CGMS-Maroc: National System for Agrometeorological monitoring

Mouanis LAHLOU

Hassan II Institute of Agronomy and Veterinary Medicine

On behalf : Balagui R., Arrach R., El Hairech T., Ajerame M.M.,

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- Part1: CGMS-Maroc
  - Objectives of the system
  - Presentation of the system
- Part 2: Operational cereal yield forecasting in Morocco.
  - Material and methods
  - Results and discussion

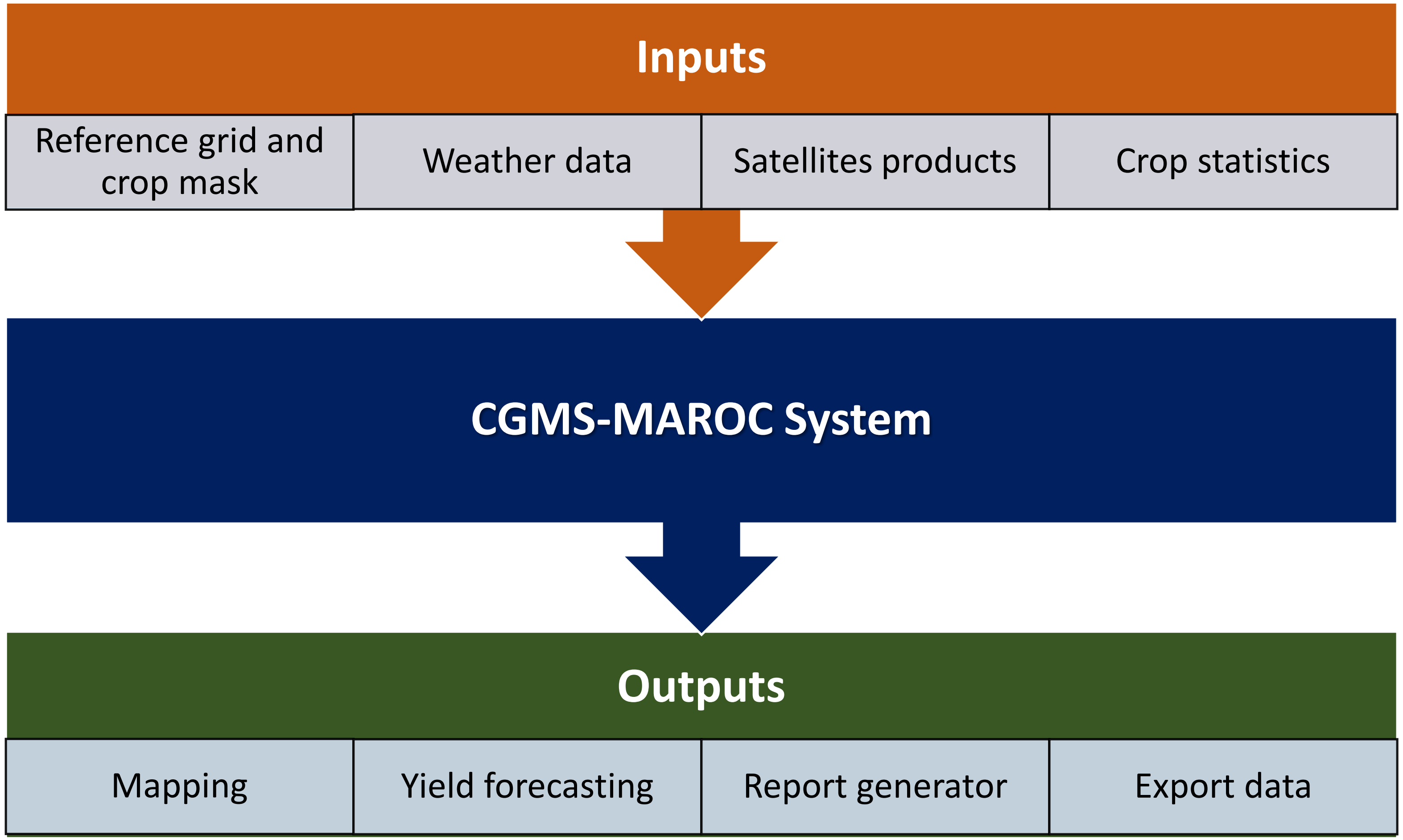
CGMS-Maroc (www.cgms-maroc.ma)

National System for Crop Monitoring

Objectives of the system

- Monitoring the agricultural season
- Support for political decision-making: Anticipating quantities to import
- Index insurance : anticipating farmers repayments
- Area of interest : the hole country

