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Discussions

Interactive comment on "Hydrological trade-offs due to different land covers and land uses in the Brazilian Cerrado" *by* Jamil A. A. Anache et al.

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We would like to thank the anonymous **referee 1** for the kind words in support of our manuscript and for the time spent reviewing our text. Here, we replied the referee's comments, which were highly insightful and enabled us to improve the quality of our manuscript. Note that the original referee's comments are identified as R1Cxx and written in **bold**, and the authors' responses are labeled as AR-R1Cxx. In addition, all comments are numbered (xx).

R1C1: The paper treat an important topic in the frame of LCLU for the Cerrado of Brazil. Until now only very few studies with experimental site data (see Oliveira, Nobrega) cover the Cerrado Biome in Brazil (most deals with Amazon

rainforest). Problem statement is clear and well written.

AR-R1C1: Thank you for recognizing the importance of the topic described by our manuscript. We hope to solve all the concerns and remarks found along the text to improve its comprehension and quality.

R1C2: In the space of row 3 – 10 an outlook on the process of further Cerrado conversion should be added and why sugarcane in the study area will be important in this process of LUC.

AR-R1C2: Thank you for the suggestions. We will add the following paragraph in the space of row 3 – 10 on page 2: "In the context of the Cerrado biome, the conversion of undisturbed vegetation and pasturelands to mechanized crop systems (e.g. sugarcane, corn and soybeans) indicates that this region in Brazil has a dynamic LCLU situation (Lapola et al., 2013). The sugarcane is the Brazilian backbone for energy security, as the ethanol production is the third most cultivated crop after soybeans and corn, reflecting the increasing demand for automotive fuels along the years (Leal et al., 2013;Rodrigues et al., 2018). Thus, the country is the world second largest ethanol producer and the Cerrado comprises the sugarcane expansion frontier due to the availability of water and pasturelands for the crop expansion (Bellezoni et al., 2018)."

R1C3: The aim of the study is well written (row 25-28). Experimental instrumentation is detailed described and adequate for the aim of longterm monitoring between the different land uses and Cerrado sensu stricto.

AR-R1C3: We appreciate your comment.

R1C4: In 2.2 following should be added for understanding the calculations later: Page 3: Time interval of soil water measurements (daily?) As basic information were ksat measurements done to understand the importance of infiltration to the groundwater of the Entisols?

AR-R1C4: The soil moisture was measured every 10 minutes; however, in this study we used daily averages as our time resolution in this study was daily. We will add the following phrase by the end of row 13 on page 3: "All instruments recorded data every 10 minutes, except the pressure transducers, which logged the groundwater table twice a day." We have ksat information of the study area: 102.279 mm h^{-1} (20 cm depth); 11.302 mm h^{-1} (50 cm depth); and 19.813 mm h^{-1} (100 cm depth). We will add this information in the revised version of the manuscript.

R1C5: Page 4 row 3: it seems better to define surface runoff as Qsur or Of (overland flow) instead of Q, because in most hydrological studies Q is defined as total discharge (see hydrological terms).

AR-R1C5: Thank you for the suggestion. We will change the abbreviation for surface runoff along the text, figures and tables to OF (overland flow).

R1C6: Evapotranspiration was calculated in the standard form on the base of Penman-Monteith (ETo). Water stress coefficient was calculated on a daily base (implied soil water measurements daily ? see above).

AR-R1C6: Yes, the water stress coefficient (Ks) was calculated using the daily soil moisture from the FDR probes. We clarify the instruments measurement interval previously (AR-R1C4).

R1C7: Include in table 3 and text page 5, row 25-28: what was assumed for the rooting zone of the Cerrado plot? Zf

AR-R1C7: The method that was used to calculate the evapotranspiration for the Wooded Cerrado did not used the rooting zone depth as an input parameter as shown in Eq. 7. However, we will add the wooded Cerrado rooting zone depth in section 2.2 (row 25, page 3), when we give more details about the land uses considered in this study: "The soil root zone in the wooded Cerrado may reach up to 18 m (Rawitscher, 1948). However, most of the water used for plants' transpiration comes from the first layers (up to 7.5 m) (Oliveira et al., 2005;Canadell et al., 1996)".

R1C8: Statistical data analysis was done well with good uncertainties estimations.

AR-R1C8: We appreciate this comment.

