The authors thank the reviewer for his constructive comments. The comments are shown in ***italic bold fonts***, our responses are in regular fonts, and adjusted text from the manuscript is marked with "Correction:".
Please note that we use 'past' tense for our corrections (e.g. "this was added"), instead of future tense (e.g. "this will be added").

Reviewer 1

Format: #Page-#line

General: With pleasure I have read this very interesting manuscript looking at a multi model / multi scenarios approach to simulate the hydrology of the Dry Chaco region in South America. It reads well and the results are supported by good quality figures. It is perhaps a bit long at some parts where results are mainly described and perhaps not enough explained / discussed. I have enjoyed the evaluation section and the diverse dataset used to evaluate your different scenarios (including the use of SMOS data!). The title focuses on deforestation pressure which we don't find much in the main body of the manuscript. Sometimes some numbers from the literature are provided but it is unclear either or not they match your own evaluation. To me this work leads to many questions towards data assimilation but also model development and this point could be stressed out in you manuscript. Perhaps a list of the next steps to work on could be clearly formulated in the conclusions. I suggest that this manuscript goes under major revision before to be considered for publication. I have annotated a pdf version of the manuscript with 58 (positive) comments and suggestion as a attempt to help.

We thank the reviewer for the positive feedback and comments. We revised the title and added an extra part in the discussion to clarify the novelty of our research, and the implications of data assimilation (see our replies to specific comments below).

Correction:
New title: Land surface modeling over the Dry Chaco: the impact of model structures and updated soil, vegetation and land cover parameters.

1-17: Ambiguous (at least to me), are you talking about the possible combination of the output of a LSM with satellite data or of the use of satellite data integrated into the LSM leading to the output? Integrating observations into models covers several aspects: (1) the dynamic integration of observations into models through data assimilation techniques, (2) the use of observations for model validation and evolution and (3) the mapping of the model parameters used to characterize the representation of land properties within the model (e.g., soil properties, land cover). In that respect I assume that most (if not all) LSMs are using satellite data.

Correction:
Line 17: The output from LSMs is used for many applications such as the monitoring of water resources, floods and droughts, and their impact on natural hazards, biomass production, ecology or soil salinity. In many cases, LSM performance is improved by the inclusion of remotely sensed observations through (i) the dynamic integration of observations into models through assimilation techniques, (ii) the mapping of model parameters to characterize the representation of land properties within the model (e.g., soil properties, land cover) and (iii) the use of observations for model validation and development. In addition, contrasting model output with remote sensing is a powerful method to identify unmodelled processes in a LSM,

such as irrigation (Kumar et al., 2015; Brocca et al., 2018), or groundwater withdrawal (Girotto et al., 2017)

1-19: Not only human-induced, more generally it permits to highlight missing processes in models

Good remark, the sentence was corrected (see corrections at 1-17).

1-23: Please add references

We added following references at line 24:

Clark, M. P.; Fan, Y.; Lawrence, D. M.; Adam, J. C.; Bolster, D.; Gochis, D. J.; Hooper, R. P.; Kumar, M.; Leung, L. R.; Mackay, D. S. & others. Improving the representation of hydrologic processes in Earth System Models Water Resources Research, Wiley Online Library, 2015, 51, 5929-5956

Wood, E. F.; Roundy, J. K.; Troy, T. J.; Van Beek, L.; Bierkens, M. F.; Blyth, E.; de Roo, A.; Döll, P.; Ek, M.; Famiglietti, J. & others. Hyperresolution global land surface modeling: Meeting a grand challenge for monitoring Earth's terrestrial water Water Resources Research, Wiley Online Library, 2011, 47

2-56: Rank by chronological order (?)

Thanks for the remark. The order of the references was corrected

3-63: It is perhaps only me but using future ("will") seems odd (?)

Correction:
Line 63: The performance of three LSMs with various soil, vegetation and land cover parameters, is evaluated over the Dry Chaco to test this hypothesis.

3-81: Don't you have more recent reference this this?

Correction:
Line 81: The ecoregion has a semi-arid climate with a north-south gradient for mean annual temperature from 24°C to 19°C and for mean annual rainfall from 898 mm/year north to 712 mm/year (Marchesini et al., 2020). Minetti et al. (1999) reports precipitation values up to 1000 mm/year in the eastern and western parts of the region and 400 mm/year in the central Dry Chaco.

