Drought management on catchment scale: Indicators, tools and challenges The Limarí Case Study, Chile

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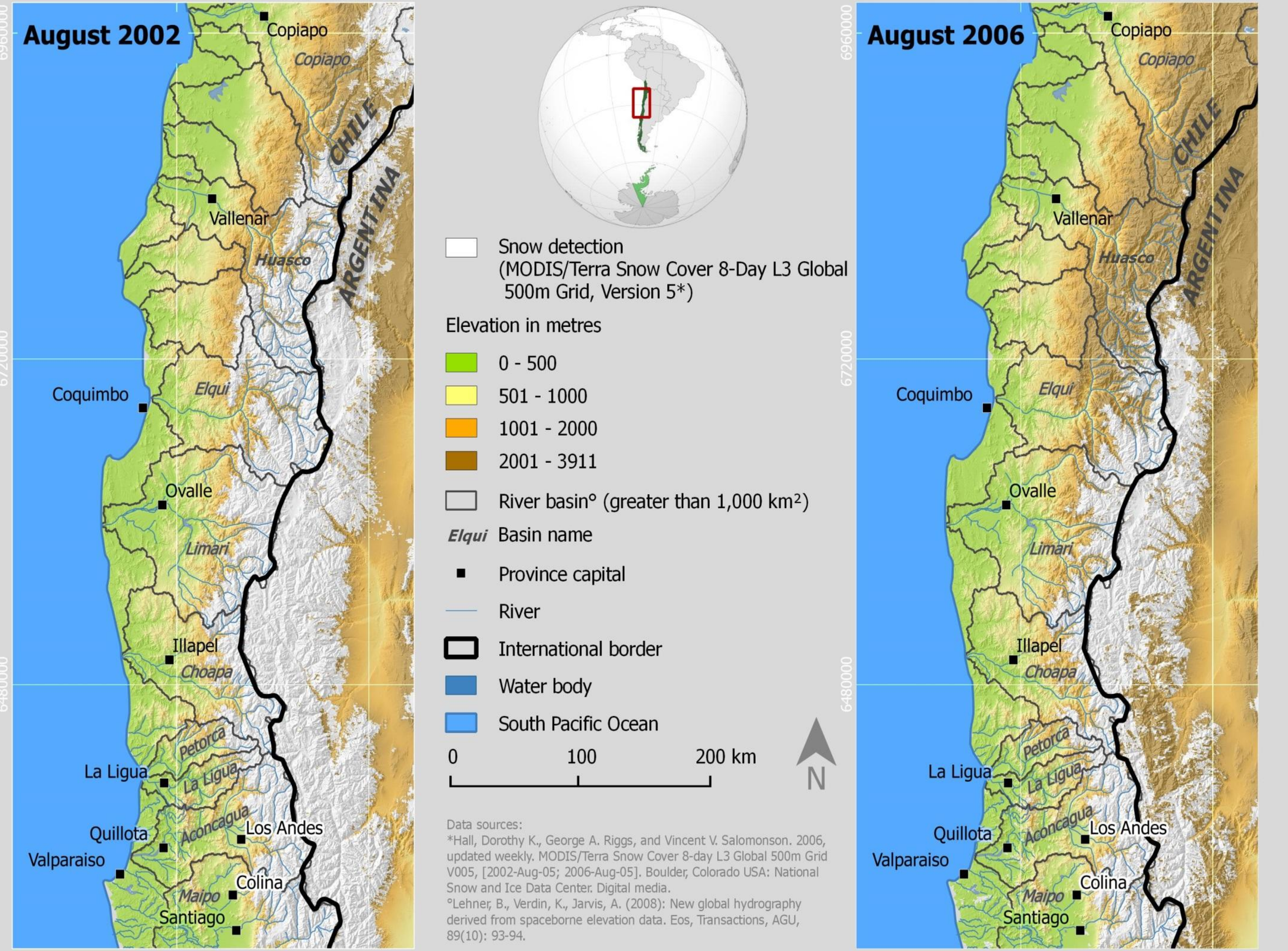
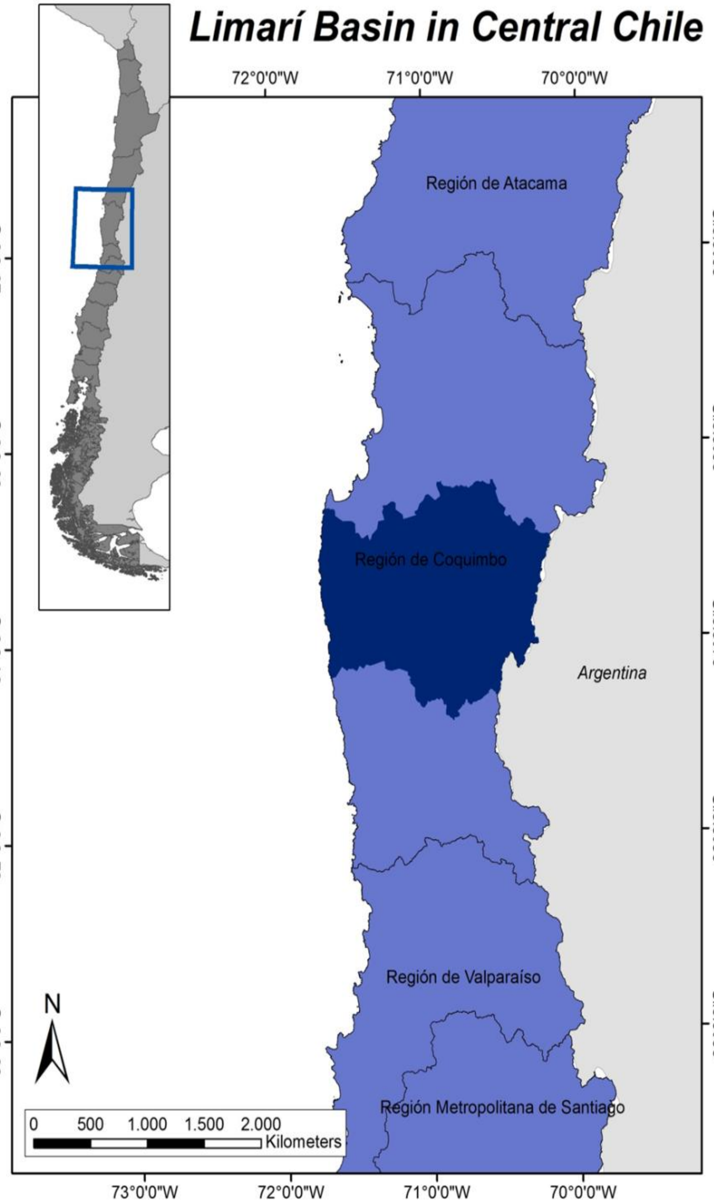
“Coping with Droughts”
Building a Community of Practice on Drought Management Tools
19th – 21st November 2014, Santiago, Chile


August 2002
August 2006
Copiapo
Vallenar
Coquimbo
Ovalle
Illapel
La Ligua
Quillota
Valparaiso
Los Andes
Colina
Santiago
Copiapo
Huasco
Elqui
Limarí
Choapa
Petorca
La Ligua
Aconcagua
Maipo
CHILE
ARGENTINA
6960000
6720000
6480000
Snow detection
(MODIS/Terra Snow Cover 8-Day L3 Global 500m Grid, Version 5*)
Elevation in metres
0 - 500
501 - 1000
1001 - 2000
2001 - 3911
River basin° (greater than 1,000 km²)
Elqui Basin name
Province capital
River
International border
Water body
South Pacific Ocean
0
100
200 km
N
Data sources:
*Hall, Dorothy K., George A. Riggs, and Vincent V. Salomonson. 2006, updated weekly. MODIS/Terra Snow Cover 8-day L3 Global 500m Grid V005, [2002-Aug-05; 2006-Aug-05]. Boulder, Colorado USA: National Snow and Ice Data Center. Digital media.
°Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93-94.



Limarí Basin, size 11.696 km

- Elevation: Pacific coast to the Andes: 0-5500 m
- Average annual rainfall: 120 mm
- strong Precipitation gradient from North to South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Climate and water availability in the Limarí Basin

