II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
May 4th and 5th, 2021 - 100% Digital

GREENHOUSE GASES (GHG) QUANTIFICATION WITH STATIC CHAMBERS IN LATIN AMERICA: IS IT IMPROVING THROUGH TIME?

Fernanda Figueiredo Granja Dorilêo LEITE [1]; Bruno José Rodrigues ALVES [2]; Gabriel Nuto NÓBREGA [4]; Renato Campello CORDEIRO [3]; Fernando Vieira CESÁRIO [5]; Júlia Graziela da SILVEIRA [6]; Natassia Magalhães ARMACOLO [7]; Renato de Aragão Ribeiro RODRIGUES [8]

[1] Agricultural and Evironmental Engineer. PhD candidate. Geochemistry Department/Federal Fluminense University (UFF); [2] Agricultural Engineer. Researcher. Embrapa Agrobiologia; [3] Biologist. Professor. Geochemistry Department/Federal Fluminense University (UFF); [4] Agricultural Engineer. Professor. Geochemistry Department/Federal Fluminense University (UFF); [5] Geographer. Consultant. Brazilian Institute for Development and Sustainability (IABS); [6] Forest Engineer. PhD candidate. Forest Engineering Department/Federal University of Viçosa (UFV); [7] Forest Engineer. PhD candidate. Agronomy Department/University of Londrina (UEL); [8] Biologist. Researcher. Embrapa Soils

ABSTRACT

Manual static chamber is one of the most widespread methods for the quantification of greenhouse gases (GHGs) emission from agricultural systems. But there are concerns about the reliability of measurements and a necessity to assess the static chambers used in the studies performed in the countries of Latin America. Thus, this study aims to investigate the quality of static chambers used for GHGs measurement in scientific articles following international recommendations and assess the confidence level of static chambers. A systematic review of databases was conducted to identify peer-reviewed articles that used the static chamber method in Latin América. A total of 90 articles were analyzed and separated according to the publication year (2000-2008, 2009-2015, 2016-2020). This time interval was selected to assess the influence of key publications with guidelines and criteria for the method published in 2008 and 2015. Six design and deployment chamber characteristics were evaluated. The chambers received a global score for a confidence level according to their characteristics scores and the weight of each one. The percentage of articles with high confidence level increased within the time, and the number of articles with low confidence level reduced. Researchers should continue to follow the Global Research Alliance protocols, especially the most updated ones.

Key words: methodology; nitrous oxide; GHG emissions

INTRODUCTION

Most of the understanding of soil greenhouse gases (GHGs) emission dynamics and emission factors (EF) are based on measurements using manual static chambers in which the gases are collected and transferred manually, or pumped directly, to glass vials with a vacuum, and then analyzed using the gas chromatography technique (CARDOSO et al., 2019; CHADWICK et al., 2018; HARVEY et al., 2020; PARKIN; VENTEREA, 2010; SHANG et al., 2020).

Different materials and designs of static chambers have been used together with different methodological procedures, which have implications and concerns on the reliability of measurements and the comparison between data in the literature (ALVES et al., 2017; BUCKINGHAM et al., 2014; LÓPEZ-AIZPÚN et al., 2020; ROCHETTE; ERIKSEN-HAMEL, 2008). Attentive to this, Rochette and Ericksen-Hamel (2008) proposed a set of sixteen criteria based on experimental data and considerations based on theories of gas dynamics to classify how reliable were the published measurements of N_2O emissions. They observed that 60% of the 356 studies from 1978 to 2007 all over the world generated results that could be characterized as very low and low confidence, which were the classification of 67% of the 27 studies from South America. Moreover, none of the chamber from studies of South America were considered of high confidence. The insertion depth of the chamber base, chamber height and the deployment period were characteristics related to chamber design highlighted as of concern according to Rochette and Ericksen-Hamel (2008). In more than 50% of the studies from South America, the index "chamber base insertion into the soil" was <5 cm h^{-1} and the chamber area/perimeter ratio was only satisfactory (good or very good rates) in less than 40% of the studies.

