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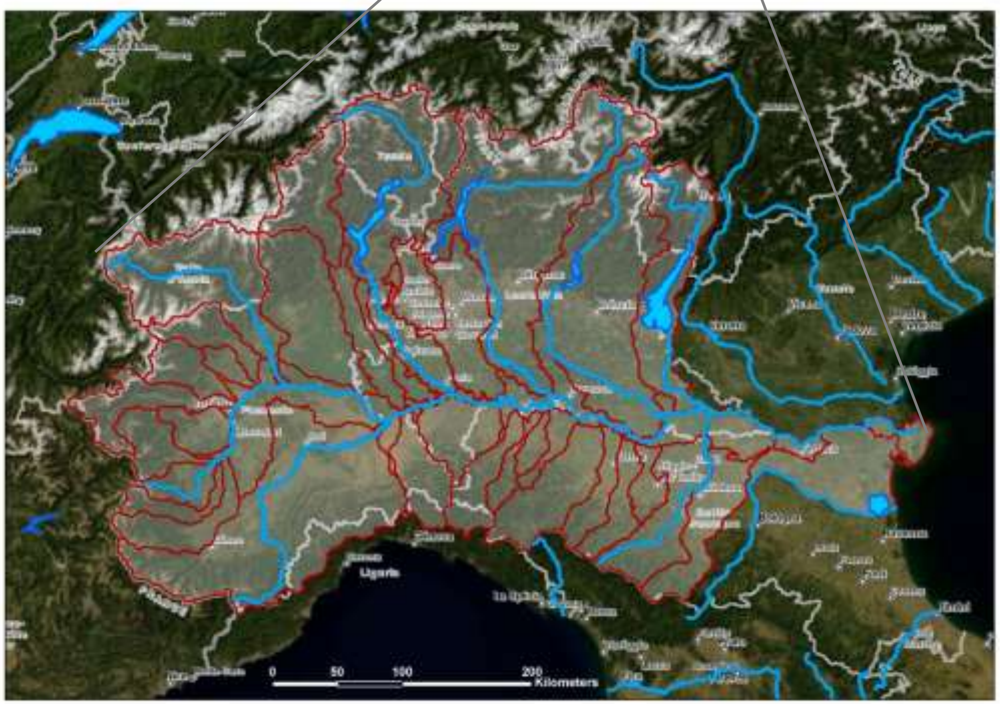
OBJECTIVES

- ✓ **arable land in Europe is a limited resource and agriculture will have to face more complex issues in the future due to climate change**
  - ✓ **Competition between food and biofuels**
  - ✓ **Water resources**
  - ✓ **Land use changes and limited land resource**
  - ✓ **Adaptation and mitigation strategies required**
  - ✓ **Environmental consequences**
- ✓ **under a changing climate, agriculture will also impact water resources in terms of quantity and quality**
- ✓ **in this context the SWAT hydrological model was applied to the Po river basin, a large agricultural watershed in Italy, to assess the impact on the water cycle and nutrient losses with respect to climate change risks and pressures.**

THE CASE STUDY AREA

The Po basin



Localization

- Large basin in the Northern part of Italy (surface of 71000 km^2)
- The main river is the Po river with an average discharge is 1500 m^3 sec^{-1} , and the basin is also characterized by a river network quite complex
- The basin drains into the North Adriatic sea in the Mediterranean Sea.

THE CASE STUDY AREA

The Po basin

Main characteristics:

- **Very intensive agricultural area in EU: 45 % is agricultural area; 33 % is forest and 16 % is pasture.**
- **Heterogeneous climatic conditions: Annual Rainfall ranges from 600 mm to 1800 mm (Avg 980 mm) and Avg temp is 13.9°C;**
- **High inputs: high density of population, high intensity farming (cattle)**
- **Intensive irrigation, water and reservoirs management**
- **Average nutrient loads are 170000 t y^{-1} N, 8000 t y^{-1} P and 13 Mt y^{-1} sediment**
- **One of the main source of nutrient loads to the Adriatic sea**

The Po basin

Landuse	*Area[10^3 ha]*	*%*
Forest-Deciduous	1511	21.1
Summer Pasture	1172	16.4
Common Wheat	702	9.8
Other crop	660	9.2
Corn	614	8.6
Forest-Mixed	455	6.3
Forest-Evergreen	376	5.2
Sorghum Hay	336	4.7
Range-Grasses	306	4.3
Residential-Medium Density	275	3.8
Rice	235	3.3
Range-Brush	181	2.5
Corn Silage	85	1.2
Quality Nineyard	68	0.9
Apple	45	0.6
Commercial	35	0.5
Soybean	28	0.4
Sugarbeet	20	0.3
Water	19	0.3
Vineyard	16	0.2
Tomato	16	0.2

Main agricultural crops :

