Managing water ressources within Mediterranean agrosystems bu accounting for spatial structures and connectivities - ALTOS

Task 4.2: Impact assessment and scenario ranking

Leader: INRGREF, Insaf Mekki

KOM ALTOS
Visio-conference

May 25-26, 2021

WP4 “Simulating fluxes and storages for possible structures modulations” combines outcomes from WP1 and WP3.

Simulations are translated into indicators for integrated analysis with stakeholders during participative seminars

WP4 also includes a cross-analysis for irrigated and rainfed agrosystems, by comparing vulnerabilities and adaptabilities on the basis of indicators related to water availability and agricultural yield.

All partners except IRTA and UNICA contribute to Task 4.1. & 4.2.

Sites for integrated analysis: **Cap Bon, Merguellil, Tensift**, *Litani*

Task 4.2: impact assessment and scenario ranking

• Stage 1: ***selection of integrated modelling schemes*** (**OpenFLUID** including MHYDAS and Aquacrop, **SWAT,** SAMIR-WEAP-MODFLOW, **SAFRAN-ISBA-MODCOU**), including as much as possible the improved versions discussed in WP3.

• Stage 2: **simulations** with integrated modelling schemes on the basis of scenarios.

When possible, runs of different schemes over a unique scenario for comparison purposes (e.g., benefit of OpenFLUID that explicitly accounts for spatial connectivities as compared to SWAT).

• Stage 3: production of indicators on the basis of integrated modelling simulations.

o **Panel of indicators** (depends upon modelling schemes): yield and water use efficiency, catchment outflow, aquifer refill (assumed to be equal to percolation losses), dam silting-reduced storage capacity (suspended matter within catchment outflows), as well as contents in chemical pollutants within soils, aquifers and surface reservoirs.

o Temporal scales: **daily / monthly / annual values, harvest time values**

• Stage 4: **Ranking scenarios**, on the basis of simulations-based indicators, during participative seminars with national / regional directorates (DG-ACTA, DG-BGTH, DGRE, CRDA, ABHT, ORMVAH, farmer associations).

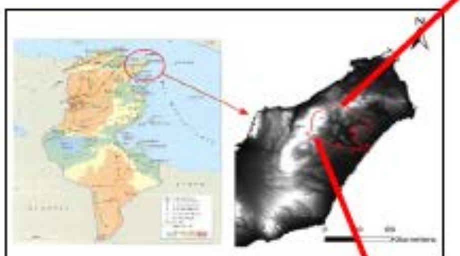
Cap Bon:
OpenFLUID-MHYDAS, SWAT

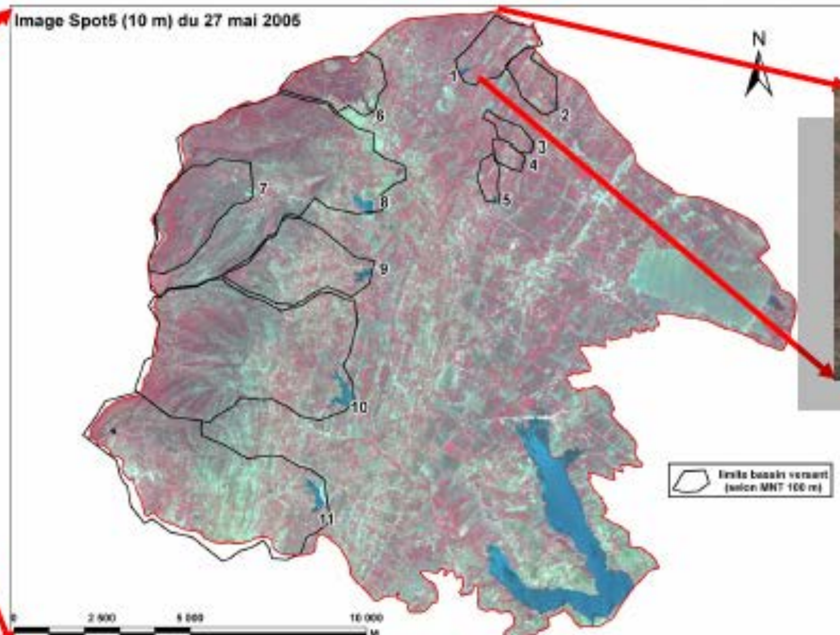
Merguellil : SWAT

Tensift: SAFRAN-ISBA

Cap Bon:
OpenFLUID-MHYDAS, SWAT

Lebna catchment
(210 Km2)



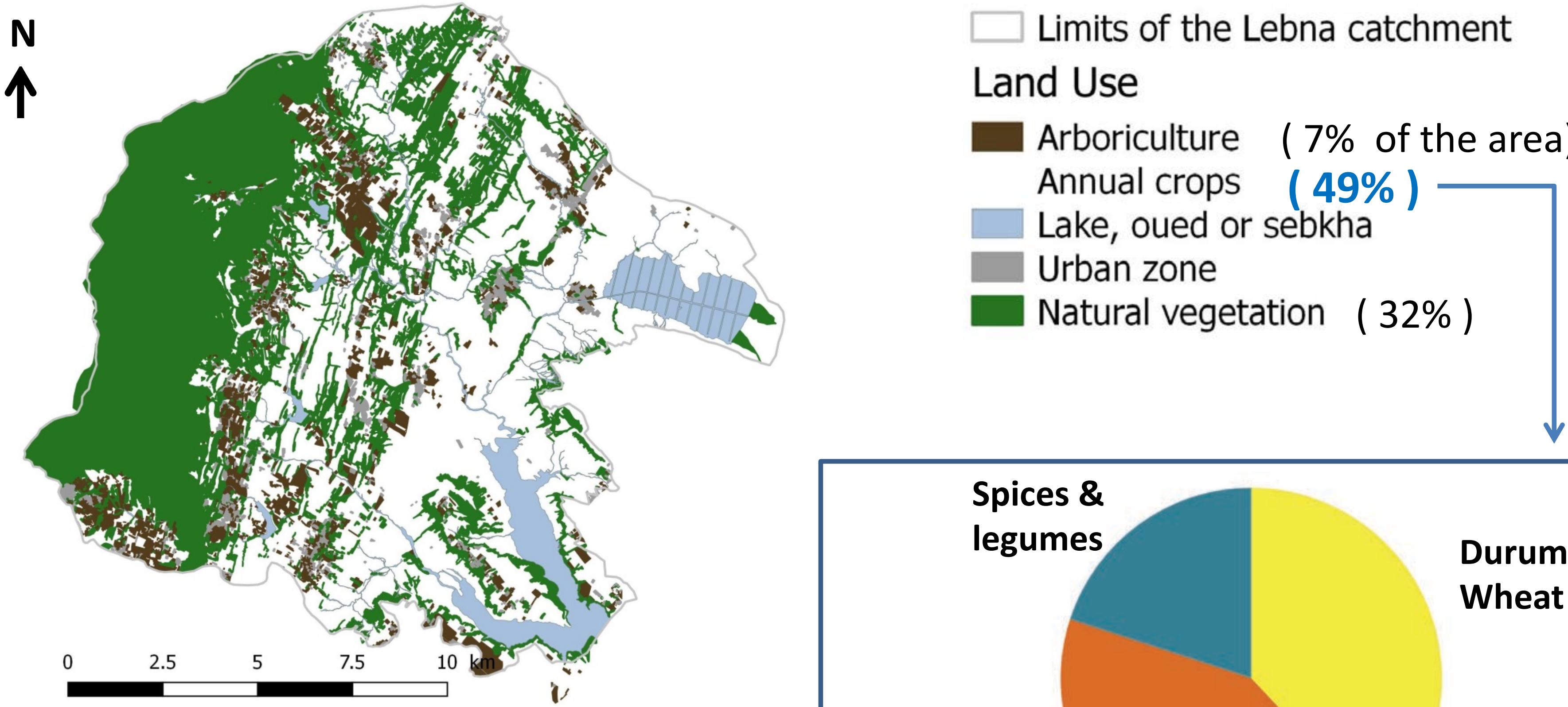


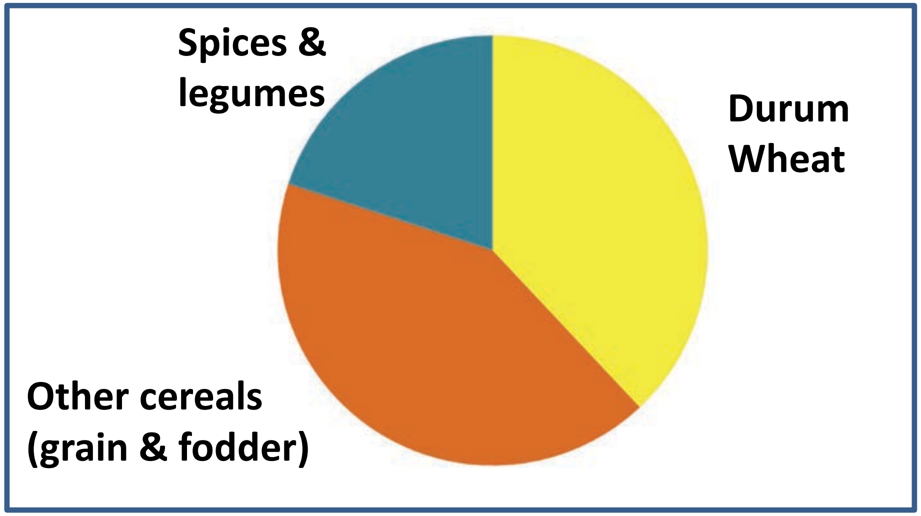
Kamech catchment
(2,5 Km2)

- Semi-arid to sub-humid climate,
- Hilly topography **:** Djebel (200-637 m), hilly zone (50-200 m), plain (0-80 m)
- Diversity of soil types

