International Journal of Plant & Soil Science

28(4): 1-9, 2019; Article no.IJPSS.49716
ISSN: 2320-7035

Emission of CO_2 and Organic Carbon Content in Different Pasture Management Systems

Déborah Hoffmam Crause[1], Edney Leandro da Vitória[1*], Carla da Penha Simon[2], Élcio das Graça Lacerda[3], Tatiana Fiorotti Rodrigues[1], Yago Soares Avancini[1], Juliana Menegassi Valle[4] and Joyce Lopes dos Santos[1]

[1]Department of Agrarian and Biological Sciences, Federal University of Espirito Santo, São Mateus, ES, Brazil.
[2]Center for Nuclear Energy in Agriculture, University of São Paulo, Piracicaba, São Paulo, Brazil.
[3]Federal Institute of Espirito Santo, Santa Teresa, Espírito Santo, Brazil.
[4]Postgraduate Program in Tropical Agriculture, Federal University of Espírito Santo, São Mateus, ES, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Authors ELDV, CDPS and DHC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TFR, YSA and EDGL managed the analyses of the study. Authors JMV and JLDS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2019/v28i430118
Editor(s):
(1) Dr. Marco Trevisan, Professor, Institute of Agricultural Chemistry and Environmental Research Centre Biomass, Faculty of Agriculture, Catholic University of the Sacred Heart, Italy.
Reviewers:
(1) Stanley Emife Nwani, Lagos State University, Nigeria.
(2) Xueming Dong, National Renewable Energy Laboratory, USA.
Complete Peer review History: http://www.sdiarticle3.com/review-history/49716

Original Research Article

Received 30 March 2019
Accepted 18 June 2019
Published 02 July 2019

ABSTRACT

Inadequate soil management is one of the primary causes of pasture degradation, aggravated by the replacement of natural forest environments with cultivated pastures. Thus, the objective of the present study was to quantify the flux of CO_2 and organic carbon of the soil in grasslands undergoing intensive and extensive management, and in a native forest. The experiment was conducted in a randomized block design, with three treatments: intensive management system (IMS), extensive management system (EMS), and native vegetation (NV). The collected soil variables consisted of CO_2 flux, organic carbon, temperature, and humidity. The CO_2 flux quantification was obtained using LI-COR 8100-A equipment, chamber model 103. Carbon

**Corresponding author: E-mail: edney.vitoria@ufes.br, vitoria.edney@gmail.com;*

determination was performed according to EMBRAPA methodology, and soil temperature and humidity were plotted using a model 5TM Decagon Devices® sensor. The respective mean CO_2 flux values for the IMS, EMS, and NV were 2.18; 4.04, and 1.69 µmol CO_2 m^{-2} s^{-1}, and the values found for organic carbon content were 32.9; 24.3, and 14.9 g kg^{-1}, respectively. The intensive management system exhibited higher CO_2 flux from the soil to the atmosphere, and the soil containing native vegetation displayed greater values of organic carbon content.

Keywords: Rotational grazing; intensive management; extensive management.

1. INTRODUCTION

The grazing area in Brazil has increased, over the last 40 years, from 154.1 to 160.1 million hectares, as a result of a significant increment in cultivated pastures. Approximately 86 million hectares represent managed areas, and 191 million hectares contain domains with native vegetation [1].

According to the intensity of use of the management system, different levels of environmental degradation can be embedded, which are proportional to the relation between the intensity with which the system is practiced and the availability of natural resources [2]. In extensive grazing, the most significant impact caused by the animal production is undoubtedly generated by overgrazing. This activity, due to excessive trampling, provokes substantial structural alterations of the superficial layer of the soil, and the reduction of the vegetation coverage, favoring erosive processes and the degradation of pastures [3].

Soils that lack or exhibit scarce vegetation covering, as can be observed in degraded or semi-intensive pastures, work as mirrors, reflecting long waves emitted by solar radiation, and returning heat to space [4]. One way to mitigate this situation is to maintain soil coverings, which can be carried out with the implantation of pastures with good coverage capacity that, besides covering the soil, will favor the process of organic matter accumulation [5] and increase carbon supply [6].