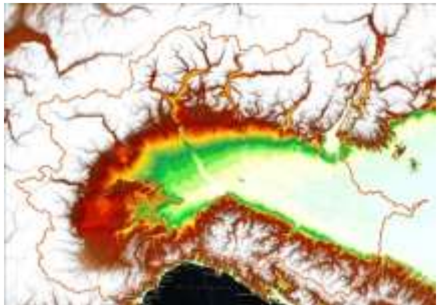
- **wheat, maize, fodder, rice, barley;**

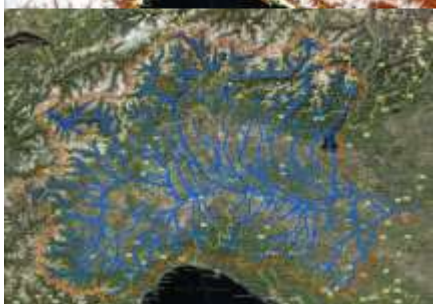
other important productions:

- **vineyard, horticulture and fruits.**

SWAT MODEL SETUP

DATA INPUT





•Digital Elevation map (**DEM)** with a resolution of 100m x 100m from a Pan-European DEM

•**SOIL** maps and data derived from the European soil database ESDB v2.0

•**Landuse** data from an European map of landuse including **crop distribution**

•**crop management**: the auto-fertilization and auto-irrigation options

• 5 big reservoirs were considered

• **daily climatic** dataset at 10’ resolution for model calibration

• baseline and **climate change scenario** (period 2001–2100) (The CC scenario is based on a one way-nested Climate Change Simulation, driven by ECHSAM5 data with the regional climate model REMO, under the A1B emission scenario)

•**Scattered dwelling and point sources** were entered for each sub-basin. These data were derived for all Europe for year 2000

SWAT MODEL SETUP

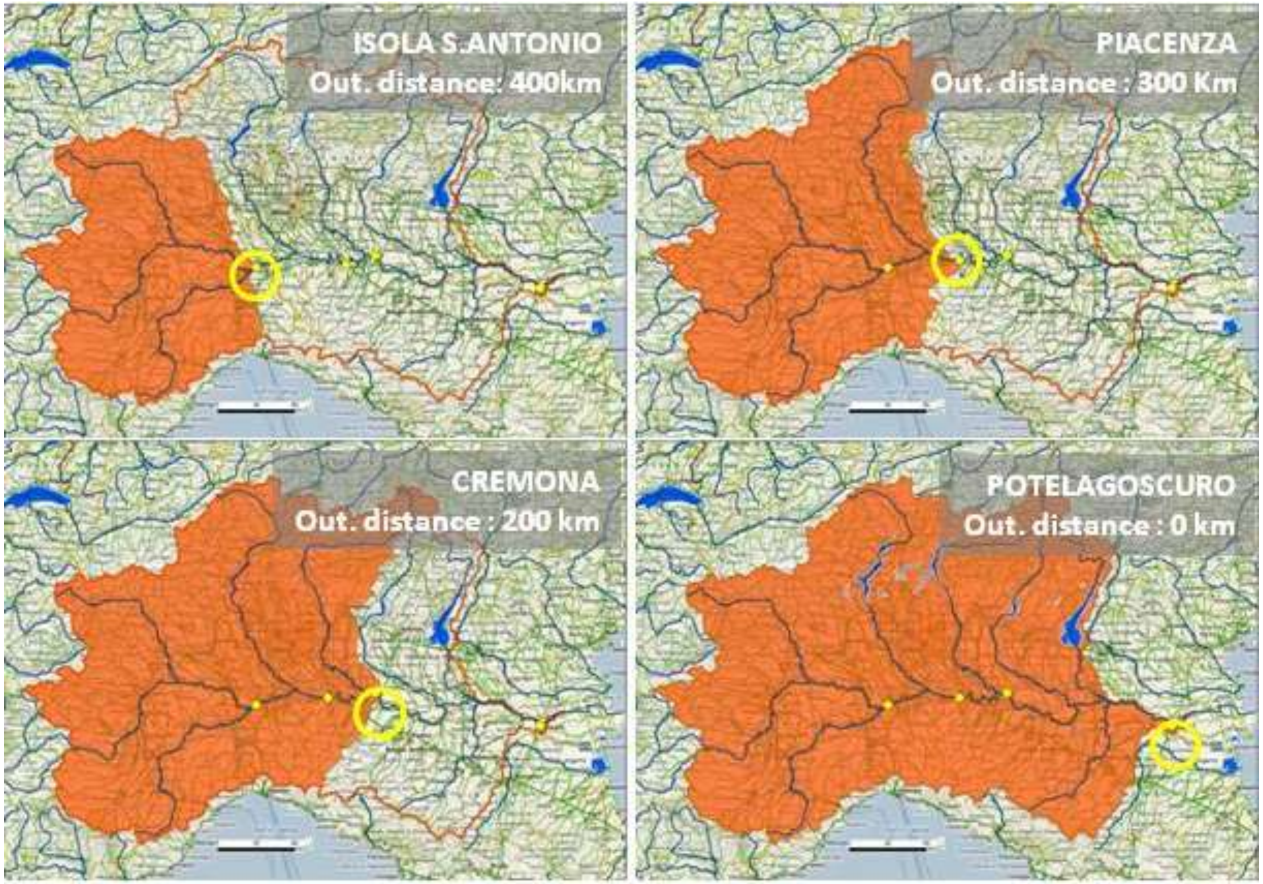
- Automatic Watershed definition : 423 basin identified (avg surface 170 km^2)
- HRU definition by combination of soil, landuse, slope resulted in 3374 units
- Import of REMO grids and daily data for BASELINE and CC (126 stations)
- Monitoring points for model calibration (water quantity and quality data limited to N and P data; no data for sediments).