From the above, a reassessment of protocols adopted in Latin America for soil N_2O measurements based on the static chamber is desirable given the increasing importance and intensity of studies on GHGs in this century and to evaluate how effective were the efforts to establish standard practices for using static chambers.

Therefore, it is necessary to reassess the reliability of the static chambers used in the studies performed in the countries of Latin America following the standard criterion recommended by reference researchers in this area (Rochette & Eriksen-Hamel 2008) and by the Global Research Alliance on Agricultural Greenhouse Gases (GRA) (DE KLEIN et al., 2020; DE KLEIN; HARVEY, 2015). Latin America is an emerging continent for global food supply, and this role can be even greater in the future depending on improvements in technology and land use (FLACHSBARTH et al., 2015; SÁ et al., 2017), to which potential impacts on GHGs emissions and the development of mitigation practices must be reported accurately.

Thus, the objective of this study was to assess the confidence level of static chambers, according to their characteristics.

MATERIAL AND METHODS

We performed a systematic literature review (BUCKINGHAM et al., 2014) to compile scientific articles that quantify soil GHGs using the manual static chambers methods in agricultural systems in Latin America. The searches were made using the Web of Science, Science Direct, and Google Scholar web-platforms databases. A set of criteria was devised to screen scientific studies for relevance to our objectives in a standardized, systematic manner, that were: (i) studies quantifying N_2O or CH_4 emissions from soil/plant residues, from fertilizers and excreta (feces and urine) from livestock in the field conditions; (ii) only to consider studies that were carried out in Latin American (i.e., Central and South America) countries; and (iii) to include field studies performed in one of the three types of agricultural systems: pastures, crops or in Integrated Crop-Livestock-Forest (ICLF) systems.

The articles were selected according to the screening criteria cited above. Thus, articles were separated into three-date intervals, e.g., those published between 2000 and 2008, 2009 and 2015, and between 2016 and 2020. We decided to evaluate these time intervals due to two main reasons: i) in 2008 was published a milestone study taken as a reference with several recommendations and criteria related to the static chamber method (ROCHETTE & ERIKSEN-HAMEL, 2008); ii) in 2015, a guideline protocol was published by the Global Research Alliance on Agricultural Greenhouse Gases (GRA), a global alliance between countries to find ways to produce more food without increasing GHG emissions (SHAFER et al., 2011). Therefore, the division of the selected articles in these three-time intervals aims to verify the influence of these key publications on the confidence level of the chambers used on studies in Latin America.

The six characteristics of the chambers evaluated in this work were related to the details of the chambers design and deployment procedures, that were: height, area, and perimeter of the chamber, insertion depth of the chamber base into the soil, duration of deployment, and the number of samples taken during the deployment time. To verify the quality of the chamber method, its characteristics were evaluated according to the criteria developed by Rochette and Eriksen-Hamel (2008), which indicate the values or ranges of values to qualify each one as very good, good, poor, and very poor (Table 1).

Table 1. Criteria used for the evaluation of chamber quality

Chamber Characteristics	Unit	Qualification			
		Very Poor (0)	Poor (1)	Good (2)	Very Good (3)
		Criteria			
Chamber height index	cm h^{-1}	< 10	10 to < 20	20 to < 40	≥ 40
Base insertion index	cm h^{-1}	< 5	5 to < 8	8 to < 12	≥ 12
Area/perimeter ratio	cm	< 2.5	2.6 to < 6.25	6.26 to < 10	≥ 10
Duration of deployment	min	> 60	> 40 - 60	> 20 - 40	≤ 20
Number of samples	Nº	1	2	3	> 3

Chamber height index: ratio of height (cm) to duration of deployment (h); base insertion index: ratio between insertion into the soil (cm) by duration of deployment (h). area/perimeter ratio: ratio of the area of the chamber (cm^2) to the perimeter (cm) (if the shape is cylindrical, the diameter is used; with the rectangular shape, the length and width are used). For the deployment duration and number of samples per deployment period, the exact numbers described in the study were used. The numbers between parenthesis are the score for each qualification class. Source: Rochette and Eriksen-Hamel (2008).

