Agricultural drought analysis in the Arrecifes basin (Pampas region, Argentina) using the SWAT model

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Outline

- *Background*
- *Objectives*
- *Study site*
- *Methodology*
- *Results*
- *Conclusions*

Instituto Nacional de
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Due to agriculture is the main economic activity in Argentina, there is a great interest concerning the **hydrometeorologic characterization** of the **Pampas region watersheds**. These watersheds are highly vulnerable to extreme climatic phenomena (i.e. flood, **droughts**), which potentially leading to significant losses in **agricultural production**.

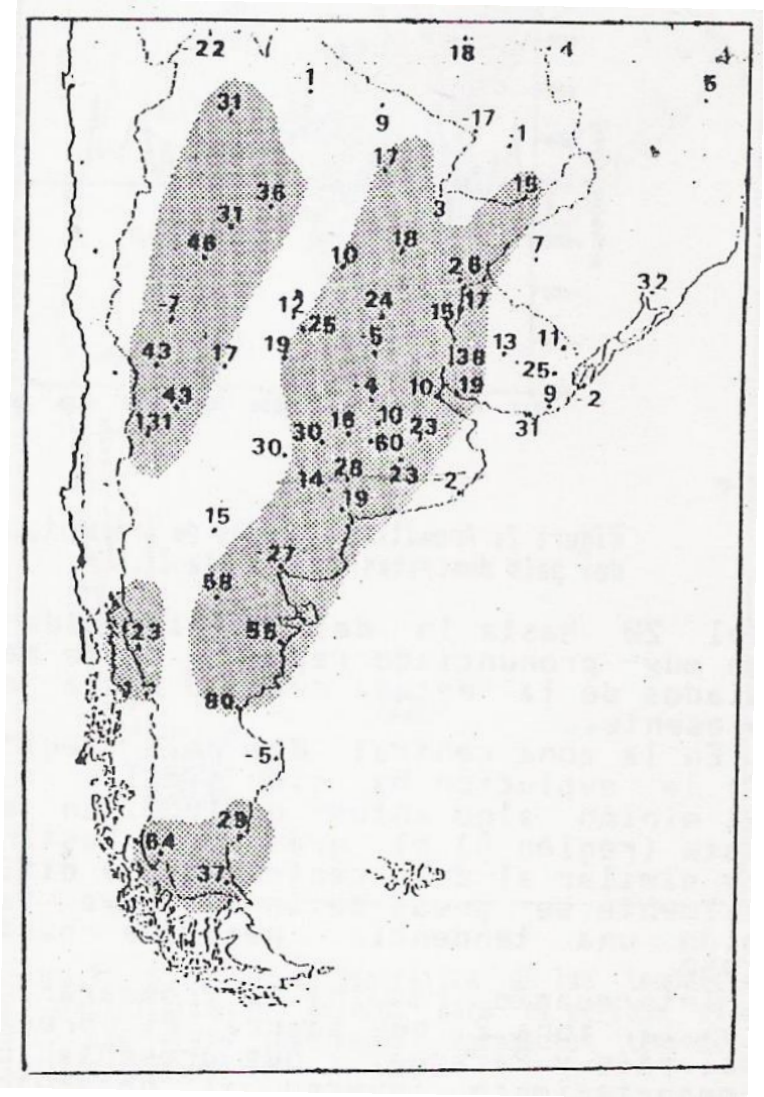
http://climayagua.inta.gob.ar/

Droughts in the Pampas region

- During the last two centurys droughts have been documented in Argentina.

- Since the 70s, agriculture has expanded westward occupying traditionally livestock areas. This change in landuse was as a result a positive trend in precipitation in semi-arid areas.

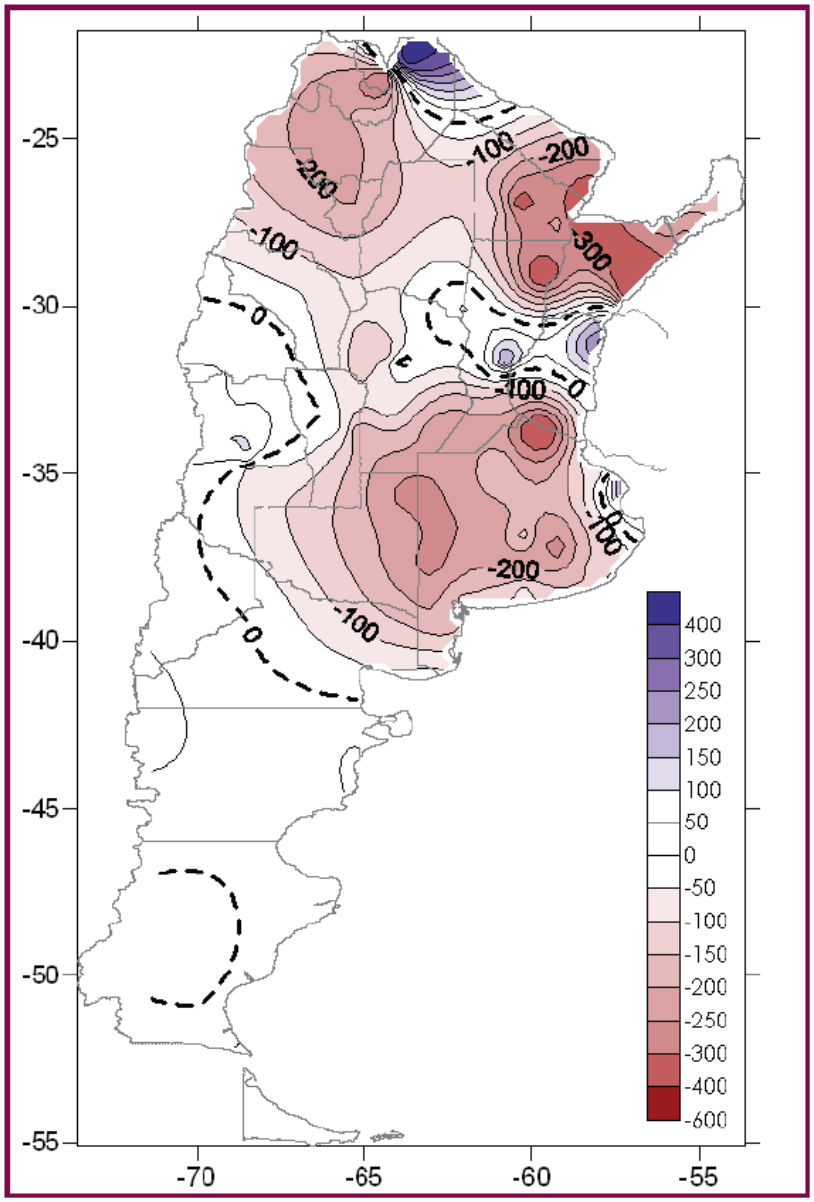
- This positive trend has been corroborated for the period 1916-1991



Geographic distribution of percentage change in precipitation between 1956-1991.

- However, in the early 70s and 80s, mid 90s and during the last decade, the Pampas region has been affected by severe droughts.

- Thus, during 2008 the rainfall of the humid and semi-humid zone of the country were the lowest in the last 47 years, what demonstrates that droughts are a thread for the Argentinean economic growth



Anomalía de la precipitación trimestre julio-agosto-septiembre de 2008. Fuente: Inst. Clima y Agua

Objetives

General objective

- To assess at a basin level the aptitude of the SWAT model combining it with other drought indicators (i.e. SPI and NDVI), as a tool to detect and characterizing agricultural droughts in the Pampas region.