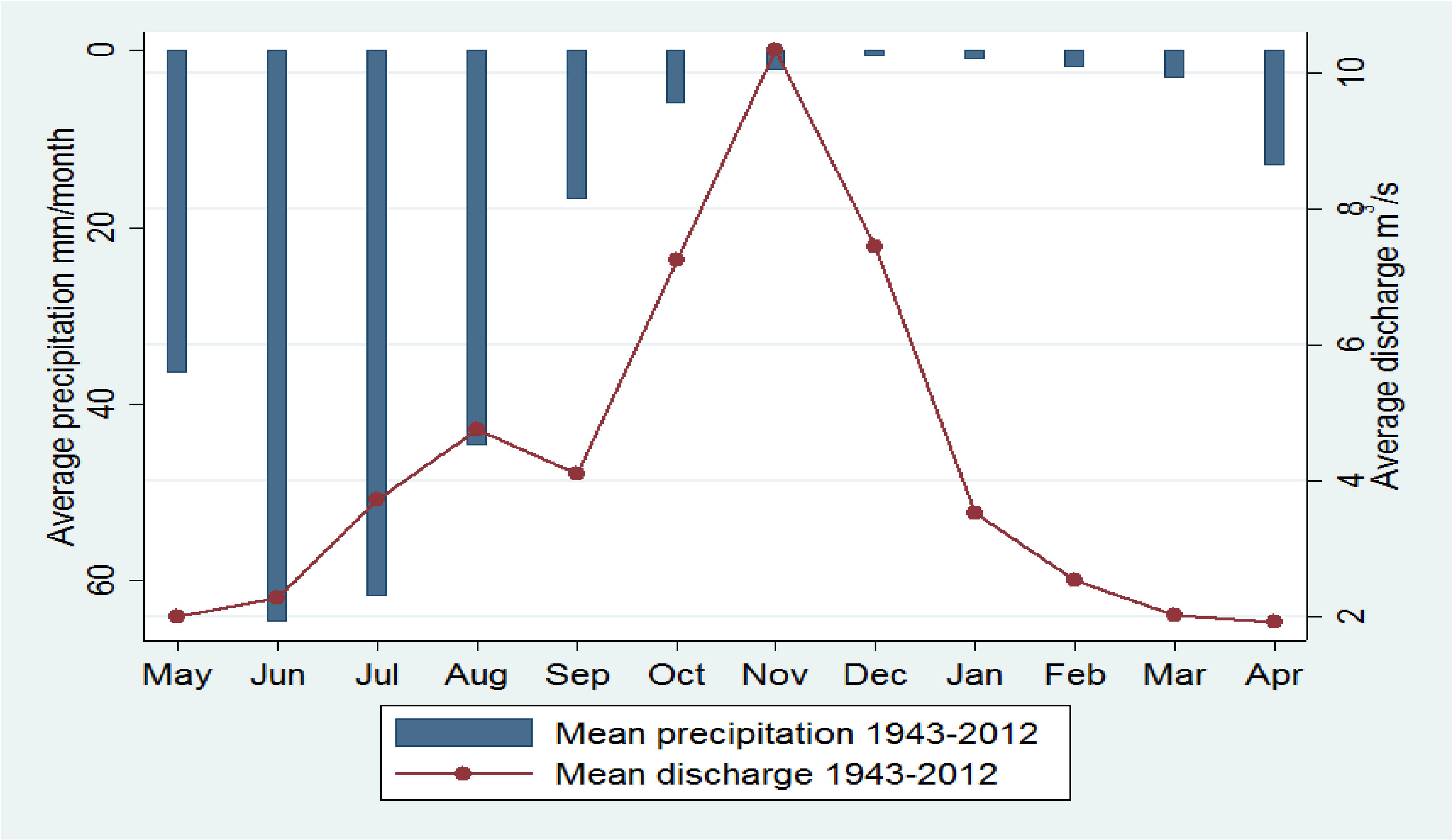
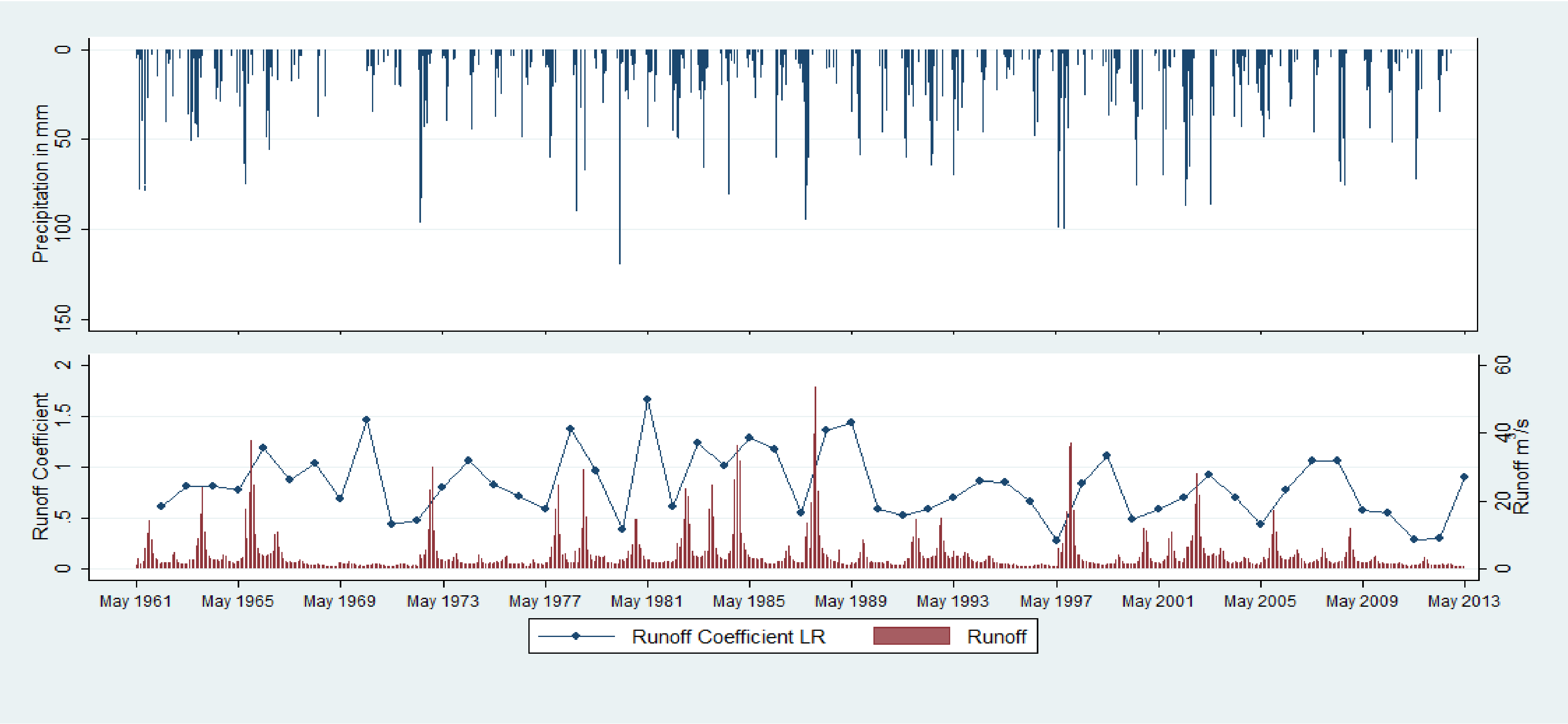


Fig: Intra-annual Precipitation-discharge distribution at Las Ramadas station – averages from 1943 to 2012

Hydrological processes



Runoff coefficients (The percentage of precipitation that appears as runoff, K=P(mm)/Q(mm)) **for each hydrological year since 1962, monthly runoff and daily precipitation at Las Ramadas Station**

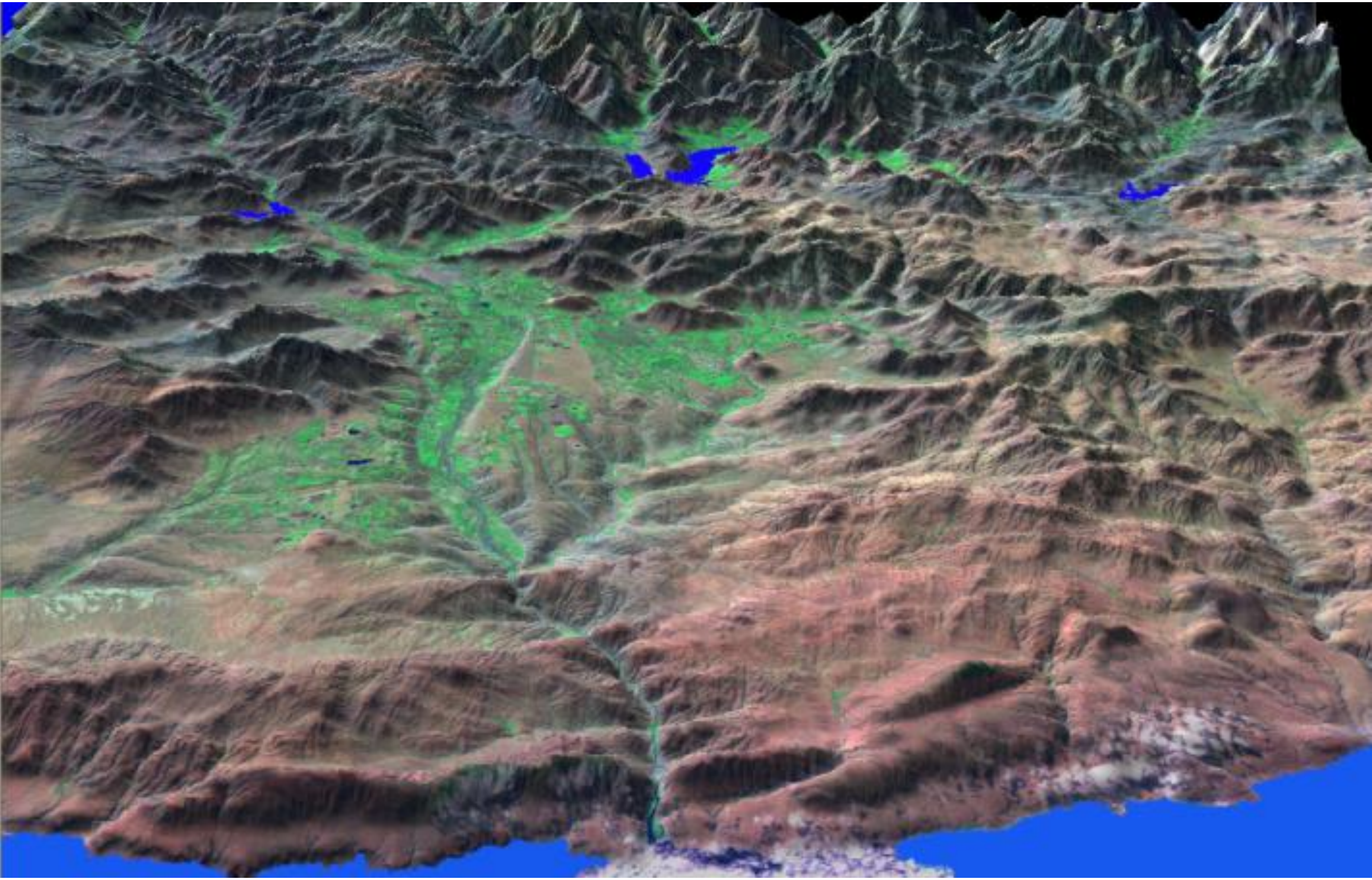

11/01/2013 15:46

ESTACION FLUVIOMETRICA
RIO TASCADERO
EN DESEMBOCADURA
AREA CUENCA 238 km²
ALTURA 1370 msnm

Agricultural Land Use

- Agricultural production depends on snow melt and mountainous hydrology
- Irrigated area: ca. 35.000 ha
- Increasing ratio of permanent crops and trees

(Census, 2007)