Calibration

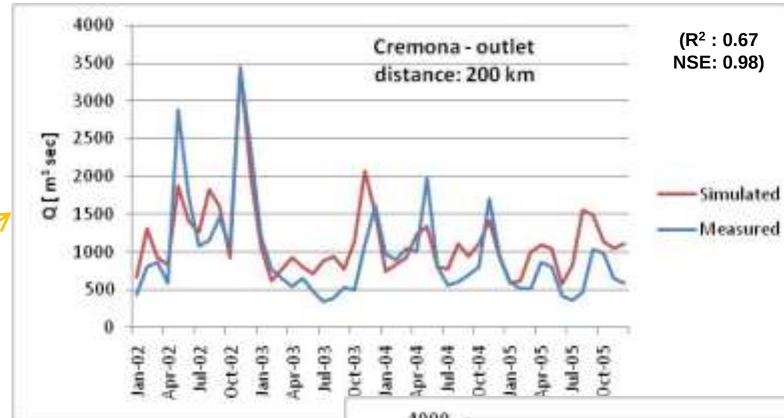
- For the model optimization the model was applied for the period 2000–2005 (well covered with complete measured data series)
- SWAT-CUP tool and manual adaptation were applied for calibration
- Most sensitive and calibrated parameters for the case study area:
  - Temperature controlling snow fall and melting [SMFM, SMFMN, SFTMP and SMTMP];
  - Curve Number [CN2];
  - Soil retention and permeability parameters [SOL_AWC, SOL_K , SOL_BD];
  - Groundwater parameters for baseflow [ALPHA-BF, GW_DELAY, GW_REVAP, GW_QMN, RCHR-DP]
  - Channel parameters for channel dimension, roughness and others char. [CANMX, CH_N2, CH_K2, ADJ_PKR[;
  - Soil water evaporation and plant uptake coefficients (EPCO, ESCO);
  - reservoirs parameterization (max water outflow, RES-RR]

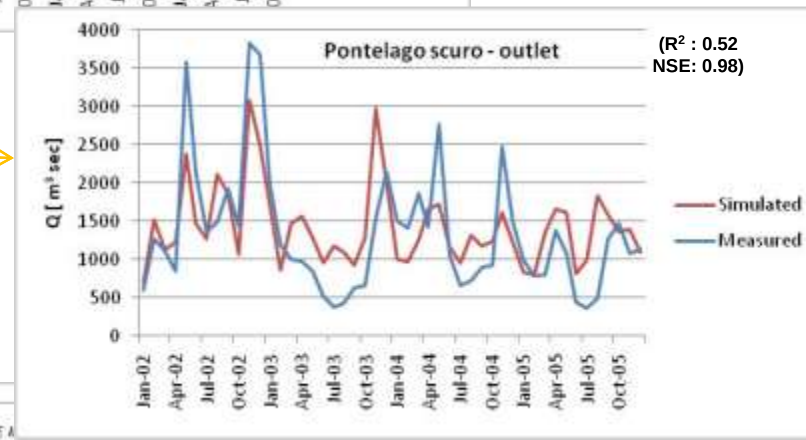
Calibration

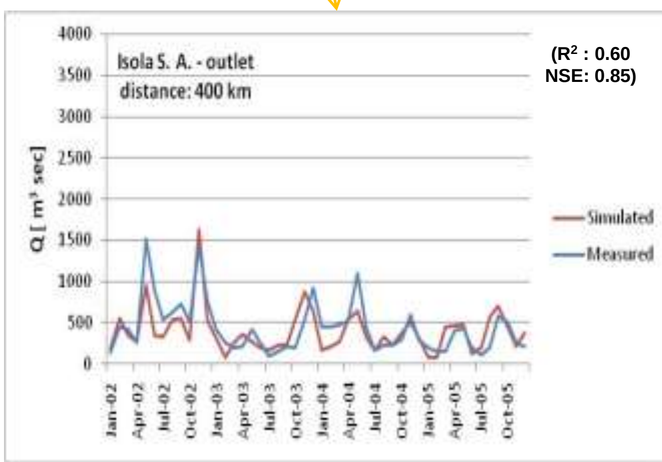
- 4 monitoring stations along the Po river were used