Specific objectives

- To develop a long term record of the soil water content in the Pampas region by using SWAT.
- To analyze the spatio-temporal variation of the Standard Precipitation Index (SPI index) and the Normalized Difference Vegetation Index (NDVI index), in order to detect the periods and areas that have suffered droughts in the past.
- To determine the correlation between the simulated values of soil water content and the indexes SPI and NDVI

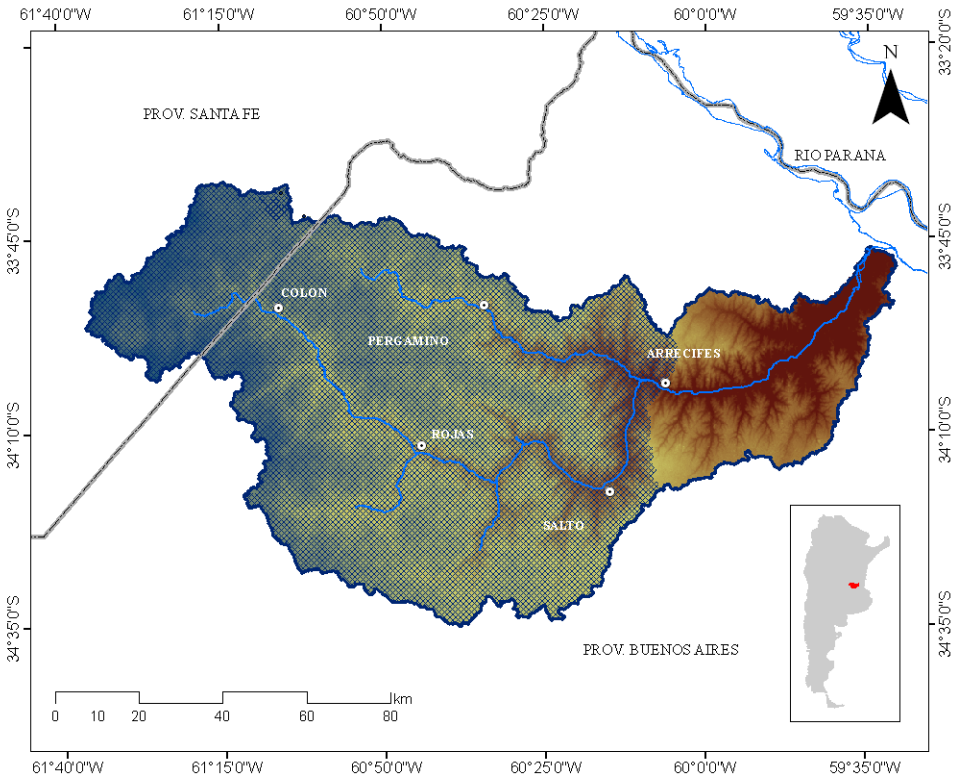
Agricultural drought

Agricultural droughts occurs when soil water content does not reach to cover the needs of crops in a particular period. This is a complex concept which depends on the kind of crop, as well as on other factors such as meteorologic, agricultural, environmental and anthropogenic.

Arrecifes basin

Location: North of the province of Buenos Aires and South of the province of Santa Fe

Outlet: flow gage (Estación balneario río Arrecifes – NH4035)



Area: 8,511 km^2

Topography: rolling plains

Height range: 77.5 m

Longitude of the basin: 176.9 km

Average slope of the basin: 0.4 m/m

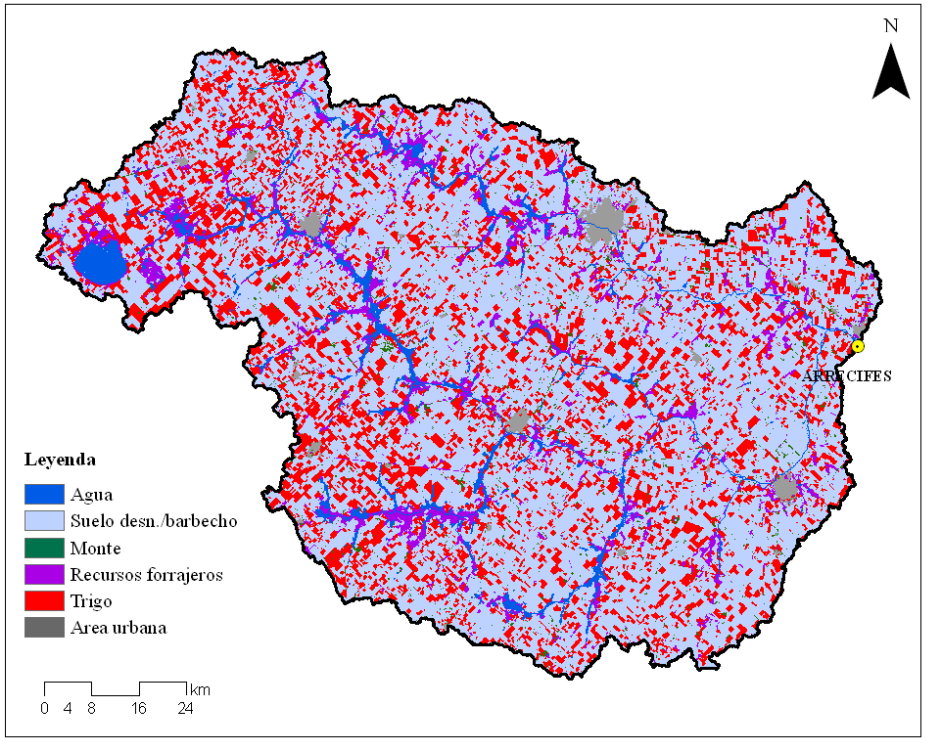
Average slope of the main channel: 0.00043 m/m

Arrecifes basin

Predominant land use: agricultural-cattle raising

Soil types:

PRINCIPAL ORDER	AREA (%)
ALFISOLES	0,4
MOLISOLES	89,2
Not classified	10,4



Climate: moderate-wet

Average annual precipitation: 940 mm

Oscilation of the average temperature: 23 and 10 °C

Invernal crops (wheat and mixture of pasture , oats and barley)

Hidrology: average annual flow module

is 21 m^3/s

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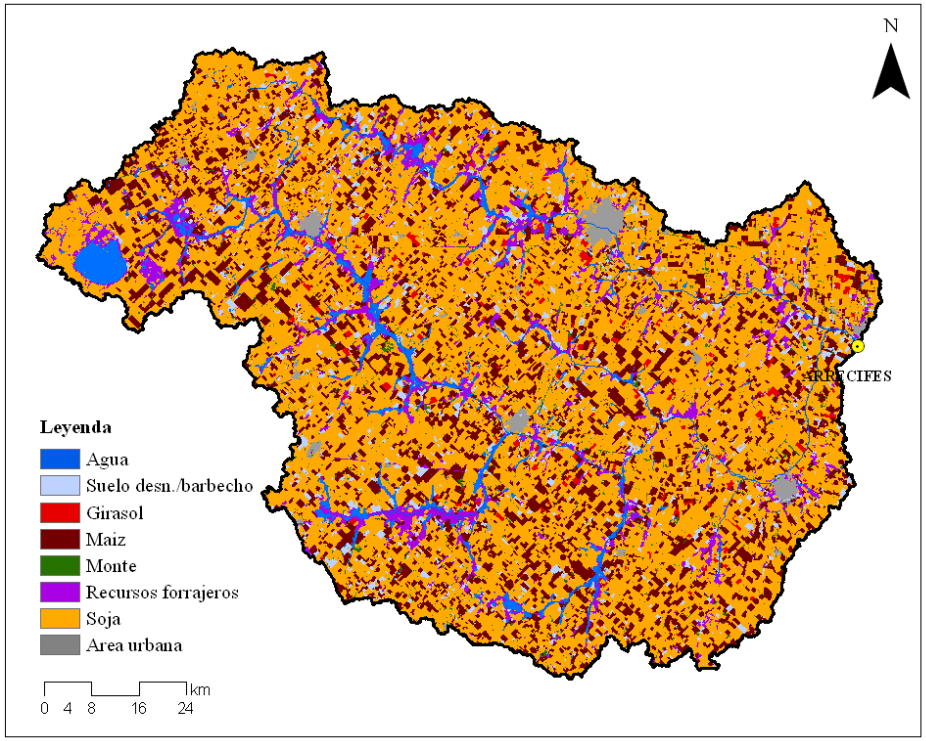