Presentation of the system



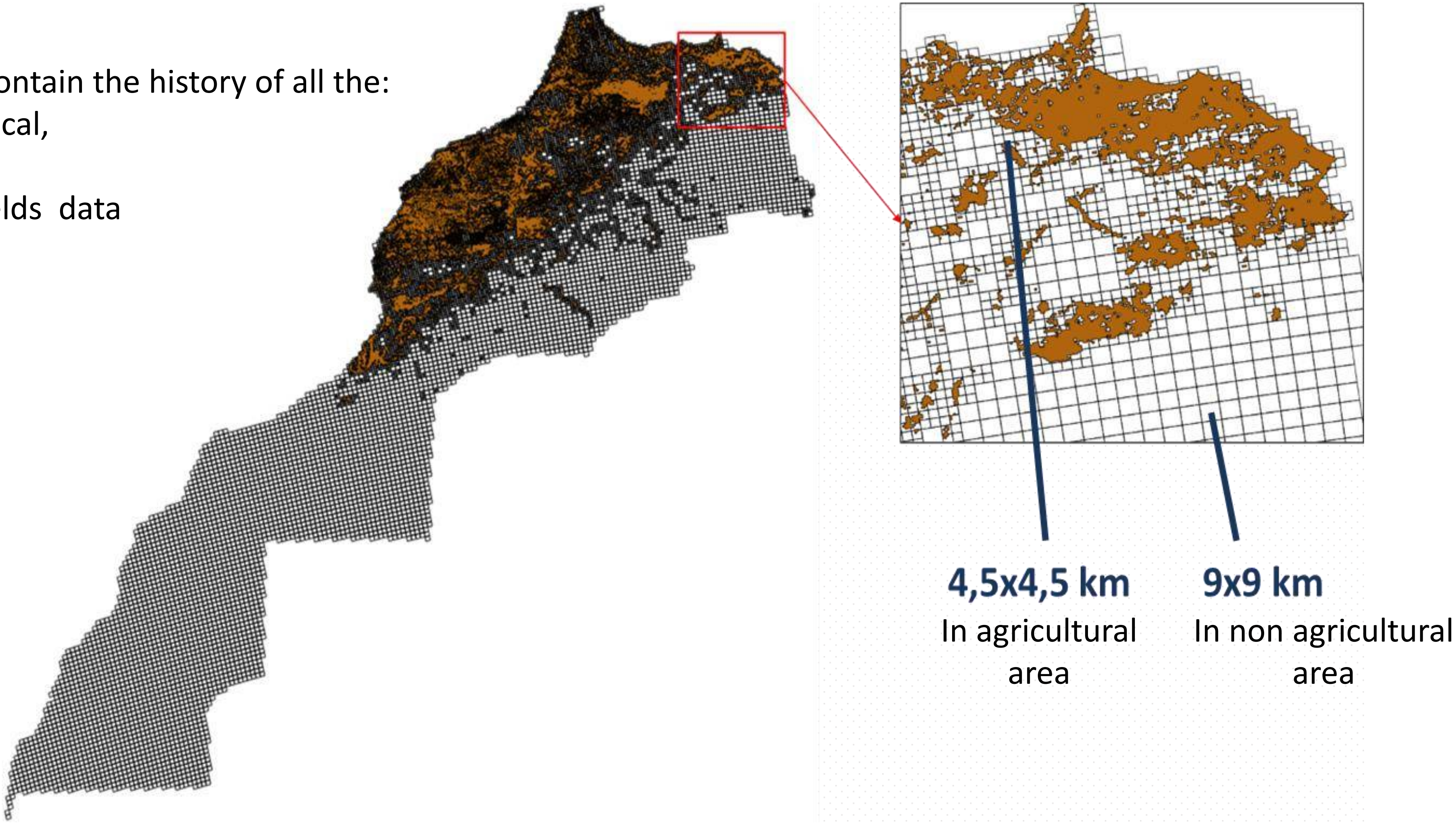
CGMS-Maroc

Data storage

Data grid and agricultural mask

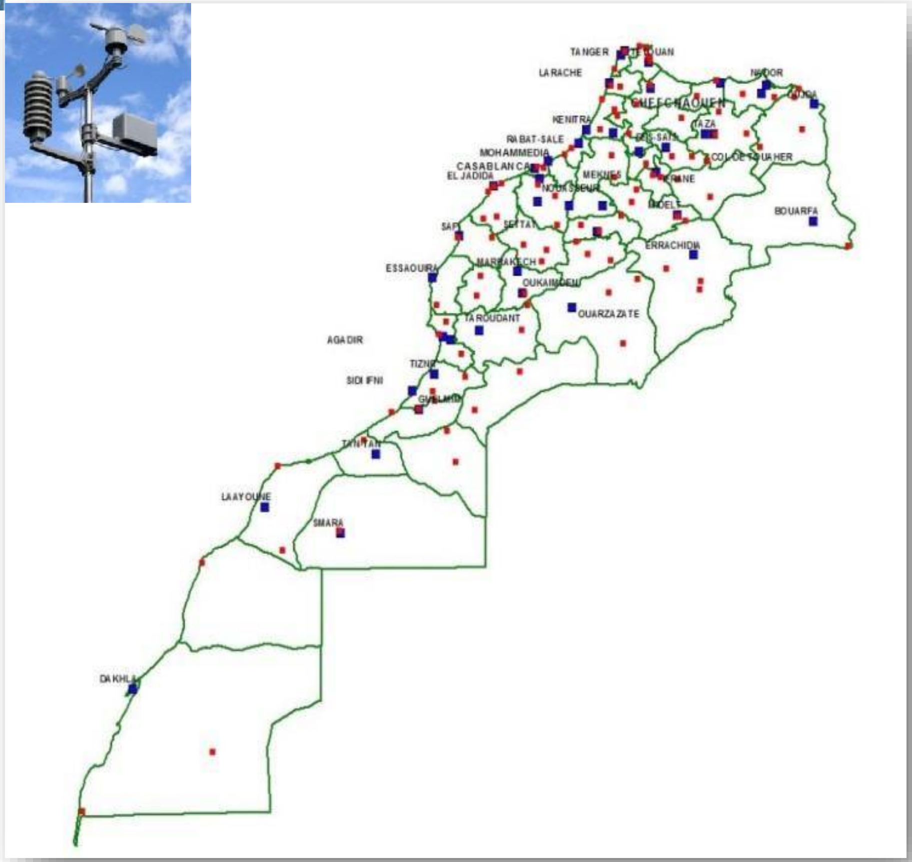
Each grid will contain the history of all the:

- meteorological,
- satellite
- and crop yields data

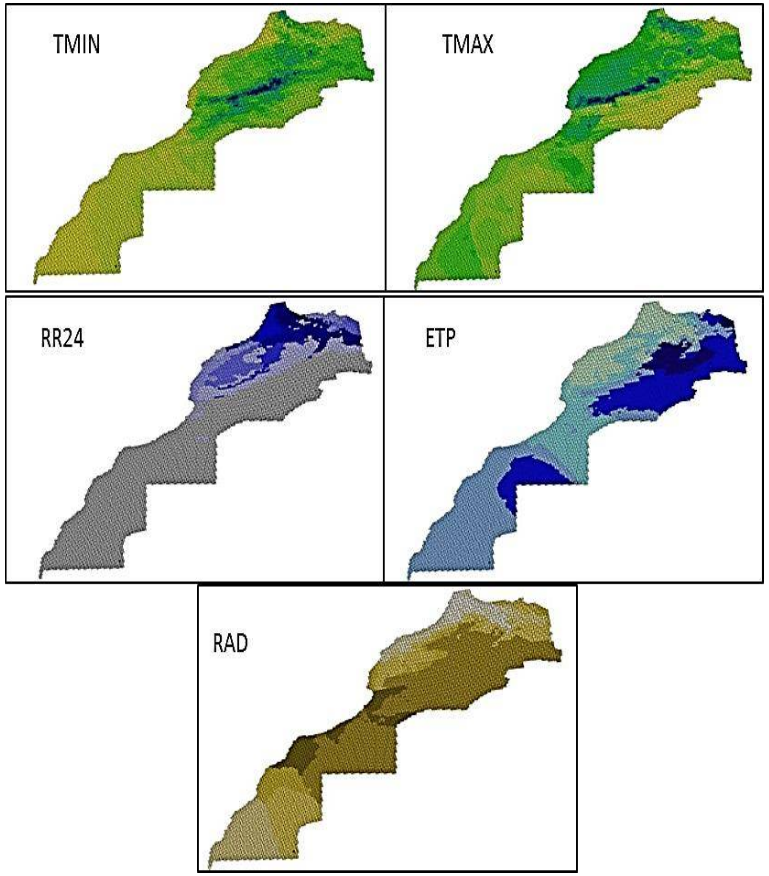


Meteorological Data: **Daily** Interpolated Data.

