Interactive comment on "Organic carbon burial efficiency in a large tropical hydroelectric reservoir" by Mendonça et al.

Philip M. Fearnside[1]

[1]National Institute for Research in Amazonia (INPA), Av. André Araújo 2936, CEP 69.067-375, Manaus, Amazonas, Brazil

Correspondence to: P.M. Fearnside (pmfearn@inpa.gov.br)

The discussion paper "Organic carbon burial efficiency in a large tropical hydroelectric reservoir" (Mendonça et al., 2015) contributes to interpreting a dataset that will be useful in the ongoing debate on the net impact of hydroelectric dams on global warming. The title needs to be changed, replacing "tropical hydroelectric reservoir" with "sub-tropical savannah hydroelectric reservoir". The dam in question (Mascarenhas de Moraes) is in a *Cerrado* area in Brazil's state of Minas Gerais. Calling this part of southeast Brazil "tropical" will imply to most readers the humid tropics of Brazil's Amazon region, which is very different from the point-of-view of dams and their greenhouse-gas emissions. Dams in the Amazonian biome have much higher emissions (*e.g.*, Barros et al., 2011). The title's reference to the 272-km^2 reservoir studied as "large" is also somewhat misleading: most in Brazil will think of reservoirs such as Tucuruí and Balbina that are over ten times larger.

The paper adds to interpretation of sediment samples collected in 2011. Previous studies of the same dataset (Mendonça et al., 2012, 2014) have presented similar results, but without calculation of "OCBE", or organic carbon burial efficiency (the ratio between buried and deposited organic carbon). The authors state (p. 18515) that "…assessments of the OC [organic carbon] burial efficiency in hydroelectric reservoirs are, to our knowledge, so far limited to one tropical (Kunz et al., 2011) and one temperate system (Sobek et al., 2012)…", referring to studies in Africa and North America. I was surprised to see no mention of the study in Brazil by Sikar et al. (2009), which presents data on carbon burial (although not expressed as a ratio).

What jumps to the eye of a reader of this paper is the lack of virtually any mention, let alone any conclusion, regarding the place of the study in the wider debate on net greenhouse-gas emissions from hydroelectric dams. The notion that carbon burial in reservoirs is partially offsetting (if not completely neutralizing) greenhouse-gas emissions from dams has been brought up by representatives of ELETROBRÁS and Hydro-Québec in various events debating the global-warming impact of dams, albeit without quantitative estimates to substantiate their implied neutrality (or even benefit) (personal observation). Citing the International Hydropower Association (IHA, 2008), an industry group, the Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Energy (Kumar et al., 2012, p. 474) emphasizes that "few studies have measured carbon accumulation in reservoir sediments" and considers net emissions from hydroelectric dams to be in doubt. Note that substantial emissions have been found in many studies, especially in tropical dams (see Fearnside, 2015a). The IPCC special report's overall conclusion on reservoir emissions that "there is currently no consensus on whether reservoirs are net emitters or net sinks" (Arvizu et al., 2012, p.

84) appears to rest on two studies cited by the head of the IHA report (Goldenfum, 2012, pp. 118-119) where carbon accumulation in sediments was credited with making the reservoirs net carbon sinks: Sikar et al. (2009) in Brazil and Chanudet et al. (2011) in Laos. The call for carbon balance studies for whole-river systems refers to this presumed benefit from dams (see Fearnside, 2015a). Note that "carbon balance" is often used in a misleading way in this debate, since the sequestration of carbon refers to carbon that, if emitted in the natural river, would be released almost only as CO_2, whereas much the carbon emitted by dams is in the form of CH_4, which has a much greater impact on global warming per ton of carbon. In addition, not all carbon buried in reservoir sediments would be emitted to the atmosphere in the absence of a dam: depending on the river in question, significant amounts would be deposited in locations such as the Amazonian *várzea* (floodplain) or in ocean sediments.

FURNAS, the ELETROBRÁS subsidiary that financed the Mendonça et al. (2015) study and owns the Mascarenhas de Moraes Dam, is the largest electricity company in South America and one of the largest in the world. The company is an important player in the high-stakes debate on greenhouse-gas emissions from dams and related questions regarding carbon credit for dams as global-warming mitigation projects and regarding Brazil's national priorities for energy development (see Fearnside, 2015b). A major FURNAS study on hydroelectric emissions claimed that dams in Brazil's *Cerrado* areas emit 100 times less greenhouse gases than equivalent fossil-fuel based generation (Garcia, 2007). The study in question (e.g., Ometto et al., 2013) has methodological problems that underestimate emissions from water passing through the turbines and spillways (see Fearnside and Pueyo, 2012).