Agricultural activities are pointed out as one of the leading responsible for the emission of pollutants into the atmosphere, which has led to increases in temperature on the planet. This increase is due primarily to the fact that this system appears, in general, to substitute natural forest environments with areas of cultivated pastures, resulting in significant releases of carbon [7]. Studies carried out on grasslands in the Amazon, Cerrado, and Atlantic Forest biomes indicate that soils under pasture can accumulate carbon at levels that are similar or superior to native vegetation, and that pasture degradation promotes accrued carbon loss [8]. In this process, the soil constitutes a valuable drain or source of greenhouse gases (GHG), depending on the management system to which it is submitted.

According to [8], systems that increase plant waste addition and carbon retention in the soil are alternatives to increase atmospheric C-CO_2 drain capacity and global warming mitigation. However, the amount of carbon found in the 0.0 to 30.0 cm layer of the soil corresponds to the amount found in the Earth's atmosphere. Therefore, the study of soil carbon dynamics has become fundamental, especially the CO_2 flux in different grazing systems.

In accordance with [9], Brazil contributed a portion of approximately 306 thousand tons with the emissions related to soil management, and 2,000 tons with pastures, thus being responsible, in the agricultural sector, for 60% of global CO_2 emission.

The present study proposed to quantify the emissions of CO_2 and organic carbon in different systems of soil farming used for grazing.

2. MATERIALS AND METHODS

The study was developed at the Federal Institute of Espírito Santo (IFES), on the Santa Teresa Campus, in Espírito Santo, Brazil, at coordinates 19°48'28.575" latitude and 40°41'2.779" longitude, and at an altitude of 125.9 m. According to the Köeppen classification, the region is of Aw tropical climate, with an average annual rainfall of 1.161 mm and a mean yearly temperature of 24.4°C.

The grazing area was located in the goat-rearing sector, which has a shelter for animals with four modules, each of which contains 23 pickets of 30.0 m², totaling an area of 2,760 m². The pasture management system was established as intensive for more than four years, consisting exclusively of Mombaça grass for medium-sized goats and sheep. After an entire day of grazing, at maximum capacity conditions, the pasture is usually cut, leaving the grass at an approximate 0.40 m in height. The remaining grass is then fertilized in order to be grazed within 30 days.

The extensive management system was comprised of Brachiaria grass, established more than 15 years ago, and the only adopted form of management consisted of the control of large-sized weeds.

The native vegetation of the region was classified as submontane semidecidual Atlantic Forest, located near the Santa Teresa Campus. Fig. 1 shows the experimental area.

The experiment was conducted using a randomized block design. There were seven days of collection in the month of March, 2017. In each experimental area seven randomly distributed necklaces were installed. The readings were performed between 08:00 and 11:00 p.m., according [10] to this period there is less variation of soil temperature and soil water content.