50 Synoptics stations
150 Vigiobs stations



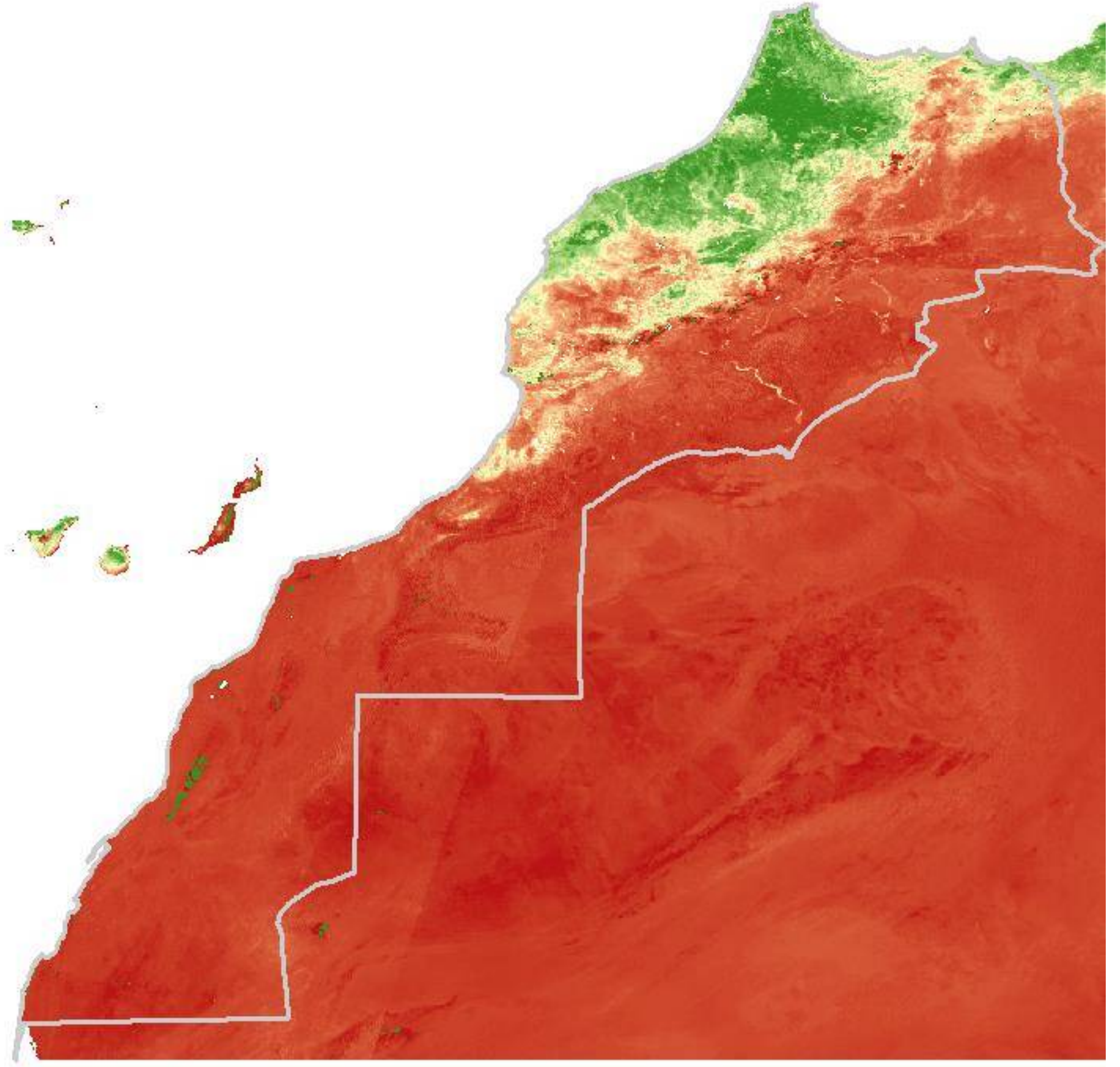
Weather station network



Ex: Grid for 09/02/2014

Satellite **decadal** data

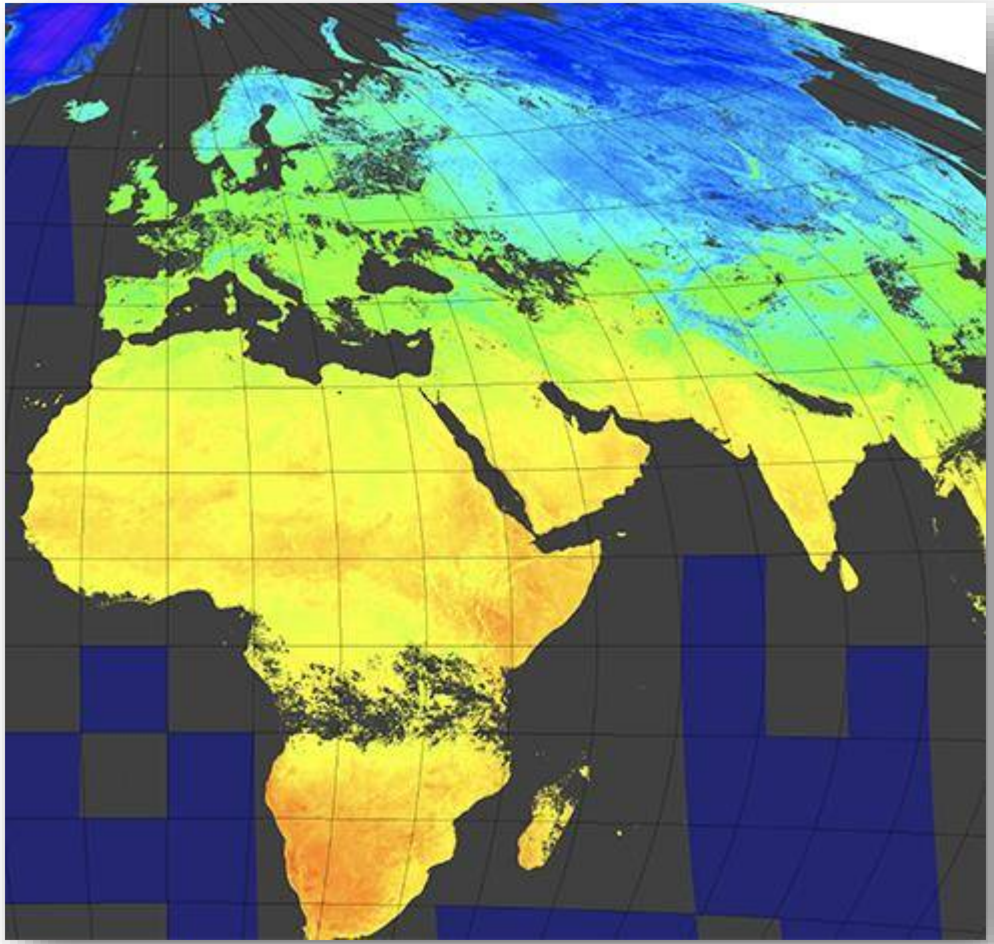
- Vegetation indices derived from satellite images available for free in **Copernicus** Global Land Service (1 km Grid) :
  - NDVI
  - FAPAR
  - LAI