4-93: Does the use of the ESA CCI Land Cover dataset permit to retrieve the 20% loss from Hansen et al., 2013, Vallejos et al., 2015 mentioned above?

Thanks for the suggestion. We compared the upscaled and reclassified ESA-CCI land cover change map (as shown in figure 1) with the deforestation dataset composed by Vallejos et al. (2015). Note that both products cover a different period. The ESA-CCI land cover product covers the period 1992-2015 upscaled to 0.125° (±12.5 km), whereas the Vallejos dataset covers the period 1972 to 2013 at 30 m resolution. When analyzing the overlapping period, we found that the general spatio-temporal of deforestation patterns match very well, but that the area of deforestation differs (23% of the Dry Chaco based on the rescaled ESA CCI-map and only 15% for the Vallejos dataset). The main reason for the discrepancy is the different resolution of both products.

Correction:
Line 94: Figure 1 shows the location of the Dry Chaco, together with the spatial and temporal extent of land cover changes for the period 1992-2015 derived from the European Space Agency-Climate Change Initiative land cover (ESA-CCI Land Cover) product upscaled to a 0.125° resolution (see section 2.5). Not shown is that the derived spatio-temporal pattern of deforestation agrees well with the 30 to 60 m resolution deforestation product of Vallejos et al. (2015). The deforested area of the Dry Chaco in the overlapping period (1992-2013) is 23% for the 0.125° ESA CCI data and only 15% for the finer-scaled dataset of Vallejos et al. (2015). The main reason for this discrepancy is the different spatial resolution of both products.

4-105: Would it make more sense to spin up 10 times the year 1992 then?

This is a valid remark. There are indeed two possibilities to spin up the models: (1) spin up 10 times the year 1992 (correct land cover, but at the risk of using anomalous meteorological conditions) or (2) spin up the models for the period 1982-1991 (incorrect land cover but including using climatological meteorology). We decided in favor of option 2.

4-106: Please provide more details, which variables are you considering?

Correction:
Line 106: The meteorological forcing data (precipitation, temperature, specific humidity, radiation, wind and surface pressure) were extracted from…

4-115: Please add reference

The relevant references were added.

Correction:
Line 115: In this study, vegetation, land cover and soil input data was revised using the Global Land Surface Satellite (GLASS) LAI (Liang et al., 2013; Xiao et al., 2016), the Global Inventory Modelling and Mapping Studies (GIMMS) NDVI (Tucker et al., 2005; Pinzon and Tucker, 2014) the ESA-CCI land cover product (Kirches et al., 2014; ESA, 2017) and HWSD soil properties (FAO and ISRIC, 2012; De Lannoy et al., 2014).

4-119: Is it an average? what about extended period of high cloud cover?

The GLASS product by itself provides already a spatially complete LAI-map every 8 days and was used as input in the different LSMs. Cloud-contaminated data are removed and gap-filled using an optimum interpolation algorithm to obtain continuous and smooth surface reflectance values (Xiao et al., 2016). The MODIS surface-reflectance data has an 8-day temporal sampling period. The maximum-value composite approach is used to composite the daily AVHRR surface-reflectance data into 8-day intervals to maintain a temporal resolution consistent with the MODIS surface-reflectance data. The approach selected the AVHRR reflectance data with the highest normalized difference vegetation index over each eight-day time (Xiao et al., 2016).

The GIMMS product is assembled from AVHRR NDVI (and does not include SPOT or MODIS data as initially mentioned in the manuscript) and provides spatially complete NDVI-map every

15 days. The maps are 15-day maximum value composites. Cloud or snow contaminated pixels are retrieved from either spline interpolation or average season profiles.

Correction:
Line 120: Cloud-contaminated data are removed and interpolated using and optimum interpolation algorithm (Xiao et al. 2016).

Line 128: The maps are 15-day maximum value composites and cloud or snow contaminated pixels are replaced by NDVI-values derived from either spline interpolation or average season profiles.

4-121 : such as?

Correction:
Line 121: According to Liang et al. (2013) and Xiao et al. (2016), the GLASS LAI features more realistic and smoother seasonal variations than the MODIS LAI product (MOD15) (Knyazikhin et al., 1998) and the first version of the Geoland2 (GEOV1) (Baret et al., 2013) LAI product.

