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Interactive comment on "Eddy covariance carbon flux in a scrub in the Mexican highland" *by* Aurelio Guevara-Escobar et al.

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Dear reviewer,

Thank you for the comments and suggestions to improve the manuscript. Below we give some replies to the raised points, and we will carefully consider all of them in a revised manuscript. Your comments are included here along with our reply.

Reviewer: This paper looks at tower-based NPP estimates at a drylands site in Mexico and compares the results to MODIS NPP product. The authors find that the site is a net carbon sink and that the MODIS product underestimated GPP at this site. While these findings are interesting, the manuscript appears to lack a clear research question, and does not propose a way forward for this work: what are the large-scale implication

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for this site being a net carbon sink even though other similar sites are not? Can the MODIS product be combined with other data to improve the comparison with the in-situ data (beyond changes to the algorithm by the MODIS science team)? Has the MODIS product been used in other studies that are therefore obtaining biased results because they did not realize the issue with the MODIS product? Overall, the data is interesting but again, it seems like the analysis needs to be taken one step further before the manuscript is publishable.

Response

There is ongoing work to combine different MODIS inputs along with onsite data to model gross primary production (GPP). One example is the ensemble of models from populations of solutions obtained using machine learning algorithms (Tramontana et al. 2016). We cited some of the literature where the agreement was not good between EC measurements and the MODIS algorithm. Some of these authors mention the problem with the MODIS land use classification.

The MODIS algorithm is based on the assumption that the radiation use efficiency of the vegetation, under well-watered and fertilized conditions, is linearly related to the amount of absorbed photosynthetically active radiation (APAR). A factor of radiation use conversion efficiency (epsilon) is used to multiply APAR and represent the actual productivity of the vegetation; epsilon varies by vegetation type and climate condition. This is the reason why the land use classification from MODIS is important, if vegetation is misclassified then the GPP estimate of MODIS would be biased.

A more detailed data analysis of EC data will be included. Site description and characterization using remote sensed data will be included from MODIS to contextualize the site within the study area. Estimates of GPP will be recalculated using the MODIS algorithm with adequate parameters for the vegetation type at Bernal site. We will use the available data layers from MODIS (Aqua and Terra) as inputs of a random forest regression ensemble for GPP to predict the GPP modeled from EC data (Tramontana

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et al., 2016).

Reviewer: Introduction There has been a lot of work recently on the importance of water-limited environments for carbon sequestration. It would be good to expand on current work, explain what the current hypothesis is for why savannas/drylands are thought to be so important for carbon sequestration and why this had been missed until recently. Properly embedding this work within this body of work would help raise its importance. After that, defining what the research question is, beyond adding one more dataset to the list, is missing.

Response

Certainly, arid and semi-arid ecosystems have been considered as a source of carbon due to their low vegetation productivity. Among others, there are two hypotheses supporting carbon sequestration by these ecosystems: the role of the soil inorganic carbon and that of the CAM photosynthetic pathway. In either case, soil water is important for the carbon cycle, as are the intermittent rainfall pulses in their intensity and frequency. Small pulses would result in predominantly soil respiration while large pulses would reflect carbon absorption (Sun et al., 2017). For succulent CAM and C3 plants, stored water in their roots and photosynthetic stems confers the ability to grow and reproduce during intensely hot and dry periods; suggesting that carbon and water fluxes would be decoupled from soil water (Sandquist, 2014).

Soil is a key component in these ecosystems, because soil inorganic carbon (SIC) content can be considerably higher compared to the soil organic carbon (SOC) (Schlesinger, 1982). Caliche is calcium carbonate that has been leached out of bedrock or detrital material by meteoric water and precipitated by evaporation in the overlying soil zone; the caliche deposit occurs either as closely spaced laminae lying parallel to the ground surface, or as a cement that binds detrital fragments. The Bernal region is characterized by having caliche deposits with layers of 2-3 m thick (Segerstrom, 1961). Carbon dioxide may be taken up during the dissolution of soil

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carbonates, but subsequent leaching of ionic calcium and bicarbonate to the lower soil profile, where carbonate precipitates, will result in a flux of carbon dioxide to the soil surface; when these deposits accumulate on non calcareous parent materials, they can represent a net sink for atmospheric carbon dioxide (Schlesinger, 2017). The interpretation of eddy covariance (EC) measurements in arid lands would benefit from measurements of changes in the SIC and then evaluate the contribution of non-biological processes and their potential as a carbon sink.