Satellite data

- Estimated agro-climatic data derived from **MODIS** available for free in USGS Land Processes Distributed Active Archive Center (1 km Grid) :
  - **LST** (MOD11A2: Land Surface Temperature)
  - **PET** (MOD16A2: Potential Evapotranspiration)
  - **RET** (MOD16A2: Real Evapotranspiration)
- **RFE :** Satellite-based rainfall: Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS)

All data are automatically download and processed using Python Script

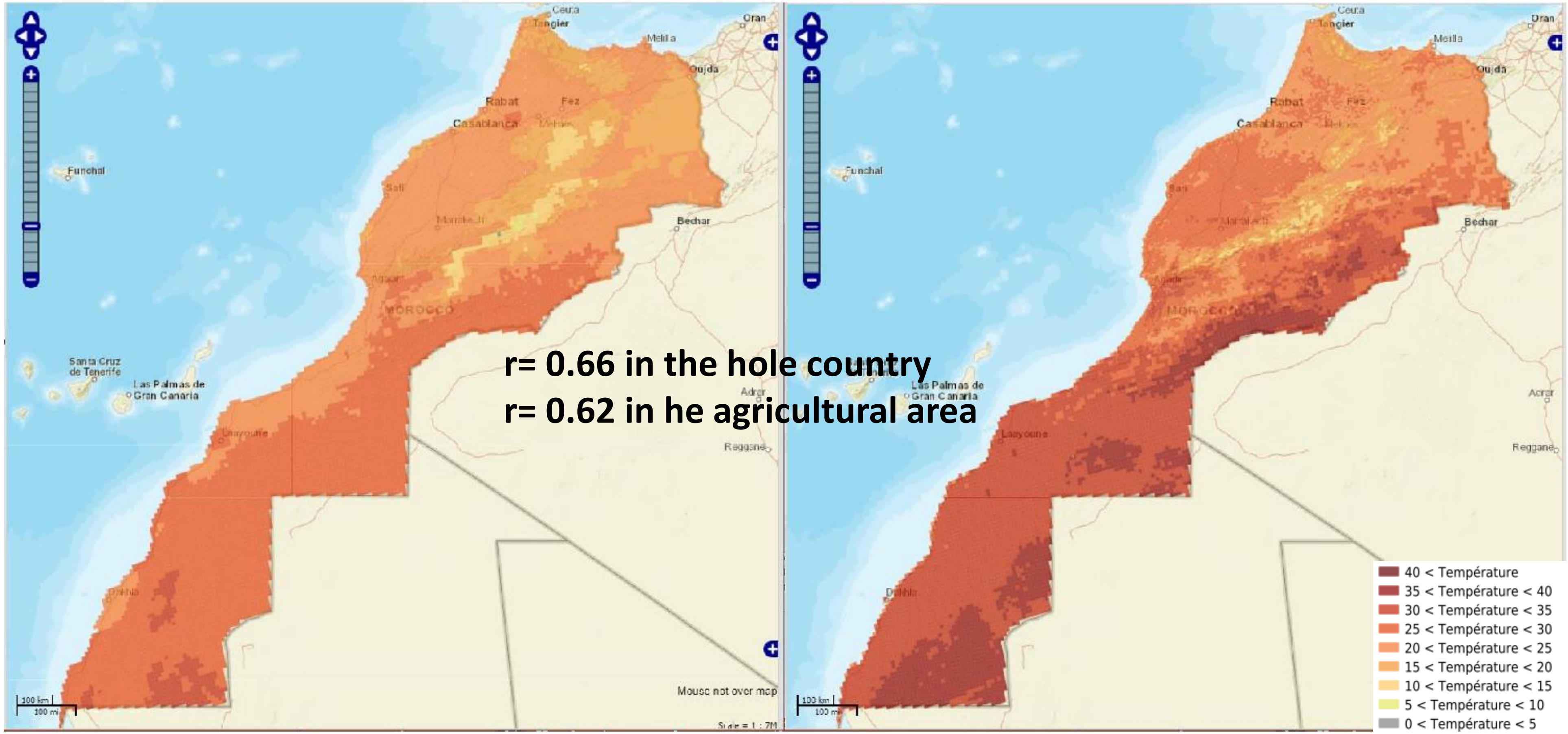


Temperature comparison

The following figures show a comparison between the average maximum temperature taken between the beginning of September 2017 and late April.