4-121 : Isn't the development proposed by Kumar et al., 2019 JHM on LAI data assimilation already implemented in LIS? see: (https://journals.ametsoc.org/view/journals/hydr/20/7/jhm-d-18-0237_1.xml) This would allow a better description of inter/intra annual LAI?

Yes, the LAI data assimilation is already implemented in LIS, but only for NOAH-MP, which has a dynamic vegetation module. The CLM and CLSM versions in LIS do not have a dynamic vegetation module. Our study focusses on long-term trends and parameter sensitivity. We believe that the implementation of 8-day LAI and 14-day GVF data is sufficient to capture most relevant intra/inter annual vegetation changes.

5-130: Better to put Land Cover in the section title (?) It is my impression than LC is not as much wide spread as LAI / NDVI (and could also have another meaning)

Thank you for the suggestion. The LC abbreviation was changed to land cover everywhere in the text to improve the readability of the manuscript.

5-139: Please also refer to ESA, 2017 Land Cover CCI Product User Guide 2 (https://climate.esa.int/media/documents/CCI_Land_Cover_PUG_v2.0.pdf)

Thanks for the extra reference. The reference was added.

5-141: Does the use of the ESA CCI Land Cover dataset permit to retrieve the 20% loss from Hansen et al., 2013, Vallejos et al., 2015 mentioned above? The analysis leading to figure 1 deserves to be enhanced further.

The question was addressed in 4-93.

6-156: Mention SMOS if appropriate. This is interesting as I have done something like that few years ago, please see: Albergel, C., Balsamo, G., de Rosnay, P., Muñoz-Sabater, J., and Boussetta, S.: A bare ground evaporation revision in the ECMWF land-surface scheme: evaluation of its impact using ground soil moisture and satellite microwave data, Hydrol. Earth Syst. Sci., 16, 3607–3620, https://doi.org/10.5194/hess-16-3607-2012, 2012.

We now mention SMOS in the paragraph. The reference to the paper was added in line 303 and following line was added:

Correction:
Line 303: For an integrated evaluation of the model sfmc, surface temperature and LAI of the various experiments, a zero-order tau-omega microwave Radiative Transfer Model (RTM) was used to convert these modeled variables into L-band Tb [K] estimates. The modelled Tb were compared to SMOS Tb observations, similar to the approach presented by Albergel et al. (2012).

6-166: Is this useful?

The' ©Stevens' was removed.

7-187: How do you then disentangle the impact of soil, vegetation and land cover parameters? I would have praised for a more incremental approach.

The impact of updated soil parameters on the water budget components is explained in paragraph 4.1.2. When comparing the REV_S water budget components with the ones of the baseline simulations, the impact of soil parameters can be analyzed.

In the REV_{SV} simulations, vegetation and land cover parameters are indeed updated simultaneously (see also below, comment 8-233). We claim that an incremental approach would have resulted in at least one set of unrealistic simulations (the ones whereby or land cover or vegetation would remain static), would lead to more questions (which set of parameters does remain static in an incremental approach?) and also further complicate our evaluation.

To disentangle the impact of land cover and vegetation parameters, sensitivity experiments were conducted. We believe that the sensitivity experiments are more relevant to get insights in model behavior related to one specific set of parameters than an incremental approach. For example, they allow for larger (even unrealistic) LAI/GVF ranges to better understand model behavior to specific parameter changes.

8-231 : Please correct me if I am wrong but my impression is that 8 and 15 days are the best possible scenario (?) what is the longest time gap between 2 observations you encounter? This is important when it comes to daily interpolation (although I assume that this is likely to happen in e.g. winter time when vegetation is dormant hence not varying a lot).

See our answer to comments 4-119

8-233: This is a very interesting procedure as models do not need directly 2D land cover information, they need 2D parameters, and the models or pre-processing uses the land cover as predictors of the parameters, this ought to be discussed at one point.

The point was already briefly mentioned in the introduction (line 45), but might not have been clear. We added some extra lines in the section to clarify the issue.

Correction:
Line 233: LSMs do not directly use land cover information per se, but model-specific surface parameters associated to each land cover type. The implemented ESA-CCI land cover information is only used as predictor of the parameters such as rooting depth, stomatal

conductance and surface roughness. The exact value and implementation of each parameter is model-dependent.