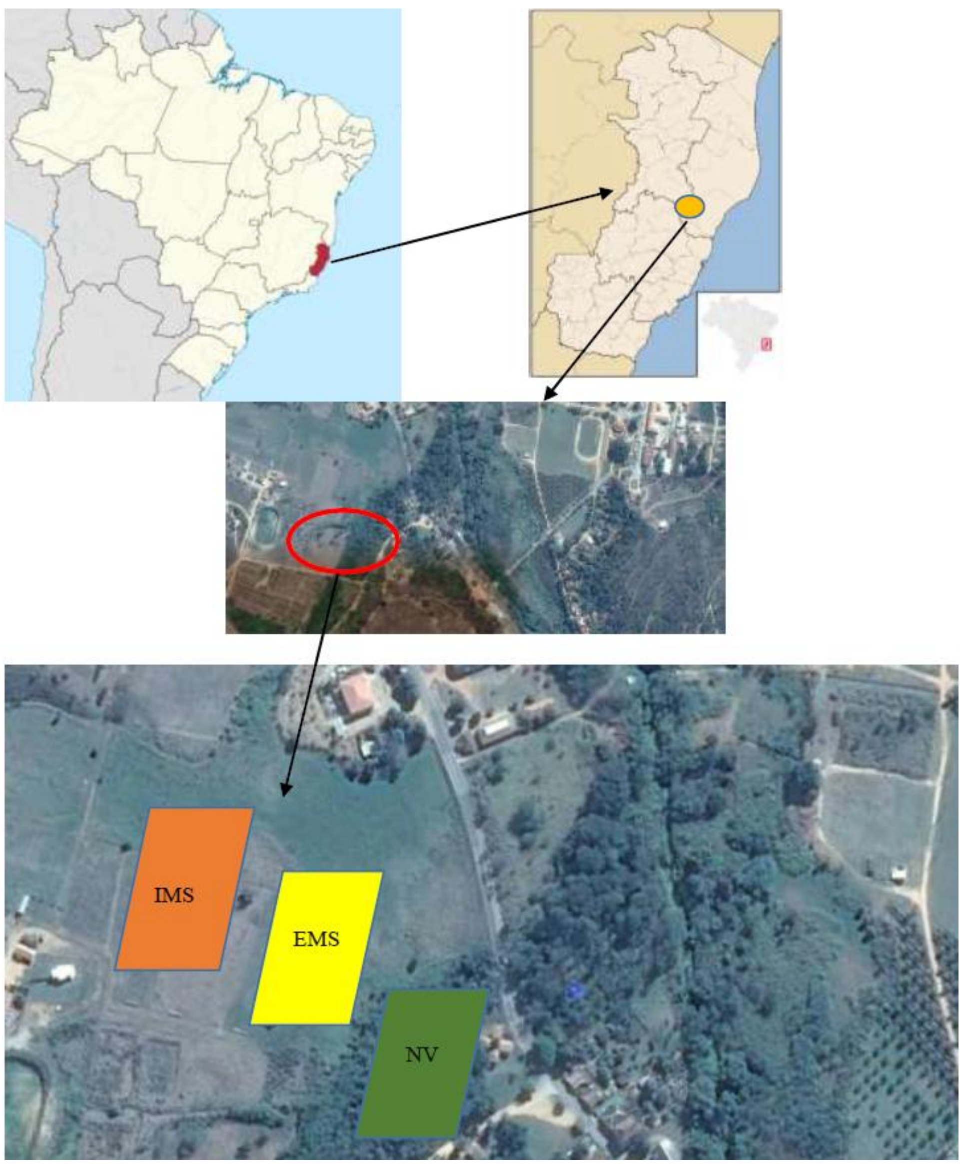


Fig. 1. Details of the experimental area

The data on CO_2 emission were obtained using a flow chamber, manufactured by the company LI-COR; model LI-8100A, chamber model 8100-103, with a volume of 4,823.9 cm³. The samples were collected during the day, at 9:00 am, and the readings at each point took place during 3 min. The measurement system was performed by monitoring the concentration of CO_2 inside the chamber. This chamber consists of a closed system, with a total volume of 5,166.7 cm^3, and a circular ground contact area of 317.8 cm^2 (0.20 m diameter). The device is required to be placed on a PVC collar at each point and should be installed at least 24 hours in advance.

The use of PVC collars is justified by the disturbances that the direct insertion of the chamber into the soil could cause, such as the rupture of the porous structure, which would increase emitted carbon dioxide, overestimating the reading.

The temperature and humidity of the soil were assessed using the 5TM sensor of the Decagon Devices® equipment, simultaneously with the collection of the carbon gas flow. The sensor was inserted into the soil as perpendicular as possible to the surface, near the installation location of the PVC collars, for the evaluation of the CO_2 emission, which was measured simultaneously.

The total organic carbon quantification was performed at each point following the method of digestion with potassium dichromate in acid medium, and titration with ammoniacal ferrous sulfate using a ferroin indicator. The data regarding CO_2 emission, organic carbon, temperature, and soil water content were submitted to analysis of variance by date of evaluation, and the averages underwent the Tukey test ($p < 0.05$). The CO_2, temperature, and humidity emission ratios were analyzed by correlation.

