Estimating total fuel load in tropical savanna using NASA's GEDI spaceborne lidar and machine learning

Rodrigo Vieira Leite[1], Carlos Alberto Silva[2], Eben North Broadbent[3], Cibele Hummel do Amaral[1], Veraldo Liesenberg[4], Danilo Roberti Alves de Almeida[5], Midhun Mohan[6], Sérgio Godinho[7,8], Adrian Cardil[9,10,11], Caio Hamamura[12], Bruno Lopes de Faria[13], Pedro H. S. Brancalion[5], André Hirsch[14], Gustavo Eduardo Marcatti[14], Ana Paula Dalla Corte[15], Angelica Maria Almeyda Zambrano[16], Máira Beatriz Teixeira da Costa[17], Eraldo Aparecido Trondoli Matricardi[17], Anne Laura da Silva[14], Lucas Ruggeri Ré Y Goya[14], Ruben Valbuena[18], Bruno Araujo Furtado de Mendonça[19], Celso H. L. Silva Junior[20,21], Luiz E. O. C. Aragão[20,22], Mariano García[23], Jingjing Liang[24], Trina Merrick[25,26], Andrew T. Hudak[27], Jingfeng Xiao[28], Steven Hancock[29], Sassan Saatchi[30], Carine Klauberg[15]

[1]Department of Forest Engineering, Federal University of Viçosa (UFV), Av. Peter Henry Rolfs, 36570-900, Viçosa, MG, Brazil; {rodrigo.leite; chamaral}@ufv.br

[2]School of Forest, Fisheries, and Geomatics Sciences, University of Florida, University of Florida, PO Box 110410 Gainesville, FL 32611; c.silva@ufl.edu

[3]Spatial Ecology and Conservation (SPEC) Lab, School of Forest, Fisheries, and Geomatics Sciences, University of Florida, Gainesville, FL 32611 USA; eben@ufl.edu

[4]Department of Forest Engineering, College of Agriculture and Veterinary, Santa Catarina State University (UDESC), Lages, SC, Brazil; veraldo.liesenberg@udesc.br

[5]Department of Forest Sciences, "Luiz de Queiroz" College of Agriculture, University of São Paulo (USP/ESALQ), Piracicaba, SP, Brazil; {daniloraa; pedrob}@usp.br

[6]Department of Geography, University of California—Berkeley, Berkeley, CA 94709, USA; mid_mohan@berkeley.edu

[7]EaRSLab—Earth Remote Sensing Laboratory, University of Évora, 7000-671 Évora, Portugal

[8]Institute of Earth Sciences (ICT), Universidade de Évora, Rua Romão Ramalho, 59, 7002-554, Évora, Portugal; sgodinho@uevora.pt

[9]Technosylva Inc, La Jolla, CA, USA, adriancardil@gmail.com

[10]Department of Crop and Forest Sciences, University of Lleida, Lleida, Spain

[11]Joint Research Unit CTFC - AGROTECNIO, Solsona, Spain

[12]Federal Institute of Education, Science and Technology of São Paulo, SP, 11533-160, Brazil; hamamura.caio@ifsp.edu.br

[13]Department of Forest Science, Federal University of Vales do Jequitinhonha e Mucuri, (UFVJM) Campus JK, Diamantina, MG, Brazil, blfaria@gmail.com

[14]Federal University of São João Del Rei – UFSJ, Sete Lagoas, MG, Brazil, 35701-970; {gustavomarcatti, hirsch_andre}@ufsj.edu.br; {annelsilva11, lucasgoya42.lr}@gmail.com; carine_klauberg@hotmail.com

[15]Department of Forest Engineering, Federal University of Paraná (UFPR), Curitiba, PR, Brazil, 80.210-130; anacorte@ufpr.br

[16]Spatial Ecology and Conservation (SPEC) Lab, Center for Latin American Studies, University of Florida, Gainesville, FL 32611 USA; aalmeyda@ufl.edu

[17]Department of Forestry, University of Brasília, Campus Darcy Ribeiro, Brasilia, DF, Brazil - 70.910-900; mairabeatrizteixeira@hotmail.com; ematricardi@gmail.com