Therefore, each characteristic received a score that was linked to its quality according to Table 1, which was: very good = 3; good = 2; poor = 1; and very poor = 0. From that, the scores were averaged for all studies found in each time interval to release a general score for each characteristic from the measurement protocol, which where: 0-0.74 = very poor; 0.75-1.49 = poor, 1.50-2.24 = good; and 2.25-3.0 = very good.

Besides evaluating the characteristics individually, weight was also placed on each of them according to the importance of each characteristic for the confidence level of the chamber. For instance, the base insertion into the soil (cm h^{-1}) is classified as a "primary" characteristic, so received the highest weight (0.3 - Table 2), due to this characteristic having a more significant impact on soil gas leaks, depending on the soil type (ROCHETTE & ERIKSEN-HAMEL, 2008). The "secondary" characteristics as the number of samples, area/perimeter ratio, and chamber height index received the weight of 0.2, and the duration of deployment received the weight of 0.1.

It was possible to obtain a global score for each chamber used in each study, by multiplying the score received by the numerical characteristic to the weight referring to it. Therefore, static chambers had their reliability classified into four levels: very low (0-0.74), low (0.75-1.49), medium (1.50-2.24), and high (2.25 -3.0). It was possible to obtain the percentage of studies that were classified in each level for all three-time intervals.

RESULTS AND DISCUSSIONS

A total of 90 studies passed through the screening criteria and were selected for the chamber evaluation. For all the analyzed periods (2000-2008, 2009-2015, and 2015-2020) it was possible to observe the highest concentration of studies at the medium confidence level. Also, it was possible to notice the number of studies with low-confidence decreasing and the percentage of high-confidence studies increasing with time.

Considering the publications from 2000 to 2008, 62.5% of the studies presented a medium level of confidence, 37.5% a low level, whereas no studies obtained a high level. For the time interval between 2009 and 2015, 8.3% of the studies were classified as of high confidence level, 75.0% medium level, and 16.7% low level. For the 2016 and 2020 studies, this proportion was 17.4% with high levels of confidence, 71.7% with medium level, and only 10.9% with low level (Figure 1).

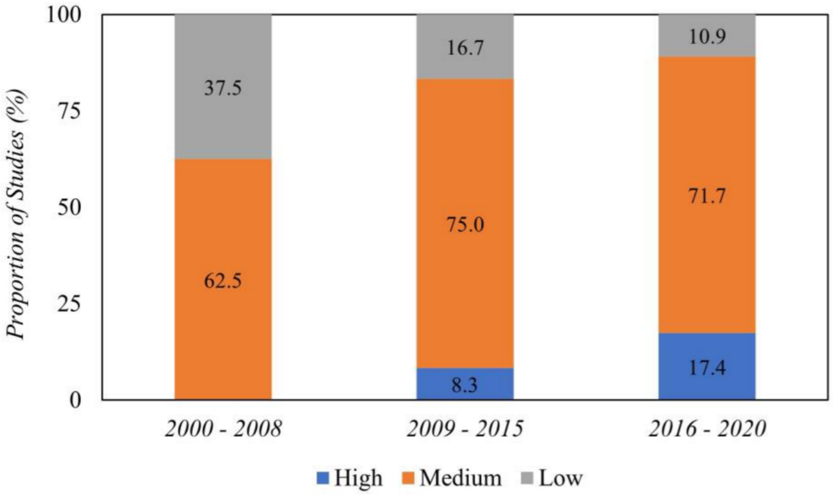

Figure 1. Proportion of studies associated with each level of confidence for each time interval.