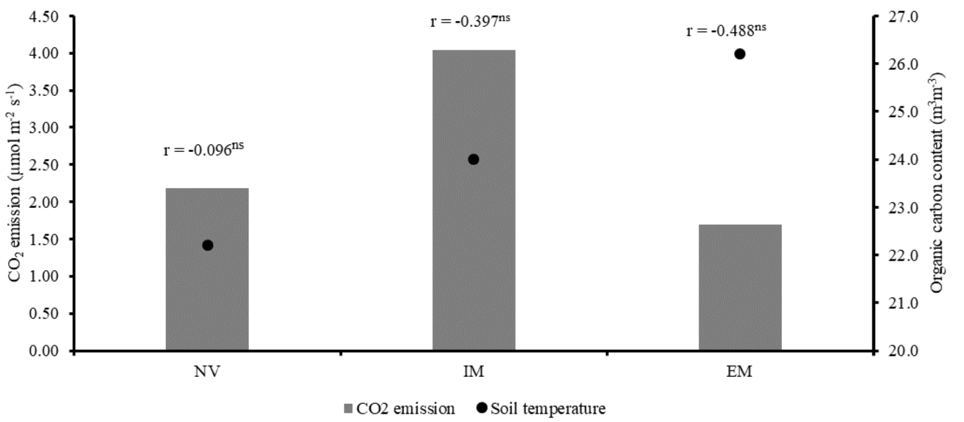
3. RESULTS AND DISCUSSION

The variables CO_2 emission, soil temperature, and soil water and organic carbon content exhibited normal data distribution according to the Shapiro-Wilk test ($p < 0.05$). In turn, regarding data variability, the soil temperature displayed low dispersion, regardless of the soil use. The other variables showed average distribution, except for the mean soil water content of the intensive grazing system and the mean organic carbon content in the extensive grazing system (Table 1), according to the classification proposed by Warrick; Nielsen (1980), classified as low (VC < 12%); average (12% < VC < 60%), and high (VC > 60%). The intensive management system exhibited a mean emission of 4.04 μmol CO_2 m^{-2} s^{-1}, significantly ($p < 0.05$) higher (46.0% and 58.1%) than the emission averages of the native vegetation and the extensive management system, respectively. The average emission observed in the extensive grazing system (1.69 μmol CO_2 m^{-2} s^{-1}) did not retain a significant difference ($p > 0.05$) when compared to the emission average of the native vegetation (2.18 μmol CO_2 m^{-2} s^{-1}) (Table 1). The mean soil temperature was significantly higher ($p < 0.05$) in the extensive management system and lower in the native vegetation, with an approximate difference of 4ºC. Soil water content was significantly lower in the extensive system, approximately 32.8% lower when compared to the intensive system. The soil water content of the native vegetation and the intensive grazing system did not exhibit a significant difference (0.184 and 0.229 m³ m^{-3}, respectively). The organic carbon content was significantly higher in the native vegetation, 26.1% and 54.7% greater than the average organic carbon values of the intensive and extensive grazing systems, respectively.

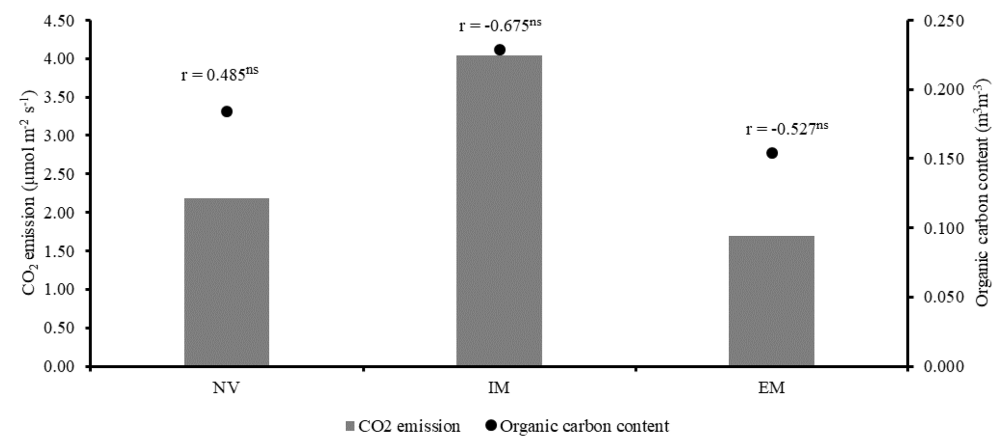
The correlation between CO_2 emission and temperature was negative, as was CO_2 emission and soil water content. However, Pearson correlation coefficients were also not significant, nor was the correlation between CO_2 emission and the organic carbon content, in which only the correlation in the native vegetation was positive (Fig. 2A, B and C).

The most significant flow of CO_2 occurred in the intensive grazing system. The emissions of CO_2 are associated with the decomposition of plant residues and respiration of the microbiota and roots, as well as the oxidation of soil organic matter [11,12]. The type of pasture management system can justify this increase in CO_2 emission due to the trimmings that were performed for clump management, at 0.40 m, which allows the constant cycling of nutrients, given the material that the animals do not harvest during grazing is deposited in the soil, covering it entirely; as well as the characteristic fertilizations of the system, which lead to high production of biomass, making the soil potentially rich in nutrients, consequently increasing microorganism activity. [13] and [14] described higher values of CO_2 emission in intensive management systems when compared to native vegetation.