Stations terrestres

Satellite



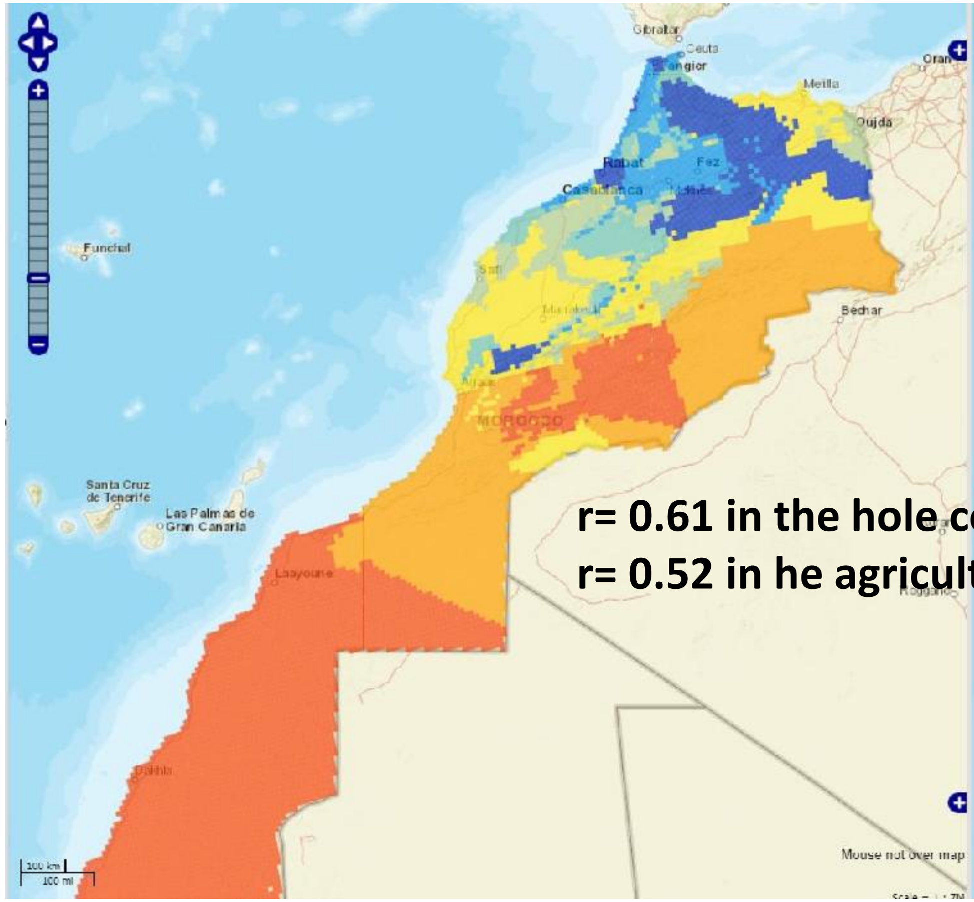
r= 0.66 in the hole country
r= 0.62 in he agricultural area

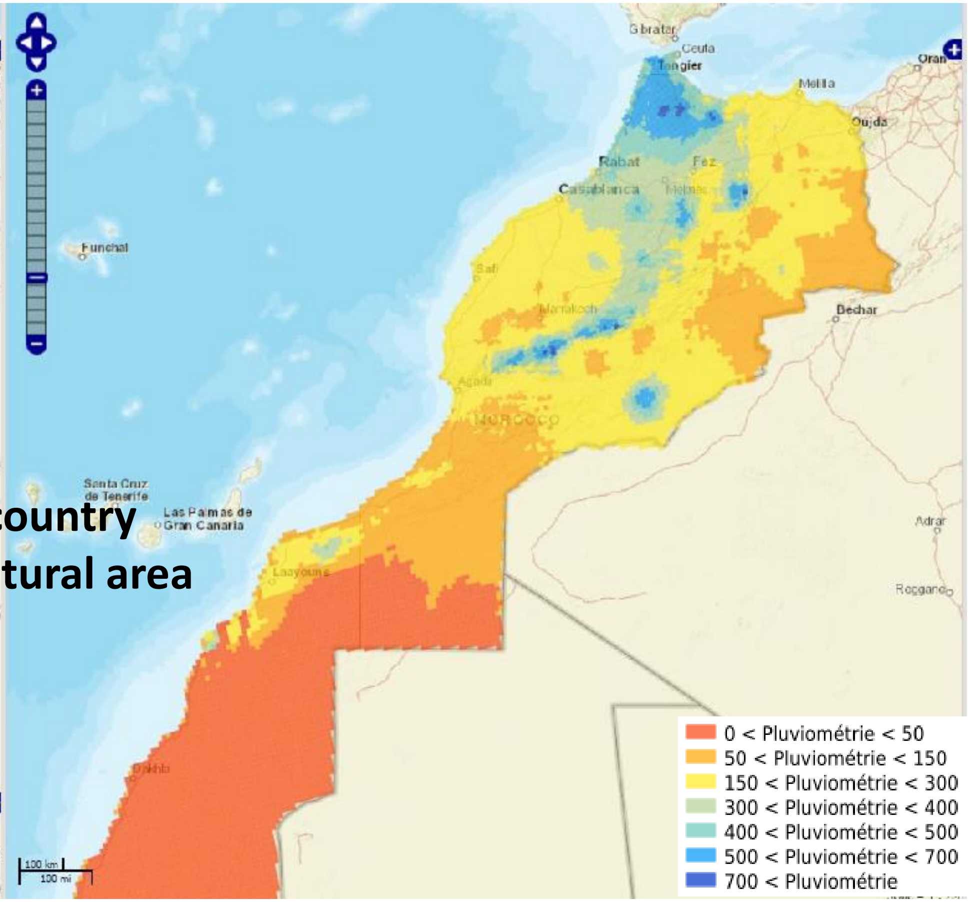
Rainfall comparison

The following figures show a comparison between the total rainfall taken between the beginning of September 2017 and late April.