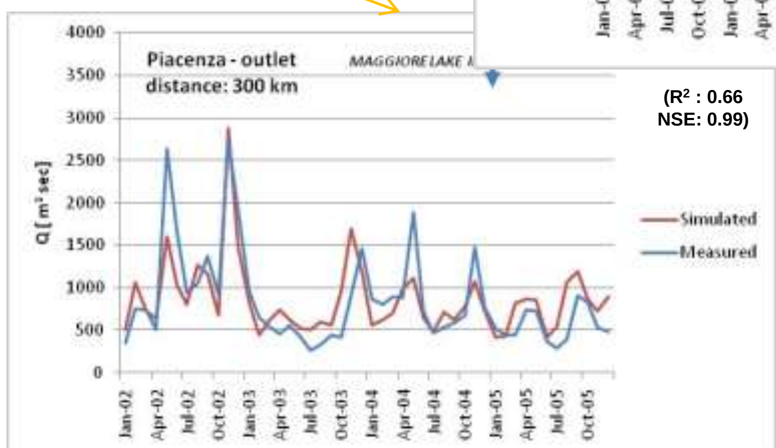


Calibration: Streamflows



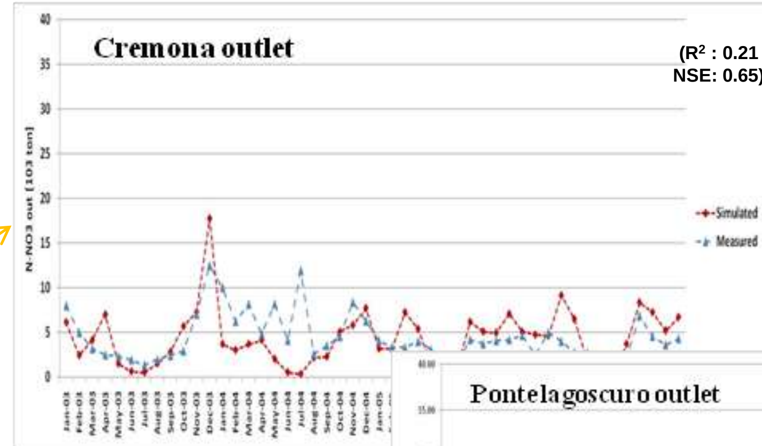


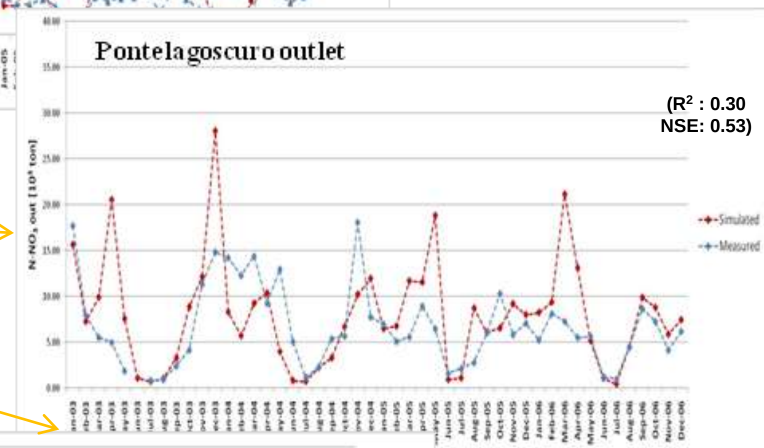


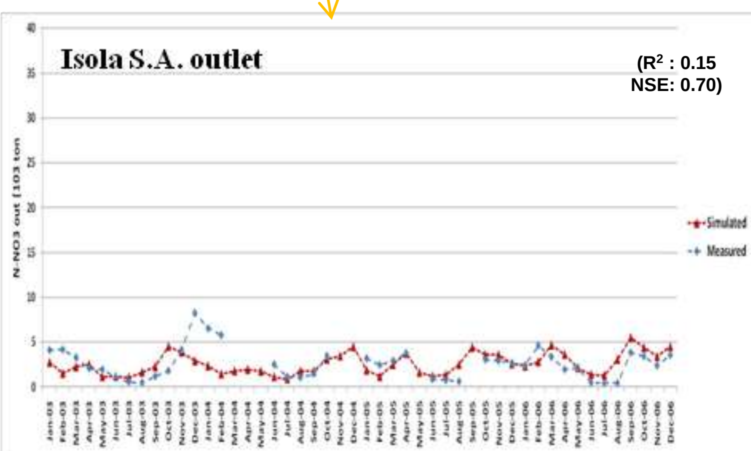


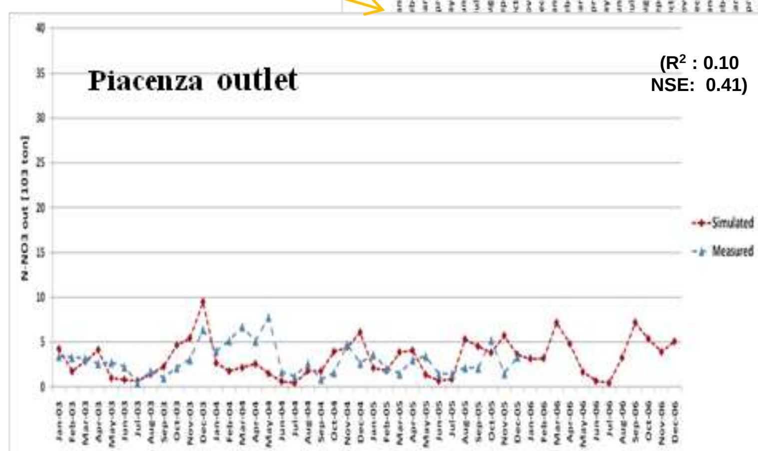
SWAT MODEL SETUP

Calibration: Nitrogen concentration





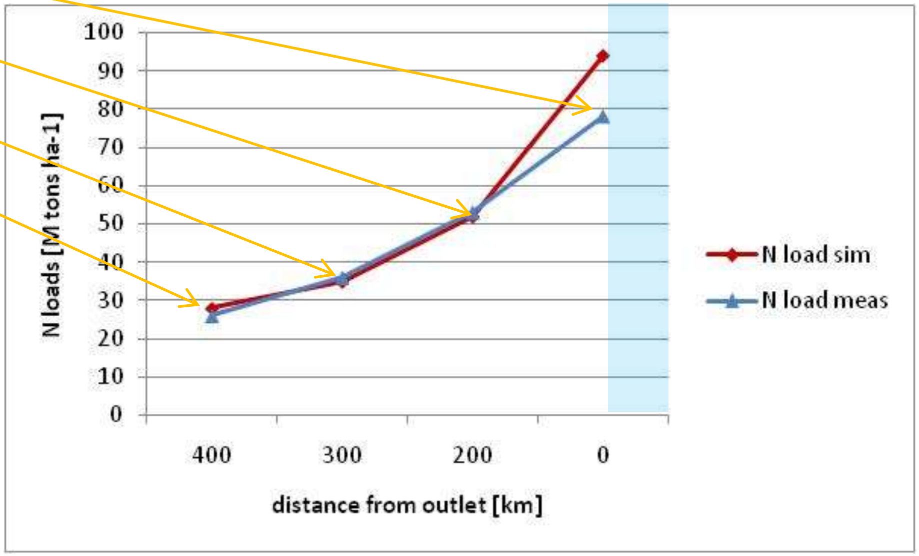




Calibration: Nitrogen loads

N loads [river 10^6 ton y^{-1}] measured and simulated in the PO

Year	400 km		300 km		200 km		0 km	
	Sim	Meas	Sim	Meas	Sim	Meas	Sim	Meas
2003	27.8	33.1	38.8	32.6	57.8	51.5	116.0	73.6
2004	26.1	22.0	29.9	44.5	40.8	79.3	73.4	108.5
2005	30.3	23.2	37.9	31.2	50.7	41.7	95.8	68.8
2006	39.3	29.0	45.9	na	58.9	41.2	94.9	64.8
Average	30.8	26.8	35.5	36.1	52.0	53.4	95.0	78.9