Summer crops (soybean, sunflower and corn)

Climate: moderate-wet

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Oscilation of the average temperature:

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Hidrology: average annual flow module is 21 m^3/s

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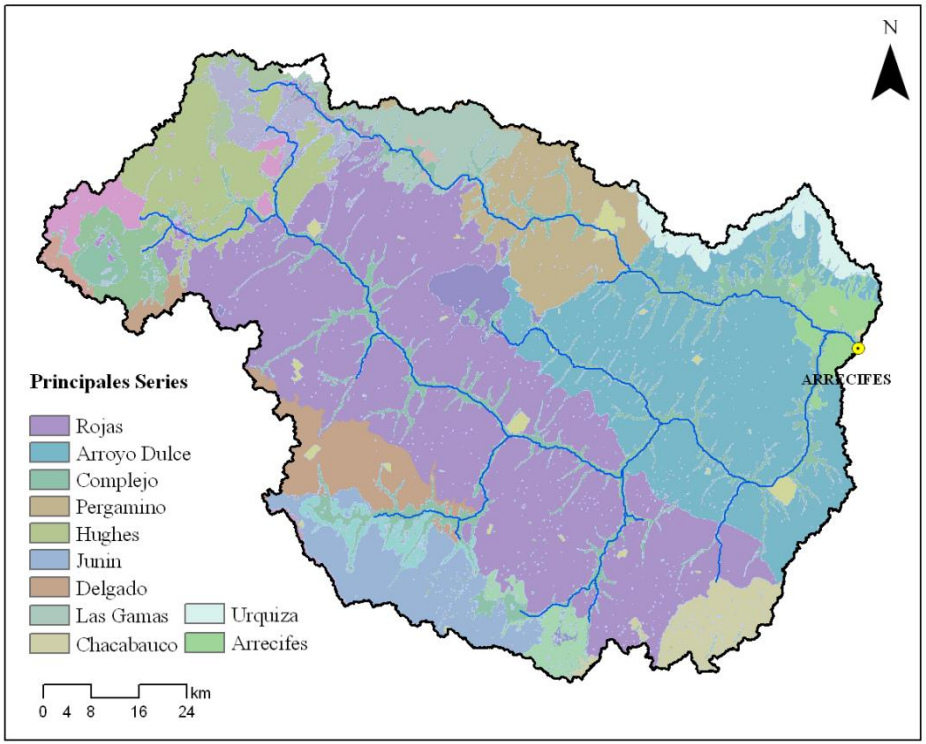

Soil map of the Arrecifes basin scale 1:50.000

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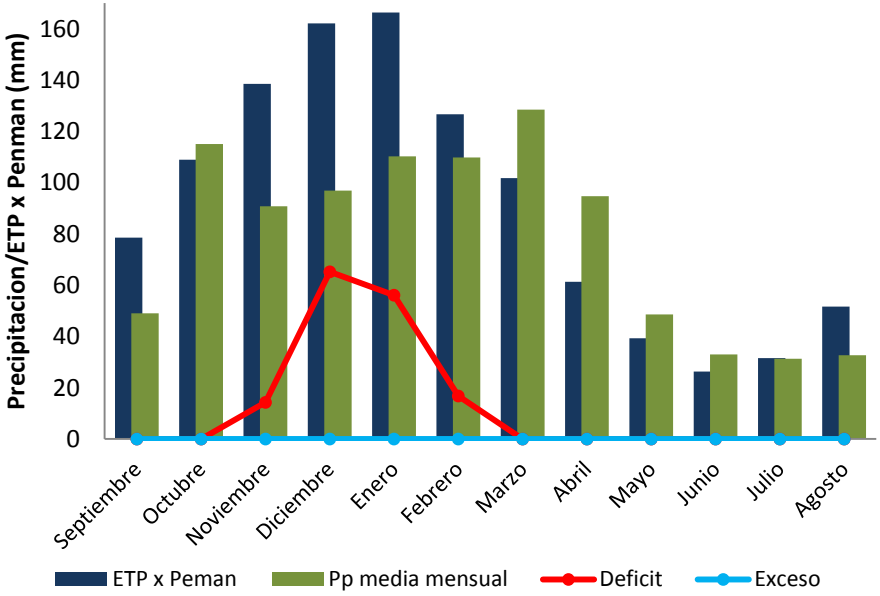

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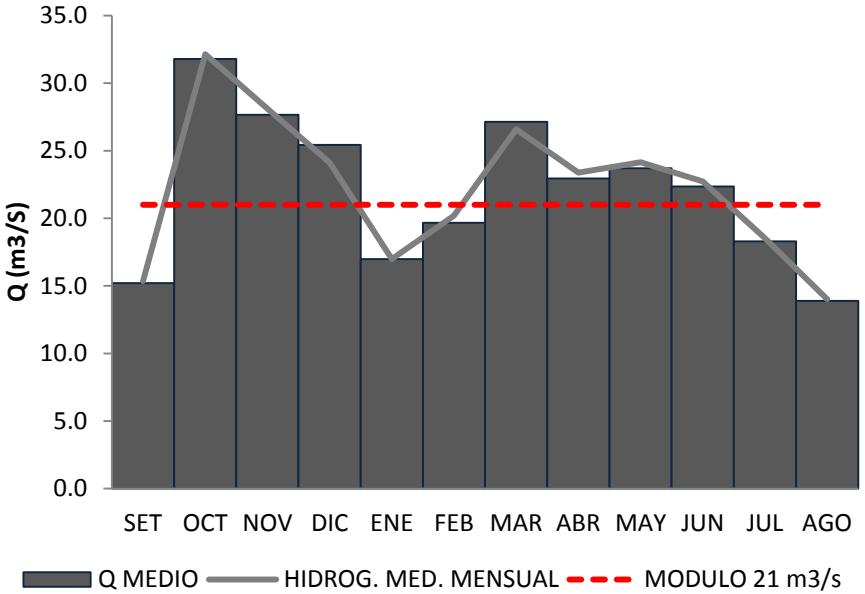

