Understanding the hydrological transition of agricultural plains under land use change: insights from the ORCHIDEE land surface model

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1 - Context and objective

Argentinean Pampas has experienced an increase in flooding and raise water table level since the end of the 1960s

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Previous studies suggest that **this is due to the replacement of deep-rooted perennial vegetation by shallow-rooted seasonal crops**

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This suggests a **decrease in total evapotranspiration through a decrease in transpiration**

Objective:

Explore whether this hydrological system transition of Argentinean Pampas can be represented by the ORCHIDEE land surface model

Southeastern South America

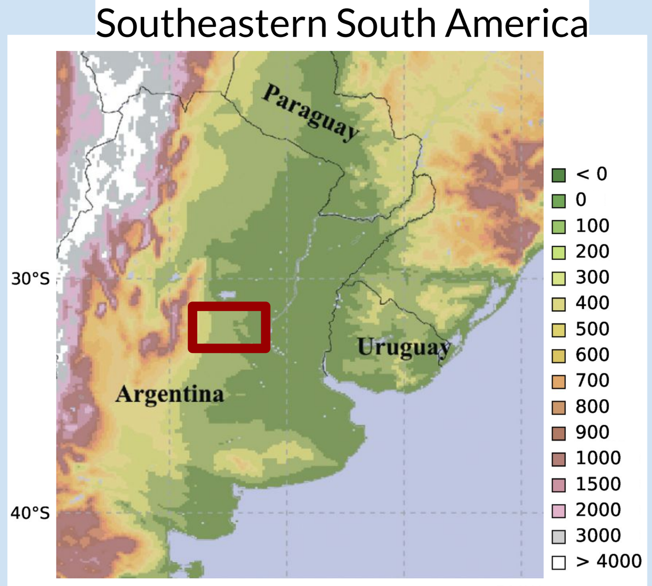

Figure 1

The study site is one of the Argentina agro-productive cores that has incremented its production in the last decades.

3 - Experiments and results

ORCHIDEE default land-use and land-cover change combined with different crop cycle configurations and atmospheric forcings to construct an ensemble of simulations

Is it important to take into account the different agricultural practices between regions?

Experiment 1: comparing ORCHIDEE supplied with default crop cycle vs supplied with crop cycle adapted to the agricultural practices of the region