Stations terrestres

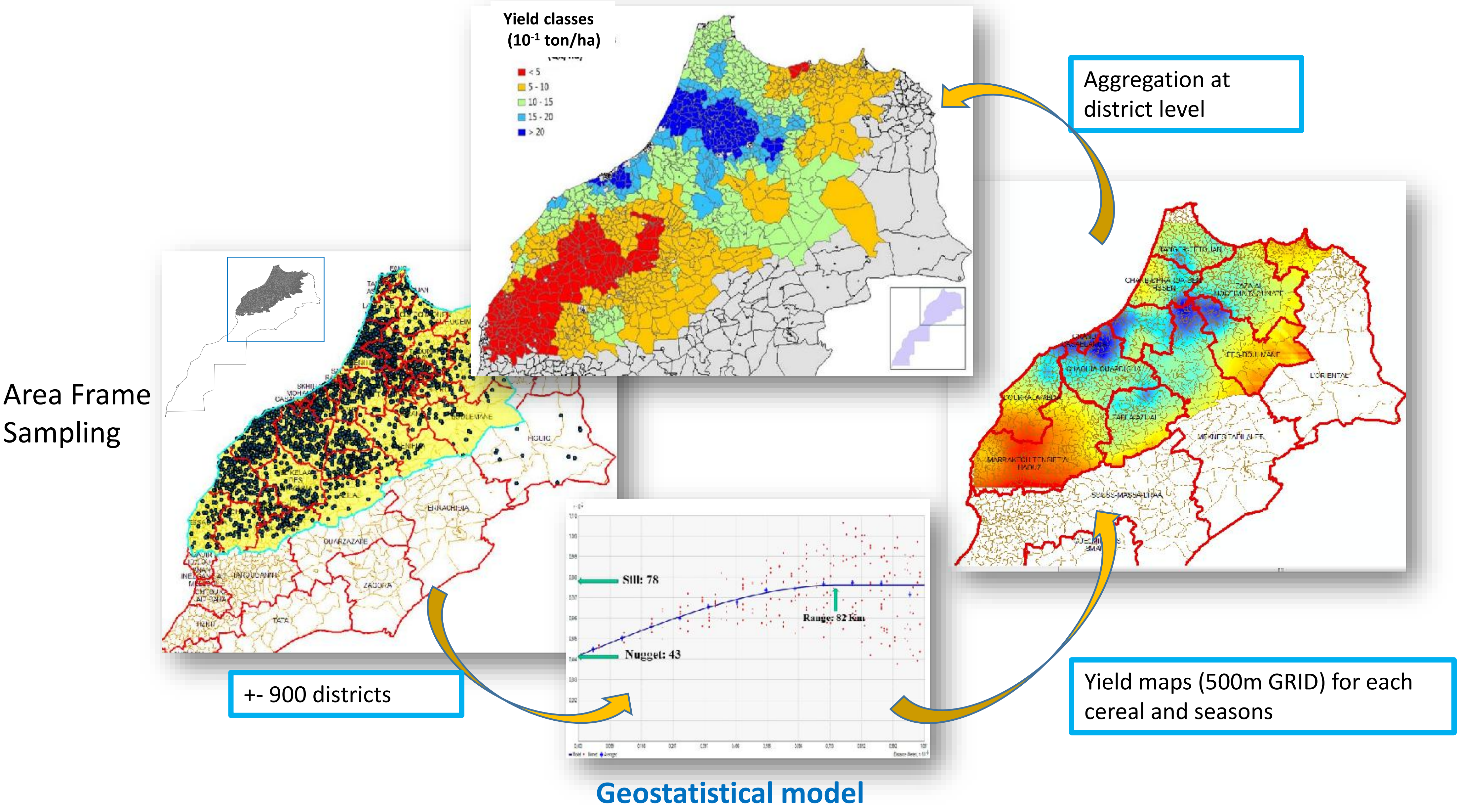
Satellite





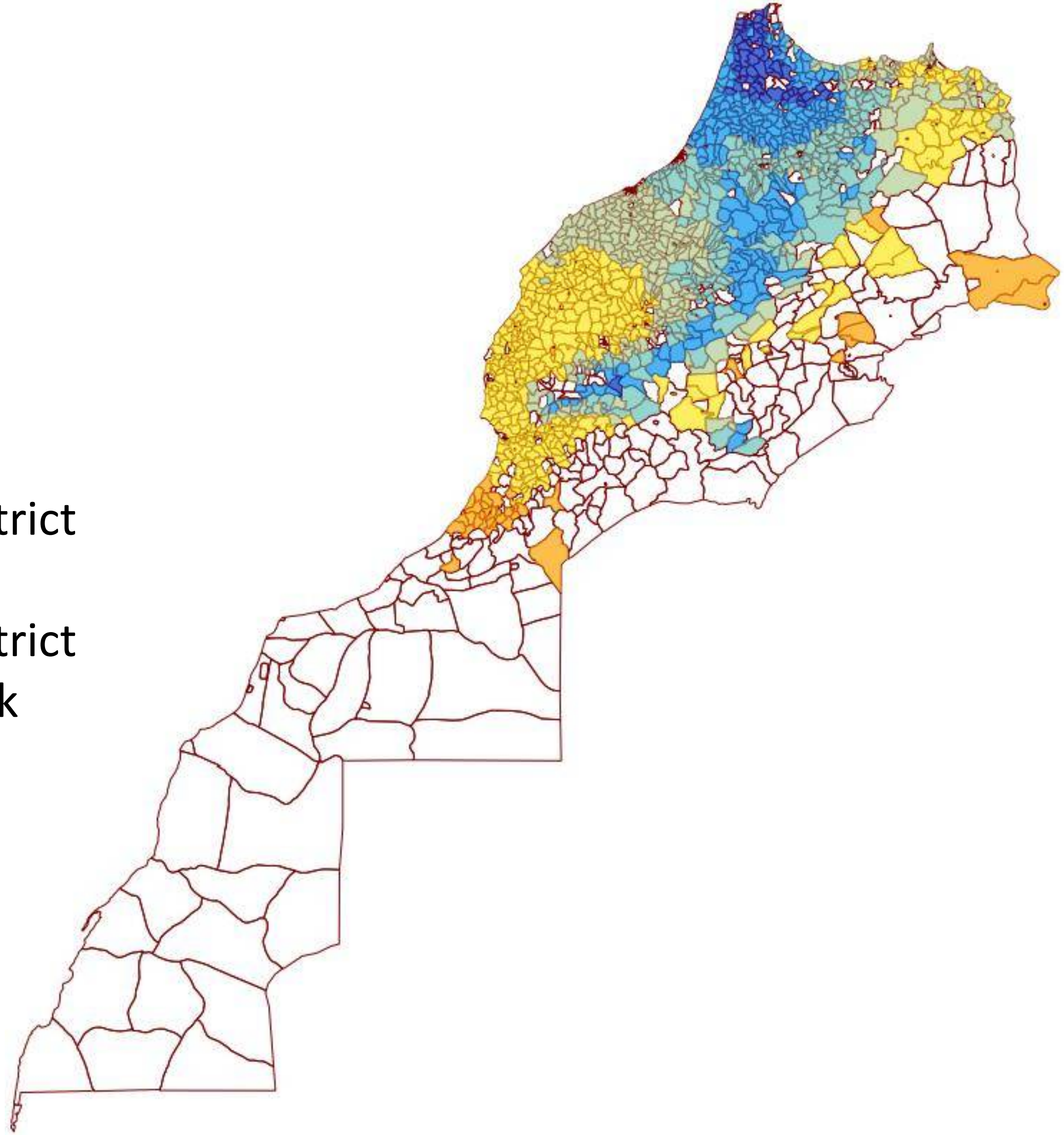
r= 0.61 in the hole country
r= 0.52 in he agricultural area