Cap Bon:
OpenFLUID-MHYDAS, SWAT

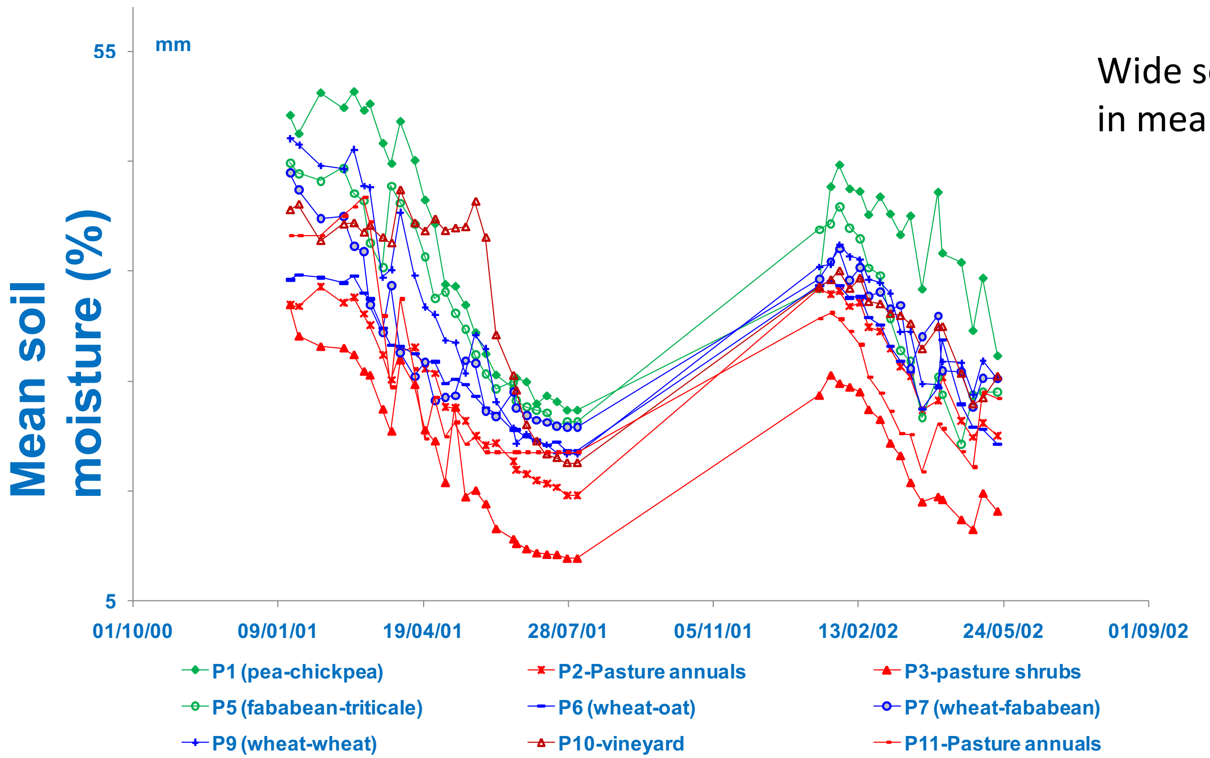
Rainfed mixed farming and livestock





Cap Bon: OpenFLUID-MHYDAS, SWAT

Impact of spatiotemporal distribution of land use and crop rotation on SWC and ETa



Wide seasonal and annual fluctuations in mean soil water content

Similar trends in relation to the infiltration-evaporation-infiltration cycle

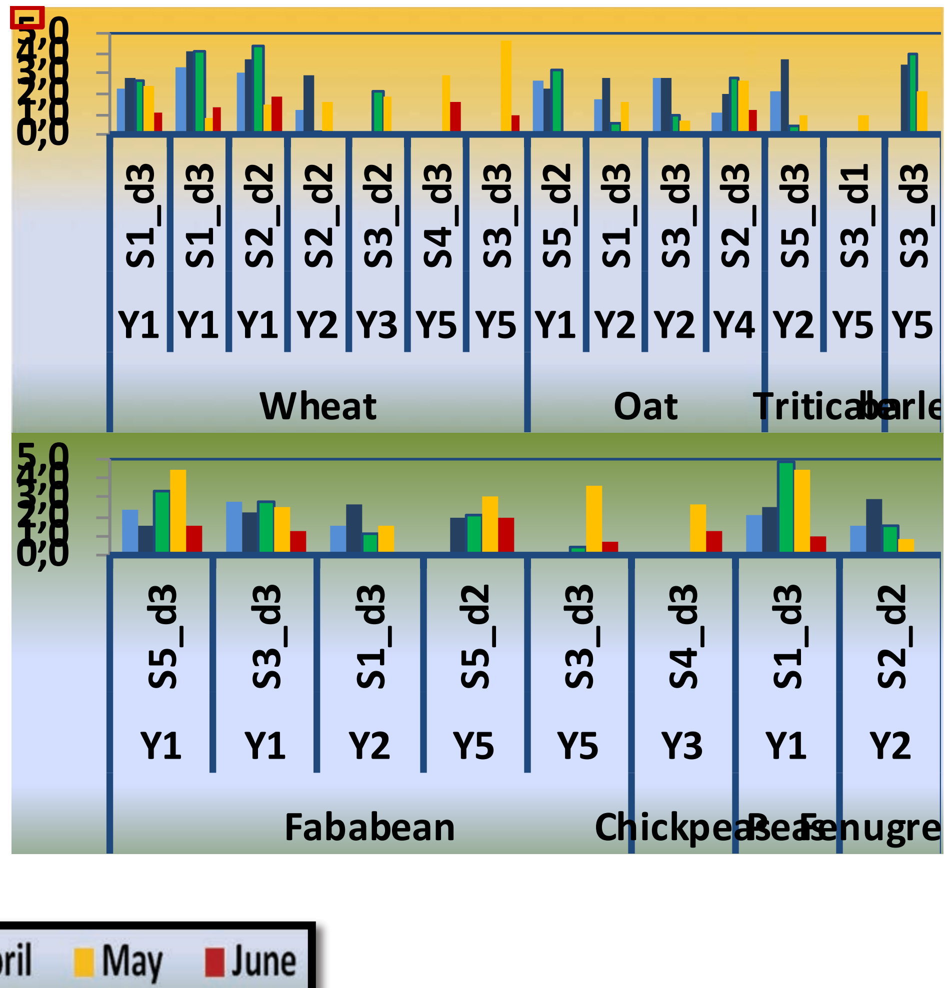
Pea and chickpea crops keep a good water content

Cereals show lower mean water content than legumes

Cap Bon: OpenFLUID-MHYDAS, SWAT

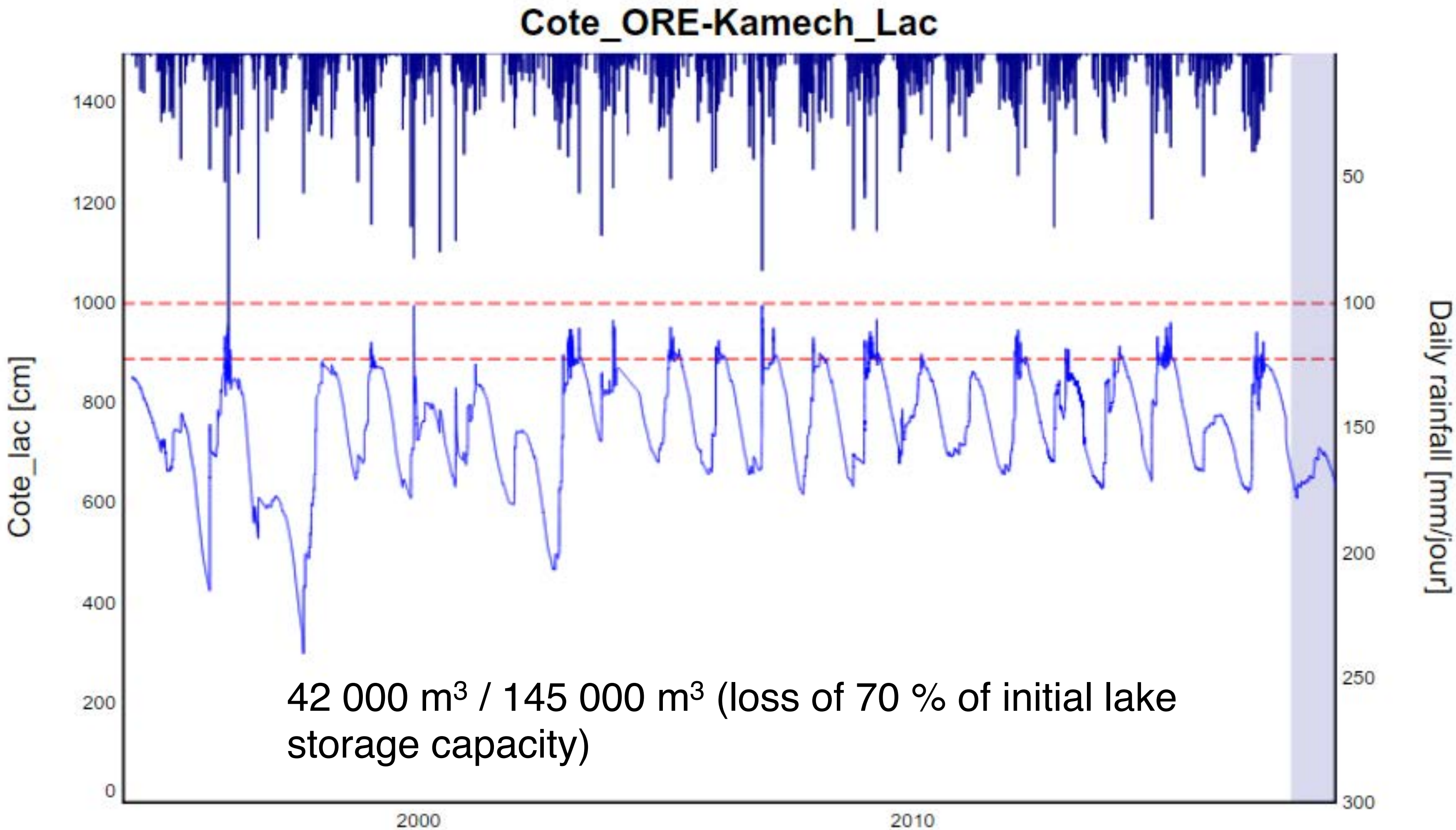
Impact of spatiotemporal distribution of land use and crop rotation on SWC and ETa

Wide seasonal fluctuations in mean ETa



Cap Bon:
OpenFLUID-MHYDAS, SWAT

Rainfall, water level at Kamech lake between 1994-2018



42 000 m^3 / 145 000 m^3 (loss of 70 % of initial lake storage capacity)

Cap Bon: OpenFLUID-MHYDAS, SWAT

For the Kamech catchment (2,5 Km2)

Averaged runoff 110 mm/year
The winter period is considered as the active period in term of erosion loads with a contribution about 75% of the total erosion loads.

- **Erosion rates:** 16t ha^{-1} $year^{-1}$
- **Sediment source at catchment scale**
  - 75% of sediment trapped in the lake come from cultivated topsoil

In 2018: silting-reduced storage capacity 42 000 m3 / 145 000 m3 (loss of 70 % of initial lake storage capacity)

For Lebna catchment (210 Km2)

Averaged runoff : 90 mm/year
Erosion rates: 20 t ha-1 $year^{-1}$

In 2003, estimated dam silting 6.22 Millions de m3, siliting-reduced capacity by about 20% of the initial dam storage capacity.