Evapotranspiration partition of the region

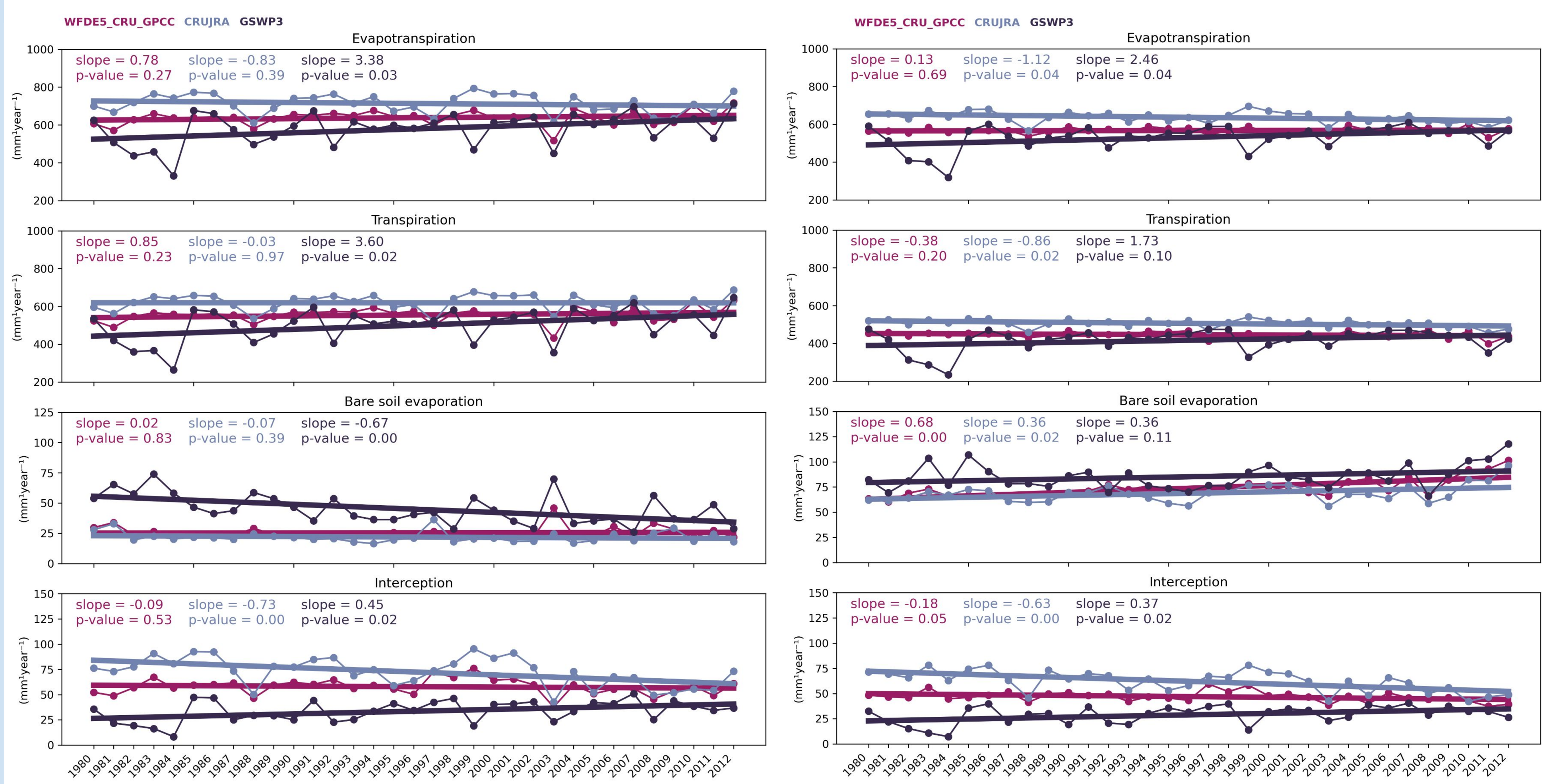

Figure 4. Partitioning of the evapotranspiration of the. Evapotranspiration, transpiration, bare soil evaporation and interception simulated by ORCHIDEE using the LAI model default (left) and the adapted crop cycle (right) are shown for the three forcings used.

Is ORCHIDEE able to simulate the decrease of evapotranspiration in the region?

Experiment 2: comparing past vs present land use and land cover

Simulations with adapted crop cycle and the three atmospheric forcings were compared by fixing the fraction distribution of PFTs of **1950 (pastures dominated)** and **2016 (agriculture dominated)** to separate the climate component from the land use and land cover component and to explore whether, as expected under the hypothesis, **transpiration in 1950 is significantly higher than in 2016.**

1950: mean ± standard deviation mm[1]year^{-1} 2016: mean ± standard deviation mm[1]year^{-1} $Mean_{1950} - Mean_{2016}$ **> 2σ (95%)**?	**WFDE5**	**GSWP3**	**CRUJRA**
Evapotranspiration	572.62 ± 18.42 561.22 ± 17.18 $X_{1950} - X_{2016} = 11.40 < 2\sigma$	540.24 ± 66.32 518.94 ± 64.31 $X_{1950} - X_{2016} = 21.30 < 2\sigma$	644.22 ± 29.14 627.48 ± 28.13 $X_{1950} - X_{2016} = 16.74 < 2\sigma$
Transpiration	466.65 ± 17.00 428.79 ± 16.52 **$X_{1950} - X_{2016} = 37.86 > 2\sigma$**	442.56 ± 61.17 390.70 ± 58.30 $X_{1950} - X_{2016} = 51.86 < 2\sigma$	528.67 ± 18.79 483.85 ± 18.85 **$X_{1950} - X_{2016} = 44.82 > 2\sigma$**
Bare soil evaporation	56.19 ± 3.38 87.61 ± 6.14 **$\lvert X_{1950} - X_{2016} \rvert = 31.42 > 2\sigma$**	66.77 ± 8.23 101.40 ± 13.07 **$\lvert X_{1950} - X_{2016} \rvert = 34.62 > 2\sigma$**	50.98 ± 5.63 84.16 ± 9.23 **$\lvert X_{1950} - X_{2016} \rvert = 33.18 > 2\sigma$**
Interception	49.73 ± 5.10 44.77 ± 4.37 $X_{1950} - X_{2016} = 4.96 < 2\sigma$	30.86 ± 9.14 26.80 ± 8.77 $X_{1950} - X_{2016} = 4.07 < 2\sigma$	64.58 ± 10.75 59.46 ± 9.03 $X_{1950} - X_{2016} = 5.11 < 2\sigma$