R1C9: Chapter 3. With the tables and figures the results are consistent documented and described. Discuss more on page 8, row 20-25: why in table 5 results for Eta differed (because of different sites with different rainfall amounts, because of different methods e.g. Nobrega.

AR-R1C9: This is an important remark. We appreciated the recognition of our tables and figures consistency. We can observe significant different values among the listed studies due to the multiple locations and methods considered. Our main idea was to evidence this huge variability among the reference studies. Thus, we will add an extra piece of discussion on page 8 (row 23) to clarify the main reason for these differences and change the paragraph structure. "(. . .) (Table 5) due to the diverse rainfall patterns among the study sites and the different methods used to measure or estimate the evapotranspiration."

R1C10: Page 8 row 30 following: discuss more the uncertainty of Cerrado vegetation rooting zone for the evapotranspiration calculation (depth of rooting zone you used is very sensitive for the residual in the water balance.

AR-R1C10: Thank you for this important remark. Actually, the methods used for the evapotranspiration estimates in the wooded Cerrado did not use the root depth as input parameter (see Equation 7). However, we recognize that it is important to discuss about the root zone depth in this paragraph. Thus, we will add a piece of discussion stating about the root zone uncertainty in the Cerrado (page 8, row 33). "However, the root zone depth of an undisturbed vegetation such as the wooded Cerrado is uncertain and may vary according to the soil characteristics (Canadell et al., 1996). It may influence the plants' transpiration (Rawitscher, 1948;Oliveira et al., 2005), and consequently the water balance residual."

R1C11: Results for LUC to pasture are well in accordance to other studies, role of soil compaction should be discussed for this land use (see Nobrega 2017 and Meister et al. 2017).

AR-R1C11: Yes, it is true to say that soil compaction in pasturelands will affect the water balance results. Thus, we will change the text at this point (page 9, row 20) to consider the suggested studies, in order to enrich our discussion: "Additionally, the deforestation and agricultural land uses may increase soil compaction, as the LCLUC influence the hydrological patterns along the soil profile by evident modifications in the soil characteristics (bulk density, infiltration capacity, etc.) (Lamparter et al., 2016;Meister et al., 2017)."

R1C12: Page 9 row 25 on: the chapter is misunderstanding comparing with Fig 4 (water table changes): Row 26: water balance residuals represent not only

soil water storage, as defined before (includes also deep infiltration – groundwater recharge !); authors argues that cerrado remove water from deeper soil horizons (that's right), but groundwater fluctuation is much higher in pasture and sugarcane (why?.

AR-R1C12: Thank you for this important question. This happens because more water reaches the water table in the pasture in comparison with the Wooded Cerrado. In the wooded Cerrado, the water uptake by the vegetation is higher due to the deeper and denser root system in comparison with pasture and sugarcane. In the sugarcane and pasture, the soil water that was not consumed by the plants and neither evaporated, continues to infiltrates along the unsaturated zone and the water uptake by the plants becomes unfeasible as the roots are shallow. Consequently, more water becomes available for deep infiltration, and this is evidenced by the significant water table fluctuation, which means that there is a higher groundwater recharge under the pasture in comparison with the wooded Cerrado (Fig 3f). This is explained in detail in section 3.2. Sections 3.1. and 3.2. will have their contents changed due to the new information added in Fig. 3.

R1C13: It will be fine, if table or figure with the soil water content over the measurement period can be added, than it can be seen how the unsaturated soil zone react different between land uses and cerrado. – In Fig. 4b 2015 there is a remarkable water table deepening, but high surplus of dS/dt – why?

AR-R1C13: We prepared a new figure containing the soil water content along the monitoring period and we attached in this revision as Fig. 3e. To answer the question about the water table deepening in 2014, we will add a piece of discussion in the text (page 10, row 3): "In the well located in the pasture, the water table fluctuated negatively along 2014 and 2015 due to the drought that happened in 2014 (Getirana, 2015). The water surplus of 2015-2016 happened due to the La Niña phenomena, that raised the rainfall pattern after the long dry season of 2014-2015 (Kakatkar et al., 2018). Consequently, the water table raised along 2016-2017."

R1C14: Discussion chapter 3.4 (should be enlarged a little with): Result that pasture and sugarcane increase surface runoff and decrease Eta are very common (not surprising); but for the residual (increased significantly) it must be discussed more carefull with differentiation in the role of deep infiltration (groundwater recharge relative high, interflow in the slope?, change of soil water content – see the measurements – not used for the discussion; infiltration rates between Cerrado and land use types are comparable? Compare with literature results.