Spatial yield interpolation from sample frames



Data storage

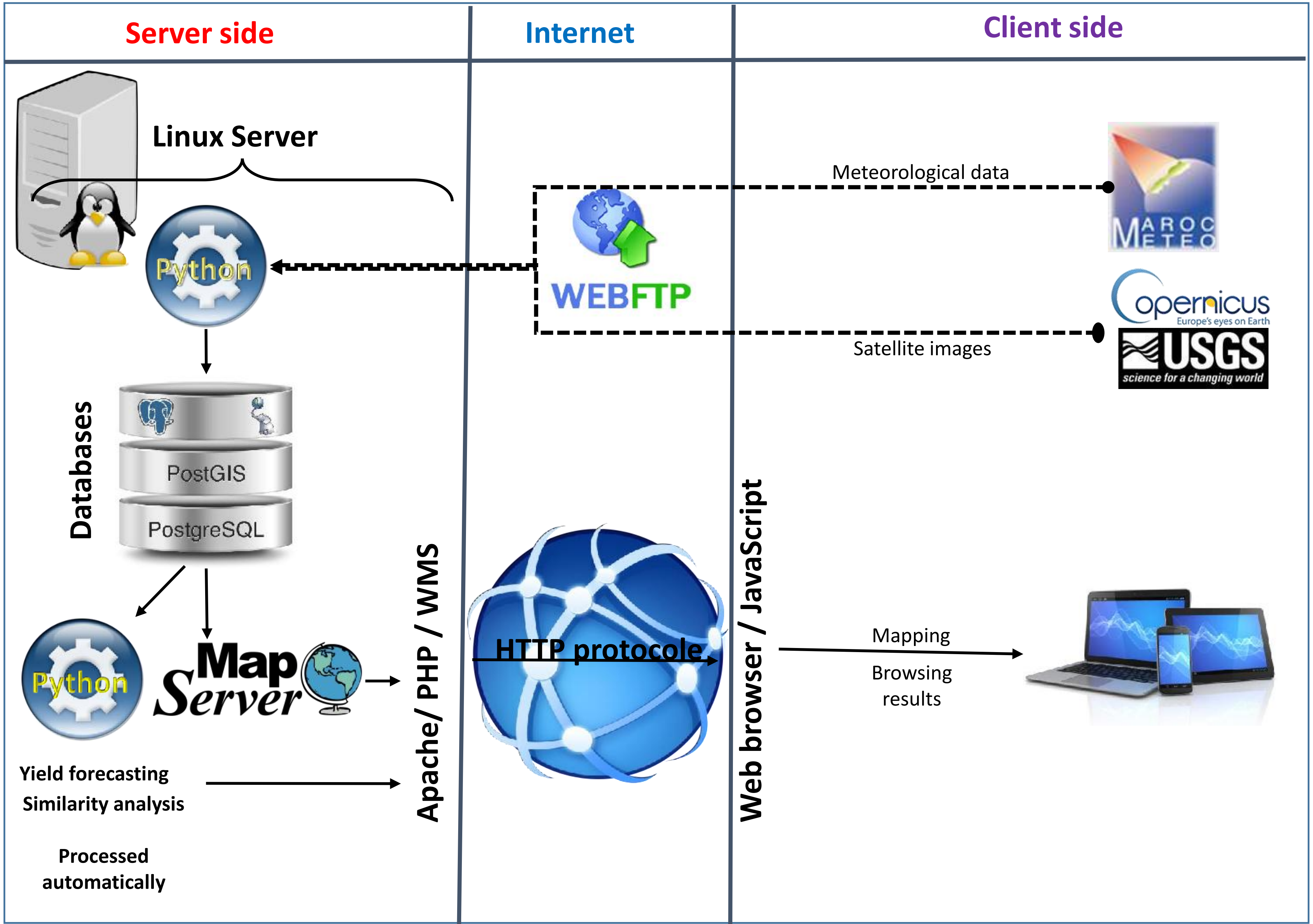
- Data grid
- Data by grid
- District division
- Aggregated data by district
- Agricultural mask
- Aggregated data by district within agricultural mask



CGMS-Maroc

System operation

System architecture (Only open Source tools were used)