From an analysis of studies from all over the world, Rochette and Eriksen-Ramel (2008) concluded that the level of confidence of the GHGs flows in 60% of these studies was low or very low due to the low scores of the characteristics or lack of reporting of methodological details. Thus, in that study, the confidence level increased with time, as the proportion of studies with high or medium confidence increased from 29% of the studies in 1990 to 50% after 2005. Besides that, the number of studies with very low confidence levels decreased from 46 to 9% between 1990 and 2005, respectively. Around 57% of all studies, they considered received very poor or poor scores for more than half of the characteristics. The characteristics that have slightly improved were chamber height and number of samples taken, from 1980 to 2007. But Latin American studies were considered weaker when compared to other regions, and this situation motivated the present work to evaluate what happened with chamber studies after 2008. Latin America is a key continent for food production in the world, making the characterization of production systems necessary with reliable analyzes of the impacts and development of mitigation strategies (CLARKE et al., 2016; SÁ et al., 2017).

was also observed that over the years, the proportion of Latin American studies about GHGs using static chambers with a high confidence level has increased while the proportion with a low confidence level has decreased. This indicates the improvement of the chambers used in the studies after the publications of standard protocols that clarify the best conduct of this methodology (ROCHETTE & ERIKSEN-HAMEL, 2008; DE KLEIN & HARVEY, 2015). The continuous improvement of the confidence level in the studies carried out after 2008 and after 2015 is a strong indication that these publications and international recommendations had contributed to improving the researches with static chambers in Latin America.

CONCLUSIONS

The evaluation made by this paper was only about the design and deployment chamber characteristics, and to determine the confidence of the complete method (storage, analytical technique, and flux calculation) it is necessary to evaluate characteristics from other important practices too. In general, there was an increase in the number of studies that had a high confidence level over the three periods evaluated. Besides, the number of studies with low confidence levels had been reduced, evidence of gain in data quality. It is recommended that researchers continue to follow the GRA protocols when working with static chambers, especially the most updated ones.

ACKNOWLEDGMENTS

We thank the scholarship financed by Higher Level Personnel Improvement Coordination-CAPES, the scholarship supported by the CGIAR Research Program on Climate Change, Agri-culture and Food Security (CCAFS), the Global Research Alliance on Agricultural Greenhouse Gases (GRA) through their CLIFF-GRADS programme to the first author, and the finance supported by ICLF Network and Rural Sustainable Project.

REFERENCES

ALVES, B. J. R.; SCIVITTARO, W. B.; JANTALIA, C. P.; DE SOUSA, R. O.; BAYER, C.; RODRIGUES, R. A. R.; BODDEY, R. M.; URQUIAGA, U.; MADARI, B. E. **Protocolo para medição de fluxos de gases de efeito estufa em sistemas aeróbicos e alagados de produção de grãos – Rede Fluxus**. Embrapa, 2017. 60p.

BUCKINGHAM, S.; ANTHONY, S.; BELLAMY, P.H.; CARDENAS, L.M.; HIGGINS, S.; MCGEOUGH, K.; TOPP, C.F.E. Review and analysis of global agricultural N2O emissions relevant to the UK. **Science of The Total Environment**, v.487, p.164–172, 15 jul. 2014.

CARDOSO, A. DA S.; OLIVEIRA, S. C.; JANUSCKIEWICZ, E. R.; BRITO, L. F.; MORGADO, E. DA S.; REIS, R. A.; RUGGIERI, A. C. Seasonal effects on ammonia, nitrous oxide, and methane emissions for beef cattle excreta and urea fertilizer applied to a tropical pasture. **Soil and Tillage Research**, v.194, p.104341, nov. 2019.

CHADWICK, D. R.; CARDENAS, L. M.; DHANOA, M. S.; DONOVAN, N.; MISSELBROOK, T.; WILLIAMS, J. R.; THORMAN, R. E.; MCGEOUGH, K. L.; WATSON, C. J.; BELL, M.; ANTHONY, S. G.; REES, R. M. The contribution of cattle urine and dung to nitrous oxide emissions: Quantification of country specific emission factors and implications for national inventories. **Science of The Total Environment**, v.635, p.607–617, 1 set. 2018.

