Responses to Referee #1

We appreciate the detailed and constructive feedback provided by the anonymous reviewer, which has been valuable in enhancing the manuscript. The reviewer's comments are categorized into main comments and those directly on the manuscript. We respond to both categories, with reviewer comments in shaded text and our responses in black.

General comment:

This paper investigates the impact of the intensive deforestation in favor of agricultural expansion on the hydro-climatic regime of the South America’s Dry Chaco region. The paper addresses some important questions about the feedback of LULCC on the vegetation growth (LAI, albedo, stomatal resistance) and the hydro-climatic response (precipitation, soil moisture and runoff). This study uses WRF modelling to simulate hydro-climatic responses to deforestation scenarios. Analysing the impacts of deforestation in the Dry Chaco on local hydrology and climate, as well as in the neighbouring (which has been little affected by deforestation), is also interesting for understanding the effects at different spatial scales.

As the reviewer positively noted our study explores how the land use and land cover changes in the Dry Chaco alter the land-atmosphere interplay locally, but also investigates what are the non-local and/or remote effects of the agricultural expansion. The analysis is based on regional climate simulations, which consistently simulate the land-atmosphere interaction constraining the balances. It enables the simulation of the hydroclimate response to different lower boundary conditions and the analysis of the involved chain of processes.

I however have a number of comments that need to be addressed – please see below.

Main comments:

1) (a) The simulations are carried out over a 2-year period (2014-2016 for the reference simulation) which seems very short to analyze the effects of deforestation on the hydro-climatic response.

If possible, I would recommend to validate WRF on the 2014-2016 period (to validate over a period with few changes in land use), and then to simulate the control and scenario simulations over a longer period (30 years or at least >10 years) so that the results are not affected by the inter-annual climate variability.

(a) We agree with the reviewer, longer simulations would allow us to investigate the impact of LULCCs under different large-scale atmospheric conditions (e.g. ENSO phase), providing more robustness to our results. Note that we conducted **a total of 12 simulations, each spanning 2.5 years**. The length of these simulations should suffice for assessing the land-atmosphere processes, which occur on shorter time scales. Conducting simulations spanning 10 years or more would provide information on large-scale modulations but would not provide new understanding of the surface processes. Long-term simulations are impractical for our research due to computational constraints. Each simulation we perform is significantly resource-intensive in terms of computational time and storage, and extending the simulation period to such lengths is currently beyond our capabilities. It's worth noting that even NCAR, responsible for the WRF model development and a benchmark in our field, was recently able to produce just one 20-year-long simulation for South America (see it on the online model evaluation dashboard). As such, conducting 12 simulations spanning 30 years, as suggested, is not feasible for our current research scope. The importance of long-term simulations and the current computational constraints that restrict their execution will be included in the new section 5 “Discussion”.

(b) The authors should at least specify whether the 2014-2016 simulation period corresponds to an El Nino or La Nina episode in order to know under which pattern of atmospheric circulation the simulations are being carried out

The simulation period includes an El Niño event, developed between Sep 2014 and March 2016 according to the Oceanic Niño Index (ONI). However, it is important to note that our region of interest, the Gran Chaco, is not very sensitive to the effects of El Niño, which have stronger impacts eastward for precipitation and northward for temperature (see the figure R1.1 below). Moreover, Vera and Osman (2018) reported that the impact of the El Niño 2015 event in South America has been weakened by the Southern Annular Mode. In light of these findings, the revised manuscript will specify the prevalent large-scale atmospheric conditions (e.g. El Niño Southern Oscillation, the Southern Annular Mode, and the Madden Julian Oscillation) for the period of simulation and also their weak influence on the region of interest, providing a clearer context for our results.

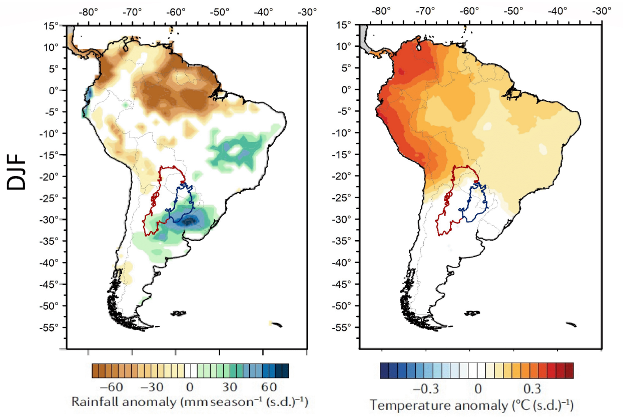


Figure R1.1. ENSO-related precipitation (left) and temperature (right) anomalies for DJF during El Niño events adapted from Cai et al (2020). Cai et al. (2020) calculated the anomalies by regressing seasonally averaged variables on the normalized DJF Niño3.4 index, using data from the period 1948–2016. The coloured lines highlight the Gran Chaco subregions: Dry Chaco (red) and Humid Chaco (green).

