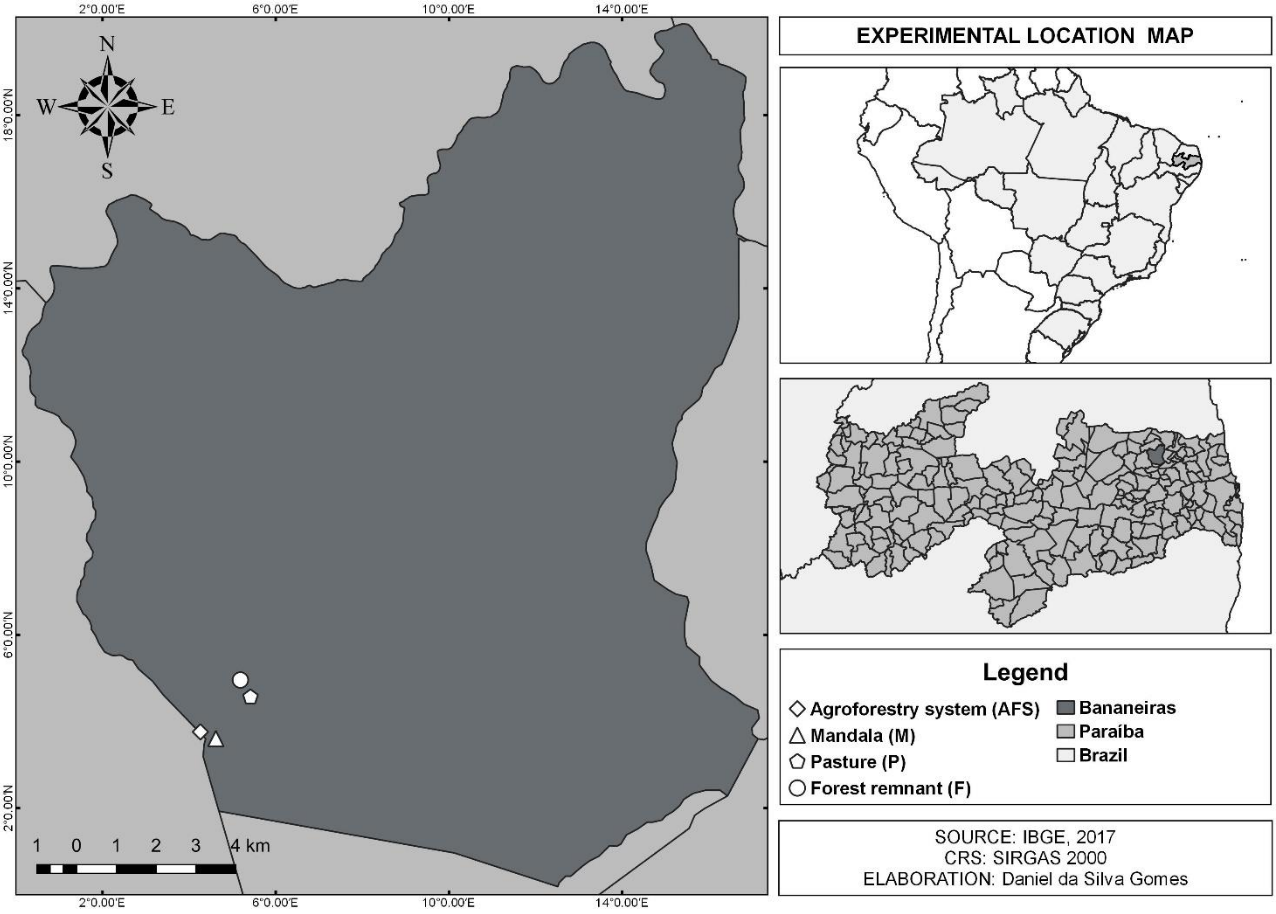

Figure 1. Location map indicating the collection points, Bananeiras, Paraíba. Font: Gomes et al. (2020).

Area I (control) - Forest remnant (F), corresponding to a fragment of native vegetation in a secondary state, is predominantly composed of Biriba (*Eschweilera ovata*), Pitombeira (*Talisia* *esculenta*), Jatobá (*Hymenaea courbaril*), among other unidentified tree species.