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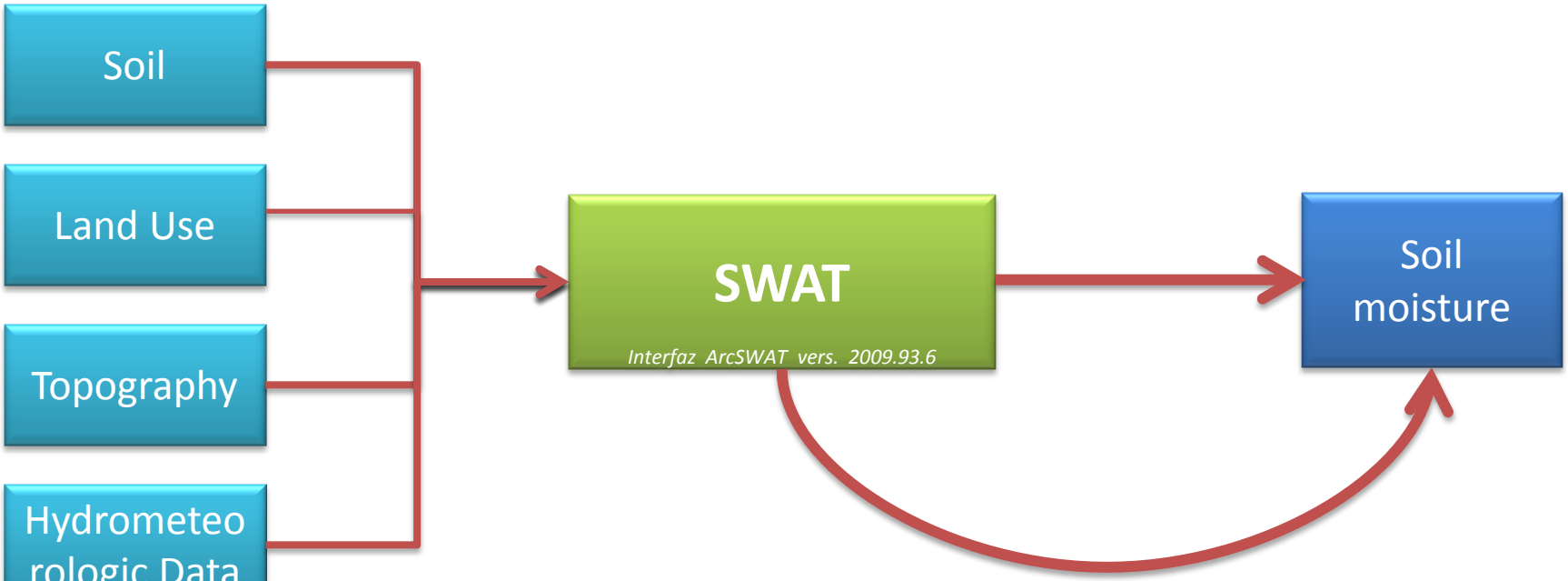
SWAT model

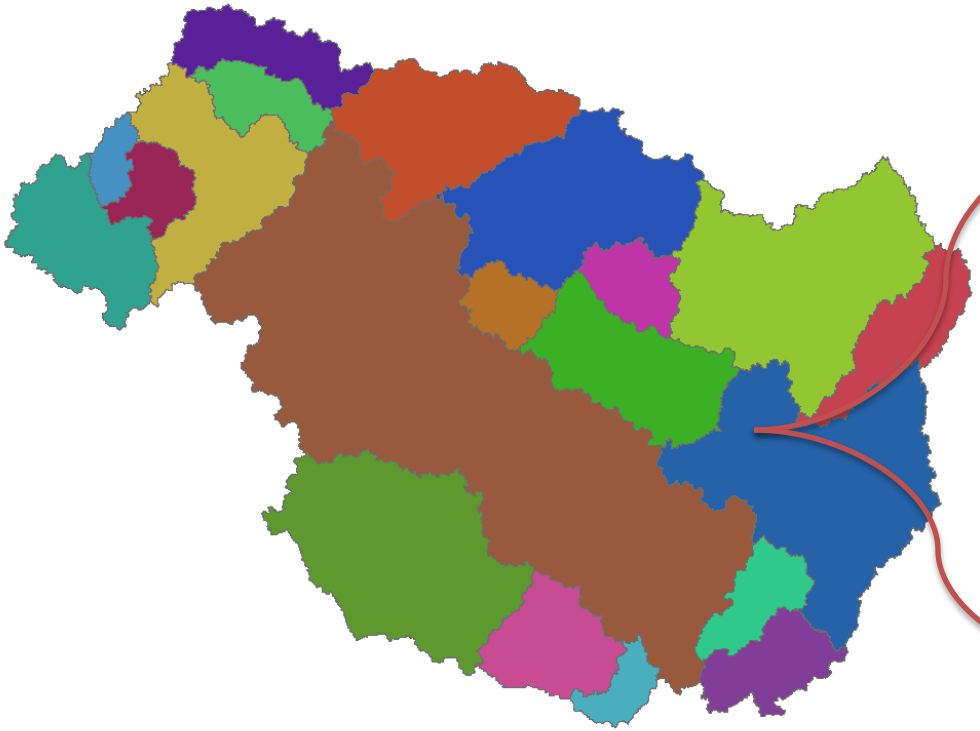


$$SW_t = SW_0 + \sum_{i=1}^{t} \left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw} \right)$$

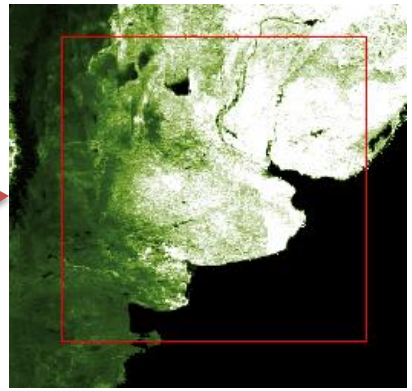
Where:

SW_t es el contenido de agua en el suelo el día t; **SW_0** es el contenido inicial del agua en el día i (mm); **t** es el tiempo (días); **R_{day}** es la precipitación diaria (mm); **Q_{surf}** es la cantidad de escorrentía diaria (mm); **E_a** es la evapotranspiración diaria (mm); **W_{seep}** es la percolación diaria (mm) y **Q_{gw}** es el flujo base.

Correlation between the simulated soil water content and the SPI/NDVI indexes

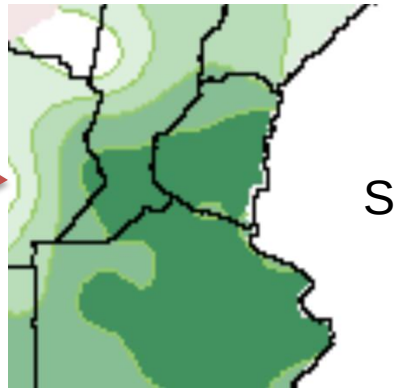


SIMULATED SOIL WATER CONTENT (SSWC)



NDVI INDEX

MONTHLY



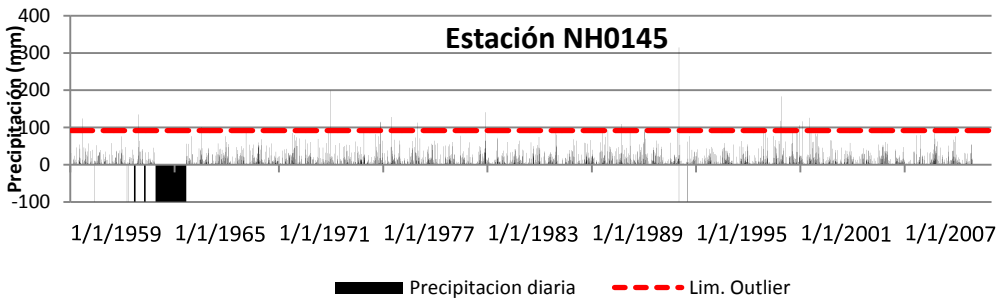
SPI INDEXI

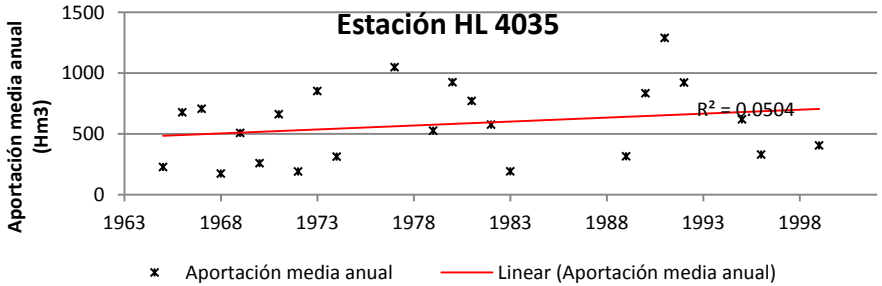
MONTHLY

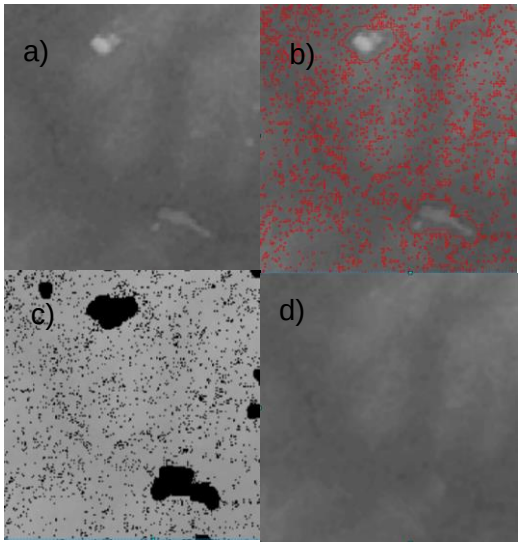
Las correlaciones se aplicaron sobre la anomalía NDVI y la anomalia de la humedad de suelo simulada.
Las correlaciones entre indices se realizaron para el periodo (1982-1998).