A tantalizingly anonymous comment on Mendonça et al. (2015) calls on the authors to "better discuss a question of role of reservoirs as a sink of carbon instead the source of biogenic gases to the atmosphere" (Anonymous, 2016). The wording "a question of role" reveals that the comment's source is Brazilian. Is this the voice of FURNAS demanding recognition of a climatic benefit from carbon burial in its reservoirs? The authors have already credited the reservoir with a beneficial carbon balance (Mendonça et al., 2012). The Mendonça et al. (2015) study simply presents their result (OCBE = 57%) without drawing any conclusions as to whether this is good, bad or indifferent with respect to emissions. Certainly the lack of a conclusion on this point is, at the least, very discreet. Given that only 57% of the carbon deposited in the reservoir sediments remains buried, much of the 43% that disappears would be released as methane, thus implying a substantial net impact on global warming as compared to the natural river. How this emission compares to fossil fuels is dependent on a series of methodological decisions that the hydroelectric industry is anxious to have decided in ways that favor dams (see Fearnside, 2015a). Most importantly, Brazil's choice is not one of dams versus fossil fuels: the country is fortunate in having many better options. These include not exporting electricity in the form of electro-intensive commodities like aluminum (Fearnside, 2016) and major opportunities for energy conservation, reduction of losses in transmission and distribution, and generation from massive potential wind and solar resources (Baitelo et al., 2013; Moreira, 2012).

Acknowledgements. The author's research is supported exclusively by academic sources: Conselho Nacional do Desenvolvimento Científico e Tecnológico (CNPq: Proc. 305880/2007-1; 304020/2010-9; 573810/2008-7; 575853/2008-5), Fundação de

Amparo à Pesquisa do Estado do Amazonas (FAPEAM: Proc. 708565) and Instituto Nacional de Pesquisas da Amazônia (INPA: PRJ15.125).

References

Anonymous: Interactive comment on "Organic carbon burial efficiency in a large tropical hydroelectric reservoir" by R. Mendonça et al., Biogeosciences Discuss., 12, C9321–C9321, 21 January 2016. http://www.biogeosciences-discuss.net/12/C9321/2016/, 2016.

Arvizu, D. and 39 others: Technical summary. in: Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change, edited by Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlomer, S. and von Stechow, C., Cambridge University Press, Cambridge, UK, pp. 27-158. Available at: http://www.ipcc.ch/pdf/special-reports/srren/srren_full_report.pdf, 2012.

Baitelo, R., Yamaoka, M., Nitta, R. and Batista, R.: [R]evolução energética: A caminho do desenvolvimento. Greenpeace Brasil, São Paulo, SP, Brazil. 79 pp. http://www.greenpeace.org/brasil/pt/Documentos/Revolucao-Energetica-2013/

Barros, N., Cole, J. J., Tranvik, L. J., Prairie, Y. T., Bastviken, D., Huszar, V. L. M., del Giorgio, P. and Roland, F.: Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude, Nat. Geosci., 4(9), 593–596, doi:10.1038/NGEO1211, 2011.

Chanudet, V., Descloux, S., Harby, A., Sundt, H., Hansen, B. H., Brakstad, O., Serça, D. and Guerin, F.: Gross CO_2 and CH_4 emissions from the Nam Ngum and Nam Leuk sub-tropical reservoirs in Lao PDR, Sci. Total Environ., 409(24), 5382-5391, doi:10.1016/j.scitotenv.2011.09.018, 2011.

Fearnside, P. M.: Emissions from tropical hydropower and the IPCC, Environ. Sci, & Policy, 50: 225-239, doi:10.1016/j.envsci.2015.03.002, 2015a.

Fearnside, P. M.: Tropical hydropower in the Clean Development Mechanism: Brazil's Santo Antônio Dam as an example of the need for change, Climatic Change, 131(4), 575-589. doi:10.1007/s10584-015-1393-3, 2015b.

Fearnside, P. M.: Environmental and social impacts of hydroelectric dams in Brazilian Amazonia: Implications for the aluminum industry, World Devel., 77, 48-65, doi:10.1016/j.worlddev.2015.08.015, 2016.