Cai, W., McPhaden, M.J., Grimm, A.M., Rodrigues, R.R., Taschetto, A.S., Garreaud, R.D., Dewitte, B., Poveda, G., Ham, Y.-G., Santoso, A., Ng, B., Anderson, W., Wang, G., Geng, T., Jo, H.-S., Marengo, J.A., Alves, L.M., Osman, M., Li, S., Karamperidou, C., Takahashi, K., and Vera, C. (2020). Climate impacts of the El Niño–southern oscillation on South America. *Nat. Rev. Earth Environ.*, *1*(4), 215-231.

Vera, C.S., and Osman, M. (2018). Activity of the Southern Annular Mode during 2015–2016 El Niño event and its impact on Southern Hemisphere climate anomalies. *Int. J. of Climatol.*, *38*, e1288-e1295.

2) This paper studies the effects of LULCC by analyzing the changes in various simulated variables (energy budget, precipitation, evapotranspiration, soil moisture, runoff, LAI, albedo, stomatal resistance) to different landuse conditions.

(a) However, the model is only evaluated using observed temperature, precipitation and soil moisture datasets. It is therefore difficult to draw any conclusions about the effects of deforestation on the other unvalidated variables.

(b) In my opinion the modelling experiment is not robust enough to draw general conclusions about the physical processes impacted by deforestation in the Dry Chaco. However, the modelling experiment remains interesting and the authors could instead present their results as a sensitivity analysis of WRF simulations to different initial landuse conditions.

(a) Validation of simulated variables

The choice of temperature, precipitation, and soil moisture, and no other variables for evaluation serves a purpose. Temperature and precipitation observations are truly independent variables as they have relatively low uncertainty given the availability of multiple monitoring sources, both in-situ and remote. Indeed, climate model validation papers are typically based on these two variables (e.g. Smiatek et al. 2009, Sánchez et al. 2015, Marta-Almeida et al. 2016, Annor et al. 2018, Almazroui et al. 2021, Lovino et al. 2021, Ortega et al. 2021, etc.). On the other hand, soil moisture falls on the set of variables with recognized uncertainties in remotely sensed soil moisture estimates. However, we included it in the main manuscript due to its key role in land cover dynamics and land-atmosphere interactions.

Other data products (e.g., radiation, heat fluxes, runoff) may have an observational basis, but they are derived from algorithms or models with their own approximations and uncertainties. A proper validation of these data products is critical if they are to be used for model evaluation. Unfortunately, this is not possible. While some of the datasets are available globally, their quality at regional scales is questionable. The Gran Chaco region, examined in this study, lacks in-situ measurements of non-conventional variables, preventing an assessment of the data quality and making a comprehensive model validation even more unfeasible.

Still, following the reviewer's suggestion, we compared model energy variables against FLUXCOM (Jung et al., 2019), which is the successor dataset to global biosphere-atmosphere flux (GBAF) products that are used as a reference in the International Land Model Benchmarking System (ILAMB; Collier et al., 2018). The FLUXCOM observational estimates have been derived from FLUXNET energy flux measurements and remote sensing as well as meteorological data by training machine-learning algorithms. Figures R1.2 and R1.3 summarise the "validation" for latent heat flux and sensible heat flux. On the positive side, WRF produces similar longitudinal gradients compared to those of FLUXCOM and effectively reproduces the seasonal variability, showing a high correlation ($r = 0.95$) for latent heat, but exhibits less sensitivity to sensible heat, indicating a one-month lag in the seasonal cycle despite a correlation of 0.62. On the other hand, WRF underestimates latent heat ($RMSE = 20.2 Wm^{-2}$) and overestimates sensible heat ($RMSE = 12.9 Wm^{-2}$) in Gran Chaco. But does this imply that the biases are all in the WRF estimates? Impossible to say. There is only one FLUXNET tower (Ar-SLu) in the entire domain (please see https://fluxnet.org/sites/site-summary/) used to calibrate the machine-learning algorithms. Moreover, the FLUXNET observations are available for the period 2009-2011. In summary, the validation is reduced to a comparison between two disparate estimates without the inclusion of a ground truth.

As a side note, we note that our work builds upon prior research efforts (Lee and Berbery, 2012, Müller et al. 2014, Sörensson and Berbery 2015, Müller et al. 2016) that have consistently demonstrated the effectiveness of the WRF model in simulating different aspects of southern South America hydroclimate. In the revised manuscript, we will clarify the rationale behind our decisions to select variables for validation.

Almazroui, M., Ashfaq, M., Islam, M.N., Rashid, I.U., Kamil, S., Abid, M.A., O'Brien, E., Ismail, M., Simões Rivolta, M., Sörensson, A., Arias, P., Muniz Alves, L., Tippett, M., Saeed, S., Haarsma, R., Doblas-Reyes, F., Saeed, F., Kucharski, F., Nadeem, I., Silva-Vidal, Y., Rivera, J., Azhar Ehsan, M., Martinez-Castro, D., Muñoz, A., Arfan Alí, M., Coppola, E., Sylla, M.B. (2021). Assessment of CMIP6 performance and projected temperature and precipitation changes over South America. *Earth Syst. Environ.*, *5*(2), 155-183.

