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Interactive comment on "The Impact of Drought on Soil Moisture Trends across Brazilian Biomes" *by* Flavio Lopes Ribeiro et al.

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Dear Reviwer #2,

Thank you so much for all your comments and suggestions. We had great discussions regarding your interaction and I am sure it will result in some improvements on our manuscript. Please, find bellow our answers.

All the best.

Reviewer comment: The manuscript is well-written but in its current form seems a good scientific report rather than an article. I struggle to find a novelty in this manuscript

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since the authors simply apply known statistical methods to near-surface soil moisture maps. Therefore I highly recommend to re-submit the manuscript by adding something interesting to relate climate drought to soil moisture drought.

Response: There are two main novelties in this article. First, we show the differential impact of drought on the soil moisture of different biomes at a national scale (using Brazil as a case study). For the best of our knowledge, there are no published articles about this issue. Understanding how each biome is affected by drought conditions from different perspectives (in our case superficial soil moisture) is crucial to assess their resilience and provide a more complete evidence-based orientations to drought mitigation and soil conservation plans. Furthermore, this data set has not been used by the disaster management community (our target audience) as a complementary source of knowledge on the systemic impact of drought at national and local scales. Motivated by this knowledge gap and the availability of this dataset on soil moisture, we present some features of using this satellite soil moisture product to drought monitoring against other approaches, for example feasibility of the soil moisture product, high temporal resolution, that the satellite moisture product is done from radar data that in theory should be more useful to explain soil properties, comparability with other areas of the world, repeatability of results, etc.

____ Reviewer comment: Some further “quantitative” analysis is required (Van Loon, 2015; von Gunten et al., 2016; Hein et al., 2019; Nasta et al., 2020). 1) Climate drought indexes: please see https://spei.csic.es/home.html and associated references 2) Soil moisture index: please see Hunt et al. (2009), Martínez-Fernández et al. (2015), Sánchez et al. (2016) Satellite measurements provide indirect estimates of soil moisture only in the topsoil, and unfortunately do not provide soil water storage.

Response: We don’t agree further quantitative analysis is required in terms of a drought analyses. As stated before, this article has the purpose of showing the advantages and disadvantages of integrating satellite soil moisture observations into drought monitoring across Brazil (and other countries) on a biome basis, and not creating another drought

index. It is targeted on disaster management communities across the globe, which still lack information and scientific evidences on how each biome respond to drought conditions especially considering our present climate emergency. However, to confirm the consistency of our results, we will create a new sub section with a validation of the 5cm SM compared with OCO-2-based SIF product (GOSIF) and linear relationships between SIF (Solar-induced chlorophyll fluorescence) and GPP (gross primary production) used to map GPP globally at a 0.05° spatial resolution and 8-day time step, as proposed by Li, X.*, Xiao, J. (2019): https://www.mdpi.com/2072-4292/11/21/2563 We even have already produced a map of primary productivity trends 2009-2015 for Brazil retrieving data form Orbiting Carbon Observatory-2 (OCO-2) which only confirms our results.

____ Reviewer comment: Moreover dense vegetation cover disturbs the satellite measurements therefore the authors should devote a sub-section on discussing on these issues.

Response: We agree in that specific conditions of dense vegetation can affect the quality of soil moisture measurements. We recognize that dense vegetation conditions e.g., across specific areas of tropical rain forest with dense vegetation are mainly located in the Amazon forest. That was the main reason why we selected a coarse scale but ecologically meaningful delineation of Brazilian biomes, to avoid the lack of information across specific areas with dense vegetation. At the biome level, we observe that the Amazon biome has the higher area of dense vegetation (but not all Amazon is dense vegetation), and probably that is the reason why we don't observe significant trends in this biome. Other biomes are not affected by this issue. We contribute with a prediction of soil moisture trends across all the country using a geostatistical approach (Figure 6 of submitted paper) aiming to contribute with better information across areas less represented with the available satellite data. We will clarify the effects of dense vegetation in satellite soil moisture and will highlight the scale of our work. We will also demonstrate in the new version of the paper that at the biome scale the trends of soil

moisture are consistent with trends in vegetation productivity data.

_____ Reviewer comment: Moreover soil moisture observations from 2009 till 2015 do not drive to strong conclusions on temporal evolution, so the authors should warn the reader that this observation is based on very short time series. Usually drought indexes require necessarily at least 30 years of observations. I understand that satellite data provide only short-term temporal evolution but the authors should highlight this issue.

Response: You're right. Drought indexes require at 30 years of observation. However, the objective was not to create a new drought index based on satellite soil moisture data, but to show the potential to use this data to have a broader comprehension on the impacts of drought on different ecological systems. The study period (2009 – 2015) was marked by successive droughts across Brazil, registered and confirmed by different monitoring instruments such as the Integrated Drought Index (IDI), which combines the Standardized Precipitation Index (SPI) and the Vegetation Health Index (VHI) (Cunha et al., 2019) and Municipal Emergency Declarations all over the country. Therefore, the period of study, even though short, it is justified because of the widespread drought conditions across the country.

_____ Reviewer comment: Are there any comparisons between satellite-based soil moisture and ground-truthing in Brazil? The authors should also comment on measurement uncertainty.

Response: No, as far as we are aware. Measurements of ground soil moisture are recent in Brazil and data availability is still low due to maintenance and spatial coverage. The largest network (Zeri et al. 2018) covers only the Brazilian semiarid region and measurements started in 2016. However, data transmission problems and lack of funding for regular maintenance make it difficult to establish long-term time series, which are essential to robust statistical analysis. Here is where the relevance of high temporal satellite soils moisture relies. We use a soil moisture product that is constantly improved and areas with potentially wrong measurements

are removed by the source. We alternative validate our work comparing our soil moisture trends with the actual emergency declaration calls from all municipalities in each biome (Fig 2). We also observe environmental differences on each biome (Fig 3) suggesting potential differences in soil moisture drivers. We also observe similar trends of soil moisture and vegetation productivity across all biomes (see Figure 1 of previous response https://editor.copernicus.org/index.php/nhess-2020-185-AC1.pdf?_mdl=msover_md&_jrl=7&_lcm=oc108lcm109w&_acm=get_comm_file&_ms=86004&c=185019&salt=1851713 We will comment on the measurement uncertainty and how the scale of biomes is appropriate for our national assessment.

Zeri, M., Alvalá, R.C.S., Carneiro, R., Cunha-Zeri, G., Costa, J.M., Spatafora, L.R., Urbano, D., Vall-Llossera, M., Marengo, J., 2018. Tools for communicating agricultural drought over the Brazilian Semiarid using the soil moisture index. Water 10, 1421. https://doi.org/10.3390/w10101421

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