Table 1. For each experiment, the difference of the 1950 and 2016 average for each evapotranspiration component is presented and compared with two standard deviations in order to assess whether the 1950 and 2016 simulations are different for a 95% confidence interval. Those differences that comply with the latter are marked in bold and highlighted orange.

2 - Materials and methods

ORCHIDEE was run in off-line mode, forced by different atmospheric datasets, by different land use and land cover and crop cycles

Temporal evolution of land use and land cover: ESA-LUH2. 15 Plant Functional types (PFTs). Annual resolution.

1950 and 2016 are extreme and opposite cases of land use and land cover of the region according to ESA-LUH2: **1950 representing predominance of pasture, and 2016 representing predominance of crops**

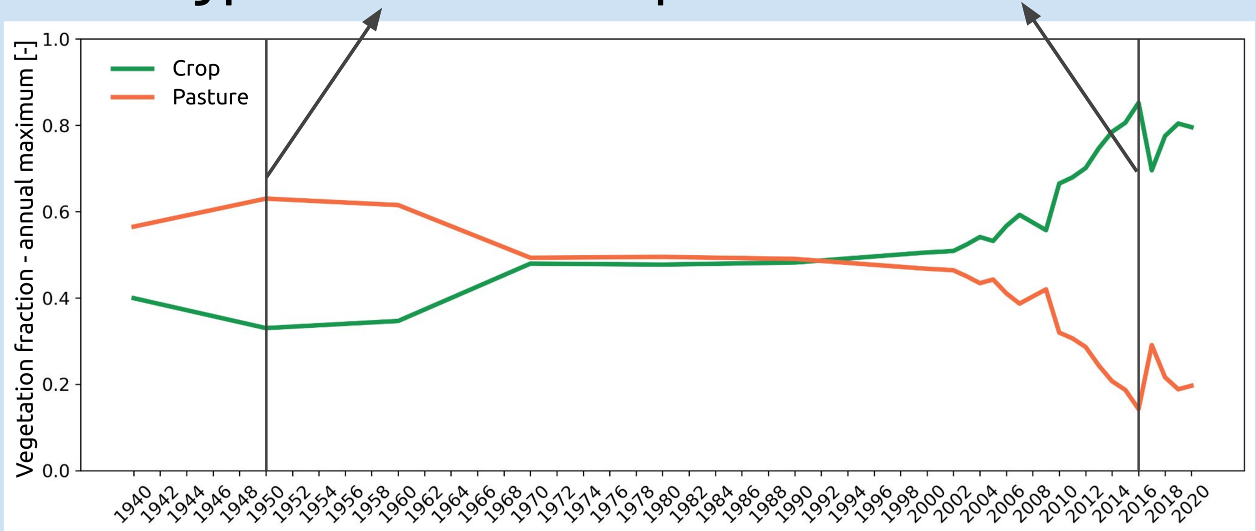

Figure 2. Maximum annual fraction of crop and pasture in the study region according to the ESA-LUH2 land use and land cover base used by ORCHIDEE for its simulations.