Water uses and demand: agricultural land use and irrigation

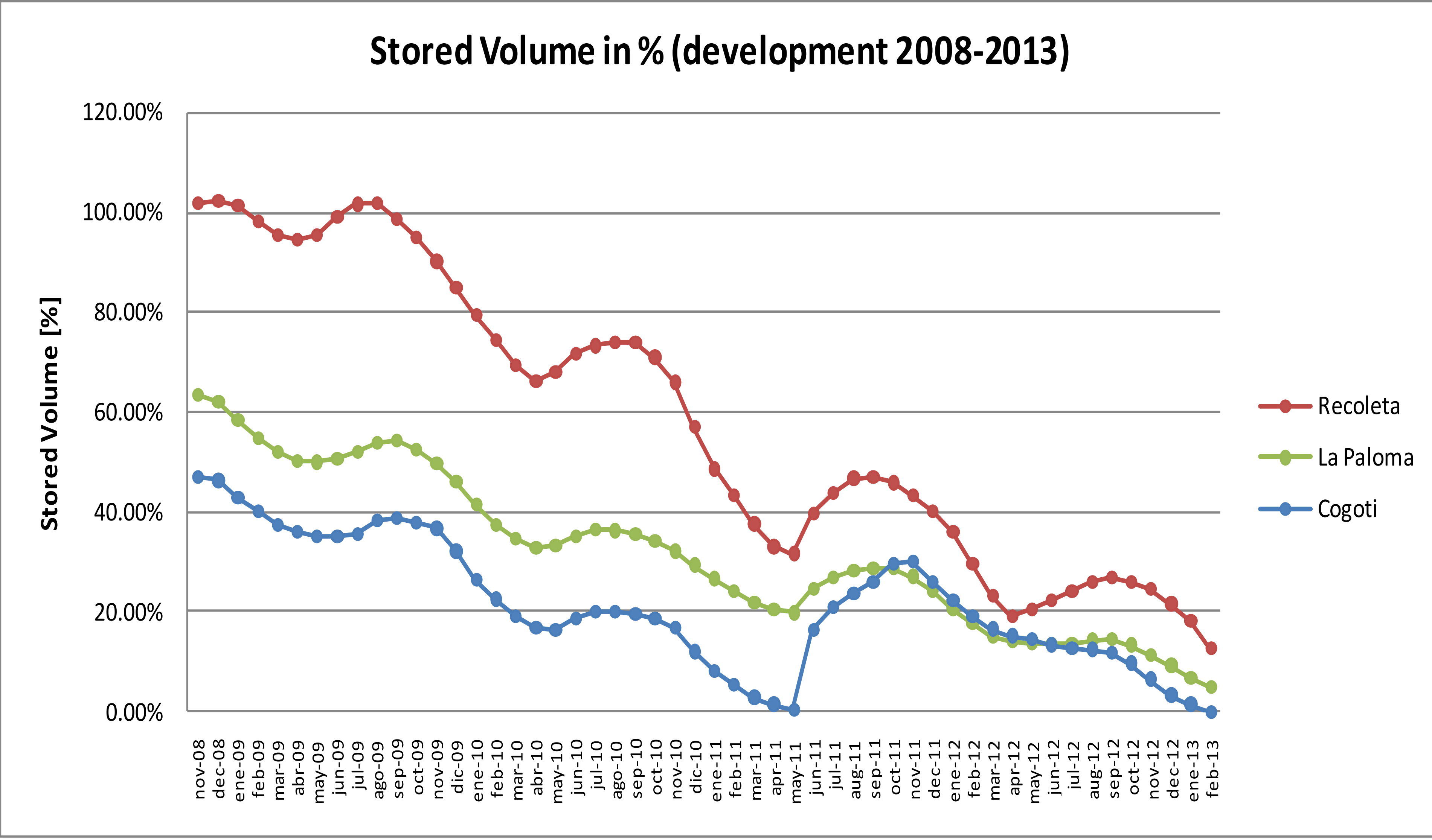


Fig.: Development of the Water Volume (in%) storage in the three main reservoirs of the system since 2008 (Nicole Kretschmer 2013, elaborated with DGA data)

WEIN

Information and monitoring system to improve water use efficiency in Northern Central Chile

Consortium:

ITT

ribeka Software GmbH

SEBA HYDROMETRIE

Development of a monitoring and information system to improve water use efficiency in the Limarí Basin - WEIN

Duration: 01.08.2012-31.12.2014

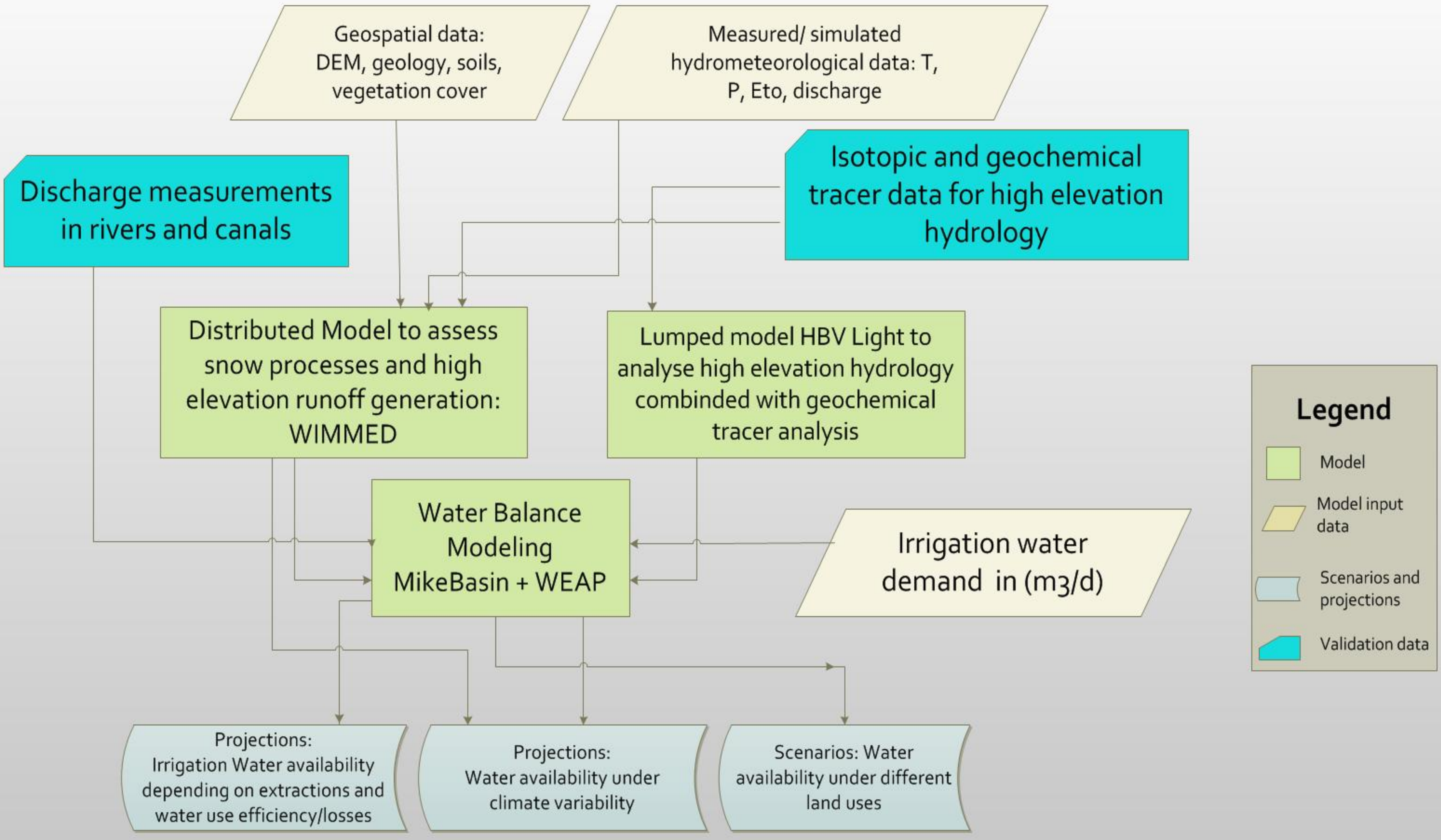
CENTRO DE ESTUDIOS AVANZADOS EN ZONAS ÁRIDAS CEAZA

UNIVERSIDAD DE LA SERENA CHILE

Funded by:

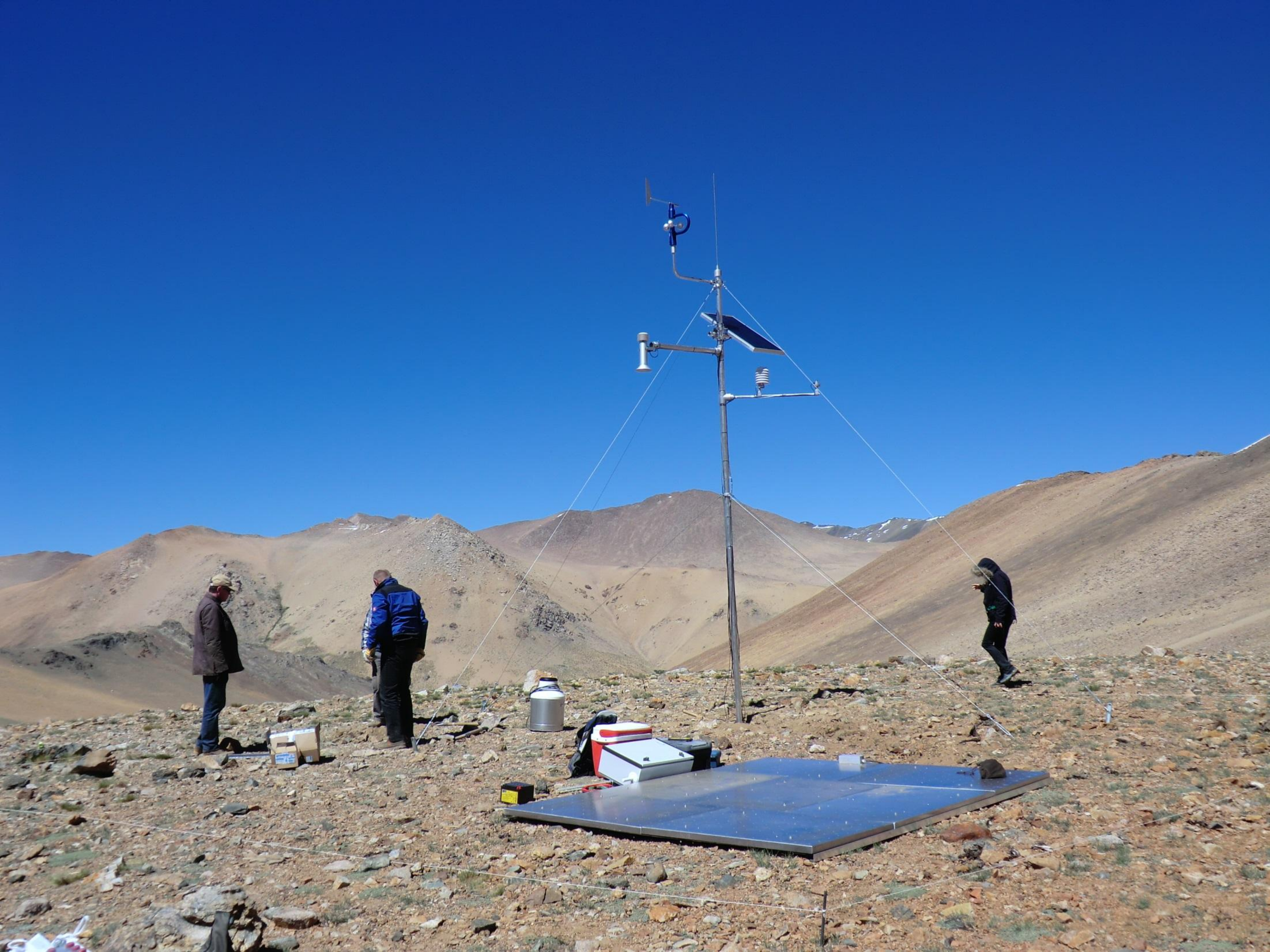
Bundesministerium für Bildung und Forschung