Annor, T., Lamptey, B., Wagner, S., Oguntunde, P., Arnault, J., Heinzeller, D., and Kunstmann, H. (2018). High-resolution long-term WRF climate simulations over Volta Basin. Part 1: validation analysis for temperature and precipitation. *Theor. Appl. Climatol.*, *133*, 829-849.

Jung, M., Koirala, S., Weber, U., Ichii, K., Gans, F., Camps-Valls, G., Papale, D., Schwalm, C., Tramontana, G., and Reichstein, M. (2019): The FLUXCOM ensemble of global land-atmosphere energy fluxes. *Sci. Data*, 6, 74.

Collier, N., Hoffman, F.M., Lawrence, D.M., Keppel-Aleks, G., Koven, C.D., Riley, W.J., Mu, M., and Randerson, J.T. (2018). The International Land Model Benchmarking (ILAMB) System: Design, Theory, and Implementation, *JAMES*, 10, 2731–2754.

Lovino, M.A., Pierrestegui, M.J., Müller, O.V., Berbery, E.H., Müller, G.V., and Pasten, M. (2021). Evaluation of historical CMIP6 model simulations and future projections of temperature and precipitation in Paraguay. *Clim. Change*, *164*, 1-24.

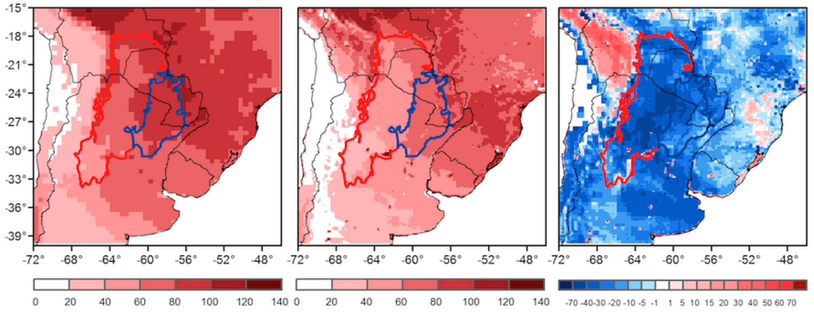
Marta-Almeida, M., Teixeira, J.C., Carvalho, M.J., Melo-Gonçalves, P., and Rocha, A. M. (2016). High resolution WRF climatic simulations for the Iberian Peninsula: Model validation. *Phys. Chem. Earth, Parts A/B/C*, *94*, 94-105.

Ortega, G., Arias, P.A., Villegas, J.C., Marquet, P.A., and Nobre, P. (2021). Present-day and future climate over central and South America according to CMIP5/CMIP6 models. *Int. J. Climat.*, *41*(15), 6713-6735.

Sánchez, E., Solman, S., Remedio, A.R.C., Berbery, H., Samuelsson, P., Da Rocha, R.P., Mourão, C., Li, L., Samuelsson, P., Da Rocha, R.P., de Castro, M., Jacob, D. (2015). Regional climate modelling in CLARIS-LPB: a concerted approach towards twentyfirst century projections of regional temperature and precipitation over South America. *Clim. Dyn.*, *45*, 2193-2212.

Smiatek, G., Kunstmann, H., Knoche, R., and Marx, A. (2009). Precipitation and temperature statistics in high-resolution regional climate models: Evaluation for the European Alps. *J. Geophys. Res. Atmos.*, *114*(D19).

(a) LATENT HEAT OBS [W m^{-2}] (b) LATENT HEAT CONTROL [W m^{-2}] (c) LH CONTROL - OBS [W m^{-2}]



(d) Latent Heat in Gran Chaco

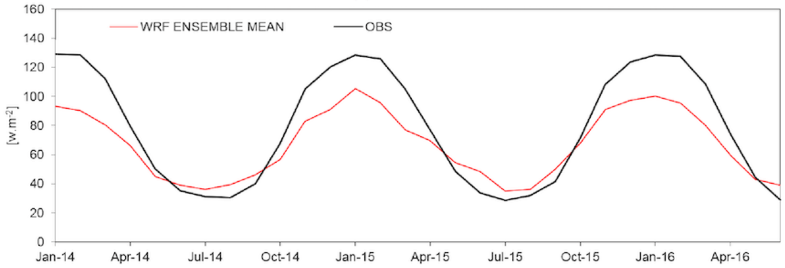
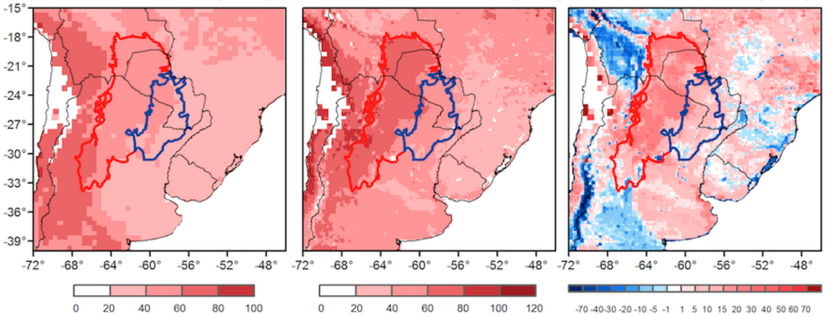


Figure R1.2: Time average of (a) FLUXCOM latent heat, (b) the CONTROL ensemble latent heat, and (c) their differences. (d) Latent heat time series averaged over the Gran Chaco.