Cap Bon: OpenFLUID-MHYDAS, SWAT

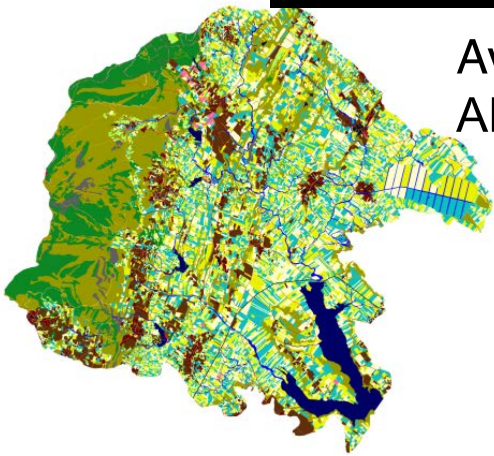
Projections for 2040, ANR TRANSMED

- **Projet ALMIRA Lebna.**

- **Principe de travail (Huard, 2018):**
  - **Modèle climatique utilisé : ALADIN-CLIMAT**
  - **Deux scénarios de trajectoire de forçage radiatif : RCP 4.5 et RCP 8.5**
  - **Variables concernées : pluie, rayonnement, température, humidité, vent -> ET_0**
  - **Résolution temporelle : pas temps journalier**
  - **Résolution spatiale :**
    - **initiale : 12 km**
    - **après désagrégation spatiale : 1 km**
  - **Période : 2021-2060**

Cap Bon: OpenFLUID-MHYDAS, SWAT

2015



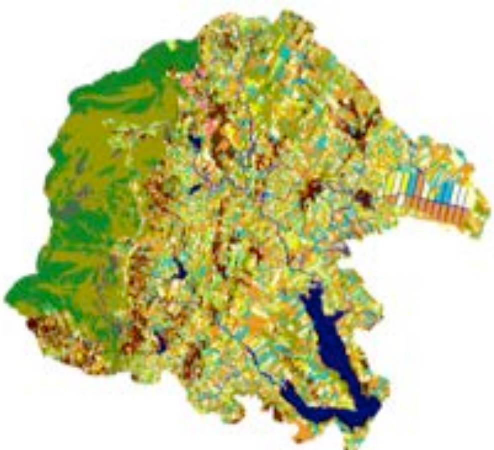
Available evolution scenarios (land use and climate 2040)
ANR TRANSMED

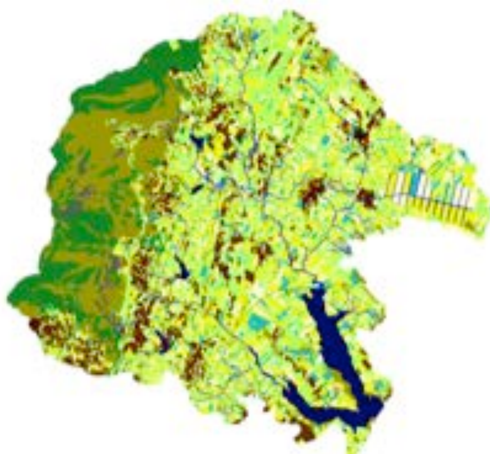
Agroforestry

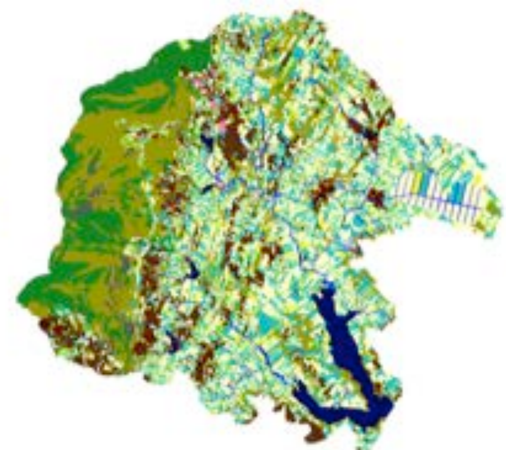
Livestock and fodder crop

Food legumes and cereals

2040







LISAH

OpenFLUID-MHYDAS

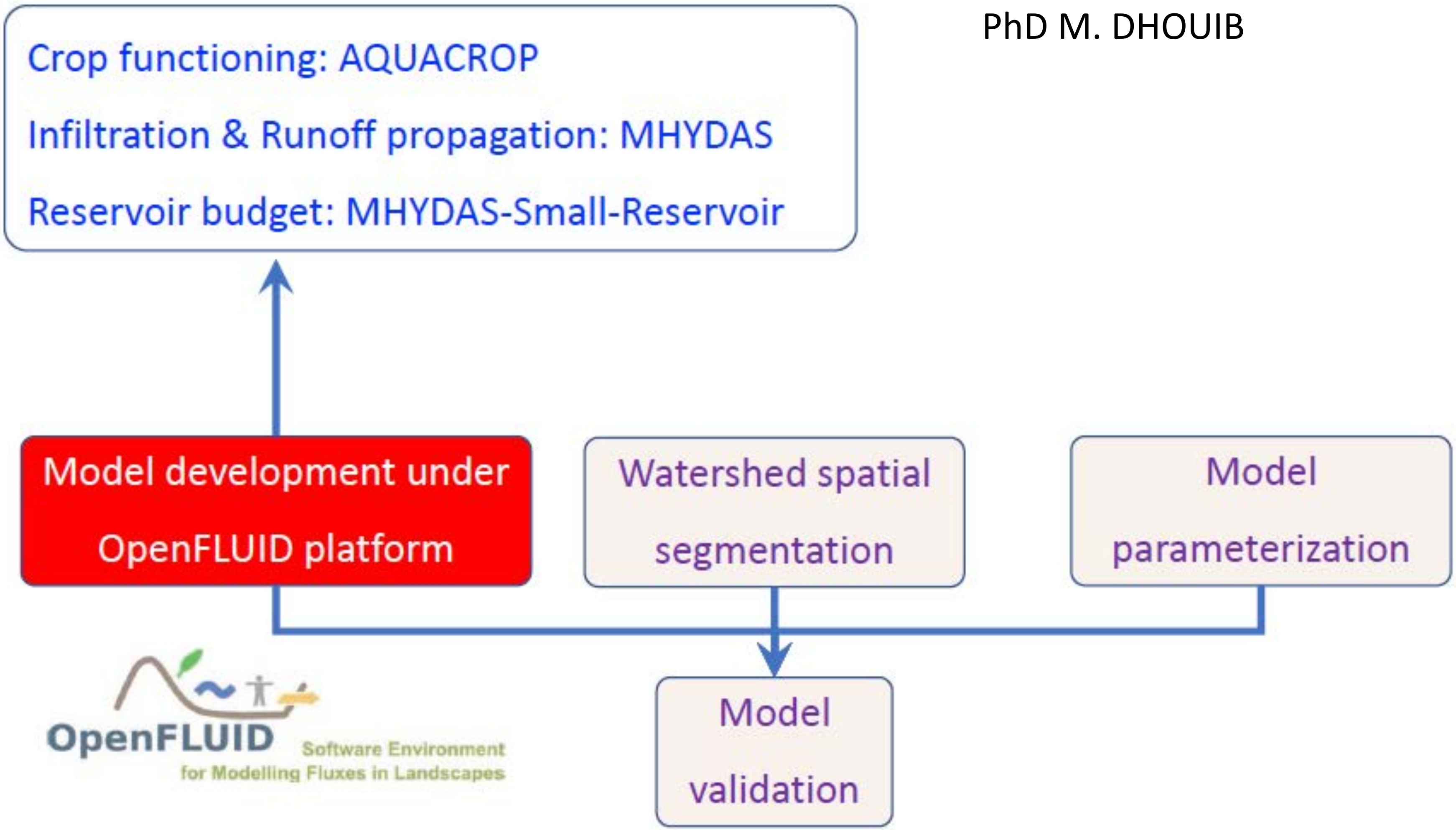
Objectives: conducting simulations of ecosystem services for given panels of scenarios, to next rank these scenarios on the basis of durability.

Method: using well known modelling tools (e.g., SWAT) and innovative tools (e.g., MHYDAS + Aquacrop within OpenFLUID integrated platform). Using a panel of indicators, in relation to spatial and temporal scales, and to targeted ecosystems services, to be analysed with stakeholders.

OpenFLUID-MHYDAS

Post-doc supervision [ALTOS granted, hiring process ongoing].

PhD M. DHOUIB



OpenFLUID Software Environment for Modelling Fluxes in Landscapes

Objectives

- Explore the use of SWAT in order to simulate the provisioning and regulating services; yields of water, sediments transport, and agricultural production (crop biomass, yield) for given panels of scenarios, to next rank these scenarios on the basis of durability.

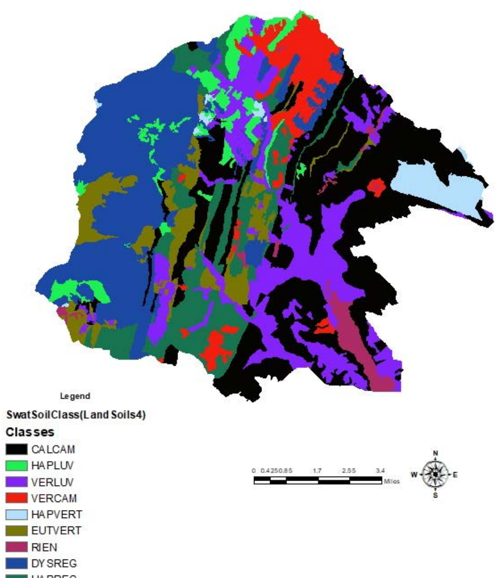
SWAT

Data available **ANR ALMIRA**

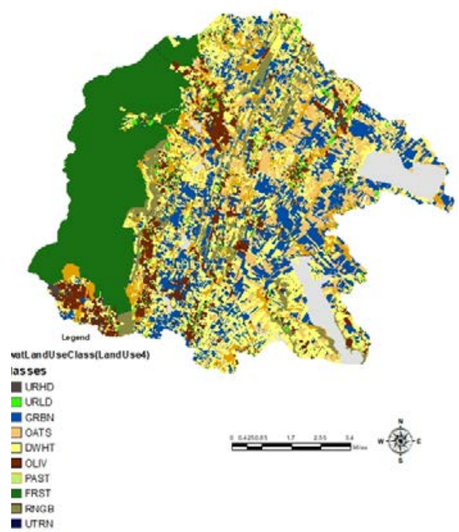
Implementation SWAT: 30 years (1986-2016), daily discharge at the outlet of Lebna catchment and Kamech sub-basins

Landscape discretization : *HRUs*

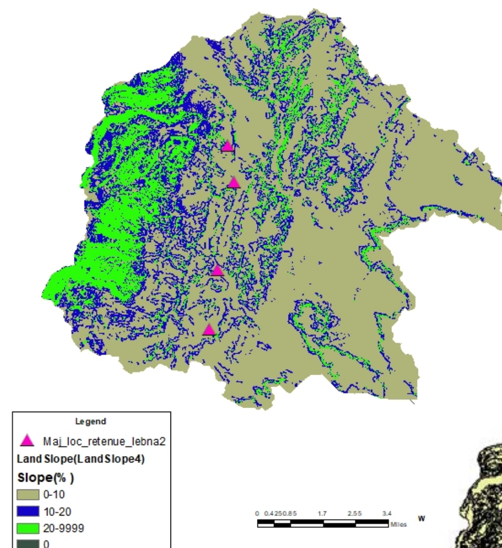
107 subasins



Soils

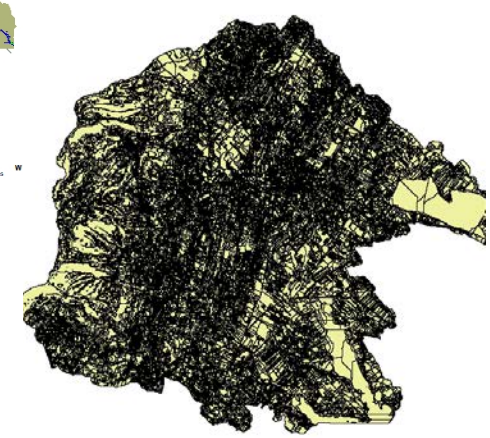


Land use



Slope

2499 HRU



PhD A. Abdelghaffar

SWAT

Multi-criteria (ETa, SWC, TSS)