Atmospheric forcings: WFDE5_CRU_GPCC, CRUJRA and GSPW3

Crop cycle: Default crop cycle of the model is based on observational data mainly from high northern hemisphere latitudes. We compare default the crop cycle of the region simulated by ORCHIDEE with a observed crop cycle that match the agricultural practices of the Argentinean Pampas:

Simulated default vegetation cycle does not correspond to the observed one. ORCHIDEE vegetation cycle was modified to be representative of the region.

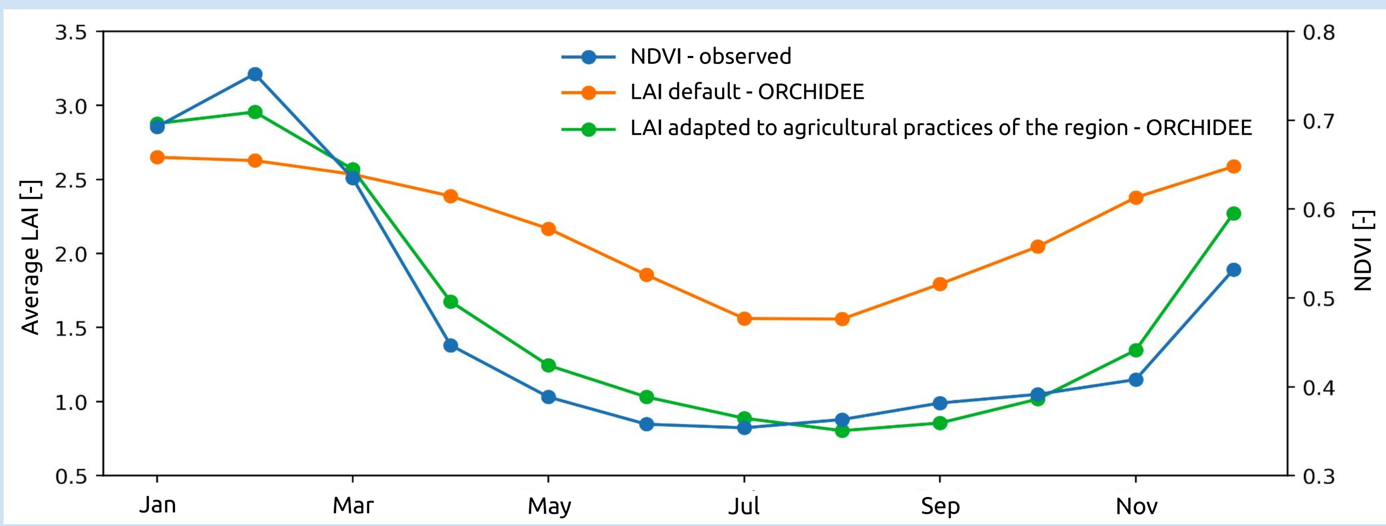

Figure 3. Annual cycle of the default LAI of the region simulated by ORCHIDEE, together with the simulated LAI adapted by using the annual cycle of MODIS NDVI of the region.

4 - Discussion and conclusions

- As for the hypothesis of **decreased transpiration, the experiments represent better this mechanism when the adjusted crop cycle is used instead of the model default**, but not in all cases significantly.
- However, **the evapotranspiration does not change its behaviour due to compensation of bare soil evaporation.** This could be an indication that **ORCHIDEE evapotranspiration is controlled by atmospheric demand or over estimated due to its parameterization.**
- For all three atmospheric forcings and with adjusted crop cycle, **when pasture dominantes, transpiration is higher than when crops dominates, in line with the hypothesis.** This difference is significant for two of the three forcings.

This work highlights the complexity of comparing observed changes of the hydrology of the Argentinean Pampas with state of the art land surface model results. The increase in flooding and raise water table level in the region during the last decades suggest that the total evapotranspiration must have decreased since no increases in precipitation has been observed. The modelling system is not able to evapotranspirate to a lesser degree than expected from observations. However, in the face of high uncertainties in atmospheric forcings and land use change data it is difficult to evaluate model performance.

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