(a) SENSIBLE HEAT OBS [W m^{-2}] (b) SENSIBLE HEAT CONTROL [W m^{-2}] (c) SH CONTROL - OBS [W m^{-2}]



(d) Sensible Heat in Gran Chaco

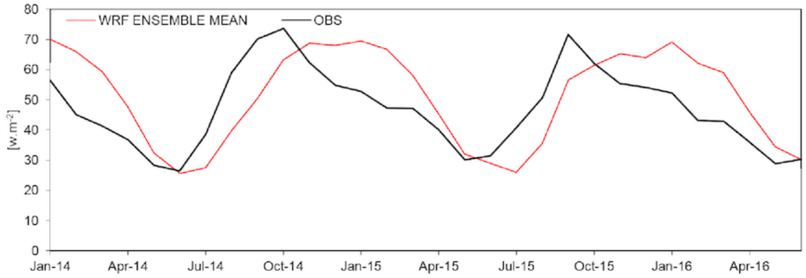


Figure R1.3: As Figure R1.2 but for sensible heat.

(b) Modeling experiments and physical processes

Climate models offer distinctive advantages, including the ability to maintain physical consistency within the Earth System, simulate a wide range of processes, and facilitate controlled experiments by modifying initial and boundary conditions. These features make climate models the only tool capable of exploring the intricate chain of processes affected by changes in initial and boundary conditions, an analysis that cannot be replicated using observed data or reanalysis. While we acknowledge the inherent uncertainties associated with models, it's essential to highlight that the WRF model exhibits a high level of skill, particularly in simulating fundamental variables such as precipitation, temperature, and soil moisture. Our extensive experience with the WRF model further strengthens our confidence in its ability to capture underlying processes. Therefore, we assert that our experiments provide a valid and unique approach to analyzing the sensitivity of land-atmosphere physical interactions to different land cover scenarios. Moreover, our response to comment #3 clearly demonstrates the small internal variability of the WRF simulations providing robustness to our experiments. We plan to delve into the potential and limitations of climate models for understanding processes related to land cover changes in the Discussion section of the revised manuscript.

Lee, S.-J., and Berbery, E.H. (2012). Land cover change effects on the climate of the La Plata Basin, J. Hydrometeorol., 13 (1), 84-102.

Müller, O.V., Berbery, E.H., Alcaraz Segura, D., and Ek, M.B. (2014): Regional model simulations of the 2008 drought in southern South America using a consistent set of land surface properties, *J. Clim.*, 27(17), 6754-6778.

Müller, O.V., Lovino, M.A., and Berbery, E.H. (2016): Evaluation of WRF model forecasts and their use for hydroclimate monitoring over southern South America, *Weather Forecast.*, 31(3), 1001-1017.

Sörensson, A.A., and Berbery, E.H. (2015). A note on soil moisture memory and interactions with surface climate for different vegetation types in the La Plata basin. Journal of Hydrometeorology, 16(2), 716-729.

3) The uncertainties related to the model and its internal variability should be discussed. How can model parameterisation and initial conditions impact on the simulated results?

Regarding the uncertainty related to initial conditions, the authors mention in the presentation of the experimental design that each scenario was conducted with an ensemble of 4 members with identical parameterisations but different initial conditions that are 24-hr apart. But the simulations obtained with the 4 members do not appear in the results (only the average). It would be interesting to analyze and show some results about the sensitivity of the simulated variables (e.g. precipitation, soil moisture, runoff) to the different initial conditions.

Regarding the uncertainty related to the model parameterisation, it would be interesting to include simulations to test the sensitivity to few selected model options or parameter, or at least discuss the results referring to studies from the literature that conducted a full internal variability analysis of the WRF model.

Uncertainty related to initial conditions:

The analysis of our WRF/Noah-MP simulations reveals minimal uncertainty associated with variations in initial conditions. In response to the reviewer's suggestion, we updated the figures of the Model Evaluation section, specifically focusing on Fig. 5d, 6g, and 7d, which presented ensemble mean precipitation, soil moisture, and temperature, respectively. To better capture the uncertainty, these panels now include a surrounding band illustrating the spread of ensemble members around the mean. In the updated panels, the time-series demonstrate relevant uncertainty only during the first month of precipitation simulation, after which the dispersion consistently remains in a narrow range. Notably, the model uncertainty is comparable to or even smaller than the observational uncertainty. In particular, the result for soil moisture is consistent with Sörensson and Berbery (2015), who found that the initialisation of WRF/Noah-MP in wet months (e.g. January) favour a quick stabilisation of soil conditions. A discussion of these findings will be provided in the corresponding figure descriptions.