Area II - Agroforestry system (AFS), corresponding to an area with approximately 16 years of implementation, possessing Gliricídia (*Gliricidia sepium*) as the main plant and coffee (*Coffea* sp.), as a secondary plant between the lines, due to the requirement of shade, characteristic of understory species.

Area III - Mandala (M), referring to an area with approximately 17 years of implementation, made up of Peppers (*Capsicum annuum* L.), Lettuce (*Lactuca sativa*), Carrot (*Daucus carota* L.), Beetroot (*Beta vulgaris*) e Cabbage (*Brassica oleracea*), in addition to unidentified medicinal plants.

Area IV - Pasture (P), composed of unidentified native grasses, Jaqueiras (*Artocarpus heterophyllus*) sparse in the area and some herbaceous plants and is often foraged by Santa Inês sheep.

Soil samples were collected from 0-20 cm deep, with three samples composed by each area. Afterward, these samples were air-dried, disaggregated with a wooden roller, and chemically and physically analyzed, through analysis of soil fertility and texture, respectively (Table 1).

Table 1. Results of soil analysis of management systems in an altitude swamp. Font: Gomes et al. (2020).

Systems	**pH**	**P**	**K^+**	**Al^{+3}**	**Ca^{+2}**	**Mg^{+2}**	**SB**	**CEC**	**OM**
		---mg/dm³---		**----------------------cmol$_c$/dm³----------------------**					**-g/kg-**
F	5.1	3.9	59.21	0.10	2.66	1.99	4.87	7.10	15.72
AFS	5.5	93.68	103.65	0.05	4,00	3.75	8,13	10.46	24.00
M	5.0	2.07	19.56	0.35	1.00	0.87	2.00	4.46	25.03
P	5.3	2.27	42.62	0.10	0.88	0.80	1.81	1.95	15.00

F = Forest remnant; AFS = Agroforestry system; M = Mandala; P = Pasture; SB = Sum of bases; CEC = Cation exchange capacity; OM = Organic matter.

The quantification of carbon dioxide followed the methodology of Grisi (1978), using released CO_2 from the soil, is captured by a solution of potassium hydroxide (KOH - 0.5N) and then quantified through titration with hydrochloric acid (HCl-0.1N), having as indicators, phenolphthalein and methyl orange, both at 1% concentration (Morita & Assumpção, 2007). The quantification of carbon dioxide occurred monthly for eight months, from February to September of 2018. In the evening CO_2 captures, glass containers containing 10 mL of the KOH solution remained in the field individually covered by a bucket between 5:00 pm and 05:00 am. Considering daytime CO_2 catches, glass containers with KOH solutions remained individually covered by a bucket in the field between 5:00 am and 5:00 pm. Four control samples were used, one for each area and these remained closed throughout the process to avoid gas exchange, and at the end, they went through the titration process. The determination of the absorbed CO_2 was done through Equations 1 and 2.

$$ACO_2 = (A - B)\ x\ 2\ x\ 2.2\ in\ mg \qquad \text{Eq.(1)}$$

$$A'CO_2 = ACO_2 x \left(\frac{4}{3} x \frac{10000}{h+S}\right)\ in\ mg \qquad \text{Eq.(2)}$$

where $A'CO_2$ = CO_2 absorption; A = difference, in mL, between the 1st and 2nd turning of the sample color; B = difference, in mL, between the 1st and 2nd turning of the control or witness color; h = period of permanence of the sample in the soil (hours); S = bucket coverage area.

The experimental design used was completely randomized, in a 4x2 factorial scheme, with four land-use systems (F, ASF, M, P) x two collection shifts (nightly and daytime), totaling eight treatments with three repetitions each, from the average of three collections for each point. Hartley's test was used to verify the homogeneity of variances. Refuting the hypothesis of equality of the previously mentioned treatments, the Tukey test was applied to analyze the difference between the means; the test was also carried out as a function of the consequences. Statistical analysis was performed using the statistical software R, version 3.4.1 (R Core Team, 2017).

Results

The variance analysis shows that, regarding the management system, the evolution of CO_2 is significant. However, it was not significant for evaluation shift and interaction between the management system and evaluation shift (Table 2).