8-241: Just a suggestion: wouldn't it make more sense to present this set of synthetic experiment before 3.2.1 and 3.2.2?

Thanks for the suggestion. We understand the confusion. We decided not to restructure any sections but to better clarify the reasoning behind them. Following sentence was added:

Correction:
Line 241: As our results will indicate (see section 4.1.3), the models react differently to the simultaneously updated dynamic vegetation and land cover. To better understand this different behavior and disentangle the impact of vegetation and land cover parameters separately, two sets of sensitivity experiments were conducted. The sensitivity of the various LSMs to LAI and GVF, or land cover changes was tested by synthetically varying the corresponding parameter values.

9-253: But then it makes no sense with the land cover? Please clarify.

To disentangle the impact of land cover changes only, the vegetation had to remain static/climatological. The experiments are synthetic and are only conducted to understand the model-behavior to different parameter-changes.

9-265: Please provide more information on how to read the results (e.g. Figure 9)

Correction:
Line 289: For each model, we plotted both the Q and ET efficiency in function of modelled soil moisture to visualize the different soil moisture dependencies. In addition, the resulting efficiency space plots for each model show how evaporation and runoff efficiencies vary with each other, as the soil gets drier or wetter.

10-290: I thought it (=P) was an input

Correct. It was decided to also evaluate the precipitation input as it is a crucial input variable in the calculation of soil moisture, evapotranspiration and other hydrological variables. To test the quality of the MERRA2-precipitation product, we claim that an evaluation with in situ data is crucial. Insights in the quality of the input-precipitation is also important for the ensuing evaluation. (Poor precipitation quality would result in poor evapotranspiration, soil moisture and Tb evaluations, when compared to independent data).

Correction:
Line 290: For each experiment, model input P, model output surface soil moisture content (sfmc) and ET were evaluated against independent data.

10-302: In a previous study we have used CMEM to do similar evaluation of a new parametrization in the HTESSEL LSM: Albergel, C., Balsamo, G., de Rosnay, P., Muñoz-Sabater, J., and Boussetta, S.: A bare ground evaporation revision in the ECMWF land-surface scheme: evaluation of its impact using ground soil moisture and satellite microwave data, Hydrol. Earth Syst. Sci., 16, 3607–3620, https://doi.org/10.5194/hess-16-3607-2012, 2012.

We referred to the study in line 303. See our reply on comment 6-156.

11-321: Interesting - is it in agreement with Minetti et al., 1999 used in the section describing the studied area?

Yes, the yearly mean values are in agreement with values mentioned in literature (Marchesini et al., 2020, Minetti et al., 1999). In addition, the observed spatial gradients (dry in the central part, and wetter eastern and western parts) are in agreement with literature.

Correction:
Line 321: …, which is in line with the findings of Marchesini et al., (2020). The spatial patterns are also similar to the ones mentioned by Minetti et al. (1999), but are not shown.

11-331: Interesting to see/note that for each model the distribution is respected amongst the 2 configurations (e.g. NOAH as higher Ev than the other)

Indeed.

12-349: Does it corresponds to the number of 20% presented above?

The deforestation patterns based on the ESA-CCI land cover product are similar to the ones mentioned by Vallejos et al. (2015). See our reply on 4-93.

12-359: Perhaps you could provide lon/lat?

Correction:
Line 357: The impact of vegetation changes on the temporal evolution of LAI and moisture content in the first two meters of the soil (mc2m) is illustrated in Figure 6 for a representative pixel (28.0625° S, 63.6875° W; marked in Figure 7a with a red circle).

12-359: OK - this is why the initial values are not the same (?)

Yes, as the climatological and inter-annually varying LAI are not the same, also soil moisture values between the REV_S and REV_{SV} simulations can differ from each other, even before the deforestation period.

12-361: It is indeed something we observed after large fires, LAI will go back to high value only few years after but not VOD or above ground biomass. Is the latter an output of your system as well?

Good point and unfortunately, VOD and above ground biomass are no output of the systems included in this study.

13-371: Is this Figure really useful? One may say that you have many figures and some are only briefly described. Perhaps that some could be moved into a supplementary file?

We agree that there are already many figures and removed figure 7 together with lines 371.