1. Input data to the model:

* Quality control of the hydrometeorologic data and database generation
* Development of landuse layer and database generation
* DEM (SRTM- 30m spatial resolution) by removing forest and other elevations not related to ground topography.
* Quality control of the soil layer and database generation

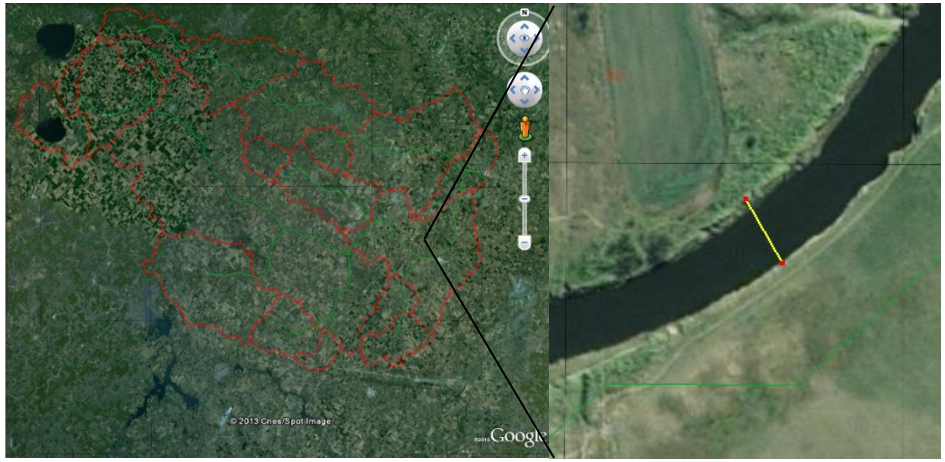






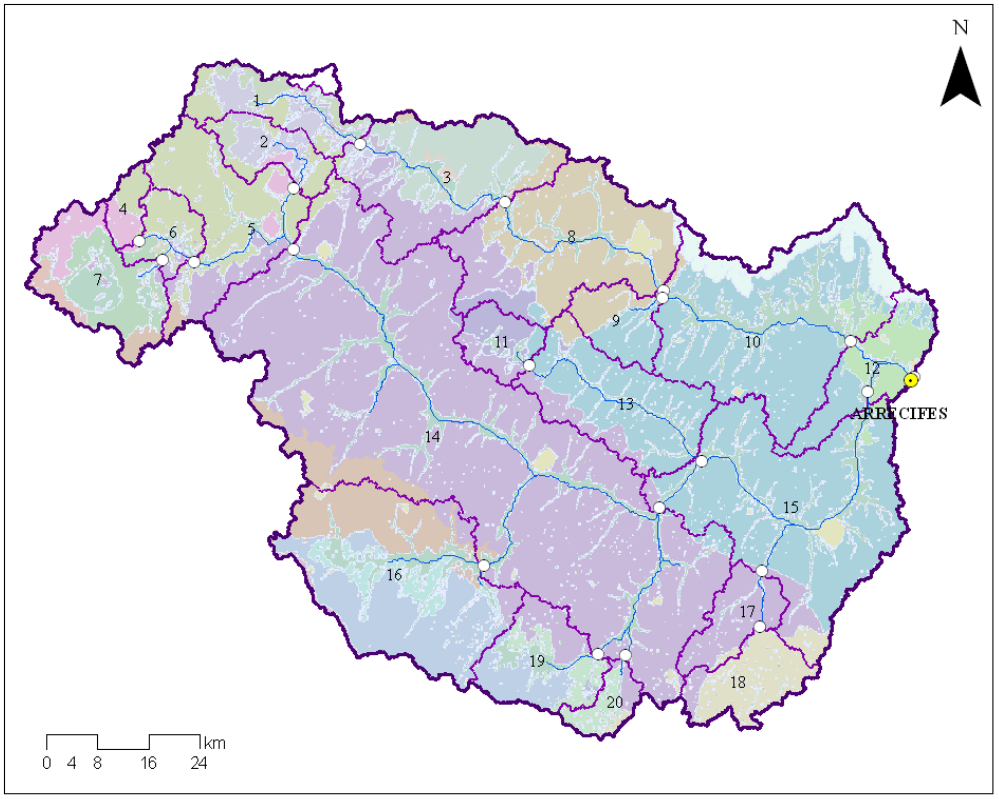
2. Input data to the model

- Characterization of conservation practices and definition of crop rotations. Generation of database.
- Search / data collecting of aquifers (for preliminary determination of the parameter ranges). Generation of databases
- Estimation of the morphologic characteristics of the channels. Generation of databases.

