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Hydrological response to land use scenarios under climate change. Adaptation measures for an agricultural basin: Rapel river basin in central Chile.

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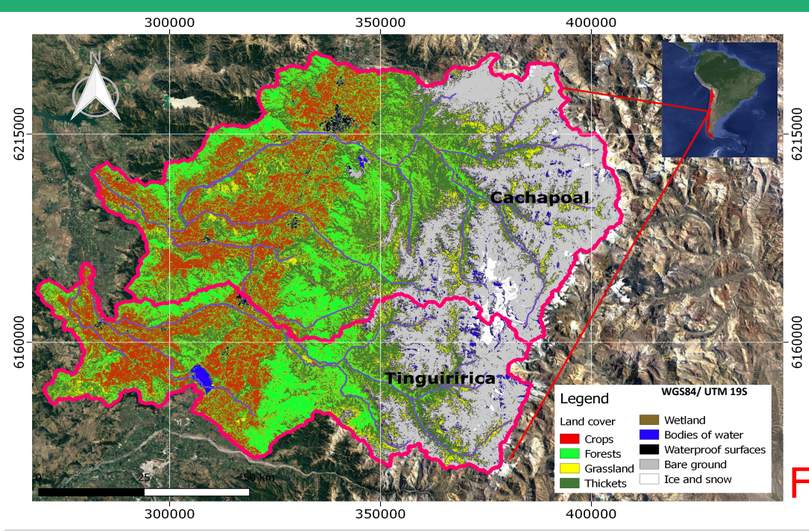
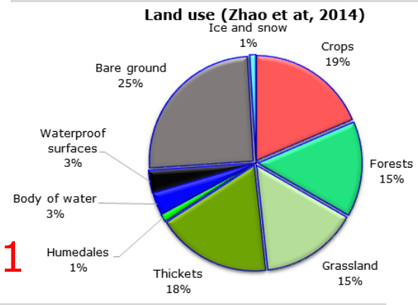
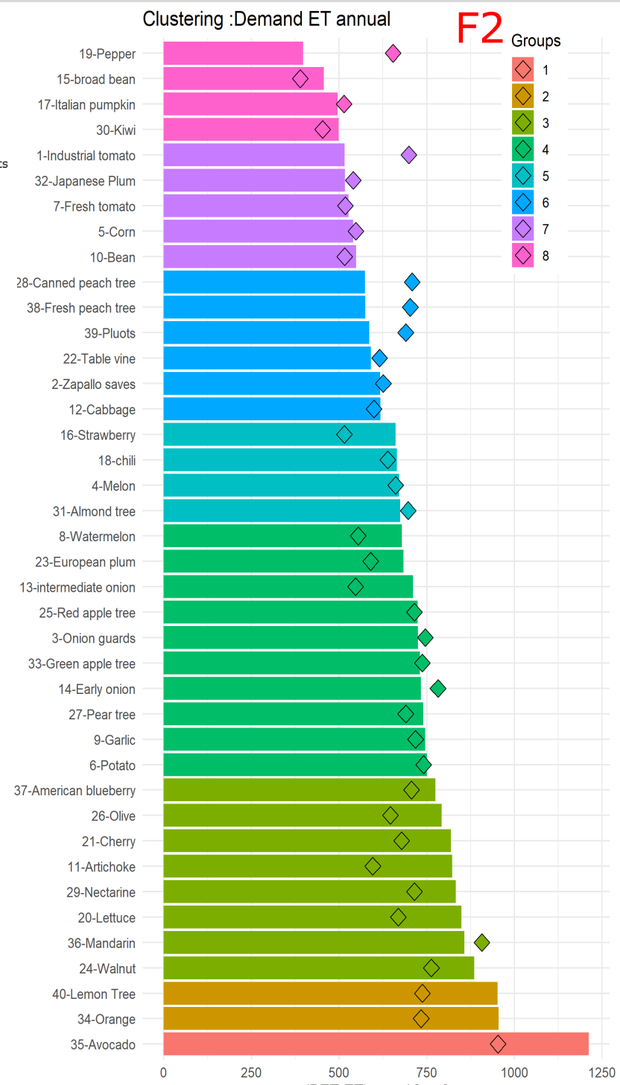


INTRODUCTION : The Rapel river basin (~34-34°S) is crucial in the development of Chile agriculture, and present a high demand for irrigation (~60% of the total consumed[1]) critical facing future water availability. We study the adaptation to climate change for the Rapel river basin based on modification in agricultural land use. The aim is to recommend land-use scenarios for the near future (2040-2060), based on the estimation of evapotranspiration demand with VIC model[2].