Table 2. Summary of the analysis of variance of CO_2 evolution (mg m^{-2} h^{-1}) as a function of management systems and assessment shifts in the altitude swamp. Font: Gomes et al. (2020).

Variation source	**Degrees of freedom**	**Mean square**

Management systems (MS)	3	0.81184***
Evaluation shift (ES)	1	0.04363ns
MS x ES interaction	3	0.01705^{ns}
Residue	64	0.01972
Treatment	7	0.36147***
CV	%	2.46

CV = coefficient of variation; ns = not significant; *** = significant to $p<0.0001$; ** = significant to $p<0.001$; * = significant to $p<0.05$.

The analysis of nightly and daytime emissions between February and September showed that the pasture and SAF systems showed the most significant release of CO_2, with no statistical difference between them. The forest remnant, on the other hand, has a lower release of CO_2 among all evaluated areas. However, it does not differ statistically from the mandala system (Figure 2). The results of nightly assessments of CO_2 emissions between February and September (Figure 3A) ranged from 187.5 to 125.0 (mg m^{-2} h^{-1}) in the forest remnant; from 206.2 to 123.4 (mg m^{-2} h^{-1}) in the mandala system; from 196.6 to 139.8 (mg m^{-2} h^{-1}) in the pasture system; and from 199.2 to 151.7 (mg m^{-2} h^{-1}) in the agroforestry system.

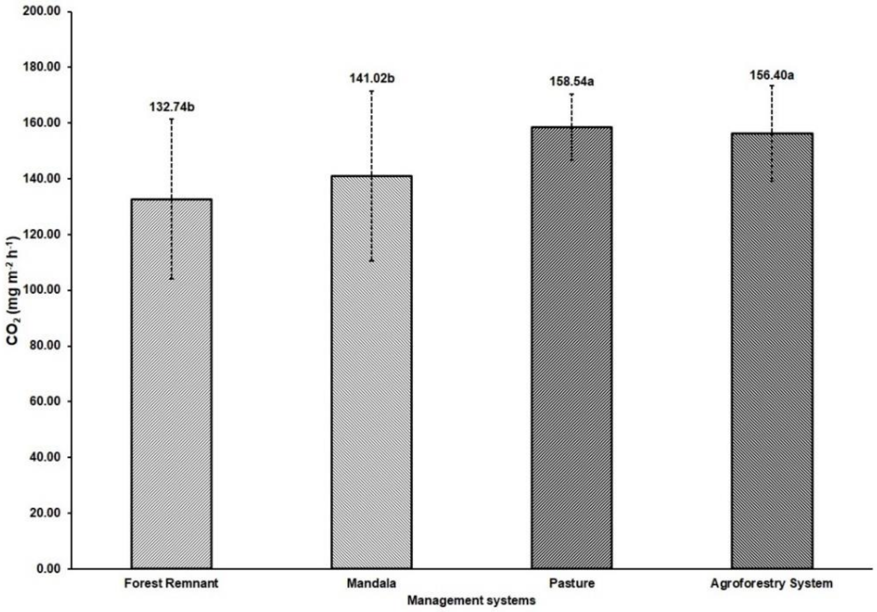

Figure 2. Evolution of CO_2 (mg m^{-2} h^{-1}) in four soil use systems in the swamp of altitude, Bananeiras, Paraíba. a,b. averages followed by different letters differ from each other by the Tukey test ($p < 0.05$). Font: Gomes et al. (2020).