(A)



(B)



(C)

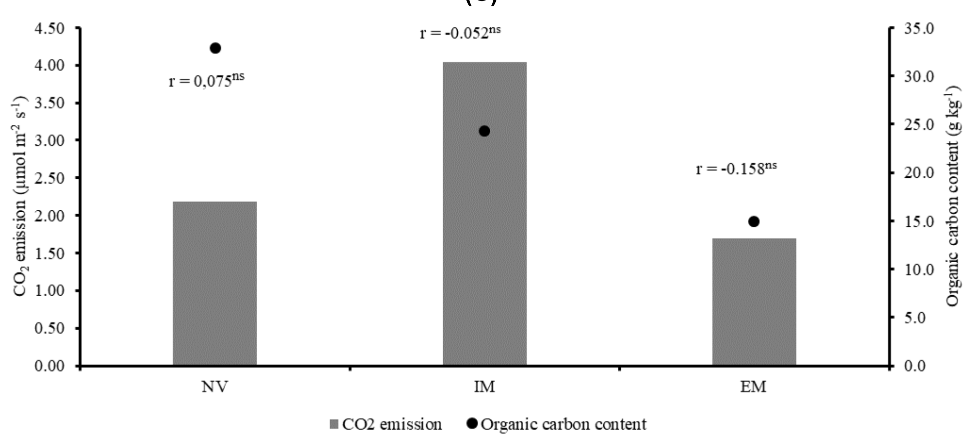


Fig. 2. Pearson correlation between CO_2 emission and temperature (A), soil water content (B), and organic carbon (C), observed in the native vegetation (NV), the intensive management system (IMS), and the extensive management system (EMS)
**Significant value ($p < 0.05$), ^{ns}Non-significant value ($p > 0.05$)*

Table 1. Descriptive statistics of CO_2 emission, temperature, soil water content, and soil organic carbon content in the intensive (IMS) and extensive (EMS) management systems, and the native vegetation (NV)

Treatment	Mean	Standard deviation	VC (%)	W
		CO_2 emission (μmol m^{-2} s^{-1})		
NV	2.18 b	0.51	23.5	0.763*
IMS	4.04 a	0.61	15.04	0.188*
EMS	1.69 b	0.65	38.69	0.496*
		Soil temperature (ºC)		
NV	22.2 c	0.27	1.21	0.469*
IMS	24.0 b	0.20	1.27	0.432*
EMS	26.2 a	0.43	1.64	0.279*
		Soil water content (m^3 m^{-3})		
NV	0.184 ab	0.034	18.5	0.481*
IMS	0.229 a	0.026	11.8	0.445*
EMS	0.154 b	0.042	27.6	0.357*
		Organic carbon content (g kg^{-1})		
NV	32.9 a	4.4	13.5	0.903*
IMS	24.3 b	5.6	23.2	0.232*
EMS	14.9 c	1.4	9.1	0.131*

*Means followed by the same letter do not differ between each other by the Tukey test ($p < 0.05$); VC = Variation coefficient; W = p-value of the Shapiro-Wilk normality test, *significant and ^{ns} not significant ($p < 0.05$)*

The temperature of the soil has a substantial influence on gas emissions. The extensive management system and native vegetation exhibited lower emissions than the intensive system. The similarity between the intensive management system and the NV can be explained by the eventful drought that affected the state of Espírito Santo and left the native vegetation weakened. Given parts of the canopy are deciduous, and the trees have not yet recovered, the drought caused the soil to undergo even more solar incidence, thus becoming drier over time. The latter effect was also due to the extensive management system, which does not use irrigation.

The temperature of the native vegetation showed to be inferior when compared to the two pasture management systems. This outcome was due to the vegetation coverage, which acts as a thermal regulator. In the native vegetation, the soil receives less solar radiation and, consequently, the air temperature inside the canopy and the soil is lower in comparison with the pastures. The higher the temperature, the smaller the activation energy that must be reached in order for a reaction to occur [15].

Therefore, the absence of correct management in the extensive grazing system enabled the direct incidence of solar rays, increasing the temperature of the soil, which, in turn, intensified microbial activity. The greater the soil exposure to the atmosphere, the lower the thermal conductivity. As a consequence, the dissipation of the thermal energy inside the soil or to the atmosphere is slower, increasing the temperature of the soil [7].