13-400: Please revise the order of the figure (?). Also it is interesting to see that the 2 configurations (SV/S) leads to different behavior for different models

We hope that by our edits described in 8-241, the order of the figures makes more sense.

15-432: Not sure that this evaluation is adding much to the study (which already contains a lot of material)?

See our answer on 10-290

15-449: Did you use daily or monthly data for the evaluation?

Daily data. This important detail was added to the text.

Correction:
Line 449: The skill of simulated total ET relative to that of GLEAM-based ET estimates is shown in Figures 12a-d for the period 1992-2015 over the entire Dry Chaco, the ET evaluation was based on daily data.

15-457: Please remind the reader what are they

Correction:
Line 457: Time series of the simulated 40° Tb_H with NOAH BL, REV_S and REV_{SV} input, and SMOS Tb_H are shown in Figure 13a. The inputs used in the RTM for the simulated Tb include simulated soil moisture (using FAO texture and related SHPs in the BL-simulations, HWSD based texture and SHPs in the REV_S and REV_{SV} simulations), temperature, LAI (climatological in $REV_{S,}$ dynamic in REV_{SV}) and land cover (static in $REV_{S,}$ yearly updated in REV_{SV}).

16-481: You have to clarify what you mean here.

Correction:
Line 481: For NOAH, the ΔR values do not increase everywhere. At some pixels with reduced REV_{SV} performance, we noticed unexpected trends in the LAI time series (not shown), i.e. LAI would not show the expected decrease during the dry season. This possibly deteriorated the Tb simulations.

17-507: please consider rephrasing

The text between brackets (= "often hardwired") was removed from the text.

17-510 : Does that mean that this model can not be trusted? needs further development?

Correction:
Line 511: LSMs could benefit from further development towards a more realistic response to vegetation changes and advances in including dynamic vegetation phenology. This should lead to more realistic simulations of the interaction between the carbon and water cycles.

18-526: But Evap is (negatively) affected right, but not through water extraction by vegetation (?)

Correct, the decreased ET in CLSM (figure 5) is caused by land cover parameter changes as indicated in line 531. An extra line of clarifications is added in line 531.

Correction:
This is related to the distinct implementations of root distribution and root water uptake (controlled by the stomatal conductance and rooting depth) in the various LSMs, impacting E_V and related water extraction from the soil.

18-530: Perhaps this could be briefly described in section 2.2 on models

Extra information was added in section 2.5 (see our reply on question 8-233).

18-547: I am not convinced that this is adding much to your manuscript (?)

See our answer on 10-290

20-617: From what is described in the manuscript, DA may not be the answer and it is rather an improvement of the different models processes that is needed (?) Perhaps a line or two could be added in the discussion to reflect this idea?

We fully agree. See correction to 17-510. We removed one sentence (line 618: "This optimization still requires more research") in the conclusions and replaced it as follows.

Correction:
Line 618: Vegetation data assimilation can only have the desired impact, if the sensitivity of simulated hydrological fluxes to vegetation changes is realistic and this may need further research, especially at the global scale.

Figure 3: Figures must be self-explanatory, please add what Qsb. Qs...are

The necessary explanations of abbreviations were added to all figures.

Figure 4: Please indicate panels (a) and (b)

Thanks for the comment, this was a small mistake in the figure caption.

Correction:
Maps of long-term (1992-2015) NOAH mc_{1m}, obtained with (c) BL and (d) REV_S parameters.

Figure 6: LAI does not impact CLSM soil moisture content (?)

Correct, the reason why is explained in the sensitivity-analysis and shown in figure 8f. We hope that with the extra clarifications, this is clear now.

Figure 8: Very difficult to see

The sub captions of figure 8d-i were moved up (above the subplots) to improve readability.

Table 2: Although presented in the caption this is not very clear

Correction:
Caption table 2: Long-term (1992-2015) distribution of the BL water budget components [mm] for CLM, CLSM and NOAH over the Dry Chaco, year-round (Annual), for the months April-September (Dry season) and the months October-March (Wet season), respectively.

Line 321: The Dry Chaco receives an average annual P of 809 mm with most P (643 mm) falling during the wet season (October-March). All LSMs confirm a water storage (ΔS) deficit for the dry season (April-September), which is compensated during the wetter months with a water surplus.