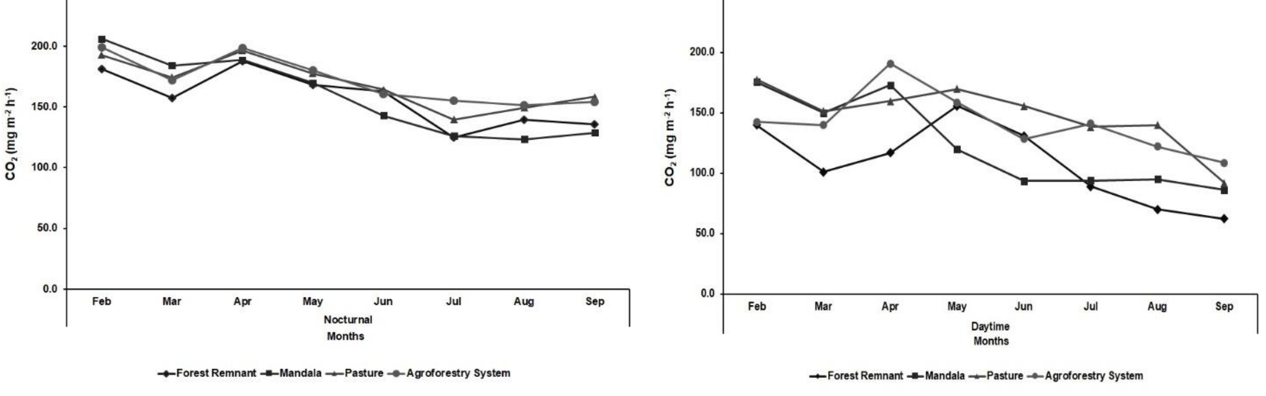

Figure 3. Night (A) and daytime (B) evolution of CO_2 (mg m^{-2} h^{-1}) in four soil use systems in the swamp of altitude, Bananeiras, Paraíba. Font: Gomes et al. (2020).

The results of daytime assessments of CO_2 emissions between February and September (Figure 3B) in the forest remnant ranged from 155.7 to 62.3 (mg m^{-2} h^{-1}); in the mandala system, it varied from 175.5 to 86.1 (mg m^{-2} h^{-1}); in the pasture system it ranged from 177.3 to 91.7 (mg m^{-2} h^{-1}), and in the agroforestry system it varied from 190.6 to 108.5 (mg m^{-2} h^{-1}). When the observation is within the system, the pasture area had less variation in its daytime CO_2 emissions.

Discussion

The area of pasture has a lower tree cover was the area that showed the greatest release of CO_2 among all systems. A similar result was found by Siqueira Neto et al. (2011), in which the highest CO_2 emission was found in the pasture area. In the study carried out by Araújo et al. (2011), the highest CO_2 emissions occurred in places with little vegetation cover and, therefore, there was a higher incidence of solar radiation on the soil. On the other hand, the forest remnant had a lower release of CO_2, as it presents the conditions closest to an “equilibrium” environment. Some researchers point out that CO_2 emissions in areas of native vegetation are lower since these environments have greater environmental stability (Alves et al., 2011; Araújo et al., 2016).

There was a higher CO_2 emission at night due to the high microbial activity in the soil, which may have occurred because of the low temperatures of this period. Some authors point out that microbial activity, and consequently a higher CO_2 emission at night, is influenced by lower temperatures (Correia et al., 2015; Araújo et al., 2016). During the daytime, there is high solar radiation and high temperatures, which directly affect microorganisms present in the soil. Also, the lack of vegetation cover can favor the increase in CO_2 emissions, as in this case, solar radiation will directly affect the soil. According to Araújo et al. (2011), variations in CO_2 release are influenced by temperature, in which the higher they are, the greater the CO_2 emissions. Carbon dioxide emissions in the pasture area may have been influenced by the lack of vegetation cover, resulting in a higher incidence of sunlight directly on the ground, providing higher temperatures.

In the pasture area, there was the smallest variation in carbon dioxide emissions during the day, presenting the highest averages, concerning the other areas, during May, June, July, and August, which corresponds to the rainy months in the Bananeiras countryside. Therefore, the CO_2 emission may have been influenced by the water content present in the soil. The increase in emissions in April may have occurred due to rainfall since this municipality has a rainfall regime between autumn and winter. In a study by Silva et al. (2016), soil moisture was a limiting factor for the higher rates of CO_2 emission from the soil in the pasture area, which caused an increase in microbial activity. Formiga et al. (2017), when studying in the Caatinga region, observed that variations in CO_2 emissions are influenced by the rainy season, greater soil moisture, favoring the release of CO_2. In the study carried out by Siqueira Neto et al. (2011), in the Brazilian cerrado, the humidity was the variable that most influenced the CO_2 emission in the soil.

Souto et al. (2013) state that edaphic breathing reflects microbial activity in the process of mineralization of organic matter present in the soil. Therefore, the edaphic breathing in the SAF may have been influenced by the large supply of organic material present on the soil surface. Correia et al. (2015) highlight that high releases of CO_2 resulting from the microbial activity of the soil indicates ecological disturbance, considering that high rates of edaphic respiration correspond to high rates of carbon losses. Thus, it can be said that microbial activity can be used as a tool to monitor environmental disturbances resulting from management (Formiga et al., 2017).