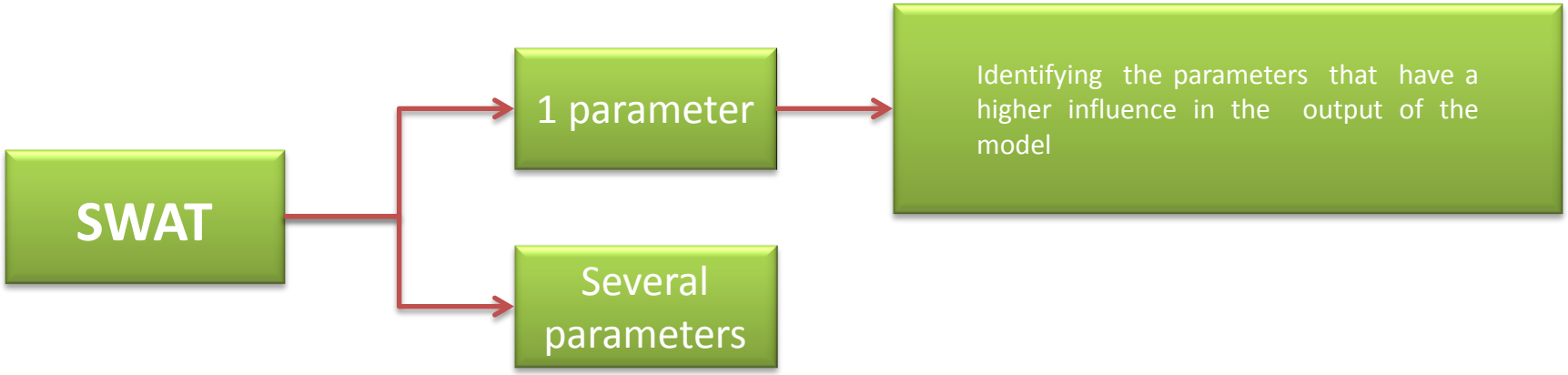


3. Basin model

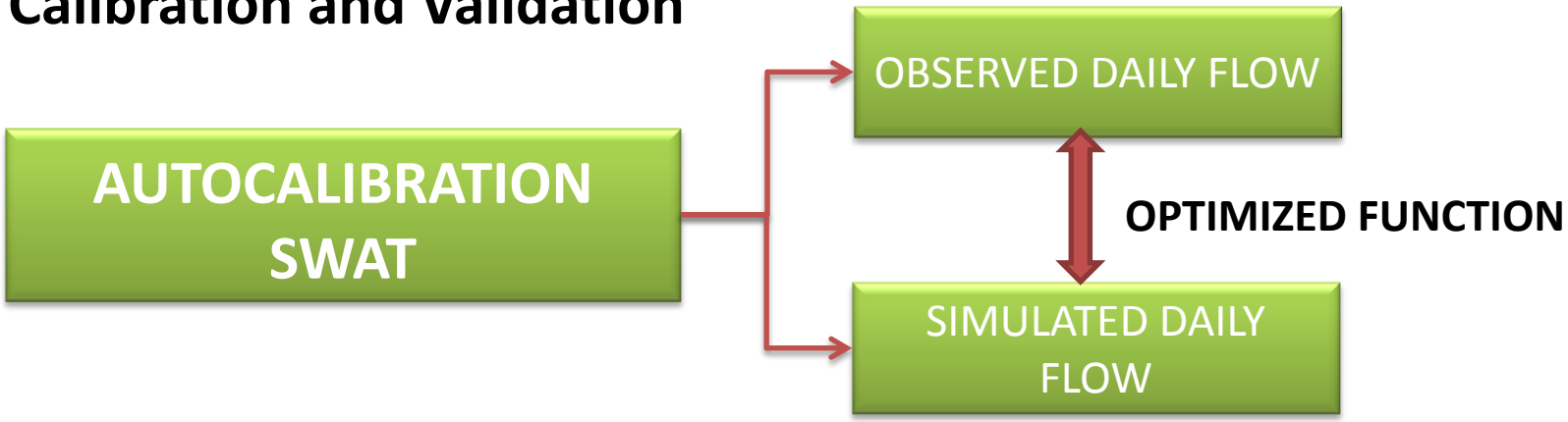
* The outlet of the model is located in the flow gage “río Arrecifes” N° HL 4035.
* Subbasins were delineated considering a threshold area of 550 ha
* 20 subbasins were obtained
* 337 HRUs were delineated



Sensitivity Analysis

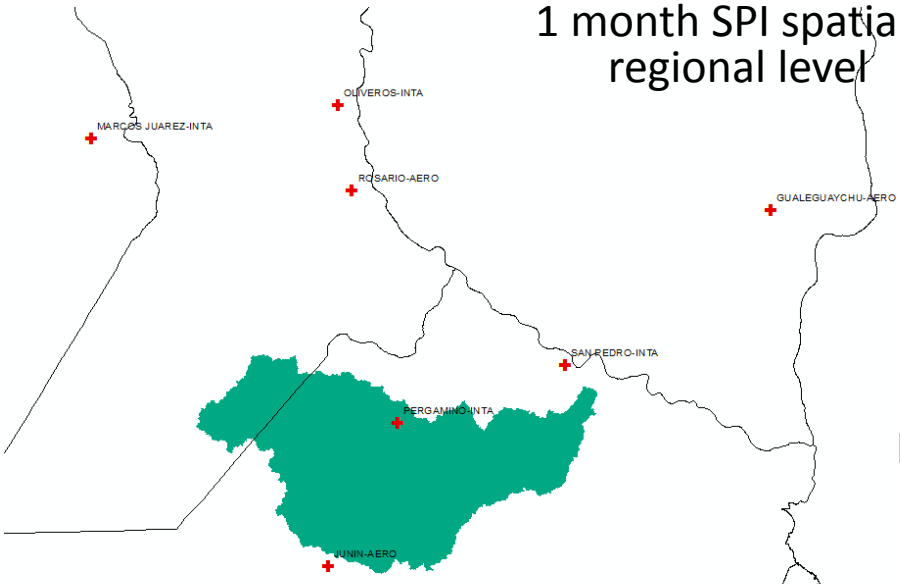


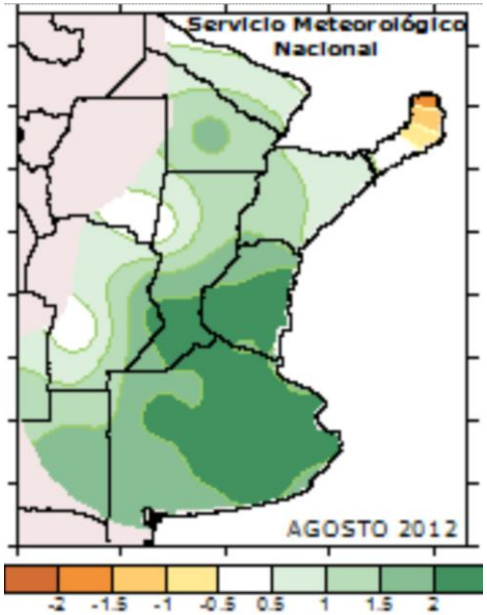
Calibration and Validation



SPI index

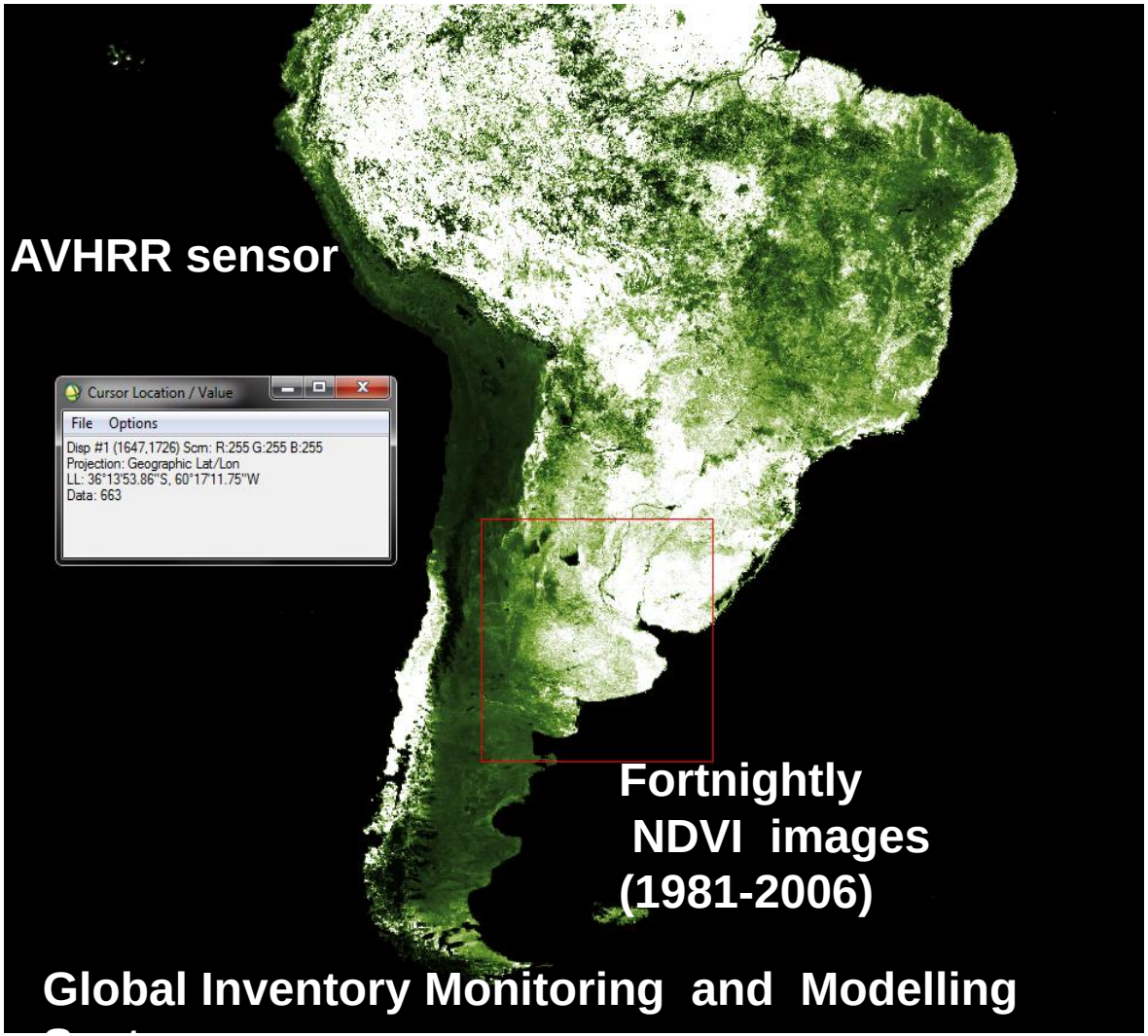
1 month SPI spatially distributed at regional level