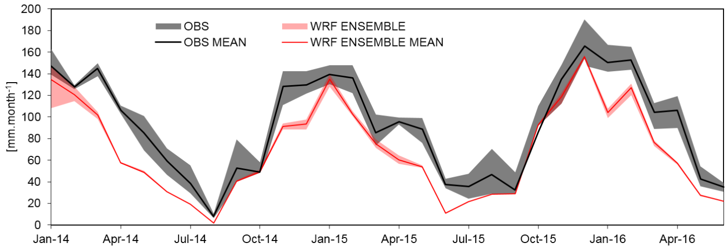


Figure 5d. Precipitation time-series averaged in the Gran Chaco region.

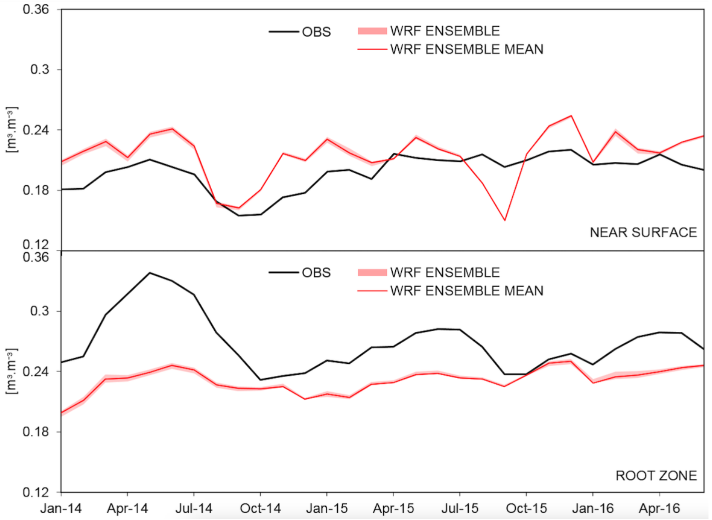


Figure 6g. Soil moisture time-series averaged in the Gran Chaco region.

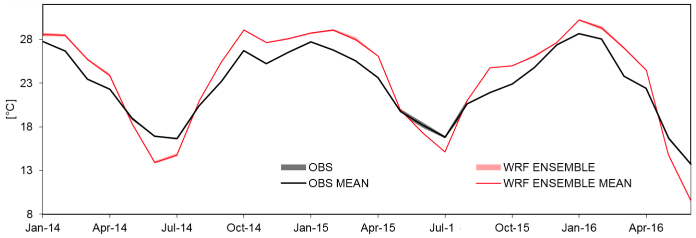


Figure 7d. Near-surface temperature time-series averaged in the Gran Chaco region.

Uncertainty related to the model parameterisation:

We have previously conducted extensive discussions about WRF parameterization in our earlier publications. For instance, in Lee (2010) and Lee and Berbery (2012), a comprehensive set of ten WRF simulations combining different surface layer schemes, atmospheric boundary layer schemes, cumulus parameterization schemes, and microphysical schemes, have been conducted to identify the configuration that exhibited the highest skill for southern South America. This optimal configuration was subsequently employed in Müller et al. (2014) to assess droughts and in Müller et al. (2016) to evaluate the model's performance in short-term forecasts. In both cases, the selected parameterisations were well-suited to represent the hydroclimate in South America. In summary, while we acknowledge that different WRF simulations may be sensitive to specific parameterisations, we have demonstrated in our previous experience that this configuration produces realistic simulations for our region of interest.

Lee, S.-J. (2010). Impact of land surface vegetation change over the La Plata Basin on the regional climatic environment: A study using conventional land-cover/land-use and newly developed ecosystem functional types. Ph.D. dissertation directed by E. H. Berbery, University of Maryland, 153 pp.

Lee, S.-J., and Berbery, E.H. (2012). Land cover change effects on the climate of the La Plata Basin, J. Hydrometeorol., 13 (1), 84-102.

Müller, O.V., Berbery, E.H., Alcaraz Segura, D., and Ek, M.B. (2014): Regional model simulations of the 2008 drought in southern South America using a consistent set of land surface properties, *J. Clim.*, 27(17), 6754-6778.

Müller, O.V., Lovino, M.A., and Berbery, E.H. (2016): Evaluation of WRF model forecasts and their use for hydroclimate monitoring over southern South America, *Weather Forecast.*, 31(3), 1001-1017.

4) The paper would benefit from (a) a more detailed literature review and (b) a proper discussion section to discuss the above points. (c) The results of the first part concerning the observed changes in the Dry Chaco between 2001 and 2015 and future trends of deforestation should also be discussed and compared with other studies from the literature.

Thank you for your valuable feedback. We have segmented your comment into three parts (a, b, and c) for a more focused response.

(a) Following the reviewer’s suggestion, the literature review of the main topics described in the introduction section will be enhanced by incorporating relevant publications, such as:

Barros, V. R., Boninsegna, J. A., Camilloni, I. A., Chidiak, M., Magrín, G. O., and Rusticucci, M. (2015). Climate change in Argentina: trends, projections, impacts and adaptation. *WIREs Clim. Change*, *6*(2), 151-169.