F1



F2

F1: In bars the historical period is represented and as symbols is representated the future (2040-2060).

STUDY ZONE: The Rapel basin is formed from the confluence of the Cachapoal and Tinguiririca rivers **(F1).** The sub-basin of the Cachapoal and Tinguiririca river has respectively an annual rainfall of 946-1097 mm, area of 6265-3535 km2 and an average elevation of 1508-1393 m.a.s.l.

METHODS:

VIC MODEL: For historical forcing (1979-2015) is used the CR2MET[3] gridded product, for future forcing (2015-2060) the RCP8.5 scenario is considered, using 4 models: CSM4, CSIRO, IPSL and MIROC. Natural balance was applied, due to the high intervention of the basin. Vegetation parameters are estimated from experimental parametrization and satellite imagery (LANDSAT 8).

AGRICULTURAL SCENARIOS: Agricultural scenarios were defined under 3 steps: and feasible cultivation areas.

- Optimal crop fraction: 40 representative crops were selected, the hydrological response was compared between the crops: runoff (E), real evapotranspiration (ET) and potential evapotranspiration (PET). And the evapotranspiration demand was estimated as PET-ET. Eight groups of crops were defined from the Kmeans algorithm.
- Optimal location: The entire growing area was simulated with a single class then the optimal locations for each crop class were identified.
- Feasible cultivation areas: Cells with a slope of less than 7, 11 and 17 degrees were determined.

The base land use is called (CBC), mixing parametrization of Zhao et al. (2014) **(see F1)** and data from the 2007 Census of Agriculture and Forestry (INE[4]).

Optimal fraction (OF) scenarios

R25 and R40, reduce the area by 25% and 40% respect to CBC considering actual crop locations. Scenarios S7, S11 and S11 use only optimal locations.

Scenarios with other distributions.

S17C_cbc, S17C_g123 and S17C_g12 consider the cultivation of all cells <= 17° slope. S17C_cbc considers the fraction of the CBC, S17-C_g123 consider the cultivation of groups 1-2-3 and S17C_g12 groups 1-2.

T1

Land use scenario	Crops fraction	Crop location	Replace forests, grasslands, or thickets?	Percentage cultivated with respect to the total area	
				Cachapoal	Tinguiririca
CBC	CENSUS-2007	CENSUS-2007	No	20,8%	28,3%
R25	OF	CENSUS-2007	No	15,6%	21,2%
R40	OF	CENSUS-2007	No	12,5%	17,0%
S7	OF	Optimal	No	21,5%	25,3%
S11	OF	Optimal	No	21,7%	25,8%
S17	OF	Optimal	No	21,9%	26,3%
S17C_cbc	CENSUS-2007	All	Yes	31,4%	35,8%
S17C_g123	Groups 1,2 y 3	All	Yes	31,4%	35,8%
S17C_g12	Groups 1,2	All	Yes	31,4%	35,8%

RESULTS:

Groups 1-2-3 have the highest ET demand, corresponding to fruit trees like avocado, citrus, walnut and olive **(F2)**

Cachapoal and Tinguiririca present historical runoff values of 4408-2901 Mm3. Maximum variation of 3% is observed between scenario S17C_g12 and S17C_cbc, where runoff is not greatly affected by agricultural land use. For both sub-basins, a reduction in runoff is observed of close to 10% for the period 2040 and 20% for 2060 **(F3 and F4).**

There is a difference of 2% between the demands of the period 2040 and 2060 **(F5 and F6)**. Also, a greater difference is observed between the demands of each scenario from October to March.