SPI	Classification	Probability (%)
2.00 >	Extremely wet	2.3
1.50 to 1.99	Very wet	4.4
1.00 to 1.49	Moderately wet	9.2
0 to 0.99	Mildly wet	34.1
0 to -0.99	Mild drought	34.1
-1 to -1.49	Moderate drought	9.2
-1.50 to -1.99	Severe drought	4.4
-2.00 <	Extreme drought	2.3

NDVI index

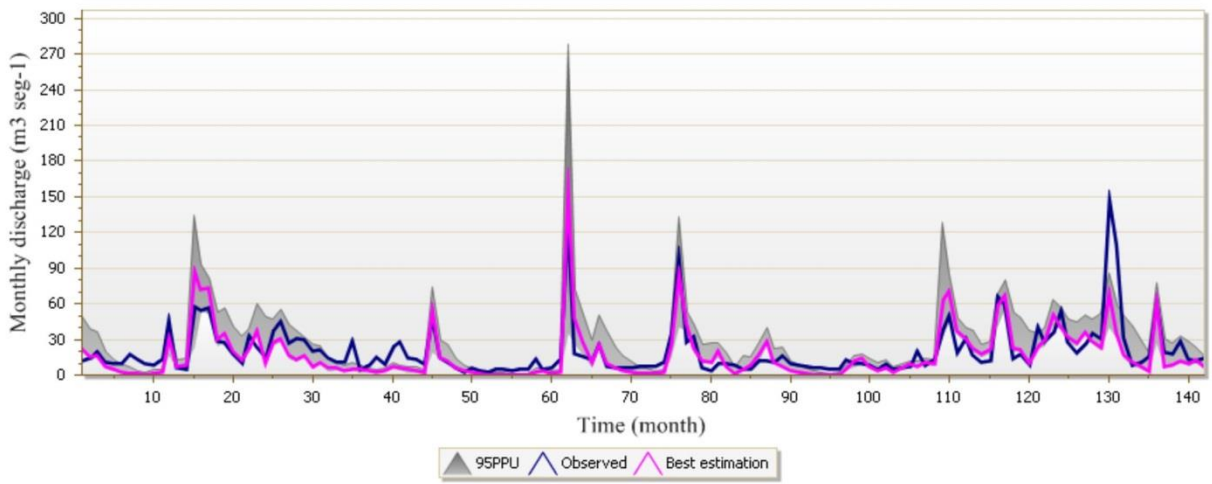

AVHRR sensor
Cursor Location / Value
File Options
Disp #1 (1647,1726) Scm: R:255 G:255 B:255
Projection: Geographic Lat/Lon
LL: 36°13'53.86"S, 60°17'11.75"W
Data: 663
Fortnightly
NDVI images
(1981-2006)
Global Inventory Monitoring and Modelling

Results

Calibration and sensitivity analysis

* Calibration period (1979-1992), including humid, normal and dry periods

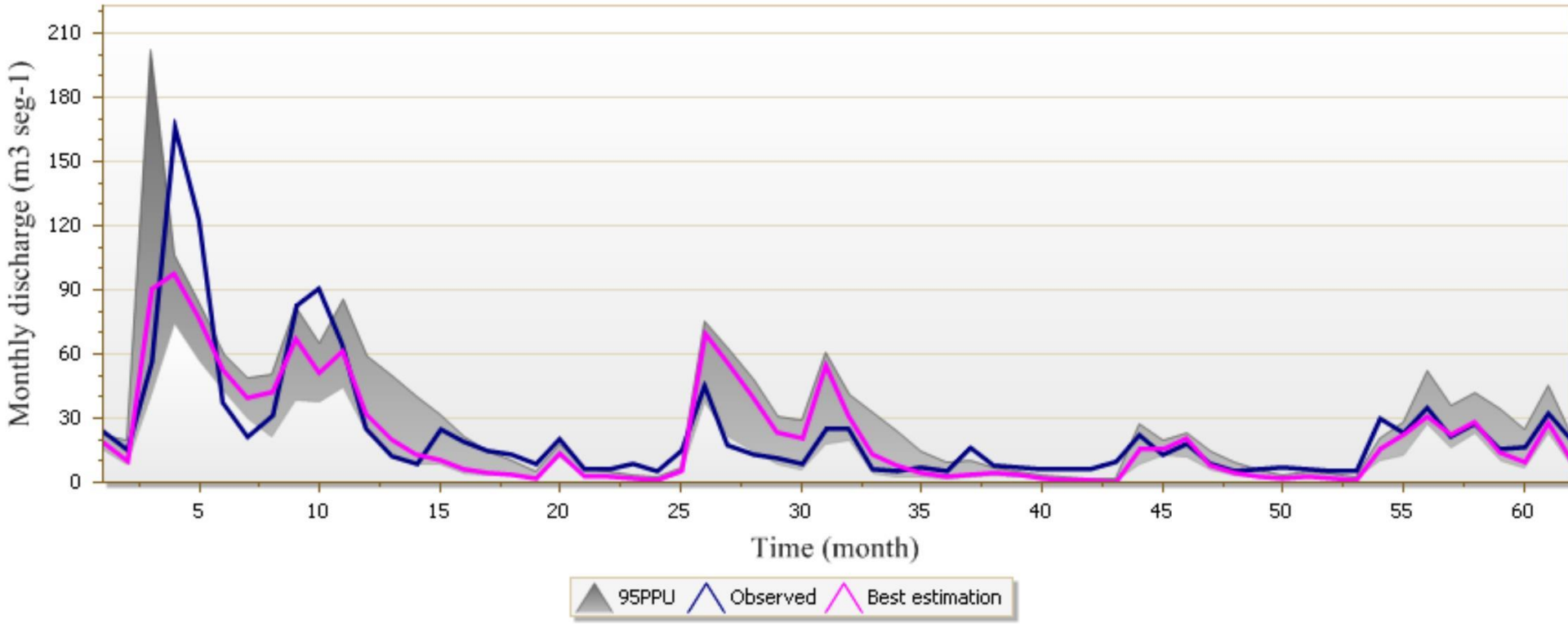
* Final optimization was achieved with 8 iteraciones (100 simulations for each one of them. R^2 =0.70; NS= 0.67



Validation

* Validation period (1993-1998), including humid, normales and dry periods.