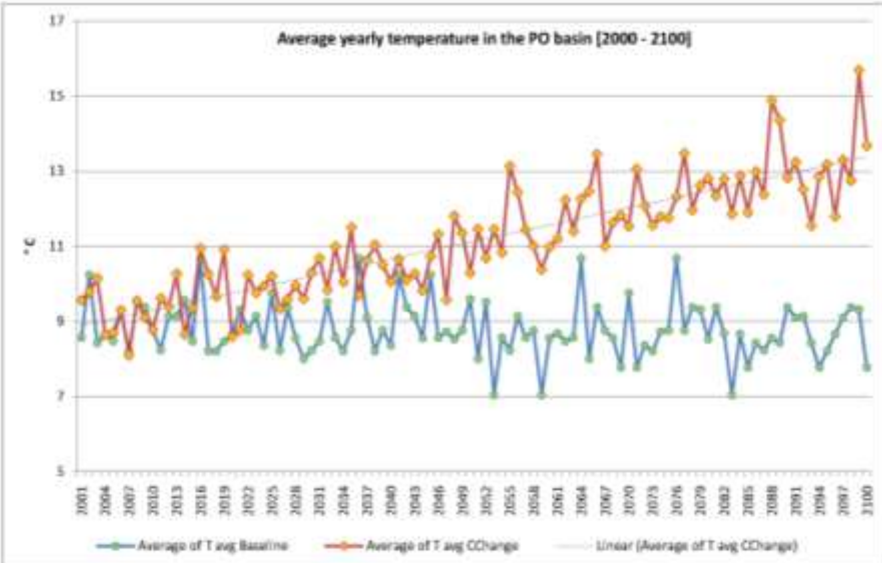
CLIMATE CHANGE

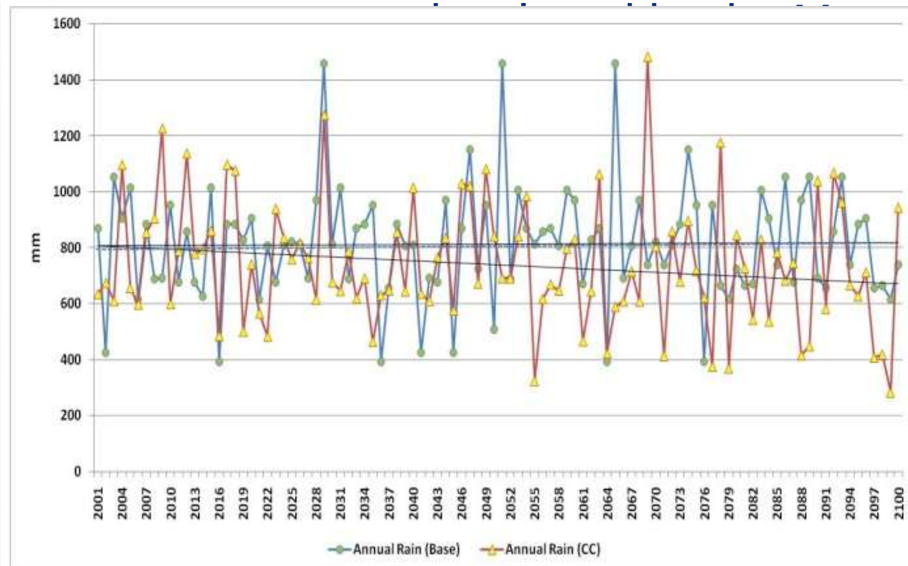
- Once optimized the model was applied with REMO meteorological dataset to assess up- and down-stream effects of Climate Changes on the water and nutrient cycles

- Crop management is defined as automatically optimized in order to assess the impact of “automatic” mitigation strategies (ex: if more water stress occurs due to climate change the model will apply more water in order to maintain optimal yield and thus reducing losses)

- Impact of climate change and adaptation on the environment (leaching, nitrogen loads)

CLIMATE CHANGE





- temperature will increase by 4°C by year 2100. It is also predicted a decrease of annual precipitation with larger inter-annual fluctuations and the occurrence of extremely dry years