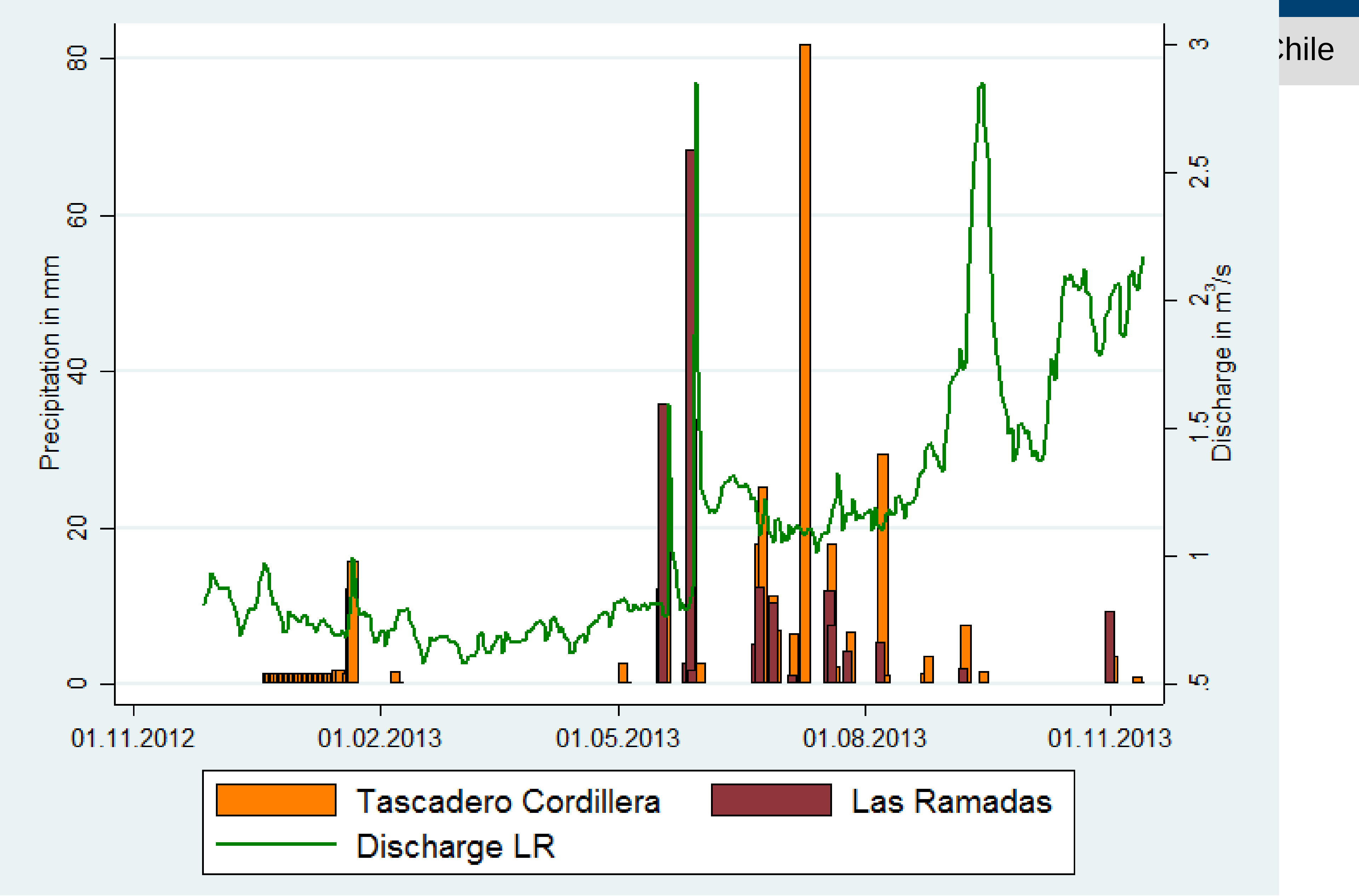
Research concept to increase water use efficiency in the Limarí River Basin



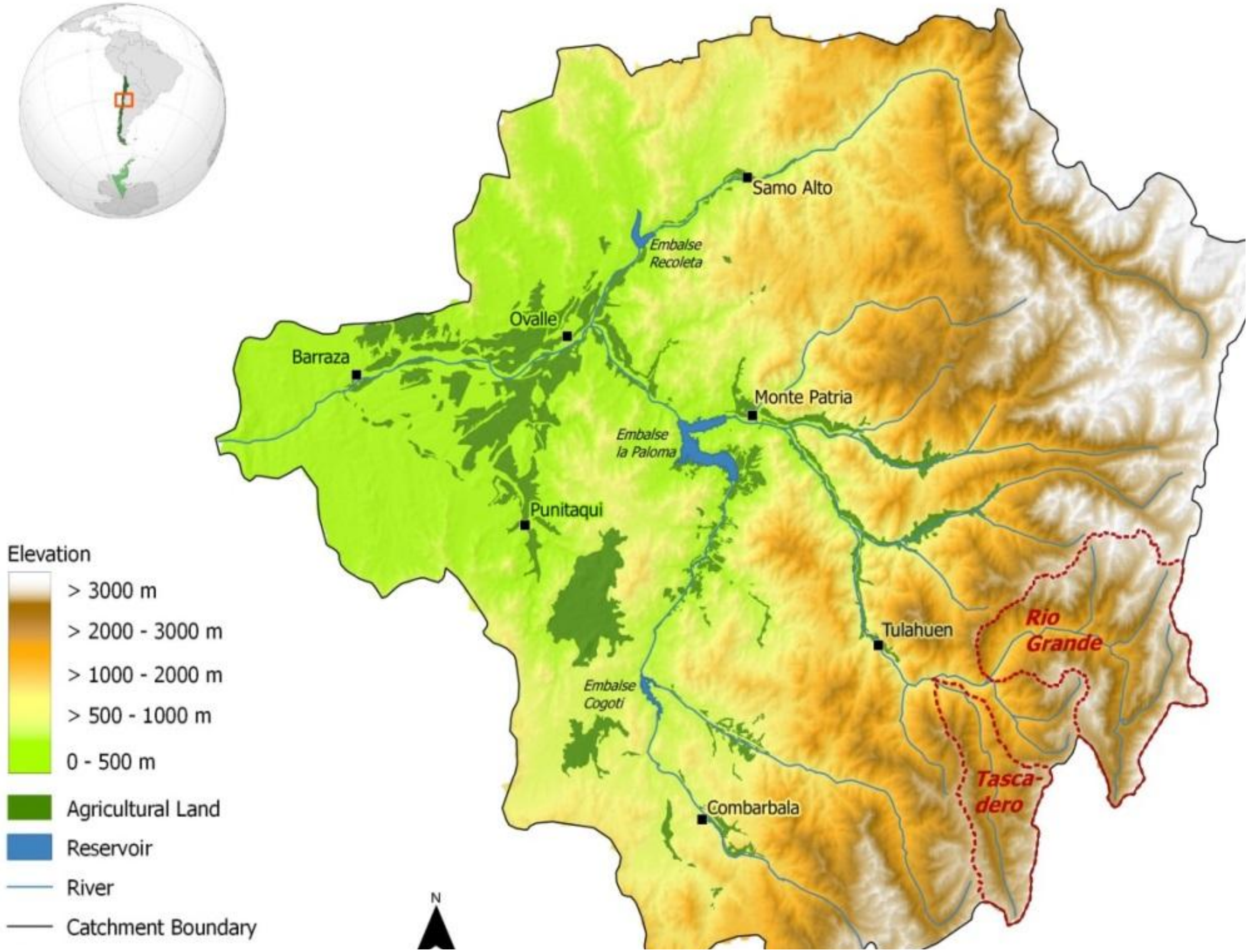
A drought assessment and management approach for a semi-arid river basin in Central Chile

Drought assessment procedure:





Precipitation recorded in the Cordillera (Tascadero station at 3500m) in 2013 compared to precipitation in Las Ramadas and discharge in Las Ramadas



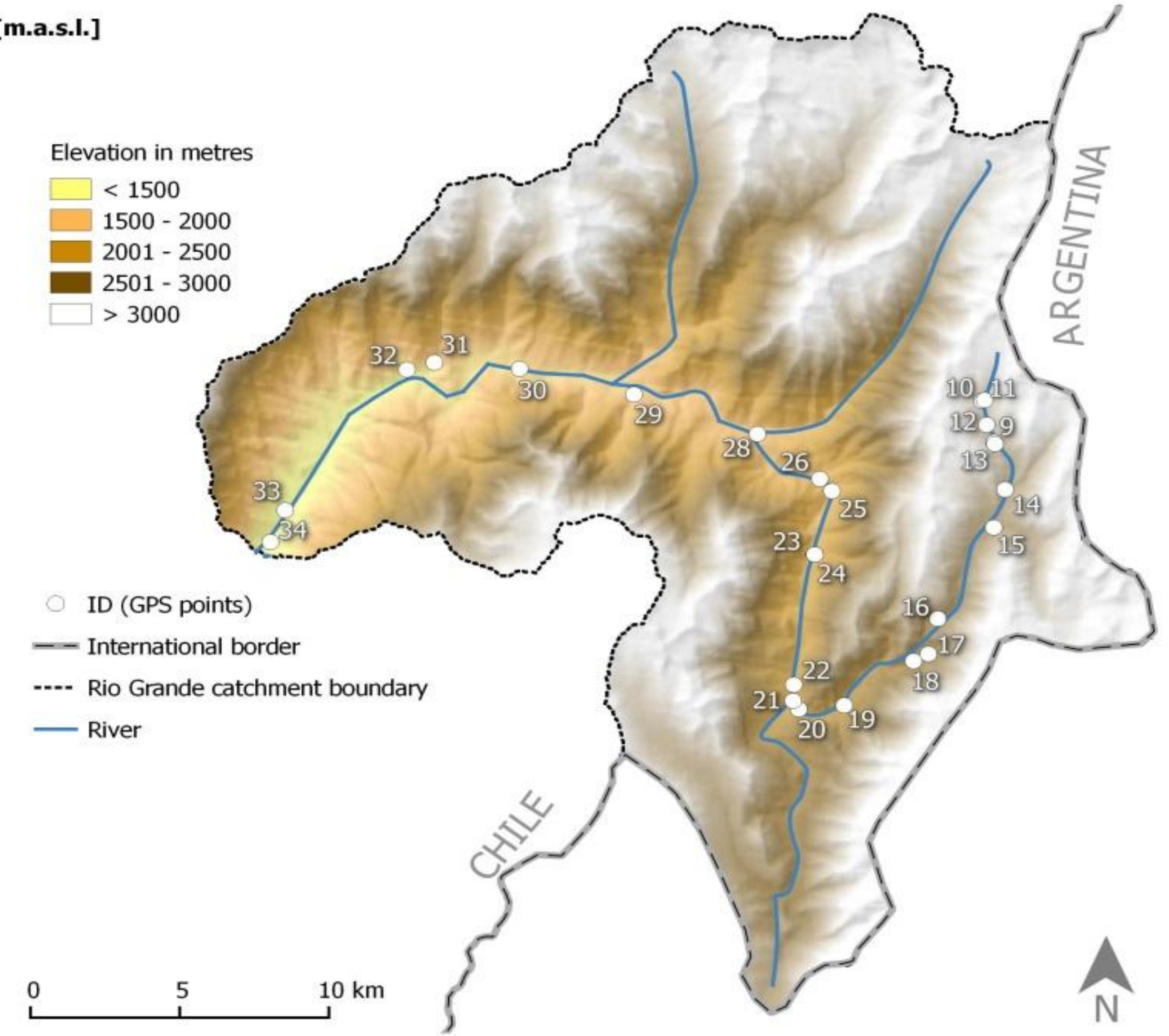
- Strong spatial and temporal variability of precipitation,
- average rainfall 120mm per year
- Pot Evapo-traspiration
- > 1000mm
- Hydrological year May to April