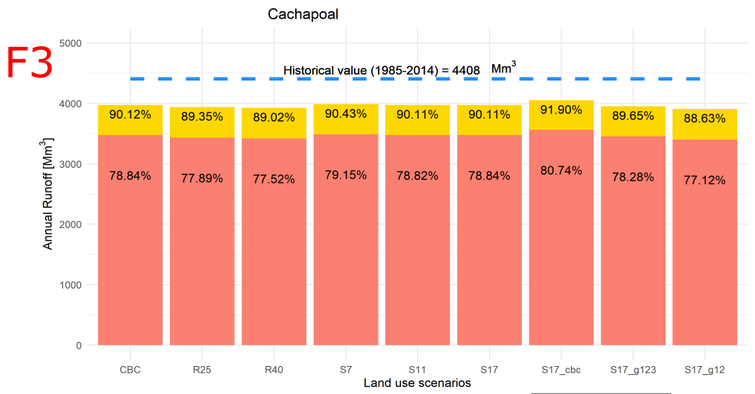
In Cachapoal the scenarios ordered according ET demand are: R40 <R25 <S7 <S11 <S17 <CBC <S17_cbc <S17_g123 <S17_g12. While for Tinguiririca the order is: R40 <S7 = S11 = S17 <R25 <S17_cbc <S17C_g123 <S17C_g12, this difference corresponds to that S7, S11 and S17 represent an area reduction, but the main idea is that these scenarios are less demanding to R25, due to the choice of optimal cells **(F5 and F6).**

In Cachapoal a deficit is observed between December and March for almost all scenarios, both for 2040 and 2060 **(F7)**

For Tinguiririca there are no deficits in 2040, but for 2060 all scenarios are in deficit between March to December and except for R40 **(F8)**

Annual Runoff

F3

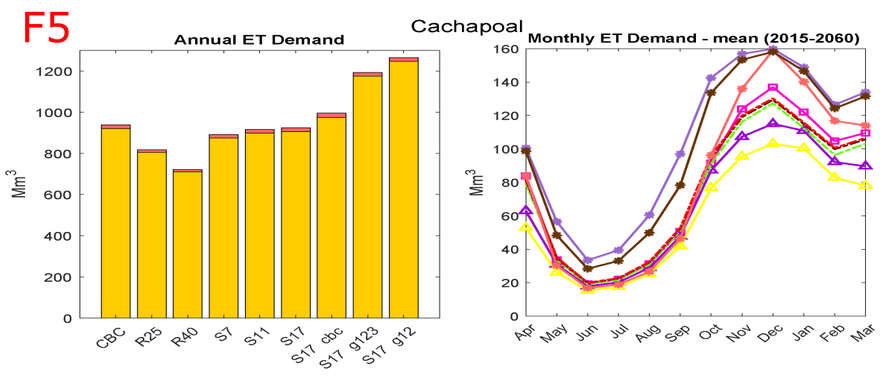


F4

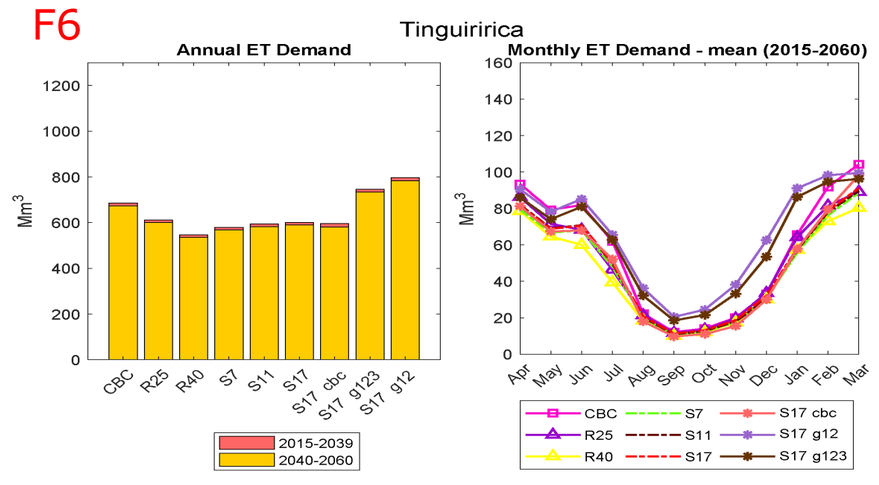
In F3 and F4 we have the annual runoff volumes for each scenario (in yellow (2040) and red (2060)), whose percentages represent the value of the period with respect to the historical (see blue segmented line).