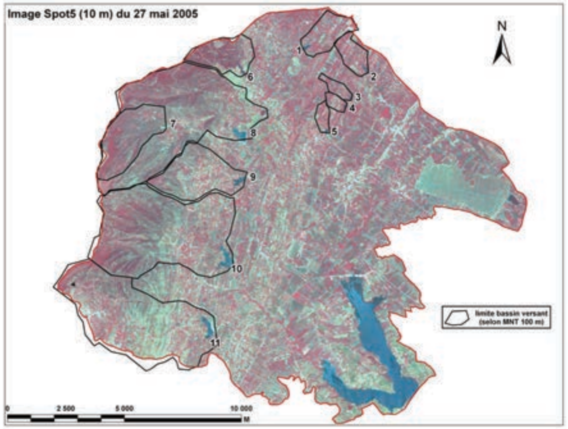
- Multisite Calibration

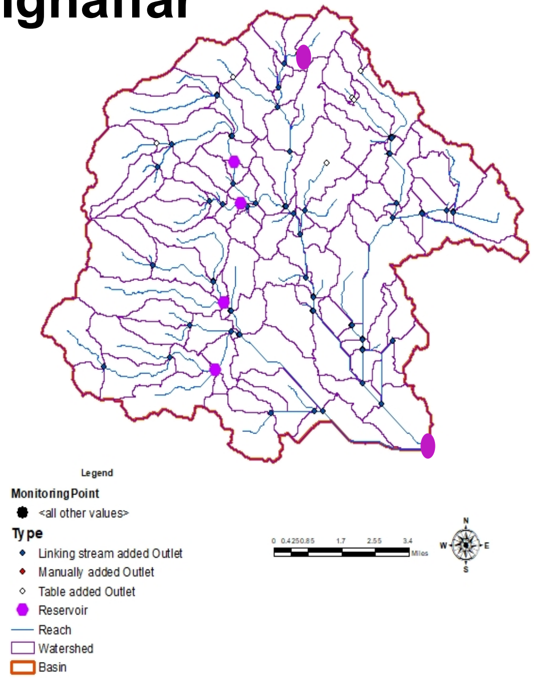
On-going

Impacts of reservoirs

cracks

On-going





- Uncertainties that may exist in the form of processes simplification and the important gap relative to the lack of attention that is given to the vegetation and crop growth processes, and cracks distribution across different land uses on vertisols and the soil and water conservation management structures,
- The availability of a reliable set of sub-daily data is likely to increase the capability of SWAT to serve a useful tool for optimizing ecosystem services water conservation, agricultural production, and soil loss preservation,
- Simulation of Land use scenarios and climate change impacts.

LISAH

INRGREF

Cap Bon:
OpenFLUID-MHYDAS,
SWAT

INAT

Institut National Agronomique de Tunisie

1898

Merguellil : SWAT

MARRAKECH

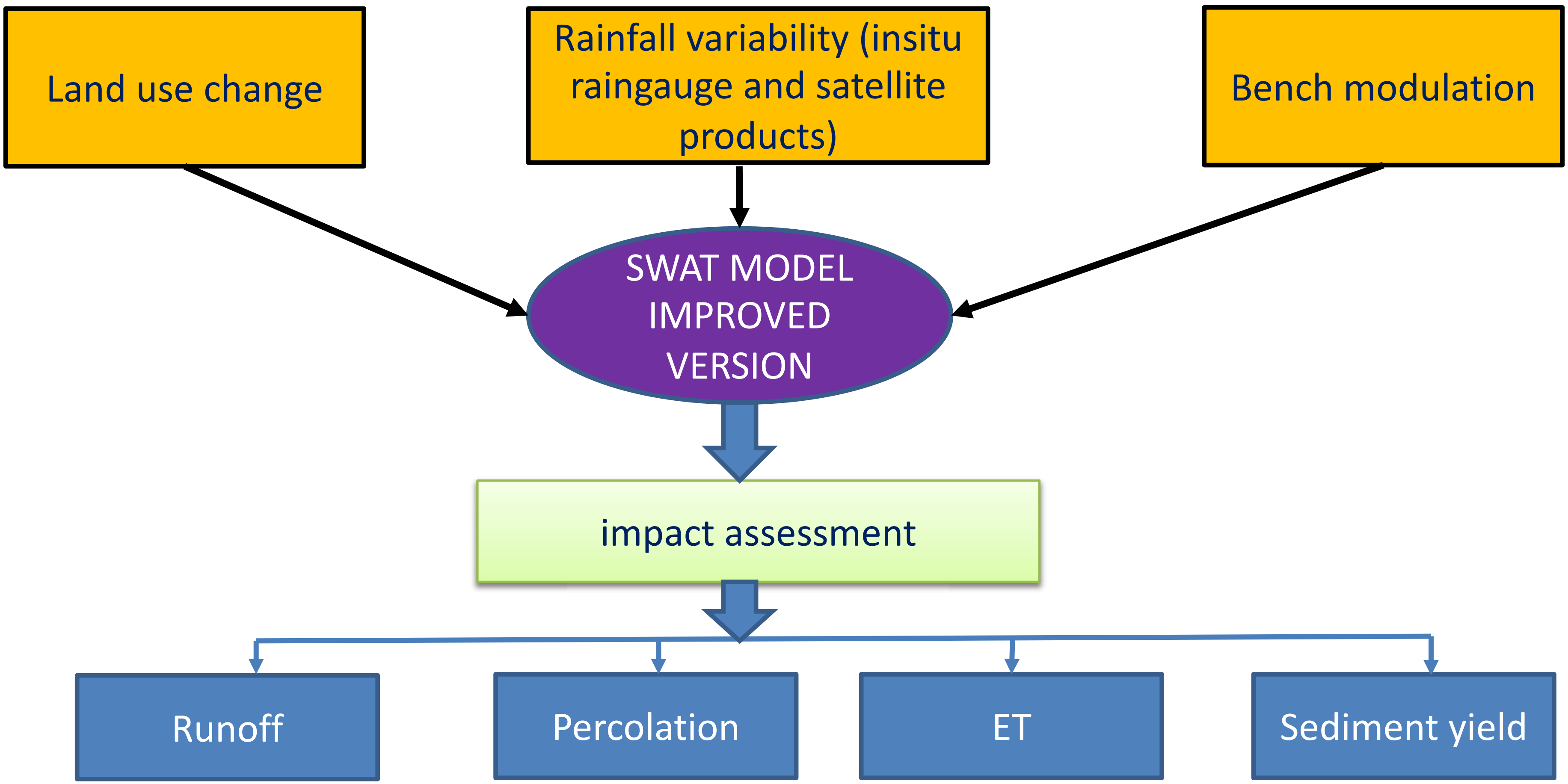
UNIVERSITÉ CADI AYYAD

CESBIO

Tensift: SAFRAN-ISBA

SWAT

The outputs of WP1 and WP2 will be used for an agrohydrological modelling



Cap Bon:
OpenFLUID-MHYDAS,
SWAT

Merguellil : SWAT

Tensift: SAFRAN-ISBA

SAFRAN-ISBA

Present and future high-resolution climate forcings over semi-arid catchments: Case of the Tensift

Ahmed Moucha, Lahoucine Hanich, Yves Tramblay, Amina Saaidi, Simon Gascoin, Eric Martin, Michel Le Page, Elhoussaine Bouras, Camille Szczypta and Lionel Jarlan.

-L3G Laboratory, Earth Sciences Department, Faculty of Sciences and Techniques, Cadi Ayyad University, BP 459, Marrakech 40000, Morocco
-Direction Génerale de la Meteorologie, Casablanca 8106, Morocco
-Centre for Remote Sensing and Application, Mohammed VI Polytechnic University (UM6P), Ben Guerir 43150, Morocco
-HydroSciences Montpellier, University Montpellier, CNRS, IRD, CEDEX, 34090 Montpellier, France
-CESBIO (UPS/CNRS/INRA/IRD/CNES), 18 Avenue Edouard Belin, CEDEX 9, 31401 Toulouse, France
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SAFRAN-ISBA

Context

Introduction:

- Increased water needs in relation to the increase in population and its standard of living, through the intensification of irrigated agriculture (Kuper et al., 2017), as well as the increase in droughts.
- The southern Mediterranean region is known as a "Hot spot" for Climate Change (Giorgi, 2006; Giorgi and Lionello, 2008; Seager et al., 2019).
- Accentuation according to the IPCC scenario (Warming, Drying) (IPCC, 2005).
- The mountainous region is expected to face increased warming compared to the surrounding plains in the future (Pepin et al., 2015).
- The climate of the southern Mediterranean mountain range is confronted with a strong spatio-temporal variability at different scales (marked orography, strong gradient of precipitation and temperature, strong seasonality of the climate with most of the precipitation concentrated during the months of 'winter') (Bolle, 2002 ; Jarlan et al., 2015)

→ *Strong pressure on the existing water resources, which are already limited.*

Aim of the work :

(1) Evaluate and adapt the SAFRAN analysis system to a complex catchment typical of the south Mediterranean region including an area of water production in the mountain with a marked orography and a downstream plain; The comparison to the MicroMet data-driven approach is also carried out.

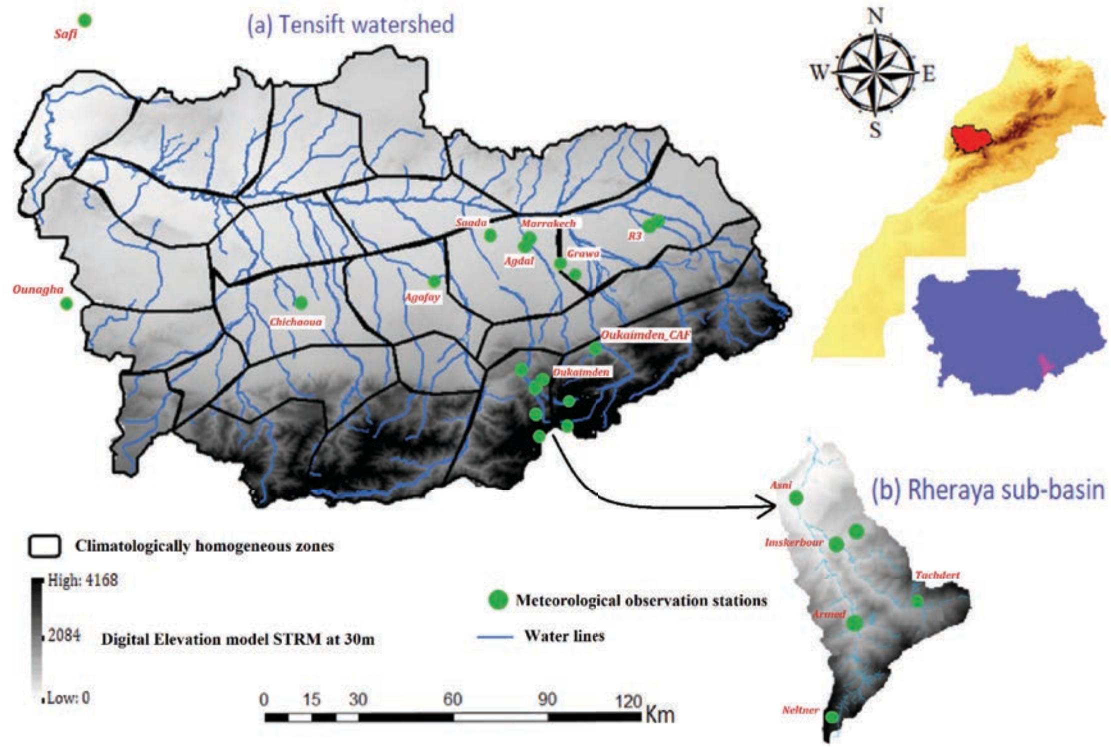
(2) Disaggregate future climate scenarios to provide spatially explicit fields of precipitation and temperature.