Bulacio, E.M., Romagnoli, M., Otegui, M.E., Chan, R.L., and Portapila, M. (2023). OSTRICH-CROPGRO multi-objective optimization methodology for calibration of the growing dynamics of a second-generation transgenic soybean tolerant to high temperatures and dry growing conditions. *Agric. Syst.*, *205*, 103583.

De Sy, V., Herold, M., Achard, F., Beuchle, R., Clevers, J.G., Lindquist, E., and Verchot, L. (2015). Land use patterns and related carbon losses following deforestation in South America. *Environ. Res. Lett.*, *10*(12), 124004.

Georgescu, M., Lobell, D.B., Field, C. B., and Mahalov, A. (2013). Simulated hydroclimatic impacts of projected Brazilian sugarcane expansion. *Geophys. Res. Lett.*, 40(5), 972-977.

Li, D., Bou-Zeid, E., Barlage, M., Chen, F., and Smith, J. A. (2013). Development and evaluation of a mosaic approach in the WRF-Noah framework. *J. Geophys. Res. Atmos.*, 118(21):11–918.

Maertens, M., De Lannoy, G.J.M., Apers, S., Kumar, S.V., and Mahanama, S.P.P. (2021). Land surface modeling over the Dry Chaco: the impact of model structures, and soil, vegetation and land cover parameters. *Hydrol. Earth Syst. Sci.*, 25, 4099–4125.

Mosciaro, M.J., Calamari, N.C., Peri, P.L., Flores Montes, N., Seghezzo, L., Ortiz, E., Rejalaga, L., Barral, P., Villarino, S., Mastrangelo, M., Volante, J. (2022). Future scenarios of land use change in the Gran Chaco: how far is zero-deforestation?. *Reg. Environ. Change.,* 22, 115.

Ribichich, K.F., Chiozza, M., Ávalos-Britez, S., Cabello, J.V., Arce, A.L., Watson, G., Arias, C., Portapila, M., Trucco, F., Otegui, M.E., and Chan, R.L. (2020). Successful field performance in warm and dry environments of soybean expressing the sunflower transcription factor HB4. *J. Exp. Bot.*, *71*(10), 3142-3156.

Richards, P.D., Myers, R.J., Swinton, S.M., and Walker, R.T. (2012). Exchange rates, soybean supply response, and deforestation in South America. *Glob. Environ. Change*, *22*(2), 454-462.

Stanimirova, R., Graesser, J., Olofsson, P., and Friedl, M. A. (2022). Widespread changes in 21st century vegetation cover in Argentina, Paraguay, and Uruguay. *Remote Sens. Environ.*, *282*, 113277.

This revision will improve the context and provide a more comprehensive overview of the relevant research.

(b) We will divide the original "Discussion and Conclusions" section into two separate sections: "Discussions" and "Concluding Remarks." The "Discussion" section will be expanded to provide a comprehensive analysis of our research findings within the broader context of climate models and their capabilities. In this revised section, we will also discuss model validation and model internal variability, offering a more nuanced interpretation of our results.

(c) To address the referee's specific concern, we will include a comparative analysis of our land cover change results with findings from other relevant studies in the literature. We expect that this comparative analysis will add depth and perspective to our research outcomes.

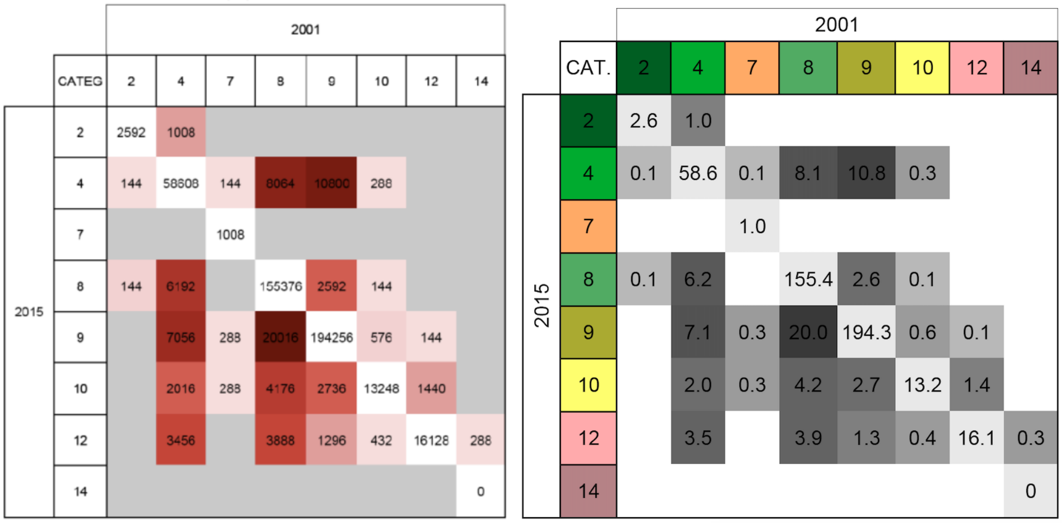
In-manuscript reviewer comments:

1) Introduction section: The reviewer suggests adding more recent references and removing a few non-relevant papers.