Monthly ET demand

F5

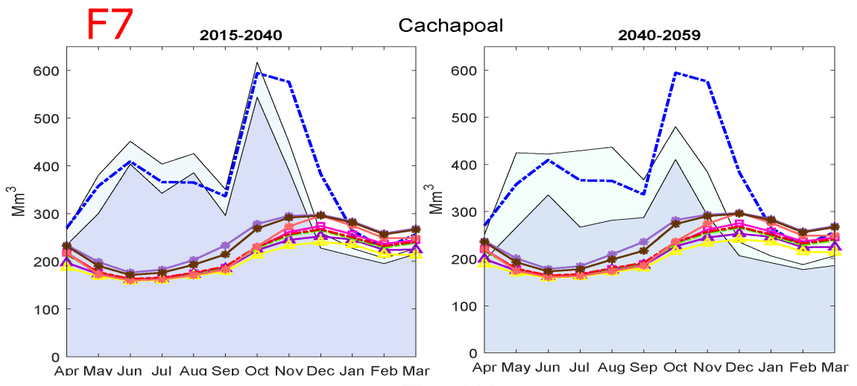


F6

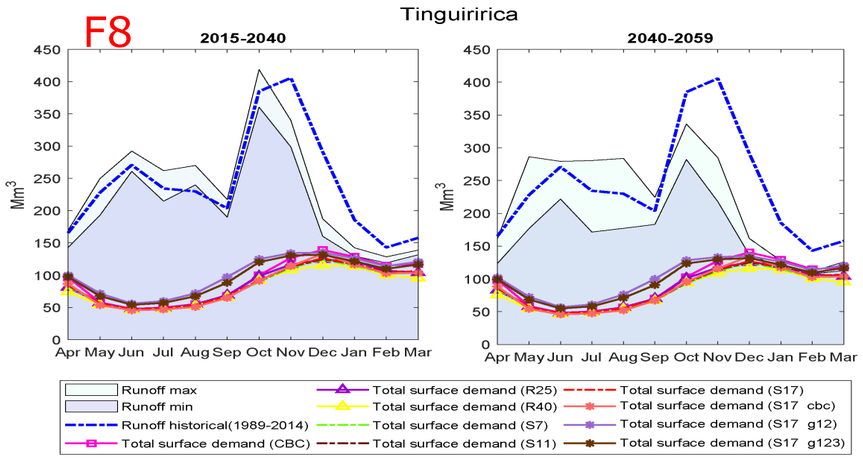


Monthly balance

F7



F8



In F7 and F8, the monthly runoff available for the period 2040 and 2060 is plotted as area, and as lines the ET demands are added to the demands for surface water from other services such as (drinking water, industry, mining, others).[1]

CONCLUSIONS

In general, a runoff reduction of 10% is expected in 2040 and 20% for 2060. This reduction occurs at the peak of melting from October to March affects directly the availability of water for irrigation, when a higher evapotranspiration demand occurs.
In the annual balance, the available surface water is enough for the irrigation demand, but monthly will be a deficit in the most demanded months. Then it is necessary to work on water management that allows storage for crucial months.
This work concludes local differences in runoff due the of agricultural land use, but in the entire basin, the impact is ~2-3%.
In Cachapoal it is recommended an area reduction scenario such as R40, however, for Tinguiririca for the period 2040, the R25, S7, S11, S17 or S17_cbc is recommended and for 2060 the scenario R40 (see table T1)
Looking at the demands of S17_cbc, S17_g12 and S17_g123, the importance of the adequate distribution of crops is patent. Remarking wich the crop location and the crop choice are important factors, and a turn away into a agriculture-focused on fruit trees is not recommended.

[1] DGA(CHILE). https://dga.mop.gob.cl/
[2] Liang, Xu, Lettenmaier, Dennis P. (1994). A simple hydrologically based model of land surface water and energy fluxes for general circulation models. Journal od Geophysical Research, vol. 99(D7). 14,415-14,428, jul. 1994.
[3] CR2MET: http://www.cr2.cl/datos-productos-grillados/
[4] INE (CHILE).https://www.ine.cl/
[5]Zhao, Y.; Feng, D., Yua, L., Wang, X., Chen, Y., Hernández, H.J., Galleguillos, M., Estades, C., Biging, G., Radke, J. & Gong, P. 2016. Detailed dynamic land cover mapping of Chile: accuracy improvement by integrating multi-seasonal land cover data. Remote Sensing of Environment 183, 170–185.