[18]School of Natural Sciences, Bangor University, Bangor LL57 2W, UK. r.valbuena@bangor.ac.uk

[19]Silviculture Department, Universidade Federal Rural do Rio de Janeiro, Rua da Floresta, Seropédica, RJ, 23897-005, Brazil; brunomendonca@ufrrj.br

[20]National Institute for Space Research, Earth Observation and Geoinformatics Division, Av. dos Astronautas, 1758, São José dos Campos SP 12227-010, Brazil, celsohlsj@gmail.com, luiz.aragao@inpe.br

[21]Universidade Estadual do Maranhão (UEMA), Departamento de Engenharia Agrícola, São Luís, MA, 65055-310, Brazil

[22]College of Life and Environmental Sciences, University of Exeter, Exeter, UK

[23]Environmental Remote Sensing Research Group, Department of Geology, Geography and the Environment, Universidad de Alcalá, Calle Colegios 2, Alcalá de Henares, 28801, Spain. mariano.garcia@uah.es

[24]Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN, USA, alpenbering@gmail.com

[25]Department of Earth and Environmental Science, Vanderbilt University, Nashville, TN 37240, USA

[26]Department of Geography, Florida State University, Tallahassee, FL, USA. tmerrick@fsu.edu

[27]US Department of Agriculture, Forest Service, Rocky Mountain Research Station, 1221 South Main Street, Moscow, ID 83843, USA, andrew.hudak@usda.gov

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[28]Earth Systems Research Center, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03820, USA. j.xiao@unh.edu

[29]School of GeoSciences, University of Edinburgh, United Kingdom of Great Britain and Northern Ireland. steven.hancock@ed.ac.uk

[30]NASA-Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA sasan.s.saatchi@jpl.nasa.gov

1. Introduction

The understanding of wildfire dynamics is important to mitigate climate change and guide conservation practices in several ecosystems in the world. Savannas are generally fire-adapted but human activities have affected fire regimes and the landscape characteristics (Bowman et al. 2013). Presently, the most flora-rich savanna in the world, the Brazilian Cerrado, has also experienced those effects (Schmidt et al., 2018).

One of the main factors affecting fire is the amount of biomass available for burning, defined as fuel load. Remote sensing technologies are used for local scale fuel load mapping mainly using airborne lidar data (Gajardo et al. 2014). However, for large scale fuel load mapping spaceborne data is required. The recently launched spaceborne lidar sensor GEDI (Global Ecosystem Dynamics Investigation, Dubayah et al. 2020) holds potential to meet this demand. GEDI was developed to penetrate forests with about 95-98% (daytime and night-time measurements, respectively) of canopy cover to efficiently retrieve the vegetation vertical structure. Nonetheless, GEDI potential for fuel load estimation has not been broadly investigated yet.

In this study, we developed a methodological approach using GEDI and field data to train a Random Forest (RF) algorithm to estimate fuel load in the Cerrado biome. Our approach allowed us to quantify the fuel load of several types of vegetation in the study area.

2. Data and Methods

We established 50 sample plots of 900 m^2 in four Cerrado conservation sites. In the field, we collected fuel loads of different vegetation layers including surface, herbaceous, shrubs, and woody layers. The study sites were surveyed with the GatorEye Gen 1 UAV system (Broadbent et al. 2021) with a dual-return lidar to obtain the high-density point clouds. The UAV-lidar 3D point cloud was used to build GEDI-like waveforms using the GEDI simulator (Hancock et al. 2019, Silva et al. 2020) that is able to reproduce the on-orbit GEDI data characteristics. We calculated waveform metrics of relative height at the 98th percentile (m), canopy cover fraction (%), plant area index and foliage height diversity using the rGEDI package (Silva et al. 2020). The metrics were used to train a RF algorithm with the total field-measured fuel load (*TFL*) as the response variable. The model's performance was assessed in a 5-fold cross-validation using the coefficient of determination (R^2), absolute (Mg ha^{-1}) and relative (%) root square mean error (RMSE) and mean difference (MD). Finally, we applied the model to the on-orbit GEDI footprints over the Cerrado biome and aggregated the estimations into 1-km grid cells.