Our response to this comment is provided in the response to the main comment 4.

2) Figure 2d: It is difficult to find the numbers on Fig 2d. Can you make Fig 2d easier to read? Perhaps use the names of the LULC classes instead of the numbers. You could also perhaps use the same classes than in Fig 2.b with the same color code.

We appreciate the reviewer's suggestion. To enhance the interpretation of Fig. 2d, we will utilize the same color code for land cover classes in the panel's headings as in Fig. 2b. Additionally, we will adjust the format of cell numbers to [1000 km^2] rounded up to one decimal, for example, expressing 155376 as 155.4. This change allows for an increased font size and improved legibility (see below the comparison between the old and the new version of Fig. 2d).



		2001							
	CATEG	2	4	7	8	9	10	12	14
2015	2	2592	1008						
	4	144	58608	144	8064	10800	288		
	7			1008					
	8	144	6192		155376	2592	144		
	9		7056	288	20016	194256	576	144	
	10		2016	288	4176	2736	13248	1440	
	12		3456		3888	1296	432	16128	288
	14								0

		2001							
	CAT.	2	4	7	8	9	10	12	14
2015	2	2.6	1.0						
	4	0.1	58.6	0.1	8.1	10.8	0.3		
	7			1.0					
	8	0.1	6.2		155.4	2.6	0.1		
	9		7.1	0.3	20.0	194.3	0.6	0.1	
	10		2.0	0.3	4.2	2.7	13.2	1.4	
	12		3.5		3.9	1.3	0.4	16.1	0.3
	14								0

Figure 2d. Quantification of LULCCs in Dry Chaco from 2001 to 2015. The cell colour is proportional to its value. Left: old version (in km^2), right, new version (in $1000\ km^2$).

3) L134: Add reference to the WRF model.

The following reference will be added:

Skamarock, W.C., Klemp, J.B., Dudhia, J., Gill, D.O., Barker, D.M., Wang, W., and Powers, J.G. (2008). A description of the Advanced Research WRF version 3. Technical report, NCAR., http://dx.doi.org/10.5065/D68S4MVH.

4) L151: The results don't show the 4 members of the ensemble (e.g. Fig.5, 6, 7). Can you explain the method: do you use the average of the 4 members? Can you discuss (or even show on a figure) the differences between the results obtained with the 4 members in order to show the uncertainty linked to the initial condition?

Figures 5, 6, and 7 show the ensemble mean. That is now clarified in the corresponding captions. As shown in our response to main comment 3, the internal model variability (as explained by the spread of the ensemble members) will be shown and discussed in the revised manuscript.

5) L154-L161: What is the time horizon (of the FUTURE ensemble)? Could you give more details about your method to compute the future expansion? What trend did you use (% of agricultural expansion per year)? Can you discuss here (or in the discussion section) if your future projection of agricultural expansion consistent with other studies that simulated future scenarios of landuse change in the Dry Chaco, such as:

Mosciaro, M.J., Calamari, N.C., Peri, P.L. et al. Future scenarios of land use change in the Gran Chaco: how far is zero-deforestation?. Reg Environ Change 22, 115 (2022). https://doi.org/10.1007/s10113-022-01965-5

Maertens, M., De Lannoy, G. J. M., Apers, S., Kumar, S. V., and Mahanama, S. P. P.: Land surface modeling over the Dry Chaco: the impact of model structures, and soil, vegetation and land cover parameters, Hydrol. Earth Syst. Sci., 25, 4099–4125, https://doi.org/10.5194/hess-25-4099-2021, 2021.

Thanks for bringing those publications to our attention. We employed a method known as 'dilation' to compute expansion imposed in the FUTURE ensemble, as mentioned in L157 with a corresponding reference. Dilation is a morphological process commonly used in digital image processing to expand target areas by adding surrounding pixels to boundaries and filling gaps. In our study, we applied dilation by adding ten lines of the 'crop' category around crop areas, and subsequently, we applied dilation again with the addition of five lines to 'grassland' areas. This will now be explained in more detail in the “Experimental Design” section.

Based on the rate of change of the global-low scenario proposed by Mosciaro et al. (2022), which is ~7812 $km^2 yr^{-1}$, the time horizon of our FUTURE scenario is 2065. The global-low scenario considers a strong global market opening with low state regulation of LUCC, where the conditions favour great agricultural and livestock expansion. This will be discussed in the new “5. Discussion” section.

6) I suggest a change in the paper structure: (a) change the "2.4 Model evaluation" subsection into a section "3. Model evaluation" because it contains results and therefore does not form part of the method section. And move "2.4.1 Evaluation datasets" to 2.4. (b) A proper section for discussion should be included here (the comment pointed to the original section “4 Discussion and conclusions”).