CLARKE, L.; MCFARLAND, J.; OCTAVIANO, C.; VAN RUIJVEN, B.; BEACH, R.; DAENZER, K.; HERRERAS MARTÍNEZ, S.; LUCENA, A. F. P.; KITOUS, A.; LABRIET, M.; LOBOGUERRERO RODRIGUEZ, A. M.; MUNDRA, A.; VAN DER ZWAAN, B. Long-term abatement potential and current policy trajectories in Latin American countries. **Energy Economics**, v.56, p.513–525, 1 maio 2016.

DE KLEIN, C.; HARVEY, M.; CLOUGH, T.; PETERSEN, S.; CHADWICK, D.; VENTEREA, R. Global research alliance nitrous oxide chamber methodology guidelines: Introduction, with health and safety considerations. **Journal of Environmental Quality**, v.49, n.5, p.1073–1080, 2020.

DE KLEIN, E. C.; HARVEY, M. **Nitrous Oxide Chamber Methodology Guidelines**, 2015. 146p.

FLACHSBARTH, I.; WILLAARTS, B.; XIE, H.; PITOIS, G.; MUELLER, N. D.; RINGLER, C.; GARRIDO, A. The Role of Latin America's Land and Water Resources for Global Food Security: Environmental Trade-Offs of Future Food Production Pathways. **PLOS ONE**, v.10, n.1, e0116733, Jan.2015.

HARVEY, M.; SPERLICH, P.; CLOUGH, T.; KELLIHER, F.; MCGEOUGH, K.; MARTIN, R.; MOSS, R. Global Research Alliance N2O chamber methodology guidelines: Recommendations for air sample collection, storage and analysis. **Journal of Environmental Quality**, v.49, n.5, p.1110–1125, 2020.

LÓPEZ-AIZPÚN, M.; HORROCKS, C. A.; CHARTERIS, A. F.; MARSDEN, K. A.; CIGANDA, V. S.; EVANS, J. R.; CHADWICK, D. R.; CÁRDENAS, L. M. Meta-analysis of global livestock urine-derived nitrous oxide emissions from agricultural soils. **Global Change Biology**, v.26, n.4, p.2002–2013, 2020.

PARKIN, T. B.; VENTEREA, R. T. Chamber-based trace gas flux measurements. In: FOLLETT, R. F. (Ed.). **Sampling protocols**. Washington, DC: USDA-ARS, 2010. P.3.1-3.39. Available at: http://www.ars.usda.gov/research/GRACEnet.

ROCHETTE, P.; ERIKSEN-HAMEL, N. S. Chamber Measurements of Soil Nitrous Oxide Flux: Are Absolute Values Reliable? **Soil Science Society of America Journal**, v.72, n.2, p.331–342, Mar. 2008.

SÁ, J.C. DE M.; LAL, R.; CERRI, C. C.; LORENZ, K.; HUNGRIA, M.; DE FACCIO CARVALHO, P. C. Low-carbon agriculture in South America to mitigate global climate change and advance food security. **Environment International**, v.98, p.102–112, Jan.2017.

SHAFER S. R.; WALTHALL C. L., FRANZLUEBBERS A. J., SCHOLTEN, M.; MEIJS, J.; CLARK, H.; REISINGER, A.; YAGI, K.; ROEL, A.; SLATTERY, B.; CAMPBELL, I. D.; MCCONKEY, B. G.; ANGERS, D. A.; SOUSSANA, J-F.; RICHARD, G. Emergence of the Global Research Alliance on Agricultural Greenhouse Gases. **Carbon Management**, v.2, n.3, p.09–214, 1 jun. 2011.

SHANG, Z.; ABDALLA, M.; KUHNERT, M.; ALBANITO, F.; ZHOU, F.; XIA, L.; SMITH, P. Measurement of N2O emissions over the whole year is necessary for estimating reliable emission factors. **Environmental Pollution**, v.259, p.113864, 1 abr. 2020.