* R^2 = 0.67; NS= 0.67

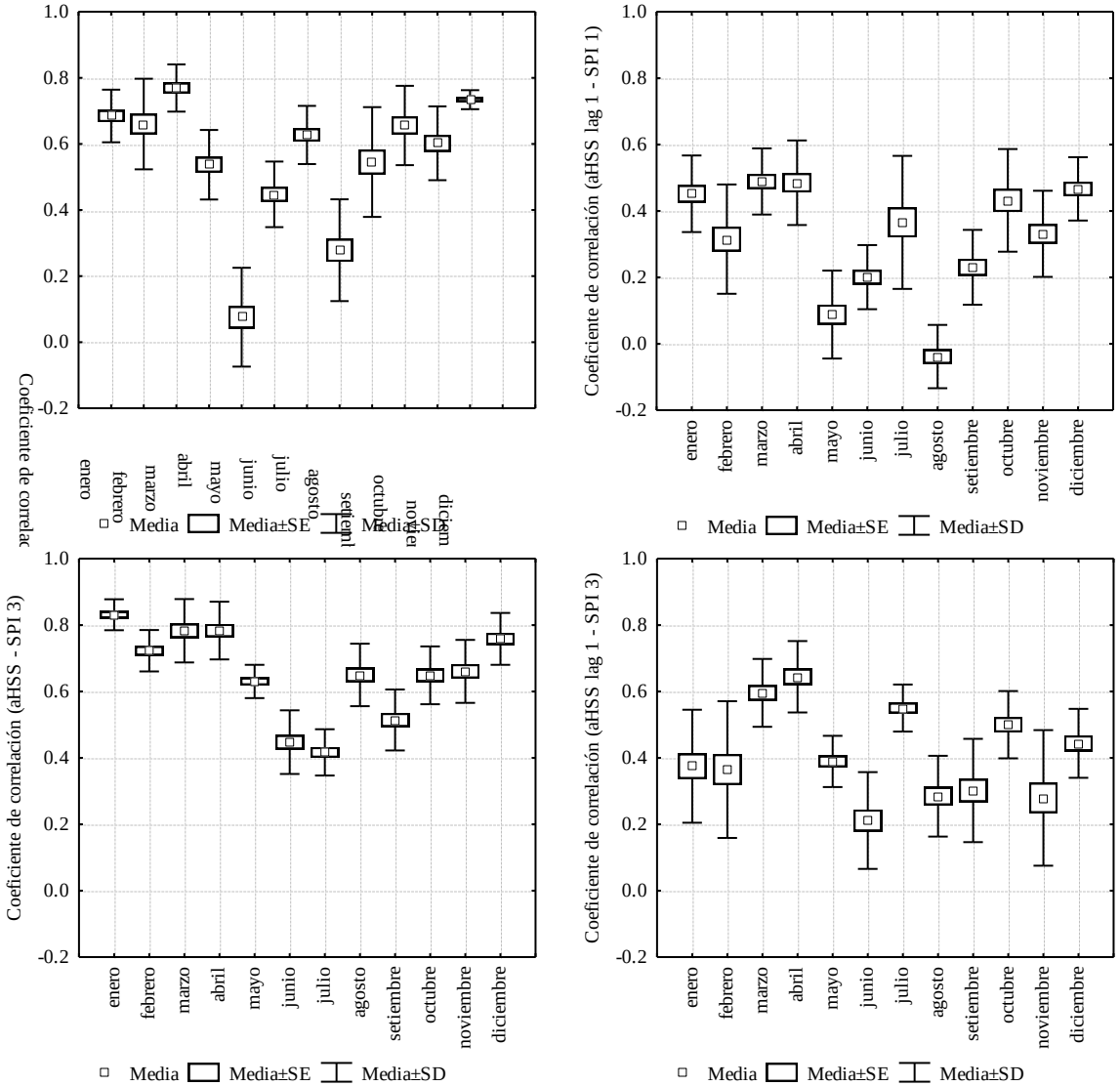


Correlation between the simulated soil water content (SSWC) and SPI

Correlations follow a seasonal patern

Higher correlations were observed between January-March and September-December, whereas lower correlations were obtained between april and september

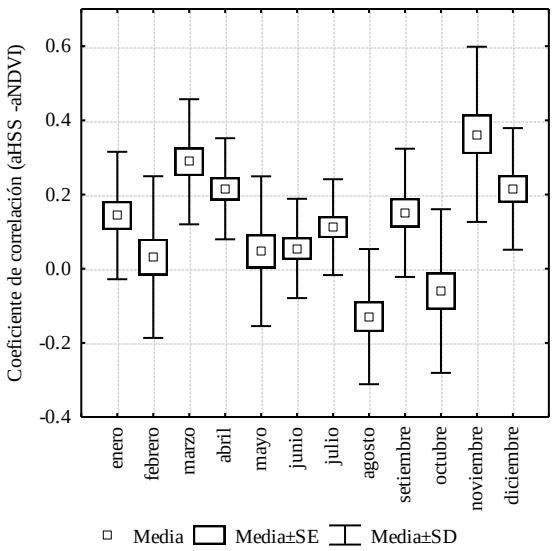
Better correlations were achieved considering 3 month SPI instead of 1 month SPI

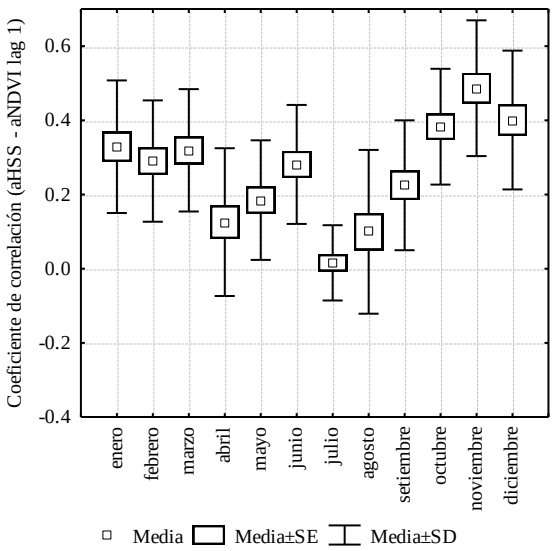


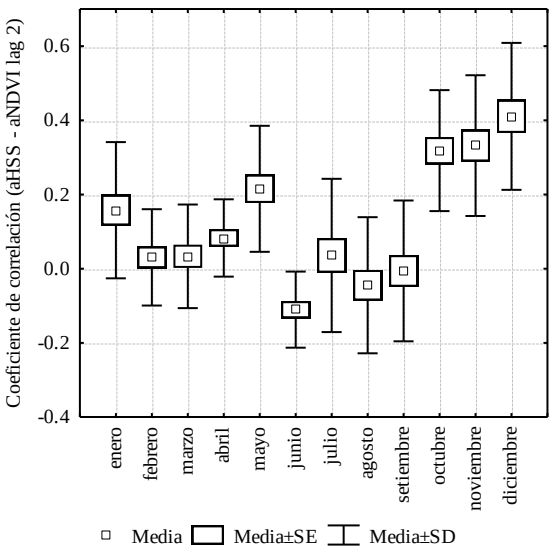
Correlation between the simulated soil water content (SSWC) and the NDVI index

Correlations follow a stational pattern

Higher correlations were observed between October-December, whereas lower correlations were obtained between april and september







CONCLUSIONS

- There was a good fit between observed and simulated flows. The greatest deviations were associated with major floods, in which the model underestimated the flow and was unable to simulate the multiple peaks in response to short and intense rainfall events.

- One of the main difficulties addressed in this research was that the calibration was performed for a single point. The above could lead to errors in the calculations of the different hydrological processes. Likewise, this may force that the fitting of parameters from calibration is achieved by sacrificing local physical ranges of some parameters.

- With proper parameterization SWAT could be applied to other similar rural watersheds in the Pampas. We also believe that the NDVI may has a good correspondence with simulation of SSM. However, the use of this index should be at such a spatial scale that enables to distinguish different types of crops, since each individual crop has its own growth cycle. Additionally, it is worth to note that when a crop is severely affected by hydric stress, another possibly may be less affected or directly it has not any affection at all