Limarí Basin, Rio Grande (544km²) and Tascasdero (254 km²), total size 11.696 km, Evaluation of the performance of different hydrological models in pristine ungauged catchments (e.g. WIMMED, HBV light, SWAT, J2000):

To improve knowledge on:

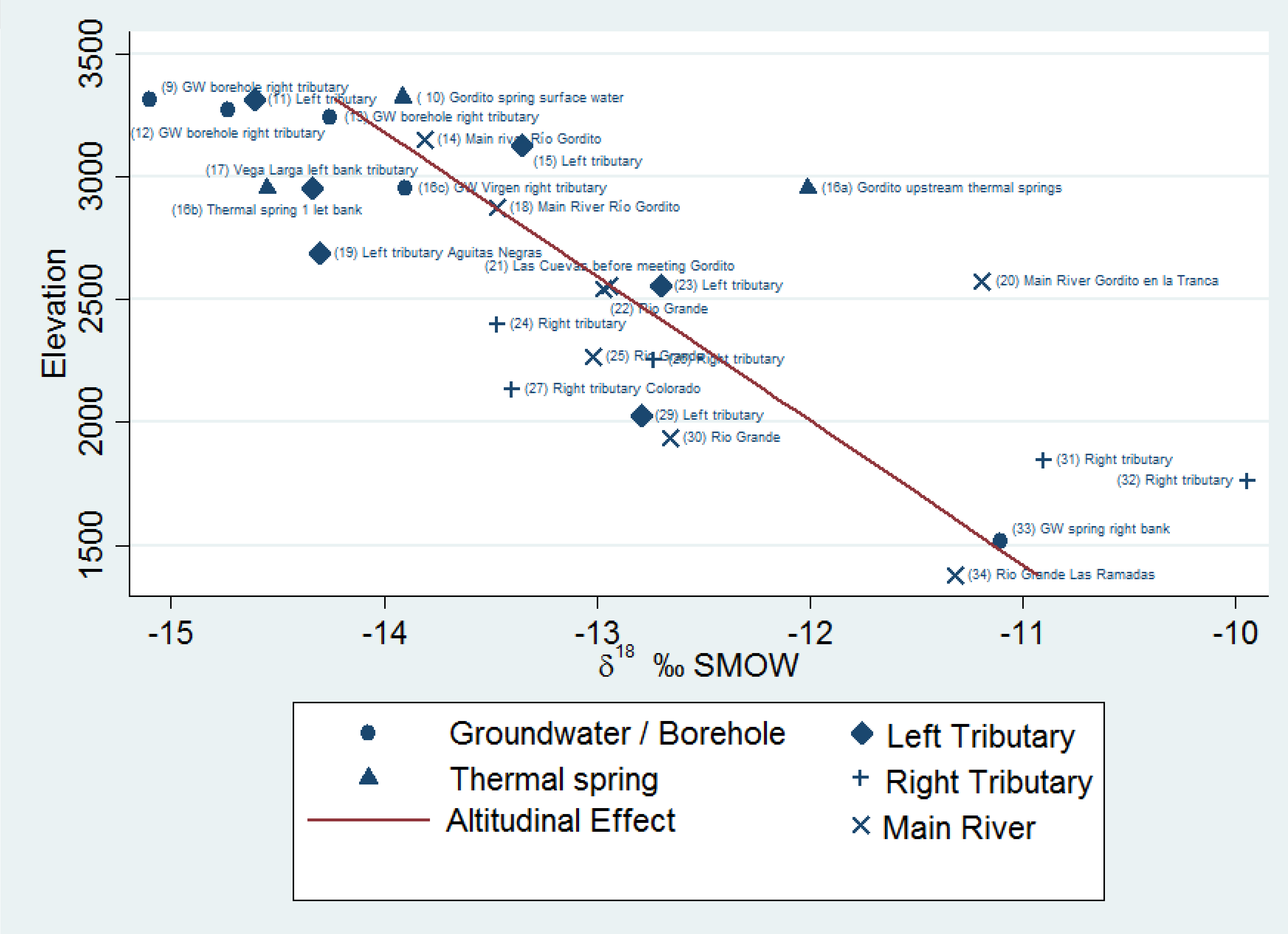
- Water balance
- aereal precipitation in mountainous catchments
- Groundwater response

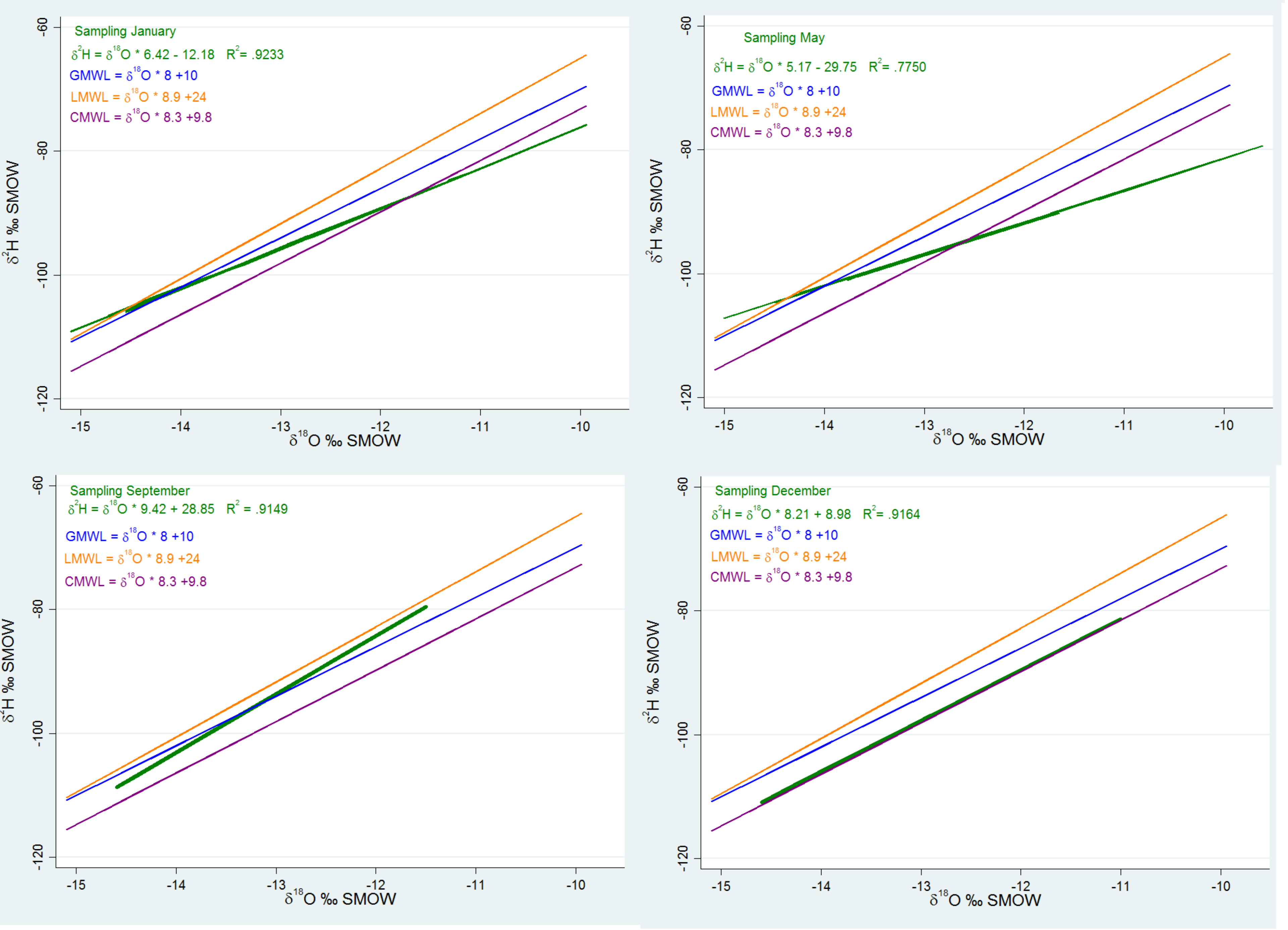
ID	Location	Elevation [m.a.s.l.]
9	GW borehole right tributary	3302
10	Gordito spring surface water	3383
11	Left tributary	3382
12	GW borehole right tributary	3333
13	GW borehole right tributary	3293
14	Main river Río Gordito	3204
15	Left tributary	3177
16	GW Virgen right tributary	3002
17	Vega Larga left bank tributary	2976
18	Main River Gordito	2942
19	Left tributary	2683
20	Main river Gordito en la Tranca	2571
21	Las Cuevas before meeting Gordito	2558
22	Rio Grande	2529
23	Left tributary	2378
24	Right tributary	2369
25	Rio Grande	2270
26	Right tributary	2246
28	Left tributary	2133
29	Left tributary	1958
30	Rio Grande	1861
31	Right tributary	1847
32	Right tributary	1765
33	GW spring right bank	1418
34	Rio Grande Las Ramadas	1386



Stable Isotope values sampled seasonaly in stream waters spring, summer and autumn

A drought assessment and management approach for a semi-arid river basin in Central Chile