Regarding the soil water content variable, higher values were observed in the intensive grazing system. This result was expected due to the irrigation system employed in the area, which enabled adequate soil moisture as a function of the implanted culture. Higher soil moisture is expected in management systems with higher coverage due to its significant protection against solar radiation, which interferes with soil evapotranspiration [16].

The water present in the soil reduces surface layer heating by occupying the micropores, which increases thermal conductivity and the efficiency in the transfer of heat between the soil layers [4]. Ribas et al. [17] observed that irrigated covered soil exhibited an average soil temperature that was 4.5°C lower when compared with irrigated soil without coverage.

Lower soil water content in the extensive grazing system suggests that soils under pastures are more compacted, which makes it difficult for water infiltration, providing higher values of saturation than soils under native vegetation. The latter retain greater organic matter content and lower apparent density, factors that influence porosity and, consequently, facilitate water infiltration in these soils [18].

The highest values of organic carbon content were observed in the native vegetation due to the continuous and varied deposition of organic substrates with different degrees of susceptibility to decomposition, and the greater diversity of species. Studies confirm that the most significant levels of organic carbon are found in soils under native vegetation [19,20]. Dortzbach et al. [21] in their study on carbon supply in forest and pasture areas in the Atlantic Forest, verified higher carbon inputs in the systems with native vegetation, in which the upper layers retained greater values when compared to deeper layers, corroborating the more intense deposition of residues on the soil surface. Similar levels of organic matter were obtained by Cardoso et al. [22], who evaluated the carbon supply in soils under native vegetation and pastures of the Pantanal Biome [3].

Xavier et al. [23] while assessing pastures in recovery, comparing degraded pastures with native forests, described higher values of soil carbon content in recovering grasslands than in areas with native vegetation.

Costa et al. [7] did not observe significant differences in organic carbon content when evaluating the soil carbon supply in a degraded and productive pasture area with different ages of use, compared to soil under native vegetation.

The soil submitted to intensive grazing displayed fewer losses of carbon supply when compared to the extensive farming system, although both were lower when compared to the native vegetation plot. This result was expected due to the more significant global contribution of organic matter provided by the native forest, and since the extensive grazing system exhibited the lowest values of carbon supply.

The native vegetation in the present study remained in its natural state, in balance due to the energy reserve maintained by several organisms, which can retain part of the energy that comes from nature. These organisms collaborate with the ecological balance, conserving the carbon cycle and the photosynthetic capacity of forest vegetation [24].

4. CONCLUSION

The intensive management pasture exhibited higher CO_2 flux from the soil to the atmosphere. The soil under the native forest displayed greater values of organic carbon content. Future studies are required to determine, over a more extended evaluation period, the effect of the soil under pastures on the flow of CO_2 in the soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Brasileiro Institute of Geography and Statistics (IBGE). Coverage and Land Use. Available:https://ww2.ibge.gov.br/home/geociencias/recursosnaturais/usodaterra/default.shtm
   (Accessed on April 13, 2019)
2. Okpara UT, Stringer LC, Akhtar-Schuster M, Metternicht GI, Dallimer M, Requier-Desjardins M. A social-ecological systems approach is necessary to achieve land degradation neutrality. Environmental Science and Policy. 2018; 89:59–66.
3. Rodríguez-González M, Albuquerque A, Martínez-Almarza M, Díaz-Delgado R. Long-term monitoring for conservation management: Lessons from a case study integrating remote sensing and field approaches in floodplain forests. Journal of Environmental Management. 2017;202: 392-402.
4. Sating C, Picon-Cochard R, Martin F, Louault K, Klumpp D, Borras G. Bellocchi. Plant acclimation to temperature: Developments in the Pasture Simulation model, Field Crops Research. 2018;222: 238-255.
5. Silva AS, de França da Silva I, Borchartt Bandeira L, de Oliveira Dias B, de França da Silva Neto L. Clay and organic