Much of the carbon uptake in water limited ecosystems is thought to be due to nocturnal carbon dioxide capture due to CAM metabolism (Osmond et al., 2008). Owen et al. (2016) estimated a 20.1 Mg dry biomass ha-1 y-1 yield for an Agave monoculture and identified a four phase alternating pattern of carbon dioxide sink at night and carbon dioxide source during the day. Cactus store massive amounts of water and other resources in the succulent roots, stems and leaves; these anatomic and physiological adaptations confer a remarkable ability to grow and reproduce during intensely hot and dry periods (Ogburn & Edwards, 2010). Cacti contain large quantities of calcium oxalate and when they decay these minerals are released and subsequently transformed to calcite and possibly later experience mobilization of colloidal complexes by movement of soil water (Garvie, 2006).

We will improve the manuscript with a deeper elaboration of the main question, which is the agreement between two methods of measurement of GPP: Eddy covariance and MODIS algorithm. To support this approach we propose: 1) Estimate GPP according to MODIS method but using the epsilon parameter and APAR calculated for our site (Heinsch et al., 2003; Running et al., 1999), 2) Using available data layers of MODIS (Aqua and Terra) and generate a random forest regression ensemble for eight-day GPP (Jung et al., 2019; Tramontana et al., 2019) and 3) Compare GPP values obtained by MODIS algorithm, MODIS with our data and modeled from the EC using a Bayesian approach (Stevens et al., 2018).

Reviewer: Methods Section 2.3 of the Methods gives the impression that the MODIS

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GPP product was consumed without a full understanding of how this product is generated from the MODIS data. Since the deviation of the MODIS product forms the in-situ data is at the core of the manuscript, it would be helpful to flesh out how GPP is estimated for the MODIS product. It would make the argument in the discussion stronger.

Response

A full description of the MODIS algorithm will be included. Also there is the topic of ecosystem respiration that needs some clarification, regarding semiarid environments and the modeling of respiration from NEE data from EC and soil temperature, but not soil water.

Reviewer: Results and discussion Lumping results and discussion together often leads to a weaker discussion, and I think it is indeed the case here: splitting the two sections would allow the authors to expand on the broader impacts of the study, linking it back to other work, and further explaining the repercussions of MODIS underestimation. The effect of the different photosynthesis mechanisms eluded to in the abstract would be interesting to further develop in the discussion as well. Finally, the link with carbon sink and overgrazing is alluded to but never actually discussed, even though it would be of interest to many other parts of the globe.

Response

We will separate the results and discussion sections. In the discussion section we will delve further into the effect of overgrazing and the different photosynthetic pathways present in the examined vegetation on the carbon sink. While the herbaceous stratum was deemed as overgrazed, the shrubs and cactus had little utilization by cattle.

Specific comments: L127: Why was Licor used only on a single occasion? Could the measurements have been repeated on a different day?

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LAI measurements were used to describe the site conditions, not to support the hypothesis of the work, we could not make more measurements due to equipment availability. Instead we will include MODIS LAI, NDVI and EVI timeseries to complete the site characterization.

L 138: which made difficult measuring their abundances.

Response

The study site is a privately managed cattle ranch. Livestock grazed freely year round in the paddock. Grass species typically are identified by their inflorescence and leaf structures are difficult to differentiate between species when the vegetation is overgrazed, basically leaves are very small and grow close to the ground. An alternative would be to use wire-mesh exclosure cages to protect the plants from grazing and measure pasture accumulation rate along with the corresponding botanical dissection for plant identification (Radcliffe, 1982).

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