Sampling January
$\delta^2H = \delta^{18}O * 6.42 - 12.18$ $R^2 = .9233$
GMWL = $\delta^{18}O$ * 8 +10
LMWL = $\delta^{18}O$ * 8.9 +24
CMWL = $\delta^{18}O$ * 8.3 +9.8
δ^2H ‰ SMOW
$\delta^{18}O$ ‰ SMOW
Sampling May
$\delta^2H = \delta^{18}O * 5.17 - 29.75$ $R^2 = .7750$
GMWL = $\delta^{18}O$ * 8 +10
LMWL = $\delta^{18}O$ * 8.9 +24
CMWL = $\delta^{18}O$ * 8.3 +9.8
δ^2H ‰ SMOW
$\delta^{18}O$ ‰ SMOW
Sampling September
$\delta^2H = \delta^{18}O * 9.42 + 28.85$ $R^2 = .9149$
GMWL = $\delta^{18}O$ * 8 +10
LMWL = $\delta^{18}O$ * 8.9 +24
CMWL = $\delta^{18}O$ * 8.3 +9.8
δ^2H ‰ SMOW
$\delta^{18}O$ ‰ SMOW
Sampling December
$\delta^2H = \delta^{18}O * 8.21 + 8.98$ $R^2 = .9164$
GMWL = $\delta^{18}O$ * 8 +10
LMWL = $\delta^{18}O$ * 8.9 +24
CMWL = $\delta^{18}O$ * 8.3 +9.8
δ^2H ‰ SMOW
$\delta^{18}O$ ‰ SMOW

Results of tracer and geochemical assessment

- First stable isotope dataset for this region: => provides consistent seasonal reference values

- Streamwater mainly fed by snowmelt in spring and groundwater in summer and autumn

Results of tracer and geochemical assessment

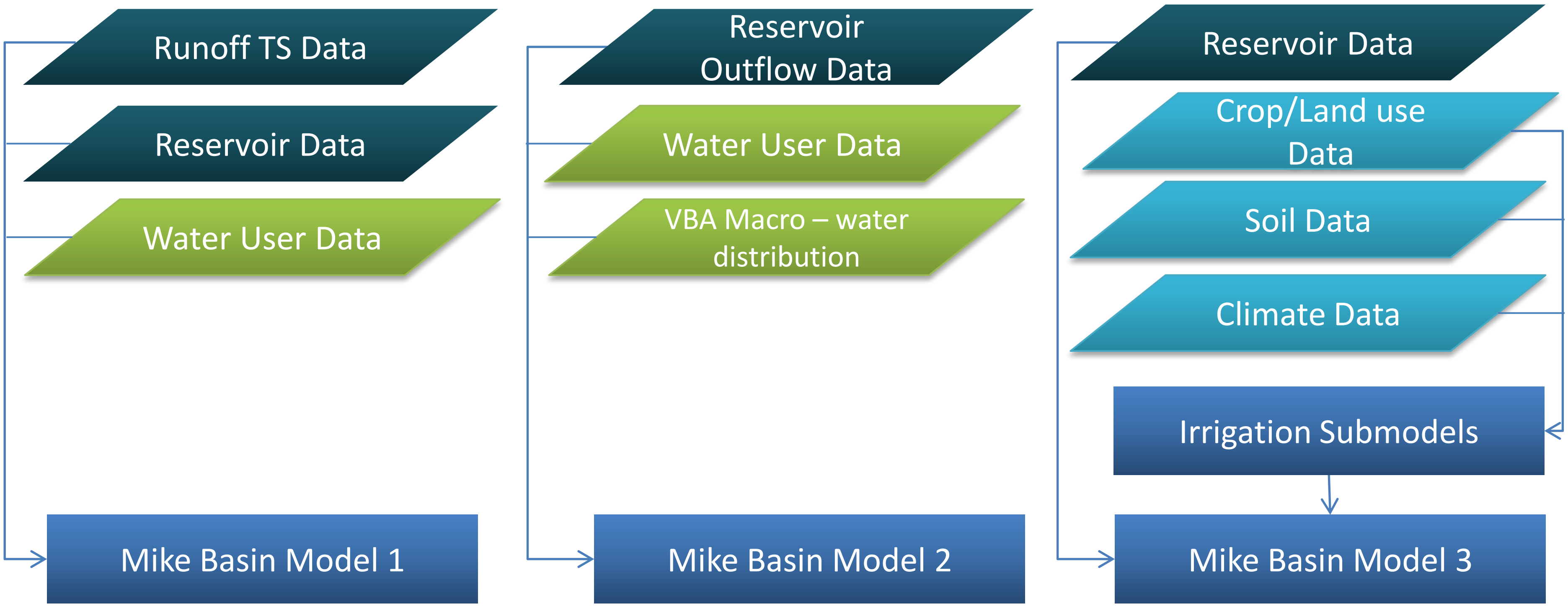
- no fossil groundwater (geochemical composition)
- Intraannual homogeinity in conductivity =>no contribution from deep groundwater
- Homogenous geochemical composition despite geothermal springs

A drought assessment and management approach for a semi-arid river basin in Central Chile

Model: Reservoir level changes

Model: Effectiveness of water distribution

Model: Land Use Changes

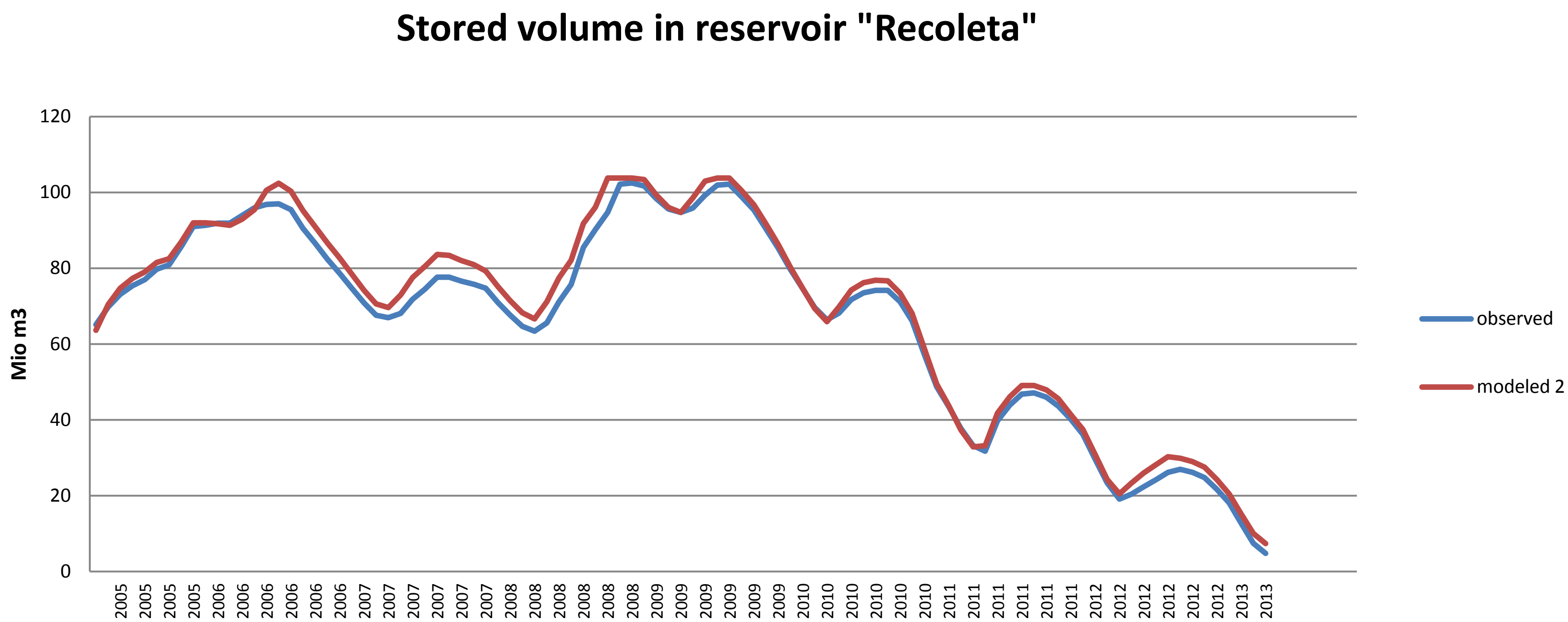


Research question:
How will water availability /reservoir levels change with different climate scenarios?

Research question:
How big are the losses due to infiltration, evaporation, illegal extraction?

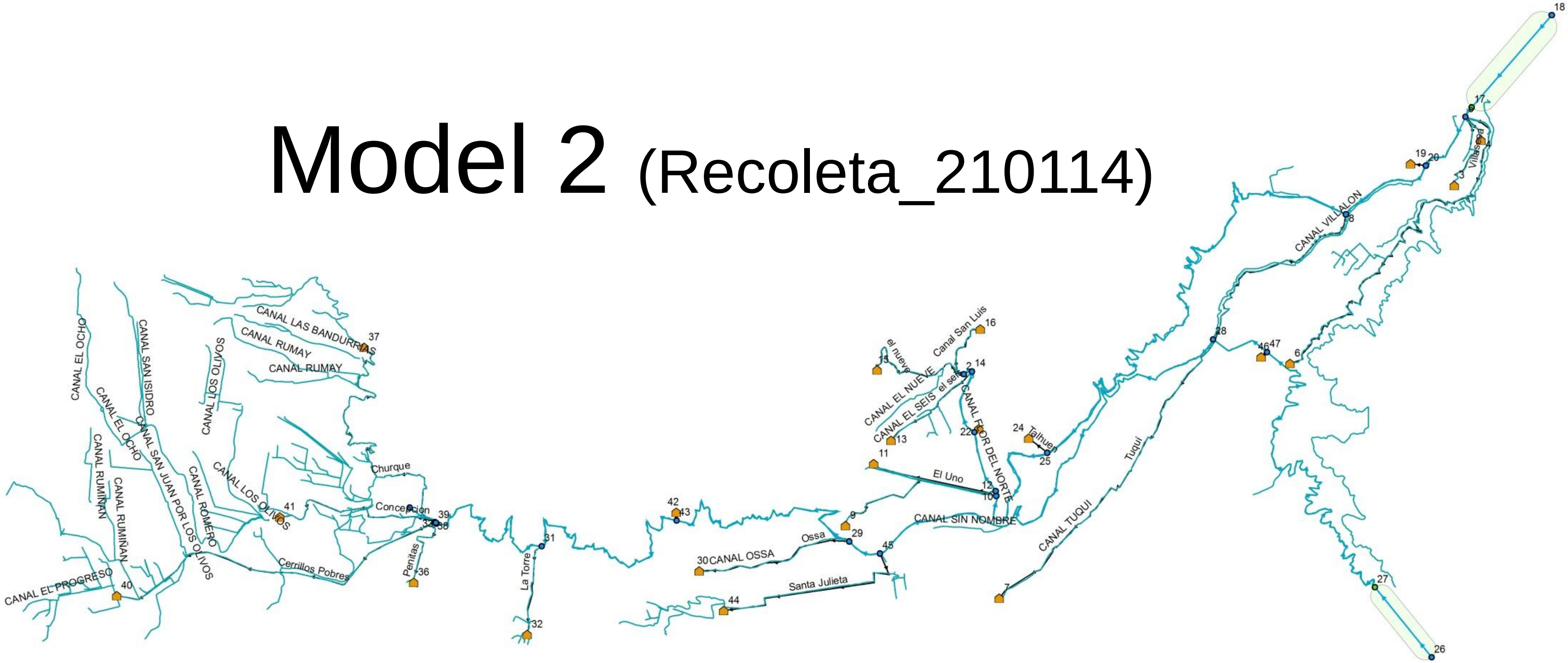
Research question:
How much water is needed to fulfil irrigation demand concerning diff. LULC scenarios?