matter and their effects on aggregation in different soil uses. Rural Science. 2014;44(10).
6. Mascarenhas ARP, Sccoti MSV, Melo RR, de Oliveira Corrêa FL, de Souza EFM, Andrade RA, Müller MW. Physical attributes and soil carbon stocks under different land uses in Rondônia, Southeastern Amazonia. Brazilian Forest Research. 2017;37(89):19-27.
7. Costa OV, Cantarutti RB, Fontes LEF, Costa LM, Nacif PGS, Faria JC. Soil carbon stock under pasture in a coastal board area in southern Bahia. Brazilian Journal of Soil Science. Viçosa, MG, Brazil. 2009;33(5):1137-1145.
8. Cerri CEP, et al. Carbon sequestration in pasture areas. In: Symposium on Strategic Management of Pastagem, 2006, Viçosa, MG, Brazil. Anais. Viçosa: UFV. 2006; 73-80.
9. Food and Agriculture Organization of the United Nations (FAOSTAT). New York, NY. USA; 2015.
Available:http://faostat3.fao.org/browse/G2/*/S
(Accessed on May 02, 2017)
10. Rutledge S, Mudge PL, Wallace DF, Campbell DI, Woodward SL, Wall AM, Schipper LA. CO_2 emissions following cultivation of a temperate permanent pasture. Agriculture, Ecosystems & Environment. 2014;184:21-33.
11. Ferreira EPB, Santos HP, Costa JR, De-Polli H, Humjanek NG. Microbial soil quality indicators under different crop rotations and tillage management. Agronomic Science Journal. Fortaleza, CE, Brazil. 2010;41(2):177-183.
12. Phillips CL, Bond-Lamberty B, Desai AR, Lavoie M, Risk D, Tang J, Vargas R. The value of soil respiration measurements for interpreting and modeling terrestrial carbon cycling. Plant and Soil. 2017;413(1-2): 1-25.
13. Salimon CI. Respiração do solo sob florestas e pastagens na Amazônia Sul-Ocidental. Dissertation (Masters in Nuclear Energy in Agriculture) – University of São Paulo, São Paulo, SP, Brazil. 2003;112.
14. Fernandes SAP, Bernoux M, Cerri CC, Feigl BJ, Piccolo MC. Seasonal variation of soil chemical properties and CO_2 and CH4 fluxes in unfertilized and P-fertilized pastures in an Ultisol of the Brazilian Amazon. Geoderma. 2002;107: 227-241.
15. Hansen L, Barros N, Transtrum MK, Rodríguez-Añón JA, Proupín J, Piñeiro V, Arias-González Ander, Gortzia N. Effect of extreme temperatures on soil: A calorimetric approach. Thermochimica Acta. 2018;670:128-135.
16. Andrade J. G. De, Seguí JP, Carlesso R, Trois C, Knies E. Loss of water by evaporation in maize with conventional and direct seeding for different levels of dead cover. I. Experimental results. Agricultural Sciences Journal. Cuba. 2011;20(2):60-64.
17. Ribas GG, Streck NA, Silva S. D. Da, Rocha T. S. M. Da, Langner JA. Soil temperature affected by irrigation and different coverages. Agricultural Engineering. 2015;35(5):817-828.
18. Mendonça LAR, Vásquez MAN, Feitosa JV, Oliveira JFF, Raimunda M, Vásquez EMF, Frischkorn H. Evaluation of the infiltration capacity of soils subjected to different types of management. Engineering. Environmental Sanitation. Rio de Janeiro, RJ, Brazil. 2009;14(1): 89-98.
19. Portugal AF, Costa ODV, Costa LM, Santos BCM. Chemical and physical attributes of a dystrophic Tb Haplic Cambisol under different uses in the Zona da Mata Mineira. Brazilian Journal of Science of the Sun. Viçosa, MG, Brazil. 2008;32(1):249-258.
20. Cardoso EL, Silva MLN, Moreira FMS, Curi N. Biological attributes of soil quality in cultivated and native pasture in Pantanal. Pesquisa Agropecuária Brasileira. Brasilia, Brazil. 2009;44:631-637.
21. Dortzbach D, Pereira MG, Blainski E, Gonzalez AP. C stock and natural abundance of 13C in reason for the conversion of forest and pasture areas in atlantic forest biome. Brazilian Journal of Soil Science. Viçosa, MG, Brazil. 2015; 39(6):1643-1660.
22. Cardoso EL, et al. Carbon and nitrogen stocks in soil under native forests and pastures in the Pantanal biome. Pesquisa Agropecuária Brasileira, Brasília, Brazil. 2010;45(9):1028-1035.

23. Xavier AAP. Evaluation of soil carbon accumulation and emission under pasture systems. Dissertation (Masters in Science) - University of São Paulo, São Carlos, SP, Brazil. 2014;101.

24. Apps MJ. Forests, the global carbon cycle and climate change. Available:http://www.fao.org/DOCREP/ARTICLE/WFC/XII/MS14-E (Accessed on May 20, 2017)

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/49716