Conclusion

The pasture area, due to its low vegetation cover, and consequently high temperature and low humidity, presented greater carbon release, in contrast, the remaining forest area, due to its greater vegetation cover, and thus lower temperatures and high humidity, presented less CO_2 release. At night, the high CO_2 emission occurred due to high microbial activity in the soil. In the daytime, the high carbon dioxide emission is correlated to the high solar radiation and the water content in the soil. The data obtained in this study is of great relevance since they contribute with information about carbon dioxide, which is one of the greenhouse gases, providing information that can contribute to the development of mitigation measures.

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Reference

Alves, T. S.; Campos, L. l.; Elias Neto, N.; Matsuoka, M.; Loureiro, M. F. 2011. Biomassa e atividade microbiana de solo sob vegetação nativa e diferentes sistemas de manejos. Acta Scientiarum Agronomy, 33, 2, 341-347. DOI: 10.4025/actasciagron.v33i2.4841

Araújo Filho, J. A. 2013. Manejo pastoril sustentável da caatinga. Projeto Dom Helder Câmara, Recife.

Araújo, K. D.; Dantas, R. T.; Andrade, A. P.; Parente, H. N. 2011. Cinética de evolução de dióxido de carbono em área de caatinga em São João do Cariri-PB. Revista Árvore, 35, 5, 1099-1106. DOI: 10.1590/S0100-67622011000600016

Araújo, K. D.; Souza, M. A.; Santos, G. R.; Andrade, A. P.; Ferreira Neto, J. V. 2016. Atividade Microbiana no Solo em Diferentes Ambientes da Região Semiárida de Alagoas. Geografia, 25, 2, 5-18. DOI: 10.5433/2447-1747.2016v25n2p5

Cordeiro, J. M. P.; Flores, I.; Souza, B. I. 2020. Mastofauna da reserva ecológica mata do pau ferro (Paraíba, Brasil): avaliação de impactos ambientais e considerações sobre a biogeografia dos brejos de altitude. Revista Continentes, 9, 17, 212-233.

Correia, K. G.; Araújo Filho, R. N.; Menezes, R. S. C.; Souto, J. S.; Fernandes, P. D. 2015. Atividade microbiana e matéria orgânica leve em áreas de caatinga de diferentes estágios sucessionais no Semiárido paraibano. Revista Caatinga, 28, 1, 196-202.

D'Andrea, A. F.; Silva, M. L.; Freitas, D. A. F.; Curi, N.; Silva, C. A. 2010. Variações de curto prazo no fluxo e variabilidade espacial do CO_2 do solo em floresta nativa. Pesquisa Florestal Brasileira, 30, 62, 85-92. DOI: 10.4336/2010.pfb.30.62.85

Embrapa. Empresa Brasileira de Pesquisa Agropecuária. 2018. Centro Nacional de Pesquisa de Solos. Sistema Brasileiro de Classificação de Solos. 4.ed. Revisada. Embrapa Solos Rio de Janeiro, 358p.

Formiga, L. D. A. S.; Andrade, A. P.; Silva, D. S.; Araújo, K. D.; Santos, A. M. S.; Lima, L. B. 2017. Dióxido de carbono liberado do solo em áreas de Caatinga sob pastejo caprino. Revista Biociências, 23, 2, 65-72.

Gomes, D. S.; Barbosa, A. S.; Santos, T. M.; Santos, S. K.; Silva, J. H. C. S.; Aquino, Í. S. 2021a. Cinética de liberação de CO2 e decomposição da fitomassa em sistemas de uso e manejo do solo. Research, Society and Development, 10, 1, e9810111413. DOI: 10.33448/rsd-v10i1.11413

Gomes, D. S; Santos, S. K.; Silva, J. H. C. S.; Medeiros, T.; Santos, E. D. V. S.; Barbosa, A. S. 2021b. CO_2flux e temperatura da superfície edáfica em áreas de caatinga. Revista Brasileira de Geografia Física, 14, 04, 1898-1908. DOI: 10.26848/rbgf.v14.4.p1898-1908

Grisi, B. M. 1978. Métodos químicos de medição da respiração edáfica: alguns aspectos técnicos. Ciência e Cultura, 30, 1, 82-88.