Model 1 (Recoleta_12052014)

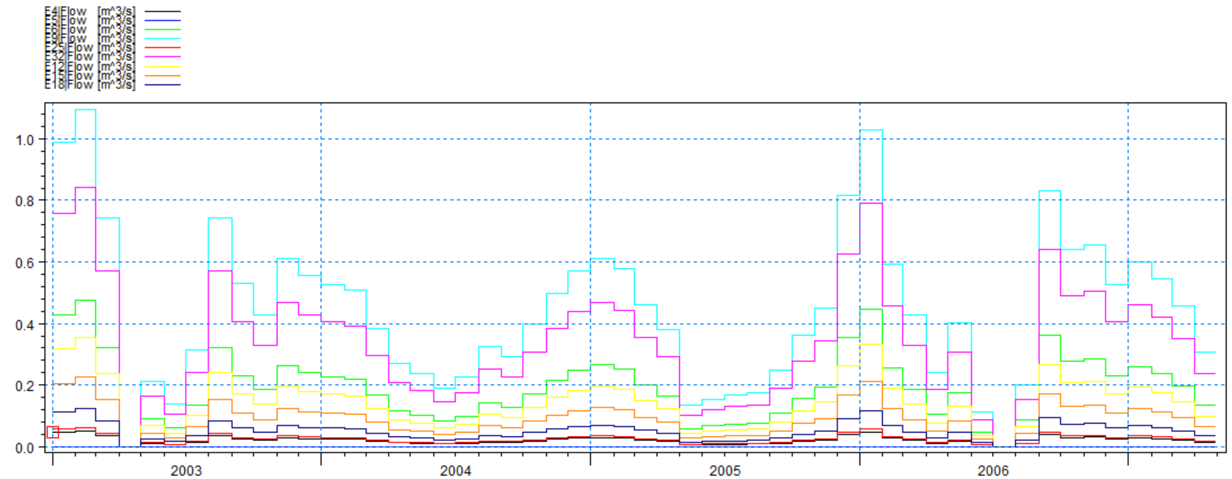


Comparison of modeled and observed values of stored water volumes in the Recoleta Reservoir 2005-2013

Model 2 (Recoleta_210114)

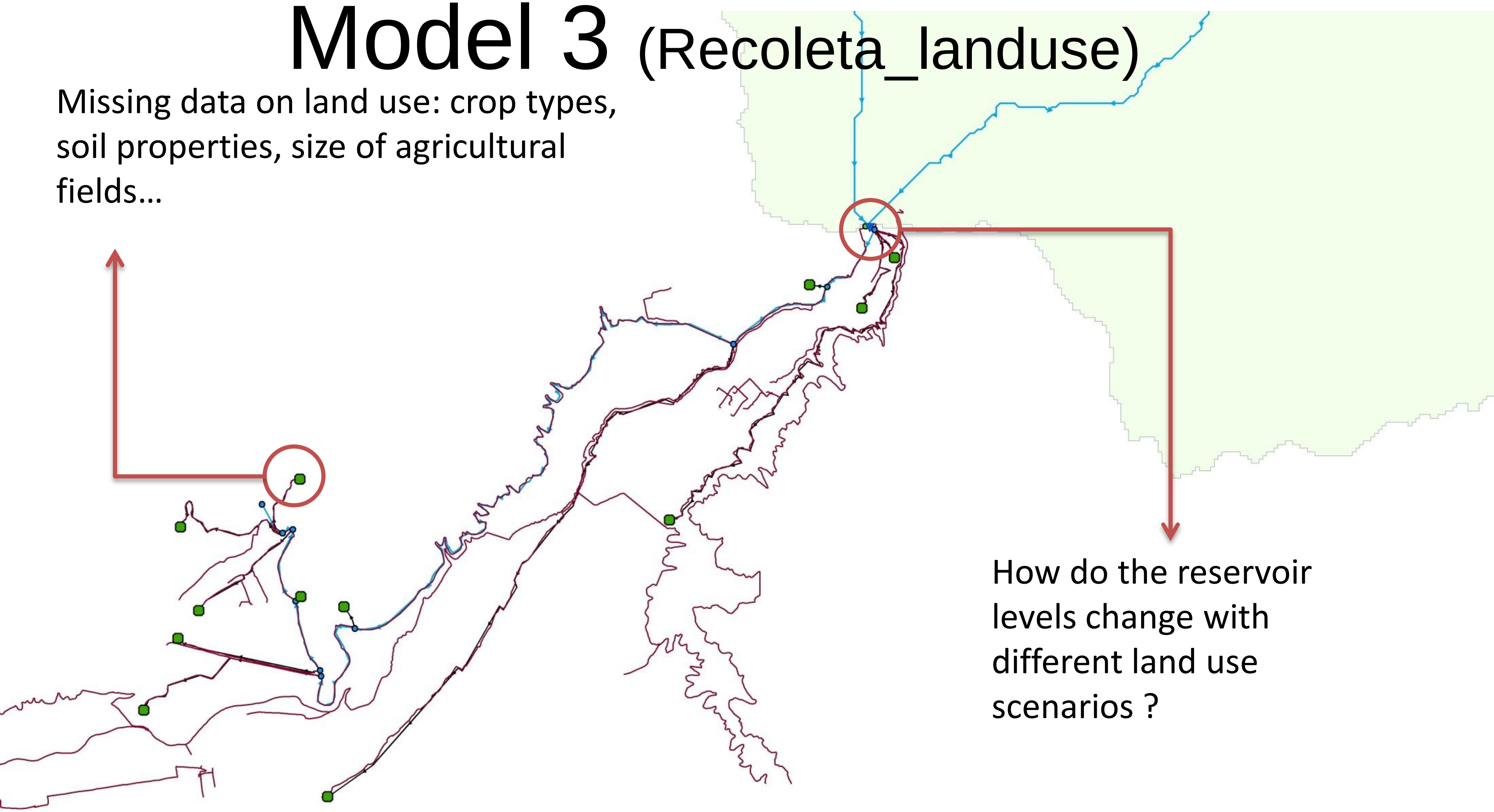


- Distribution of water according to water rights per channel (using VBA Macro script)
- Losses? Trading of water rights? – unknown parameters



Model 3 (Recoleta_landuse)

Missing data on land use: crop types, soil properties, size of agricultural fields…



How do the reservoir levels change with different land use scenarios ?

Conclusions

- More monitoring and data are needed: hydro-meteorological data above 1000m, land use data and crop type, water allocation information: water rights versus real extractions

=> results and data needs will be discussed with water users

- Hydrological models which are able to adequately address ground water storage and snow melt perform well close the water balance and represent the base flow

- Drought management tools and user friendly products need to be further discussed and developed with the stakeholders

- Large scale drought monitoring should be combined with the catchment scale


Thank you!!!

Component 3: Provide transparency and efficiency for water allocation

- Establish the water balance for different years, quantify water extractions: Mike Basin, WEAP
- Analyse census 2012, improve the understanding of land cover/use and hydrology interactions
- Simulate future projections and derive recommendations for water management and allocation

Component 4: Develop a site specific drought index based on SWSI

(Shafer and Dezman, 1982, David, C Garen, 1993):

- Snow accumulation/snow water equivalent
- Precipitation
- Reservoir levels
- Discharge

$$SWSI = \frac{A*P_{nieve} + b*P_{precipitación} + c*P_{caudal} + d*P_{embalse} - 50}{12}$$

Available data:

- Daily hydrometeorological data 16 stations 1965-2012: DGA, CEAZA
- Snow: satellite images (Modis, Landsat USGS), DGA, samples UChile
- DEM 30x30 (USGS)
- GIS shapefiles: DGA, ULS, CEAZA
- Soil data: FAO, Uni La Serena
- Vegetation: FAO, Uni La Serena, Satellite images (Landsat, SPOT)

WIMMED Input data:

- DEM, horizons, river raster
- distributed climate data: P, T, Eto, WS, Rad.,
- 8 soil maps (raster=>ASCII)
- Geology map
- Aquifer functions
- land cover

⇒WIMMED calibrated for wet years to project runoff

- not suitable for dry years
- results suggests that precipitation rates in wet years are 50% higher at an elevation of 4500 m
- river flow is receiving a ground water input as had been assumed by other authors.
- temperature decrease with a lapse rate of 5.5º/km during the melting season in summer and with 7º/km in winter.

HBV light calibrated for wet, dry and average year :

Input data: pot. Eto, PTQ, elevation zones lapse rate

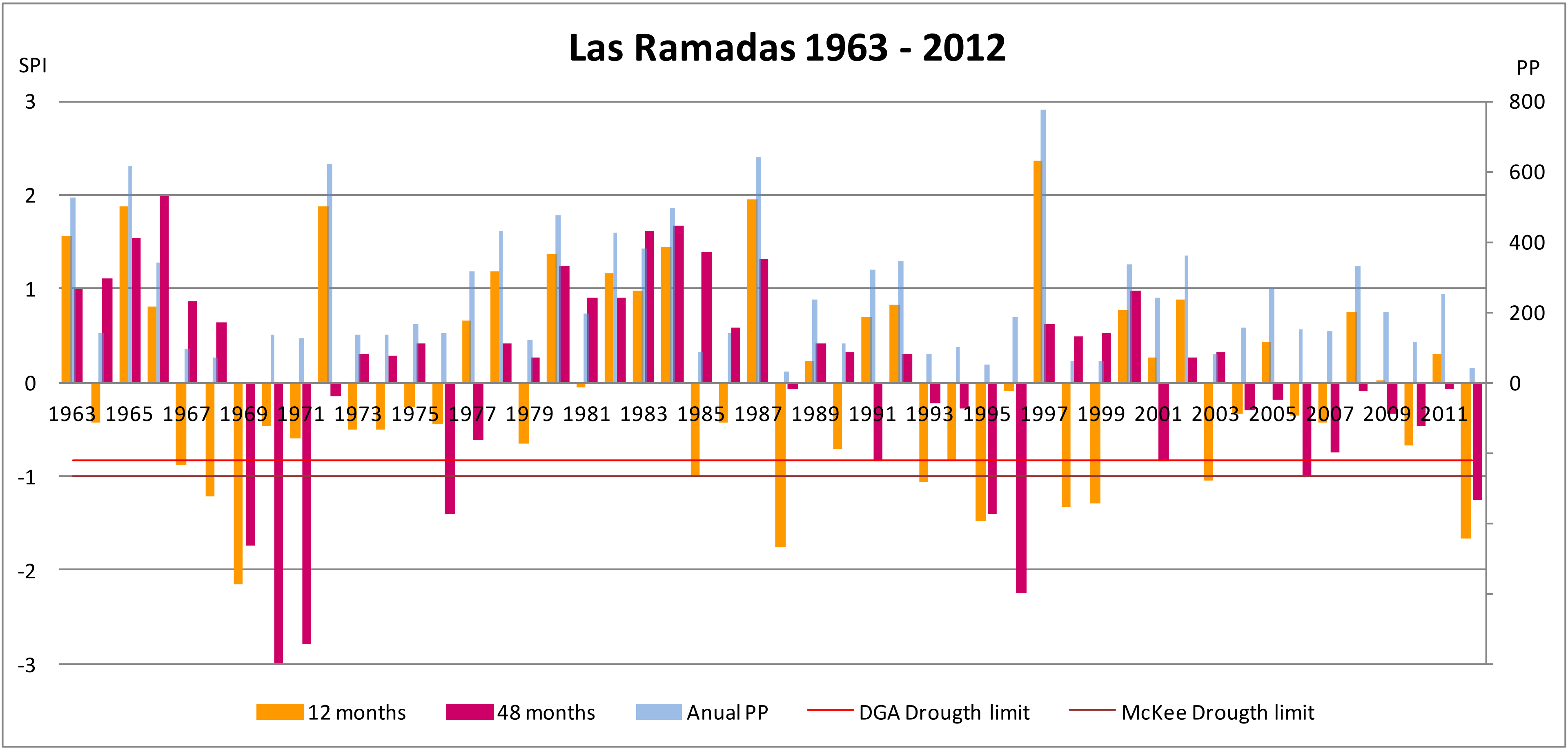
Performance:
snow routine, gw routine (two ground water boxes), soil routine