SAFRAN-ISBA

Study Area & Data used

Tensift Watershed

- Surface area of 20000Km².
- Characterized by a semi-arid to arid climate.
- The basin is composed of two zones with contrasting hydrological functioning:
  - High Atlas in the south: Water tower with a mixed rain/snow regime (~800 mm/year).
  - Haouz Plain: Water consumption area (irrigated agriculture); ~200 mm/year.
- Very scattered measurement network except for the Rheraya.



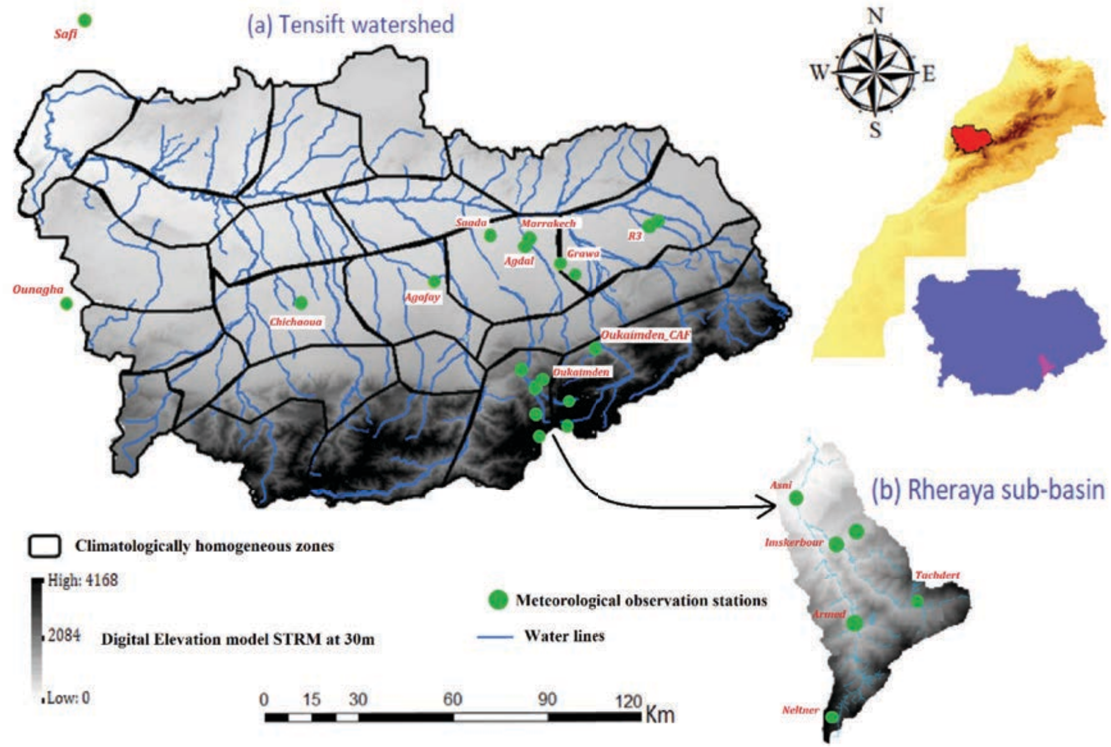
Fg. 1: The Tensift catchment and the orography (digital elevation model STRM at 30m). The location of the meteorological stations and the division of the catchment area into 23 climatically homogeneous zones for the SAFRAN system are superimposed.

SAFRAN-ISBA

Study Area & Data used

Data

- 18 meteorological stations 2004-2014 (one with daily snowfall/rainfall partition)
- Daily snow cover fraction (SCF) product MOD10A1 at 500 m resolution (filtering: Marchane et al., 2015)
- Euro-CORDEX climate change scenarios under the RCP4.5 and RCP8.5 at 12 km from 4 RCMs
- Monthly water distribution at the irrigated perimeter scale.



Fg. 1: The Tensift catchment and the orography (digital elevation model STRM at 30m). The location of the meteorological stations and the division of the catchment area into 23 climatically homogeneous zones for the SAFRAN system are superimposed.

SAFRAN-ISBA

Material & Methods

SAFRAN:

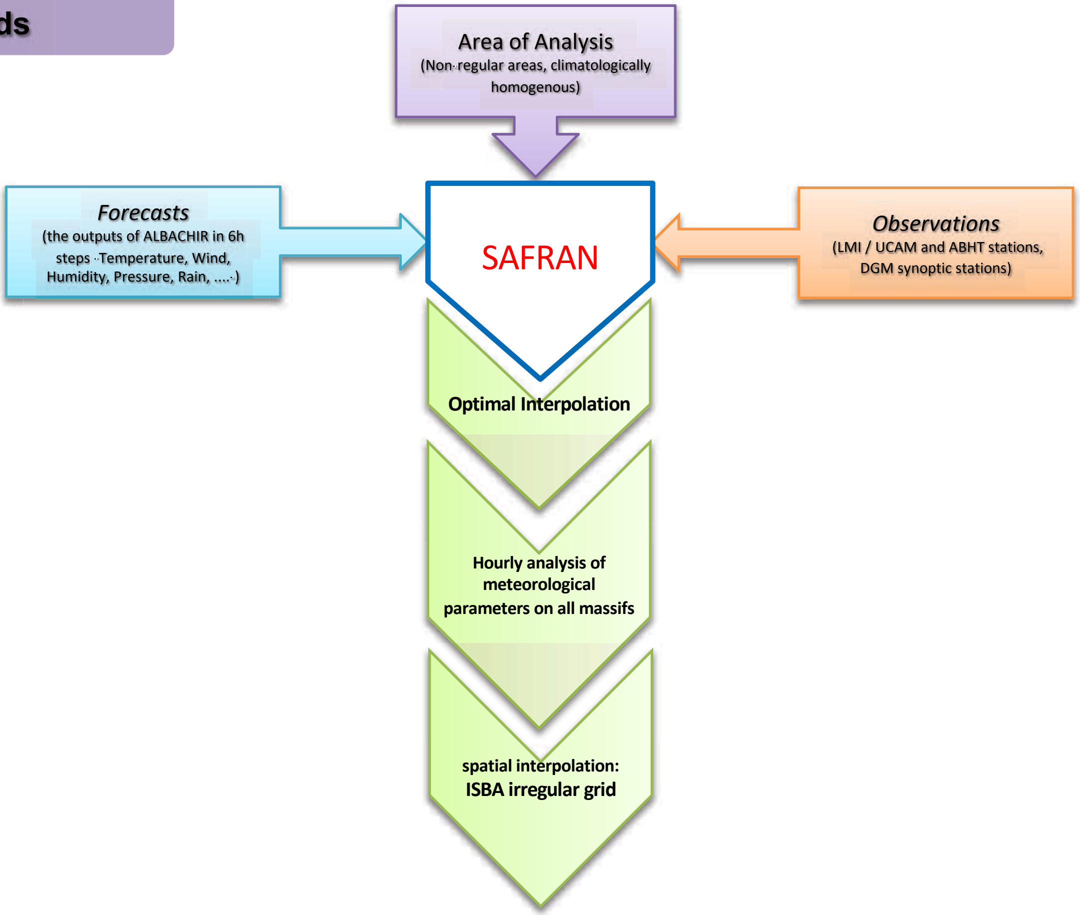


Fig 2 : Diagram of SAFRAN calculation.

SAFRAN-ISBA

Material & Methods

***first part:* SAFRAN assessment.**

I. by a station-level validation based on the leave-one-out (LOO) approach from August 2004 to July 2014. It was used for a mountain station (Aremd) and at a plain station (Chichaoua);

II. Via a comparison with MicroMet monthly averages over the Rheraya catchment;

III. by comparing the rain/snow partition to the snow surface area derivec from the daily MODIS product and to the *in situ* snow depth measurements.

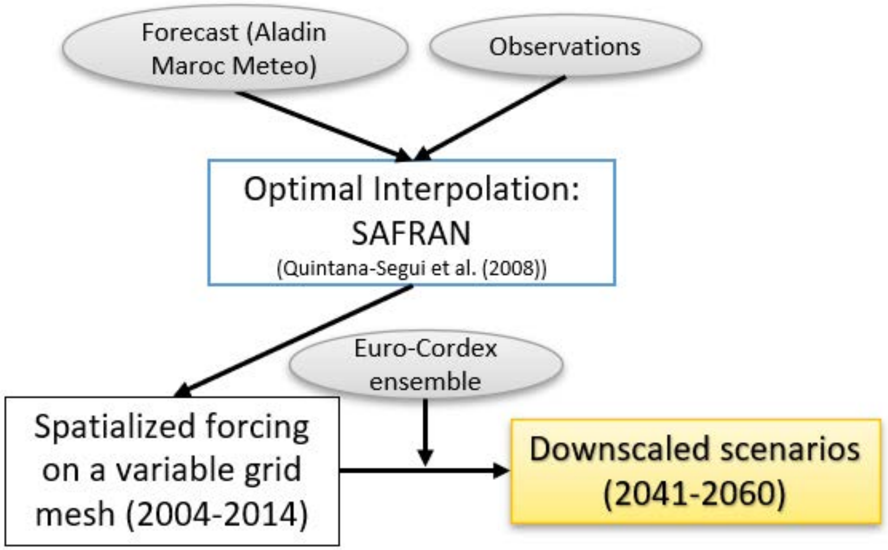
***Second part:* Projection of SAFRAN re-analysis at 2041-2060.**

the projection of SAFRAN re-analysis was carried out using a 3 steps approach:

I. Disaggregation of the plain and the mountain station using Q-Q method.

II. Application of the transfer functions to Euro-CORDEX scenario.

III. Applying the delta change coefficients to SAFRAN for RCP4.5 and RCP8.5 at 2041-2060.

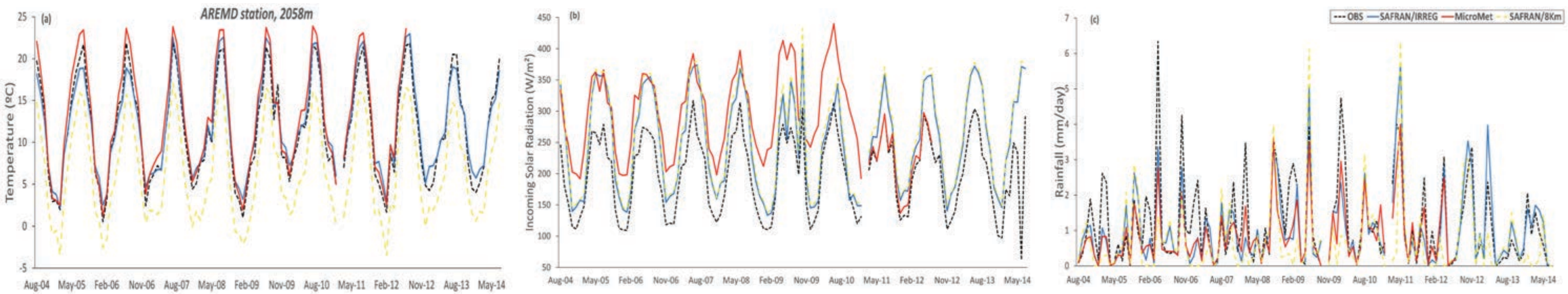


SAFRAN-ISBA

Part I: SAFRAN assessment.