Fearnside, P. M. and Pueyo, S.: Underestimating greenhouse-gas emissions from tropical dams, Nat. Climate Change 2(6), 382–384. doi:10.1038/nclimate1540, 2012.

Garcia, R.: Estudo apoia tese de hidrelétrica "limpa": Análise em usinas no cerrado indica que termelétricas emitem até cem vezes mais gases causadores do efeito estufa, Folha de São Paulo, 1 May 2007, p. A-16, 2007.

Goldenfum, J. A.: Challenges and solutions for assessing the impact of freshwater reservoirs on natural GHG emissions, Ecohydrol. & Hydrobiol., 12, 115-122, doi:10.2478/v10104-012-0011-5, 2012.

IHA (International Hydropower Association): Assessment of the GHG Status of Freshwater Reservoirs - Scoping Paper. IHA/GHG-WG/3, United Nations Educational, Scientific and Cultural Organization (UNESCO)Working Group on Greenhouse Gas Status of Freshwater Reservoirs and International Hydropower Association, IHA, London, UK, 28 pp. Available at: http://unesdoc.unesco.org/images/0018/001817/181713e.pdf, 2008.

Kumar, A., Schei, T., Ahenkorah, A., Caceres Rodriguez, R., Devernay, J.-M., Freitas, M., Hall, D., Killingtveit, A. and Liu, Z.: Hydropower. in: Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change, edited by Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlomer, S. and von Stechow, C., Cambridge University Press, Cambridge, UK, pp. 437-496. Available at: http://www.ipcc.ch/pdf/special-reports/srren/srren_full_report.pdf, 2012.

Kunz, M. J., Anselmetti, F. S., Wuest, A., Wehrli, B., Vollenweider, A., Thuring, S. and Senn, D.B.: Sediment accumulation and carbon, nitrogen, and phosphorus deposition in the large tropical reservoir Lake Kariba (Zambia/Zimbabwe), J. Geophys. Res.-Biogeo., 116, G03003, doi:10.1029/2010jg001538, 2011.

Mendonça, R., Kosten, S., Sobek, S., Barros, N., Cole, J. J., Tranvik, L. and Roland, F.: Hydroelectric carbon sequestration, Nat. Geosci., 5, 838–840, doi:10.1038/ngeo1653, 2012.

Mendonça R., Kosten, S., Sobek, S., Cardoso, S. J., Figueiredo-Barros, M. P., Estrada, C.H.D. and Roland, F.: Organic carbon burial efficiency in a large tropical hydroelectric reservoir, Biogeosciences Discuss., 12, 18513–18540, 2015.

Mendonça, R., Kosten, S., Sobek, S., Cole, J., Bastos, A., Albuquerque, A., Cardoso, S. and Roland, F.: Carbon sequestration in a large hydroelectric reservoir: An integrative seismic approach, Ecosystems, 17, 430–441, doi:10.1007/s10021-013-9735-3, 2014.

Moreira, P. F. (ed.): Setor Elétrico Brasileiro e a Sustentabilidade no Século 21: Oportunidades e Desafios. 2ª ed. Rios Internacionais, Brasília, DF, Brazil. 100 pp. Available at: http://www.internationalrivers.org/node/7525, 2012.

Ometto, J. P., Cimbleris, A. C. P., dos Santos, M. A., Rosa, L. P., Abe, D., Tundisi, J. G., Stech, J. L., Barros, N. and Roland, F.: Carbon emission as a function of energy generation in hydroelectric reservoirs in Brazilian dry tropical biome, Energy Policy, 58, 109-116, doi:10.1016/j.enpol.2013.02.041, 2013.

Sikar, E., Matvienko, B., Santos, M. A., Rosa, L. P., Silva, M. B., Santos, E. O., Rocha, C. H. E. D. and Bentes Jr., A. P.: Tropical reservoirs are bigger carbon sinks

than soils, Verhandlungen Internationale Vereinigung fur Theoretische und Angewandte Limnologie, 30, 838–840, 2009.

Sobek, S., DelSontro, T., Wongfun, N. and Wehrli, B.: Extreme organic carbon burial fuels intense methane bubbling in a temperate reservoir, Geophys. Res. Lett., 39, L01401, 10, doi:10.1029/2011gl050144, 2012.