3. Results and Discussion

The RF had a relatively good performance to estimate *TFL* with R^2 = 0.71, RMSE = 23.01 Mg ha^{-1}, RMSE (%) = 40.78, MD = 0.22 Mg ha^{-1} and MD (%) = 2.09. This performance is related to the GEDI's potential of better obtaining vegetation structure over previous spaceborne lidar missions. Part of the uncertainty may be due to the inclusion of near-surface vegetation layers, such as herbaceous and ground fuels, that are commonly not considered but represent an important fuel component. The GEDI footprint density varied for different Cerrado regions for which the models were applied to map the total fuel load (Figure 1). Most of the data gaps are expected to be filled with upcoming data releases. Alternatively, data fusion with other spaceborne sensors can be used to derive wall-to-wall maps and or improve spatial resolution of the fuel load map. The presented framework represents a key point for advancing the understanding of fuel load accumulation over large areas and its effects on ecosystem functioning and carbon emissions. This is especially important in Cerrado where integrated fire management solutions that depend on large-scale fuel load characterization are taking place to preserve fire history and biodiversity (Schmidt et al., 2018).

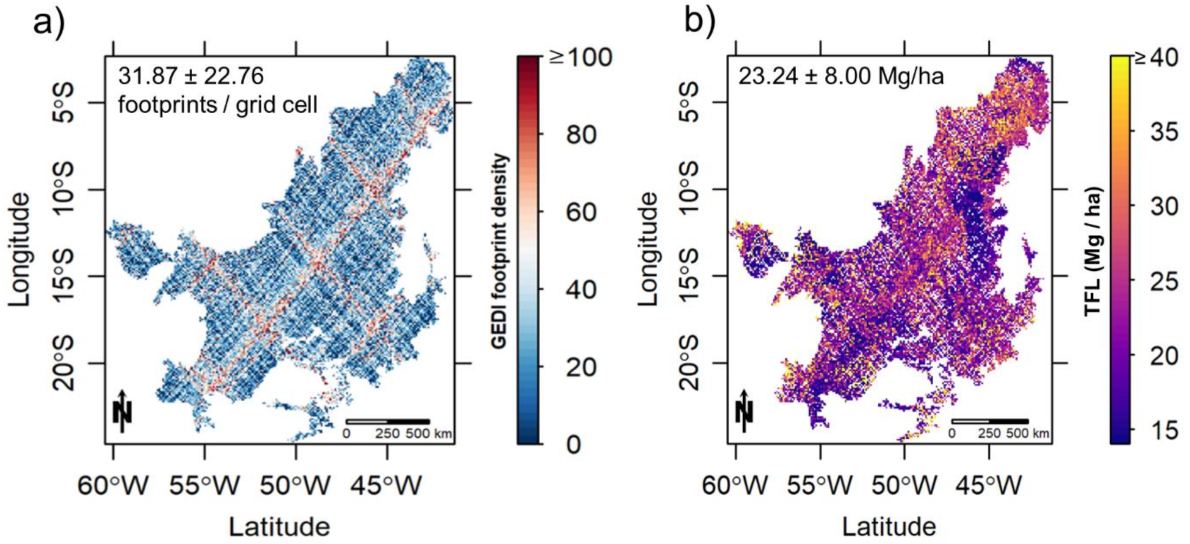

Figure 1. GEDI footprint density (a) and total fuel load (*TFL*) estimates (b) at 1km grid cells for the entire Cerrado biome. Values within plots represent mean ± standard-deviation of *TFL* estimates and GEDI footprints in (a) and (b), respectively.

4. Conclusion

We evaluated the potential of using GEDI data to estimate total fuel load in the Cerrado biome. Our methodological approach based on GEDI footprints showed relatively high accuracy to estimate total fuel load in the study area. Our modeling approach is an advance for large-scale fuel load mapping in the Cerrado biome and it shows potential to be applied to other fire-prone ecosystems worldwide.

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