Results

A. *Validation of SAFRAN (Leave-One-Out): Mountain station- Aremd (2058m):*



Fg. 3: . Comparison of the evolution of the reanalysis of SAFRAN (8 km and irregular) and MicroMet model with the observation at the Aremd station, for the period 2004–2014: (a) Air temperature; (b) Incoming Solar Radiation and (c) Rainfall;

- Clear improvement of precipitation and temperature re-analyses with the irregular grid in mountain areas.
- Little difference in plain area (not shown).

Parameter	*Average Observed*	*Average Analyzed*			*Bias*			*RMSE*			*Simple Correlation*		
		Irregular	*8km*	*MicroMet*	*Irregular*	*8km*	*MicroMet*	*Irregular*	*8km*	*MicroMet*	*Irregular*	*8km*	*MicroMet*
Incoming Solar Radiation (W/m²)	*199,69*	*251,19*	*259,57*	*287,72*	*51,5*	*59,87*	*86,25*	*161,96*	*165,88*	*351,68*	*0,888*	*0,89*	*0,353*
Surface temperature(°C)	*11,55*	*12,13*	*6,76*	*13,07*	*0,59*	*-4,79*	*1,52*	*3,58*	*6,19*	*3,82*	*0,886*	*0,849*	*0,881*
Wind (m/s)	*2,05*	*2,43*	*3,17*	*1,81*	*0,38*	*1,12*	*-0,34*	*2,16*	*2,62*	*2,02*	*0,352*	*0,338*	*0,365*
Precipitation (mm/day)	*1,18*	*1,02*	*0,72*	*0,88*	*-0,16*	*-0,46*	*-0,37*	*3,83*	*4,41*	*3,09*	*0,608*	*0,373*	*0,833*
Specific humidity (g/kg)	*4,65*	*5,61*	*3,96*	*5,45*	*0,97*	*-0,69*	*0,81*	*2,13*	*1,98*	*1,71*	*0,663*	*0,595*	*0,758*

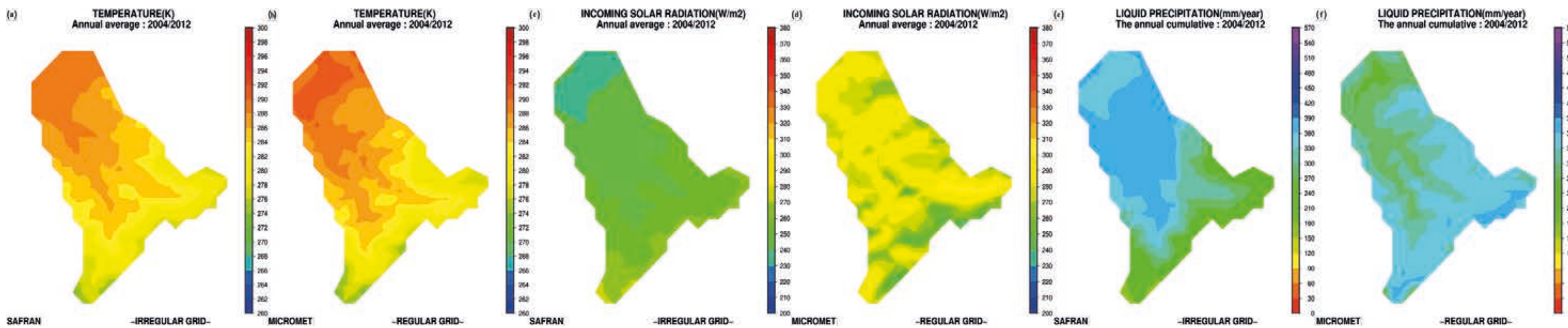
Tb. 1: Evaluation of SAFRAN (8 km and Irregular) and MicroMet model at the Aremd station 2004–2014. (The evaluation of MicroMet was carried out between 2004–2012).

SAFRAN-ISBA

Results

Part I: SAFRAN assessment.

B. Comparison of SAFRAN-irregular grid with Micromet on the Rheraya sub-basin:



Fg. 4: Map of yearly average air temperature (a,b), incoming solar radiation (c,d) and rainfall (e,f), for the two models SAFRAN (left) and MicroMet (right) on the Rheraya sub-basin for the period 2004–2012.

- Strong MICROMET bias on Incoming Solar Radiation.
- Better representation of precipitation with MICROMET although the bias is lower with SAFRAN.

DATE	Temperature (ºC)		Incoming Solar Radiation (W/m²)		Rainfall (mm)		Snow (mm)		Wind Force (m/s)	
	SAFRAN	MicroMet	SAFRAN	MicroMet	SAFRAN	MicroMet	SAFRAN	MicroMet	SAFRAN	MicroMet
2004/2005	11,0	12,0	260,7	284,7	186,6	129,9	61,7	50,0	2,8	2,1
2005/2006	10,8	11,5	253,6	282,7	314,3	260,8	91,4	77,1	2,9	2,2
2006/2007	10,9	11,6	260,2	291,7	272,0	193,4	79,9	69,1	2,3	2,0
2007/2008	11,4	11,8	263,5	293,6	282,4	319,9	73,3	65,0	2,4	2,1
2008/2009	10,4	10,6	235,2	304,0	466,9	490,2	141,3	95,5	2,9	2,2
2009/2010	12,4	12,6	240,9	315,0	324,1	362,5	72,7	57,2	2,8	1,8
2010/2011	12,0	12,1	229,8	259,1	502,1	541,9	76,2	64,3	2,8	1,9
2011/2012	11,6	11,6	252,7	210,3	235,0	288,4	84,7	80,1	2,5	1,5
Average (2004/2012)	11,3	11,7	249,6	280,1	322,9	323,4	85,2	69,8	2,7	2,0

Tb. 2: Annual average (or cumulative for rainfall and snowfall) of the meteorological variables predicted by SAFRAN and MicroMet over the Rheraya sub-basin.

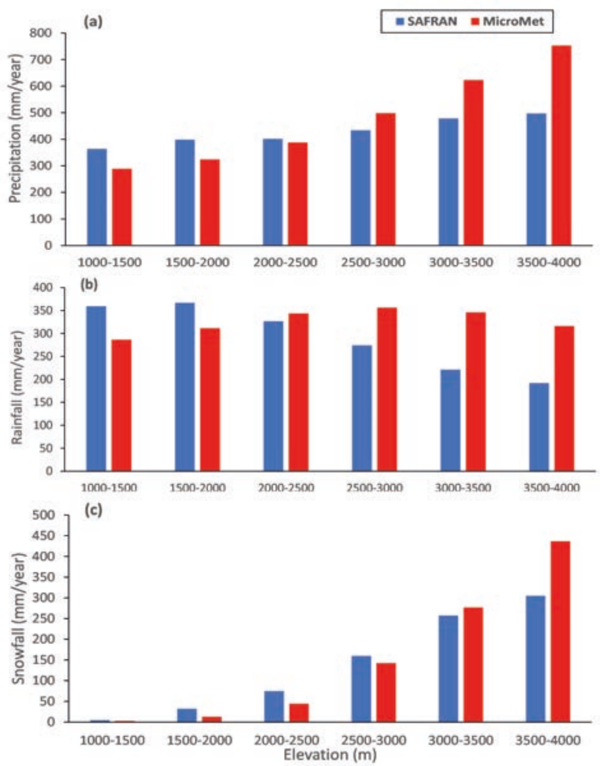
SAFRAN-ISBA

Results

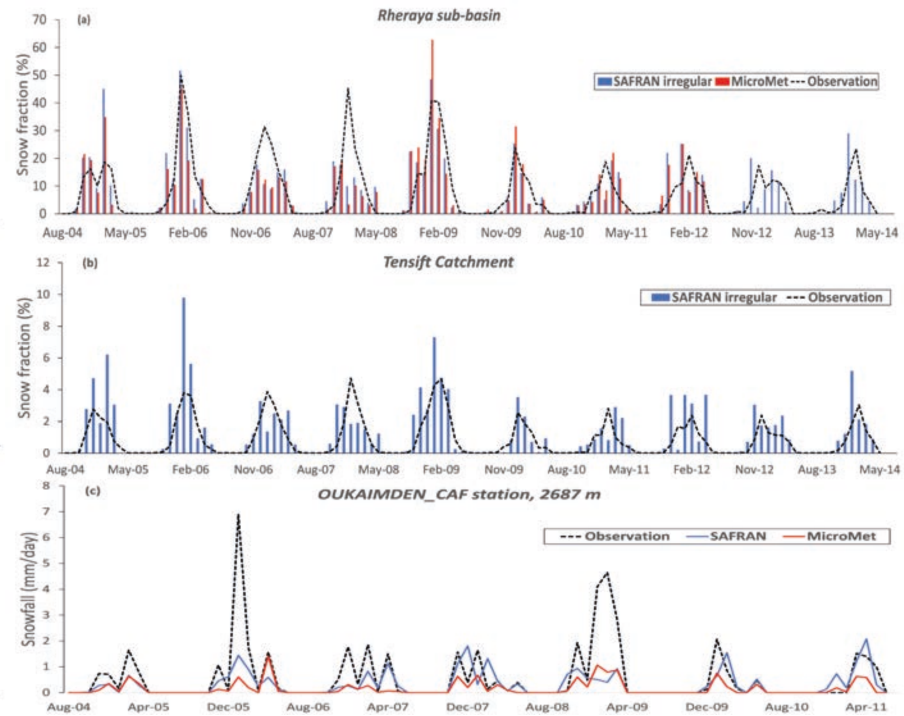
Part I: SAFRAN assessment.

C. Snow/Rain assessment :

- MicroMet systematically predicts higher precipitation than SAFRAN except for the lowest elevation ranges.
- MicroMet predicted significantly more rainfall than SAFRAN on the highest part of the catchment while the oposite is true for the lowest elevation area to the north.
- SAFRAN and MicroMet predict the snowfall reasonably well.



Fg. 5: .Average annual precipitation (a), rainfall (b) and snowfall (c) as a function of altitude for MicroMet and SAFRAN irregular grid on the Rheraya sub-basin, over the period 2004–2012.



Fg. 6: Snow cover fraction for (a) the Rheraya sub-basin and (b) the Tensift catchment over the period 2004–2014 derived from SAFRAN (irregular grid) and MicroMet and from the daily MODIS products (see text); (c) time series of monthly snowfall (mm/day) predicted by SAFRAN (Irregular grid) and MicroMet and observed at the Oukaimden_CAF station for the period 2004–2011.