AR-R1C14: Thank you for the suggestion. We will add new citations in this section and a new paragraph explaining how significant is the water balance residual to the aquifer recharge (water table fluctuation).

R1C15: Conclusions: page 12, row8: avoid term change in soil water storage (you mean the residual, much more than soil water storage (see above) Page 12 row 11,12: no documentation that higher infiltration rates in wooded Cerrado compared to pasture and sugar cane – add this in the paper.

AR-R1C15: We will change the term "soil water storage " along the text to "water balance residual" and we will define this terminology on session 2.2 (page 3, row 30). "The water balance residual (dS/dt) includes subsurface flow, soil water storage, deep percolation and groundwater recharge." We will also comment along the text that due to the decreased runoff of the wooded Cerrado in comparison with pasture, sugarcane and bare soil, more water infiltrates through the soil and become readily available for the plants' consumption (page 9, row 24): "These reduced surface runoff

rates in the wooded Cerrado increase soil water infiltration in comparison with pasture, sugarcane and bare soil. Thus, higher infiltration rates increase plant water availability (Krishnaswamy et al., 2013)."

R1C16: I agree, that such long term monitoring studies must be done, to compare it with often done pure water balance simulation studies. Point out in 4., what for important results in detail are valuable for further studies and water balance modelling for Cerrado Biome. In total: acceptance with mayor revision

AR-R1C16: We acknowledge the insightful comments about our manuscript and the kind words in support of its publication. We will also add in conclusions that our results are useful for future research, both for discovery and modeling sciences.

R1C17: Please add in the references: PROCESS-BASED MODELLING OF THE IMPACTS OF LAND USE CHANGE ON THE WATER BALANCE IN THE CERRADO BIOME (RIO DAS MORTES, BRAZIL) Sarina Meister, Rodolfo L. B. Nobrega, Wolfgang Rieger, Ronja Wolf and Gerhard Gerold ERDKUNDE 2017, 71/3, 241-266 Lamparter, G.; Nóbrega, R.. L. B.; Kovacs, K.; Amorim, R. S. and Gerold, G. (2016): Modelling hydrological impacts of agricultural expansion in two macro-catchments in Southern Amazonia, Brazil. In: Regional Environmental Change. https://doi.org/10.1007/s10113- 016-1015-2

AR-R1C17: Thank you for the suggested references. As commented in AR-R1C11, we cited these studies to support the discussion of our results.

Figure caption

Figure 3: Water balance components for different LCLU rainfall, P (a); evapotranspiration, ET (b); surface runoff, Q (c); soil water storage, dS/dt (d); Right

axes present the cumulative sum of the variables represented by graphs (a), (b), (c) and (d). Soil moisture (e) for pasture, sugarcane and wooded Cerrado; and water table (f) depth of the monitoring wells located in site 1 (pasture) and site 2 (wooded Cerrado).

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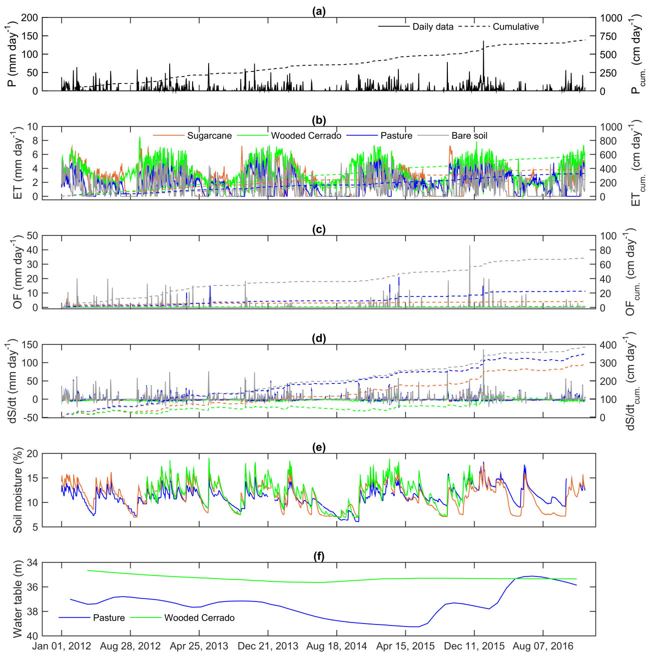

Fig. 1. Figure 3 (see caption above)