Haugwitz, M. S.; Bergmark, L.; Priemé, A.; Christensen, S.; Beier, C.; Michelsen, A. 2014. Soil microorganisms respond to five years of climate change manipulations and elevated atmospheric CO_2 in a temperate heath ecosystem. Plant and Soil, 374, 1-2, 211-222. DOI: 10.1007/s11104-013-1855-1

Köppen, W.; Geiger, R. 1930. Handbuch der klimatologie. Gebrüder Borntraeger, Berlin.

Medeiros, R. L. S.; Souza, V. C.; Barbosa Neto, M. A.; Araújo, L.; Barbosa, A. S.; Medeiros, R. L. S. 2016. Estrutura da regeneração natural de *Anadenanthera colubrina* em fragmento de brejo de altitude em Bananeiras, PB. Pesquisa Florestal Brasileira, 36, 86, 95-101. DOI: 10.4336/2016.pfb.36.86.887

Morita, T.; Assumpção, R. M. V. 2007. Manual de soluções, Reagentes & Solventes: Padronização, Preparação, Purificação. Edgard Blücher, São Paulo.

Pereira, V. C. 2018. Efluxo de CO_2 em diferentes sistemas de cultivo. 2018. Tese de Doutorado, Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brasil, 65p.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing.

SEEG. Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG) – Observatório do Clima (OC). Base de Dados de Estimativas de Emissões de Gases de Efeito Estufa no Brasil 1990-2018. Available in: http://seeg.eco.br/tabela-geral-de-emissoes/. Accessed in: March 01, 2020.

Silva, C. M. D.; Vasconcelos, S. S.; Mourão, M.; Bispo, C. J. C.; Kato, O. R.; Silva, A. C. D.; Castellani, D. C. 2016. Variação temporal do efluxo de CO_2 do solo em sistemas agroflorestais com palma de óleo na Amazônia Oriental. Acta Amazonica, 46, 1-12. DOI: 10.1590/1809-4392201500193

Silva, D. A. P.; Campos, M. C. C.; Mantovanelli B. C.; Santos, L. A. C.; Soares, M. D. R.; Cunha, J. M. 2019. Variabilidade espacial da emissão de CO_2, temperatura e umidade do solo em área de pastagem na região Amazônica, Brasil. Revista de Ciências Agroveterinárias, 18, 1, 119-126. DOI: 10.5965/223811711812019119

Silva, J. H. C. S.; Barbosa, A. S.; Araújo, M. B.; Gomes, D. S; Miranda, A. A. C.; Aquino, I.

S. 2021. Indicadores qualitativos do ambiente edáfico e serviços ecossistêmicos em diferentes sistemas de ocupação da terra. Nativa, 9, 5, 519-527. DOI: 10.31413/nativa.v9i5.13079

Siqueira Neto, M.; Piccolo, M. C.; Costa Junior, C.; Cerri, C.C.; Bernoux, M. 2011. Emissão de gases do efeito estufa em diferentes usos da terra no bioma cerrado. Revista Brasileira de Ciência do Solo, 35, 1, 63-76. DOI: 10.1590/S0100-06832011000100006

Sousa, R. M.; Pereira, R. R.; Soares, F. 2018. Indicadores visuais de qualidade do solo em agroecossistemas familiares na Amazônia maranhense. Acta Tecnológica, 13, 1, 109-120.

Souto. P. C.; Souto, J. S.; Santos, R. I.; Bakke, I. A.; Sales, F. C. V.; Souza, B. V. 2013. Taxa de decomposição da serapilheira e atividade microbiana em área de Caatinga. Cerne, 19, 4, 559-565. DOI: 10.1590/S0104-77602013000400005

Zapparoli, I. D.; Souza, A. M.; Sesso Filho, U. A.; Brene, P. R. A.; Câmara, M. R. G. 2018. Análise dos transbordamentos nas emissões de dióxido de carbono: Brasil, Rússia, Índia e China-BRIC. Revista Econômica do Nordeste, 49, 1, 149-164