Following the reviewer’s suggestion, the outline will change as follows:

Original outline	New outline
1 Introduction 2 Data, model, and experiments 2.1 Study region 2.1.1 Geographical features 2.1.2 Land cover and its evolution in DC 2.2 The WRF model and its configuration 2.3 Experimental design 2.4 Model evaluation 2.4.1 Evaluation datasets 2.4.2 Precipitation 2.4.3 Soil Moisture 2.4.4 Temperature 3 Experiments’ results 3.1 Scenario OBS_LULCC: Actual LULC … 3.1.1 Effects on the energy budget 3.1.2 Effects on the water budget 3.2 Scenario AG_INT: Intensive expansion … 3.1.1 Effects on the energy budget 3.1.2 Effects on the water budget 3.3 Process-based analysis 4 Discussion and conclusions	1 Introduction 2 Data, model, and experiments 2.1 Study region 2.1.1 Geographical features 2.1.2 Land cover and its evolution in DC 2.2 The WRF model and its configuration 2.3 Experimental design 2.4 Evaluation datasets 3 Model evaluation 3.1 Precipitation 3.2 Temperature 3.3 Soil moisture 4 Experiments’ results 4.1 Scenario OBS_LULCC: Actual LULC … 4.1.1 Effects on the energy budget 4.1.2 Effects on the hydrological response 4.2 Scenario AG_INT: Intensive expansion … 4.1.1 Effects on the energy budget 4.1.2 Effects on the hydrological response 4.3 Process-based analysis 5 Discussion 6 Concluding remarks

7) How do you explain this spatial heterogeneity?

The corresponding sentence will be removed.

8) LAI, albedo, runoff, stomatal resistance and energy budget are not validated for the CONTROL simulation. Can you explain why ? Since there are some observed datasets (e.g. MODIS) for these variables, could you extend the validation of the CONTROL simulation to other variables ?

Our response to this comment is provided in the response to the main comment 2a.

9) Section “Experiments’ results” A general comment for this section is that it is difficult for the reader to assess the significance of the changes on the energy budget and hydrological response compared to the model's internal variability.

The analysis of the internal variability will be included in the new version of the manuscript, as explained in our response to the main comment 3.

10) Change “Effects on the water budget” to "Effects on the hydrological response". The effects are only studied during the DJF period and the term "water cycle" is misleading and suggests that these results show changes on the hydrological regime (i.e. all year hydrology). Also, even though it is mentioned line 236 that the analysis is conducted during the DJF period, it could be helpful to remind it later on, particularly in the titles of the figures.

We agree with the reviewer, “Effects on the hydrological response” is more adequate given that we just evaluate the changes in summer. We will add DJF to the titles of the corresponding figures.

11) Please explain what these uncertainties are and what are the model limitations in the discussion section.

As discussed in our response to the main comments 3 and 4b, the model limitations and uncertainties will now be discussed in the “Discussion” section. In particular, the new version of the manuscript will include an analysis of the uncertainty related to the internal variability of WRF for the region of interest, while the uncertainty related to the model parameterization will be supported by previous publications.

12) Figures 9, 10, 12, 13: Instead of the average over the pixel grids, could you show 2 box plots (one for local and one for Non-local grid cells) to show the difference between the 2 distributions of grid cells ? (same comment for next figures)

We thank the reviewer for this valuable idea. The arrows in the insets will now be replaced by box plots, which give more information about the effects of the LULCCs on the different hydroclimatic variables. As an example, please see the comparison between the old and the new (draft) version of Figure 12a.

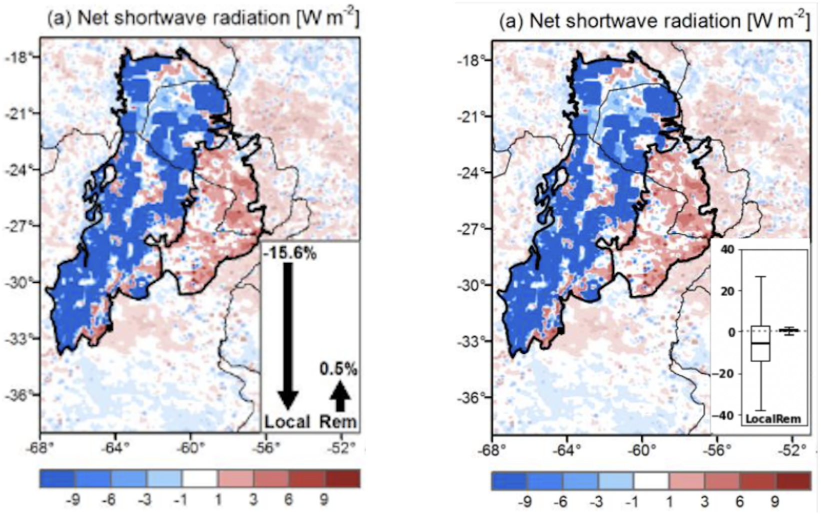


Figure 12a: Old (left) and new (right) version of the differences in net shortwave radiation in the AG_INT scenario.

13) Figure 10 is averaged per month whereas Fig5 and Fig6 are averaged per day. It would help to show results with the same time aggregation in order to better assess the significance of these changes.

Figures 5 and 6 will be shown in $[mm\, month^{-1}]$ consistently with the units used in Figure 10.