SAFRAN-ISBA

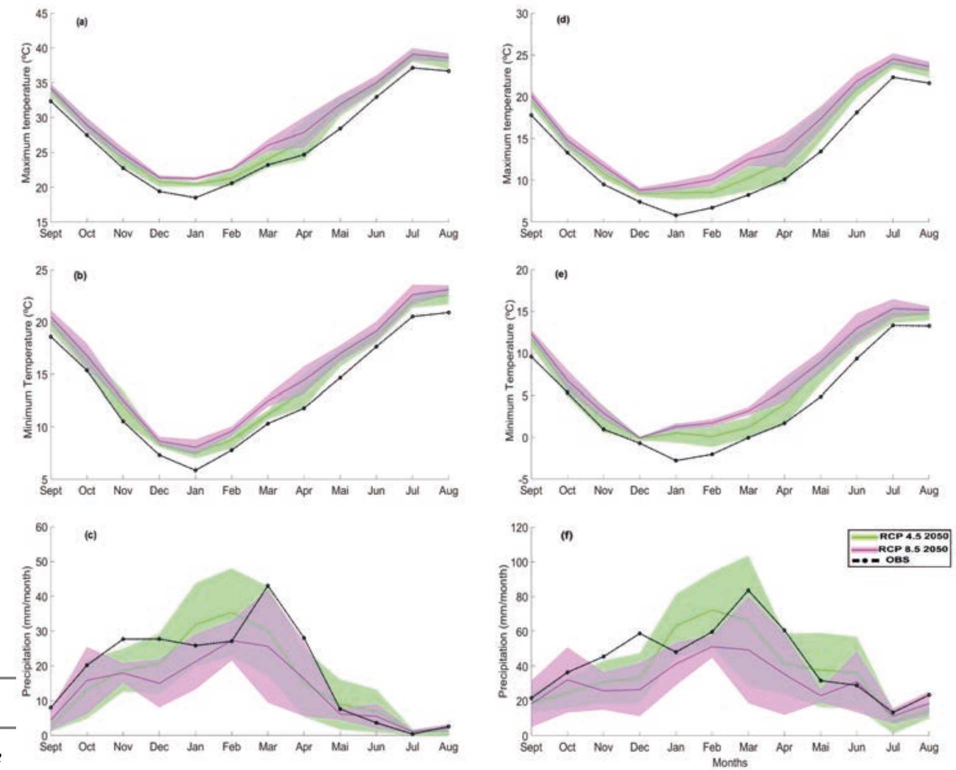
Part II: Projection of SAFRAN re-analysis.

Results

- A high degree of warming is observed for both stations.
- Stronger warming may be expected during the winter and spring months than for the rest of the year.
- The mountainous station could face warming of up to 4.3 ◦C and 3.2 ◦C in March for RCP8.5 and May for RCP4.5 scenarios, respectively.

Tb. 3: Annual changes considering the median of temperature (Tmax, Tmin) and precipitation (reduced or gain) by the model ensembles on the stations of Marrakech and Oukaimeden_CAF over 2050.

	Tmax (ºC)		Tmin (ºC)		Pr (mm/year)	
	Marrakech	*Oukaimeden*	*Marrakech*	*Oukaimeden*	*Marrakech*	*Oukaimeden*
RCP4.5	+1,6	+1,9	+1,3	+1,8	-48 (-22%)	-96 (-19%)
RCP8.5	+2,2	+2,8	+1,9	+2,7	-70,8 (-32%)	-181,2 (-35%)



Fg. 7: The future projections of minimum and maximum temperature and precipitation at the Marrakech (left) and Oukaimeden_CAF (right) stations according to the two scenarios RCP4.5 and RCP8.5 for the horizon 2041-2060. The lines represent the mean of the models, and the hatched section corresponds to the mean ± standard deviation of the 4 RCM models.

SAFRAN-ISBA

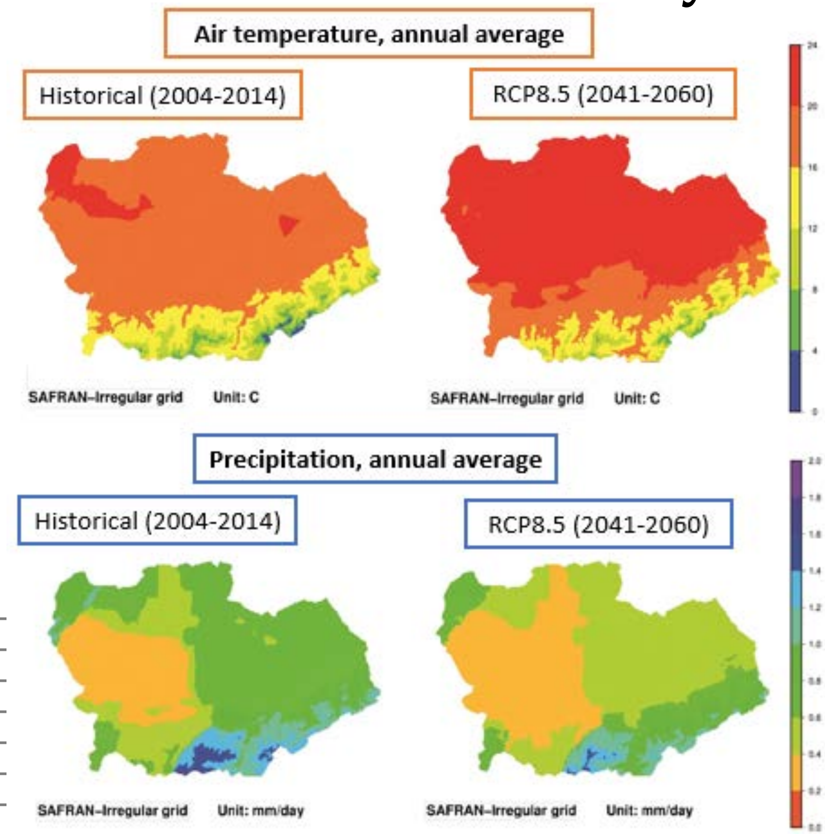
Part II: Projection of SAFRAN re-analysis.

Results

- The SAFRAN projection predicts greater warming projected for the mountains than for the plains.
- A significant decrease of precipitation in mountainous areas (altitude> 1000 m) for the scenario RCP8.5.

Tb. 4: Annual changes considering the mean of temperature (Tmax, Tmin) and precipitation (reduced or gain) by Euro-CORDEX and SAFRAN on the basin, the plain and mountain part over 2050.

	Mean temperature (ºC)			
	RCP45		*RCP85*	
	SAFRAN	*Euro-CORDEX*	*SAFRAN*	*Euro-CORDEX*
basin	+1,64	+1,5	+2,38	+2,2
plain	+1,48	+1,5	+2,12	+2,1
mountain	+1,71	+1,7	+2,5	+2,5
	Precipitation (mm/year)			
	RCP45		*RCP85*	
	SAFRAN	*Euro-CORDEX*	*SAFRAN*	*Euro-CORDEX*
basin	-32,99 (-11%)	-36,2 (-15%)	-58,5 (-20%)	-72,31 (-31%)
Plain	-34,66 (-16%)	-35,78 (-16%)	-65,19 (-30%)	-69,33 (-31%)
mountain	-32,22 (-9%)	-37,32 (-14%)	-55,4 (-16%)	-80,30 (-32%)



Fg. 8: Futuristic projections of SAFRAN-irregular grid on the Tensift Basin, according to RCP8.5 for 2041-2060.

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Conclusions and prospects

Climate data spatialization:

I. Due to complex orography, Irregular grid outperformed the regular grid -8 km- for temperature, wind speed, precipitation and to a lesser extent incoming solar radiation;

II. the timing (start and end) of the snow season is properly reproduced both by MICROMET and SAFRAN in comparison to the MODIS daily snow cover area product;

III. At the Oukaimeden station: the comparison of the amount of snow predicted by SAFRAN and MICROMET with observation shows a good temporal prediction but also large underestimation by both models; however, better prediction by SAFRAN.

Projection of SAFRAN re-analysis:

I. Mountainous areas are expected to face a higher increase in air temperatures than the plains (up to +2.5°C for RCP8.5 2041-2060 and +1.71°C for RCP4.5 -same horizon- for SAFRAN);

II. This high resolution historical and future climate forcing available for the first time in this region is to be used for impact studies in particular concerning water resources.

Recent publication

Moucha, A.; Hanich, L.; Tramblay, Y.; Saaidi, A.; Gascoin, S.; Martin, E.; Le Page, M.; Bouras, E.; Szczypta, C.; Jarlan, L. Present and Future High-Resolution Climate Forcings over Semiarid Catchments: Case of the Tensift (Morocco). Atmosphere 2021, 12, 370. https://doi.org/10.3390/atmos12030370

Panel of indicators

Task 4.3: comparing irrigated and rainfed agrosystems

- Cross-analysis for studying vulnerabilities and adaptation capabilities.
- Production and comparison of simulation-based indicators for the above-discussed scenarios.

o Times series of water stress occurrences. o Yield and water use efficiencies.

o Spatial allocations between blue and green water compartments. o Sectorial allocation of water.

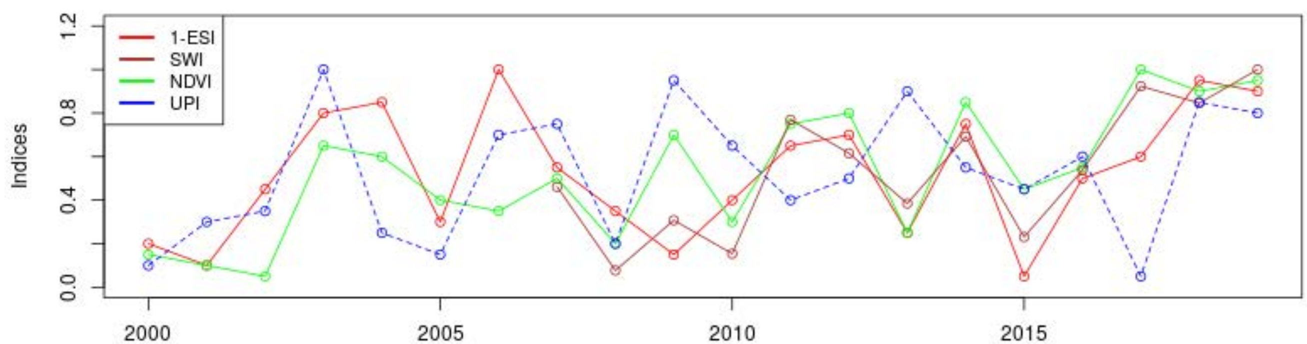
- Spatial scales for indicators are farm / irrigated perimeter / land use class / catchment.