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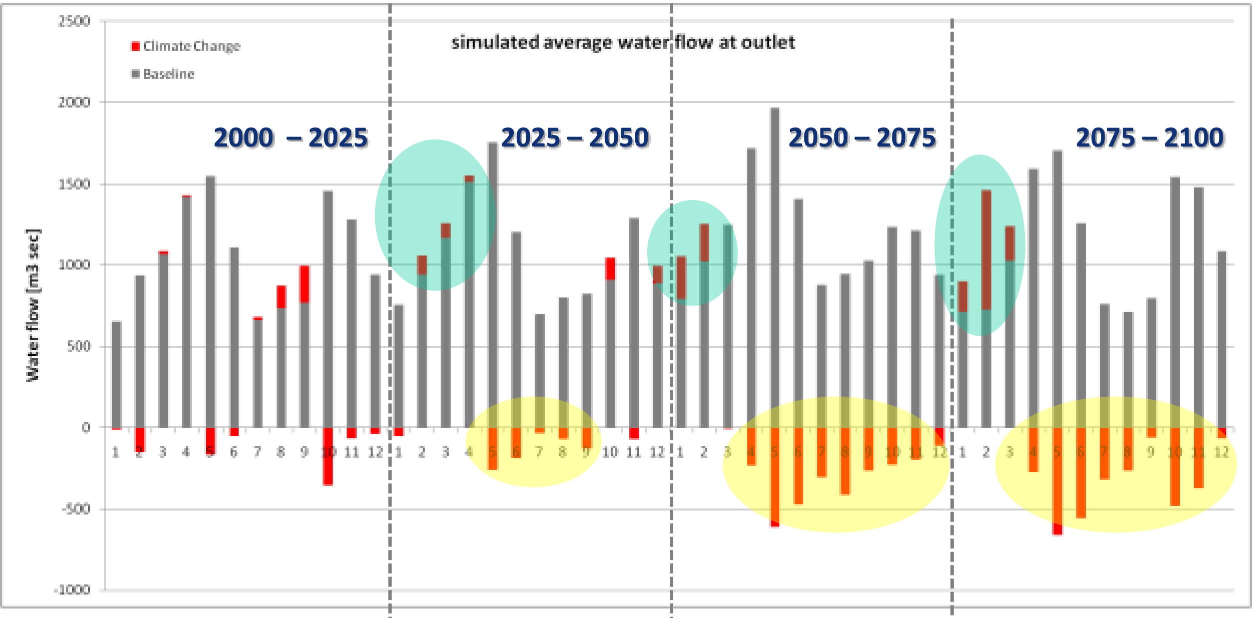
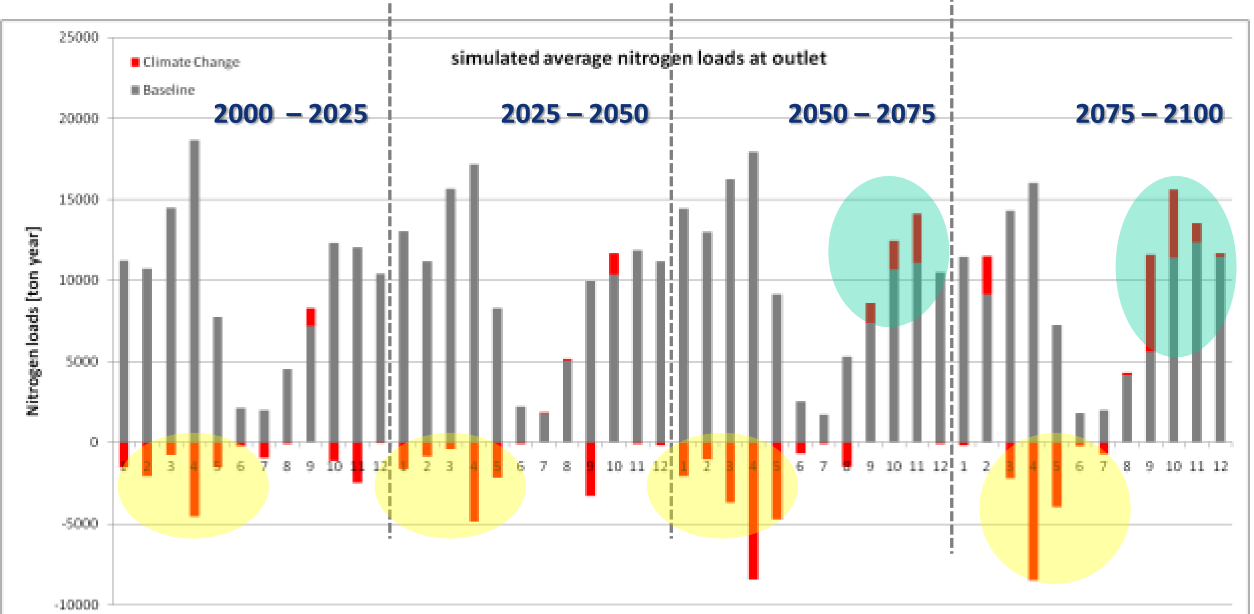
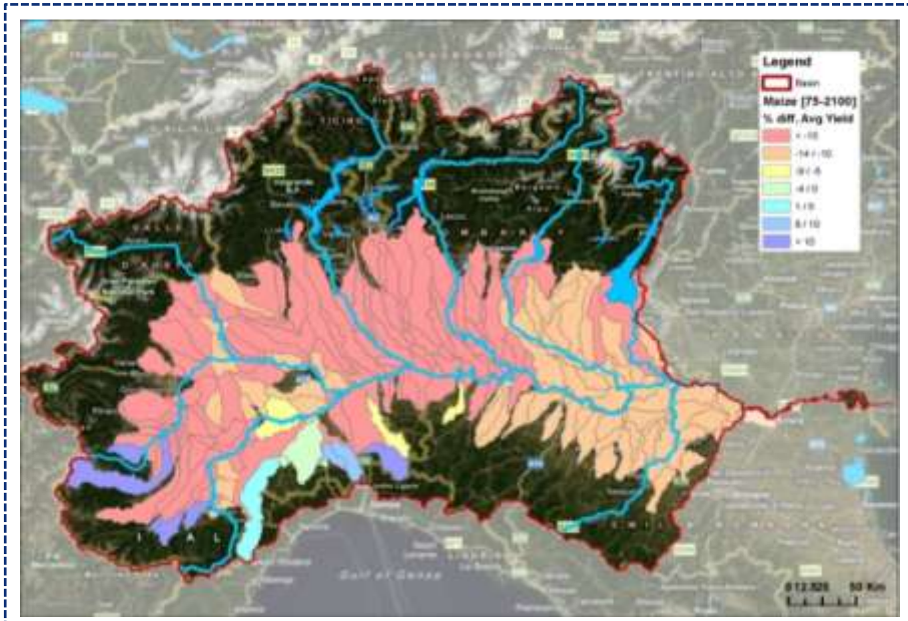
CLIMATE CHANGE