Auto calibration:
- 40 years: NSE~0.4 and lnNSE~0.58)

- snowmelt onset is still too early and peakflows are underestimated

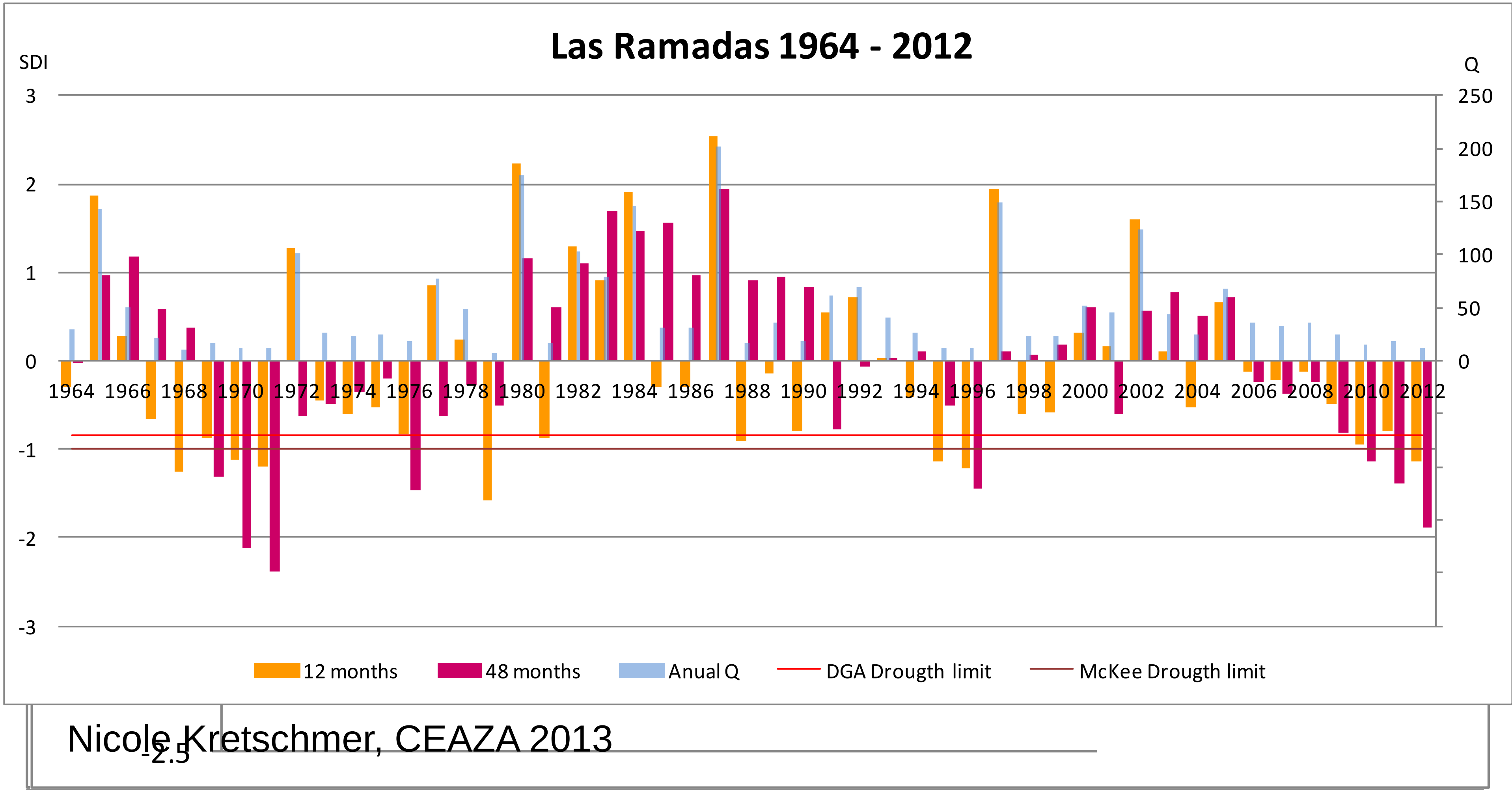
- groundwater model with snowmelt => long-term assessment of snowmelt influence on the groundwater system

SPI



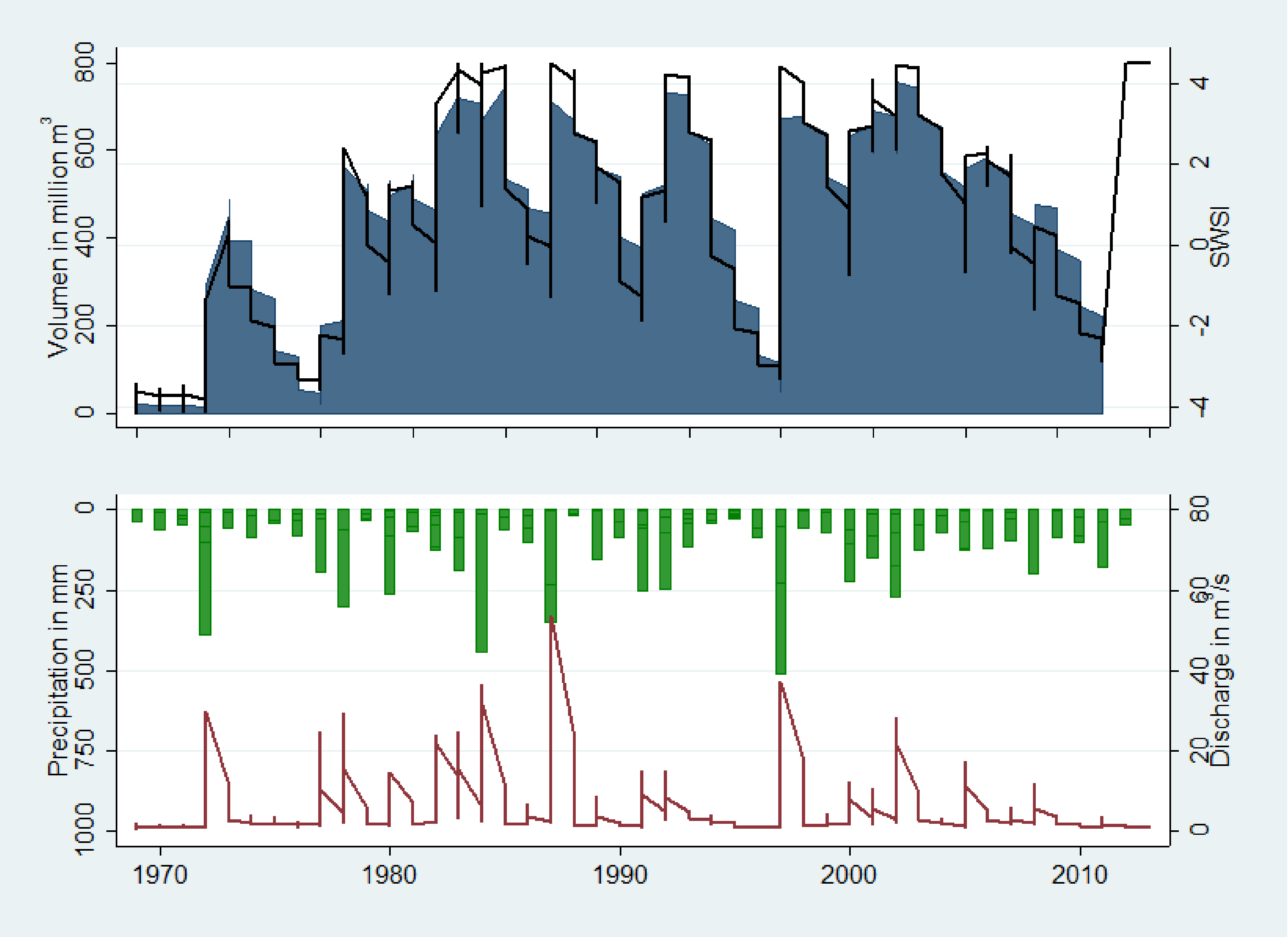
Nicole Kretschmer, CEAZA 2013

- “SDI” Standarized discharge index



Nicole Kretschmer, CEAZA 2013

SWSI 1972-2010



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- While Palmer's indices are water balance indices that consider water supply (precipitation), demand (evapotranspiration) and loss (runoff), the ***Standardized Precipitation Index (SPI)*** is a probability index that considers only precipitation. The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive.

Souvignet et al. (2011) carried out a trend analysis using the Mann-Kendall test for temperature, runoff and precipitation data (1973-2006) for the whole Coquimbo region taking into consideration 22 stations for temperature, 72 for precipitation, and 58 for discharge.

⇒ significant increase in both daytime **temperatures** of 0.46°C and nighttime 0.38°C per decade at the regional level over the last 34 years. This might contribute to a rise of the snow line and diminish water storage potential at higher elevations.

⇒ For precipitation, an increase was detected over the last decades with an intra-annual shift of the rainy season over the last 42 years (Souvignet et al, 2011).