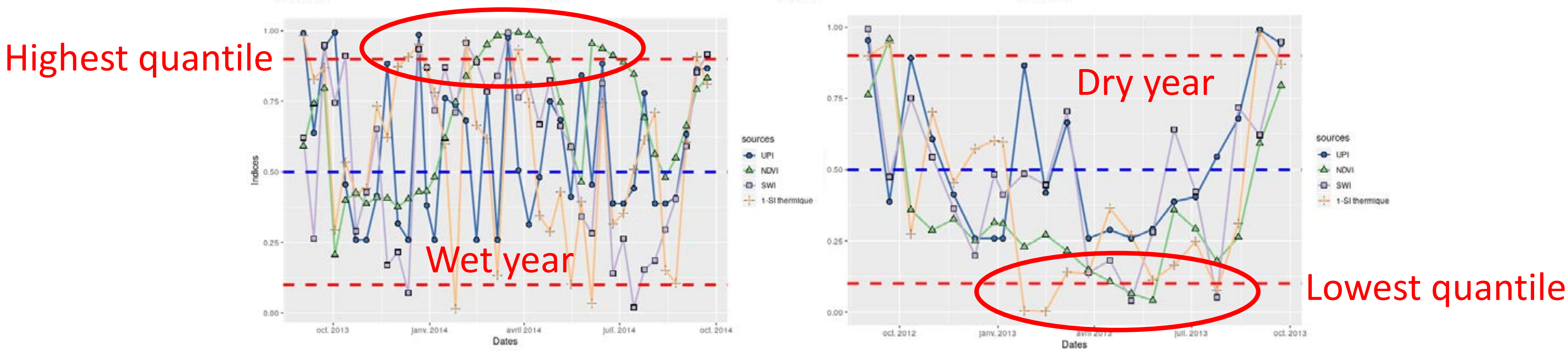
-> historical droughts over Kairouan plain using low resolution RS products: NDVI, SWI (µwave), ESI (TIR) vs UPI (rain)

-> agronomical drought indicators in the mediterranean

-> impact of CC on yield

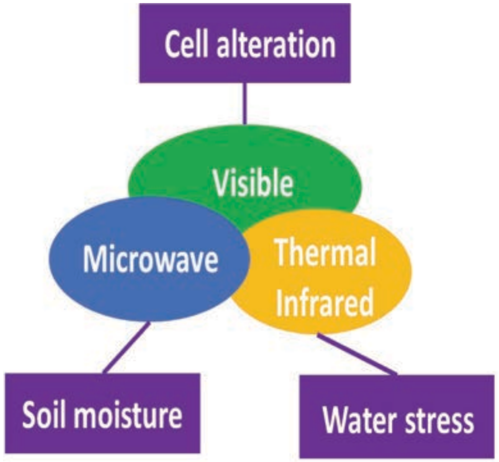
PhD Nesrine Fahrani



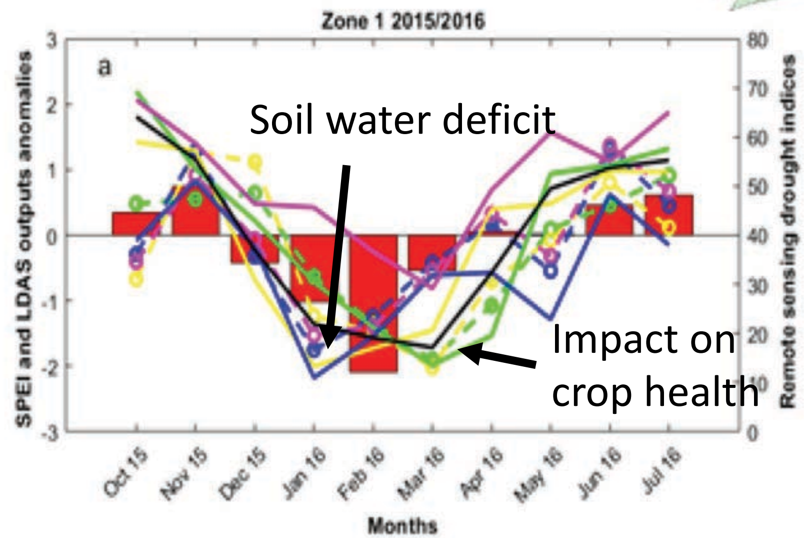


Agronomical drought indicators

Drought indicators

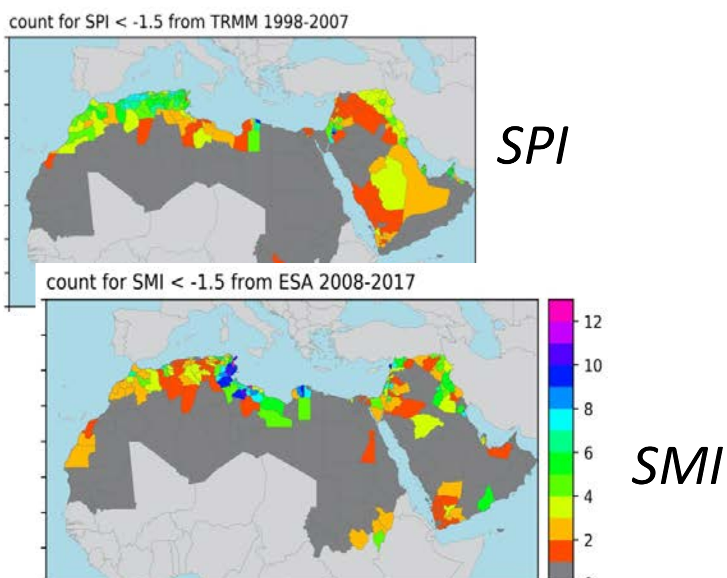


Timing of droughts impact



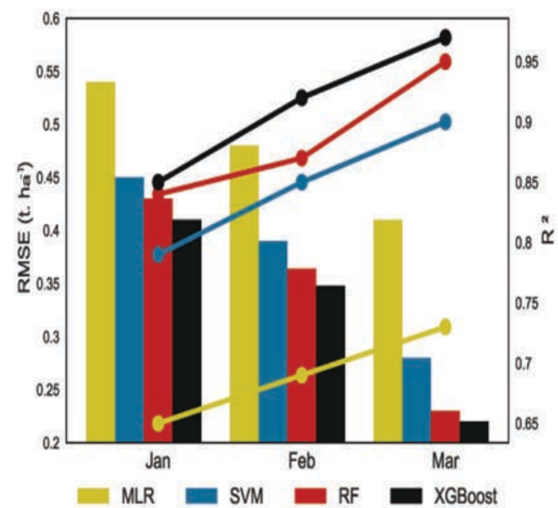
Bouras et al., MDPI/Remote Sensing, 2020

Drought mapping (Comparison of rainfall and SM products)



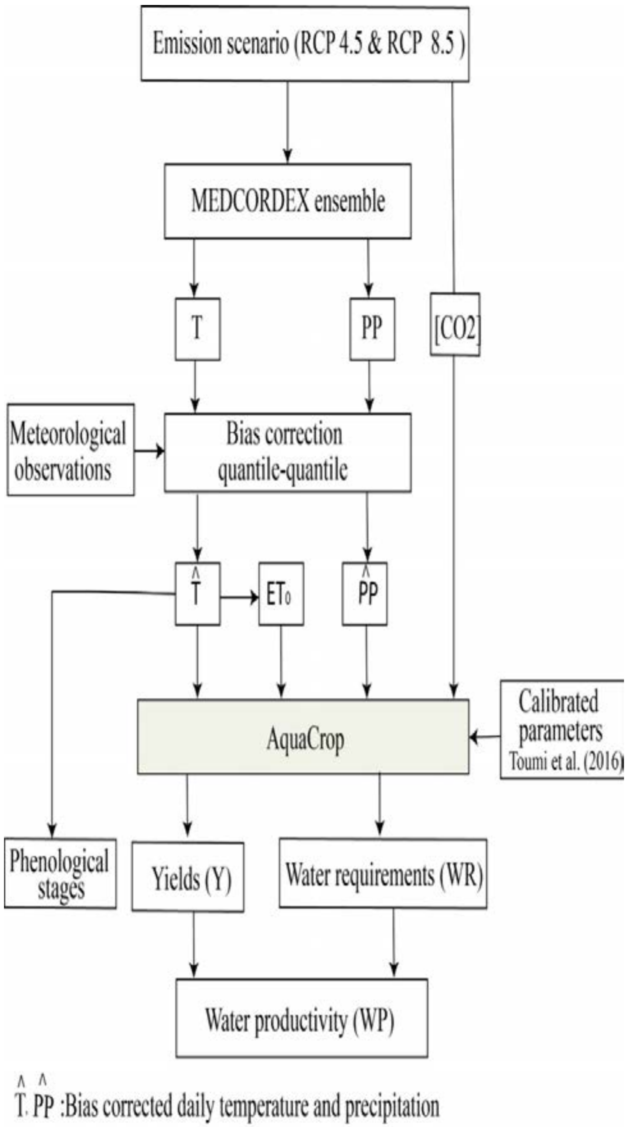
Najem et al., Nat. Scie. Rep., en révision

Drought indices for early forecasting of yields

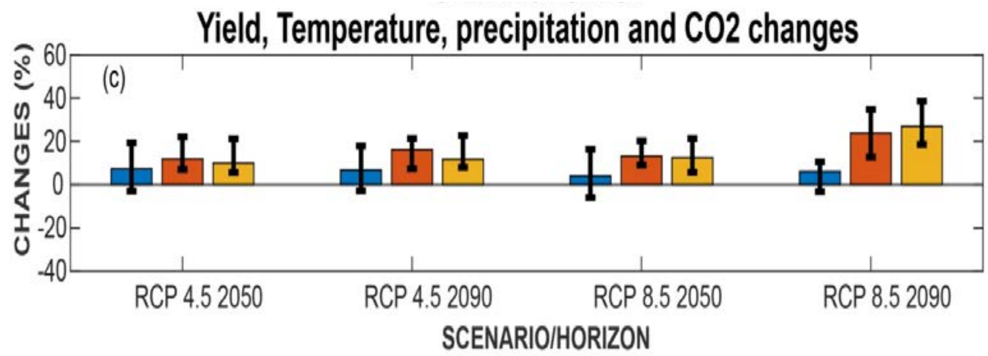


Bouras et al., MDPI/Remote Sensing, soumis

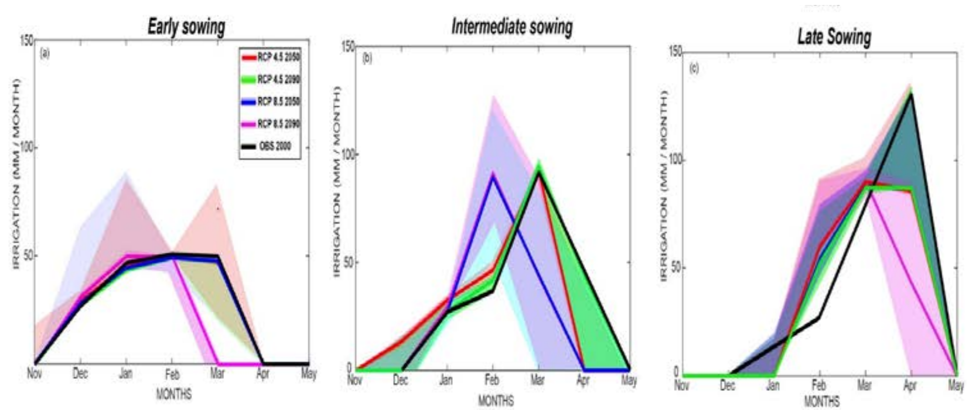
Impact of Climate change on yield production



Yields



Water needs



Bouras et al., Nat Scie Rep, 2019

Deliverables

- D4.2.1 [Task 4.2]: scenario ranking from participative seminars on the basis of simulation-based indicators, in the form of report @ Month 33 to be included into project website and disseminated to stakeholders (WP5).
- D4.2.2 [Task 4.2]: 2 submitted publications about scenario design / analysis / ranking from simulation- based indicators @ Month 36