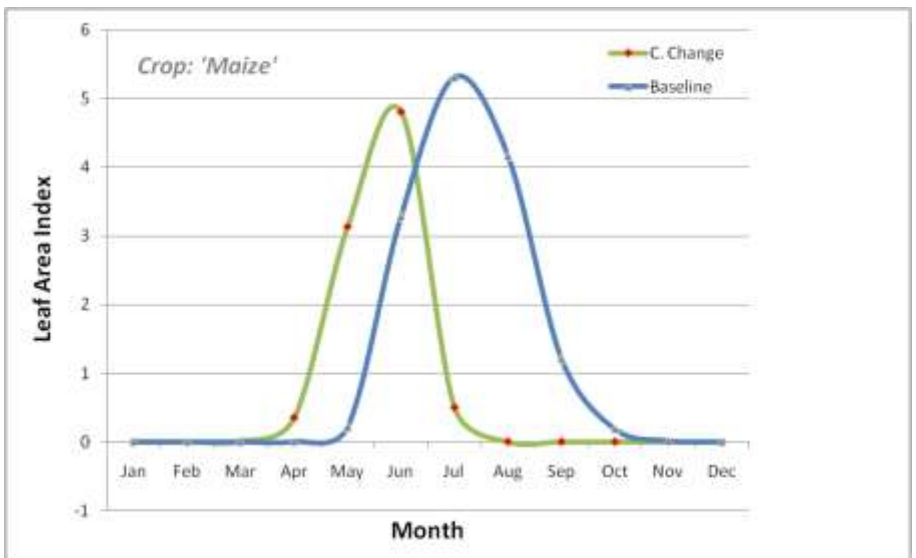


✓ Average annual water flow at outlet basin decreases
✓ Higher and earlier snowmelt
✓ Total runoff is lower in last periods due to higher temperatures, earlier snowmelt, and lower precipitation, nut it can be anticipated
✓ Water flow and availability is lower mainly during summer season when is required by crop management irrigation practices



✓ due to annual water flow decrease also tot nutrient loads decrease
✓ nutrients loads are similar to baseline scenario, generally lower (N loads -1.6% in the 75-100)
✓ there is a redistribution of nitrate losses (lower in spring – summer higher in autumn → N Min)
✓an increase in nitrogen leaching losses is also observed in agricultural areas





CC impact on crop Yield

✓ Maize is one of the main crop in the basin an it is sensitive to CC
✓ It is irrigated and fertilized
✓ For the last CC period (2075-2100) the effects are much more evident: the average yield decrease is -13.4%, with an increased irrigation (7.6%) and N leaching loss (+40%)
✓ in the warmer period (75-2000) auto-irrigation consumes all water available for irrigation in the aquifer: so we used an unlimited irrigation source to simulate a strategy of maintain crop yield (yield reduction with limited irrigation source is -18%)
✓ N leaching increase is quite high (10.8 → 15.3 kg ha^{-1}) probably because of more irrigation /percolation and less crop uptake

✓new strategies would be required un climate change
✓ ws days are higher under cc also increasing water use
✓ new crop types and management will be required (shorter period of growing season, see LAI)

CC impact on crop Yield

- ✓ **Other important crops in the basin are wheat, sorghum and rice**
- ✓ **Under CC scenario there is also a general yield decrease: more important for sorghum (-16%) and rice (-18%) and lesser for wheat (-13%) [average loss is 0.5 t ha^{-1}]**
- ✓ **N leaching decrease in the case of wheat**
- ✓**for rice and sorghum there is an increase but it is not significant**
- ✓ **Irrigation with rice increase (+13%)**

CONCLUSIONS

- **The model was successful in reproducing water and nitrogen flow in the basin**

- **Under the CC scenario (A1B driv.) there is a decrease of the annual water flow by 1.8% in the period 2025-2050, 14% in the period 2050-2075 and 8% in the period 2075-2100, however with important seasonal variation (flow increases from Jan to March and decreases in July-Aug and Oct-Nov ;**

- **CC scenario points out a decrease in Runoff (-4% in 2000-2050 and -17% in the 2050-2100);**

- **Nutrient and sediment river loads are generally lower for this CC scenario, but there is an increase in nitrogen leaching (much more evident in intensive agricultural area);**

- **Irrigation practices can reduce crop yield loss, but impacting on limited water resource (even more scarce) and increasing nitrogen leaching;**

- **We should consider other CC scenarios (not yet available at this stage)**

- **Another important issue will be the inclusion of landuse change linked with cc in order to consider possible trade off effects**

Acknowledgements

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