CGMS-Maroc

Interface

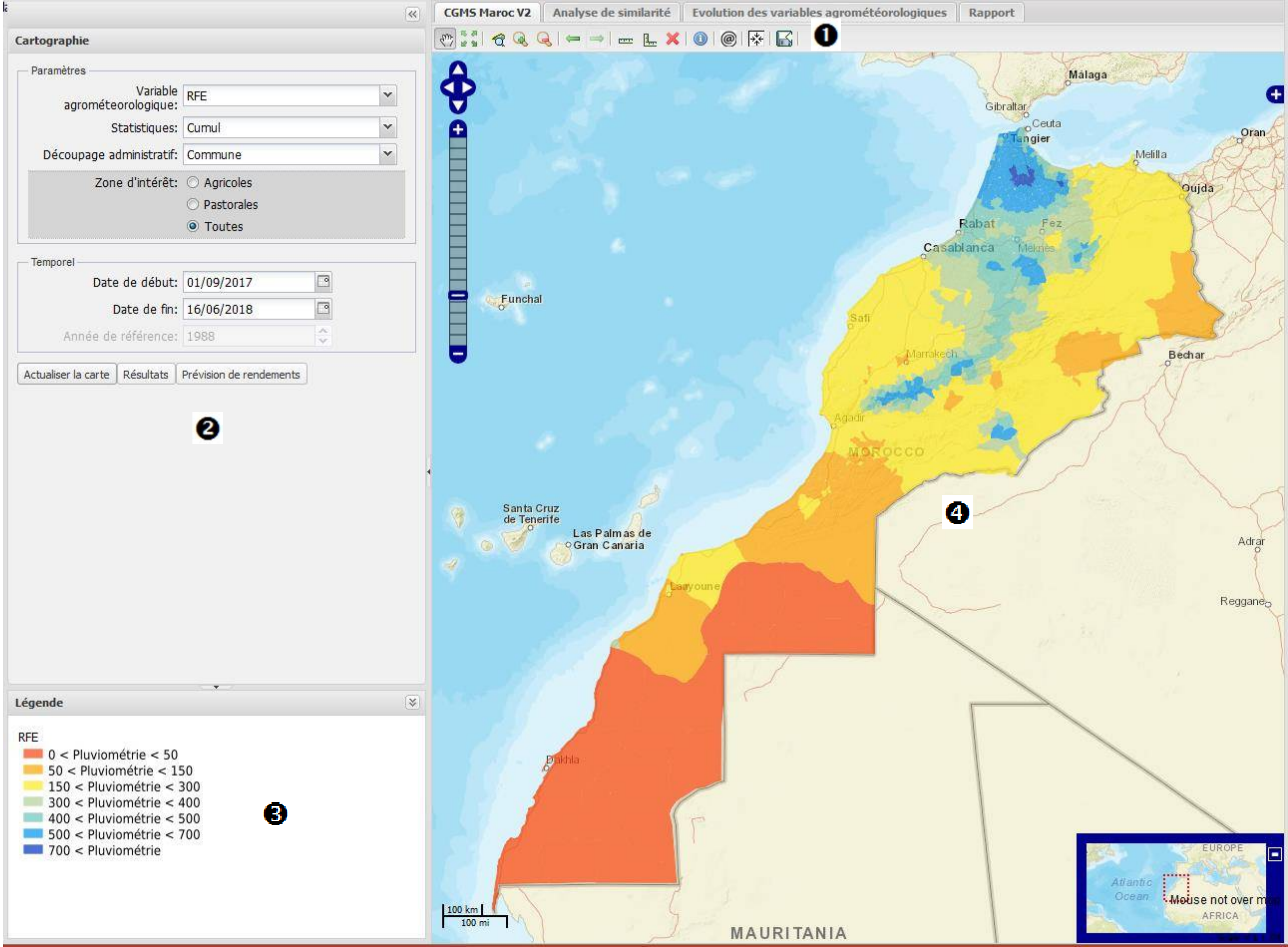
Main interface CGMS-Maroc

Friendly interface with:
(1) toolbar navigation,
(2) query selector,
(3) legend frame,
(4) the map frame

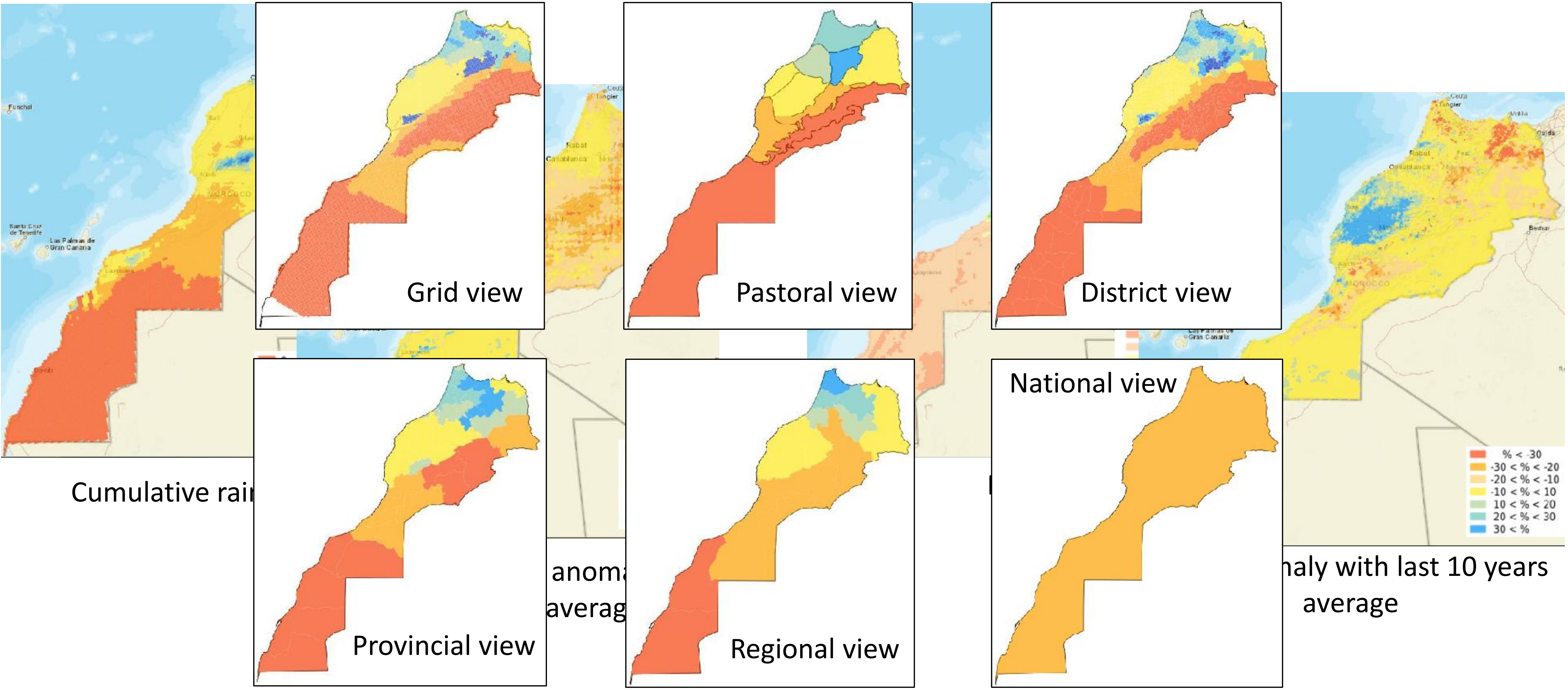
&

4 Applications

- Mapping
- Daly yield forecasting
- Similarity analysis
- Agro-climatic indicators evolution (data/graph)
- Report generator



Mapping


Grid view
Pastoral view
District view
Provincial view
Regional view
National view
Cumulative rai
anoma
averag
naly with last 10 years
average
% < -30
-30 < % < -20
-20 < % < -10
-10 < % < 10
10 < % < 20
20 < % < 30
30 < %

CGMS-MAROC: Yield forecasting

Performed automatically each day from the beginning of February at provincial level with Python script

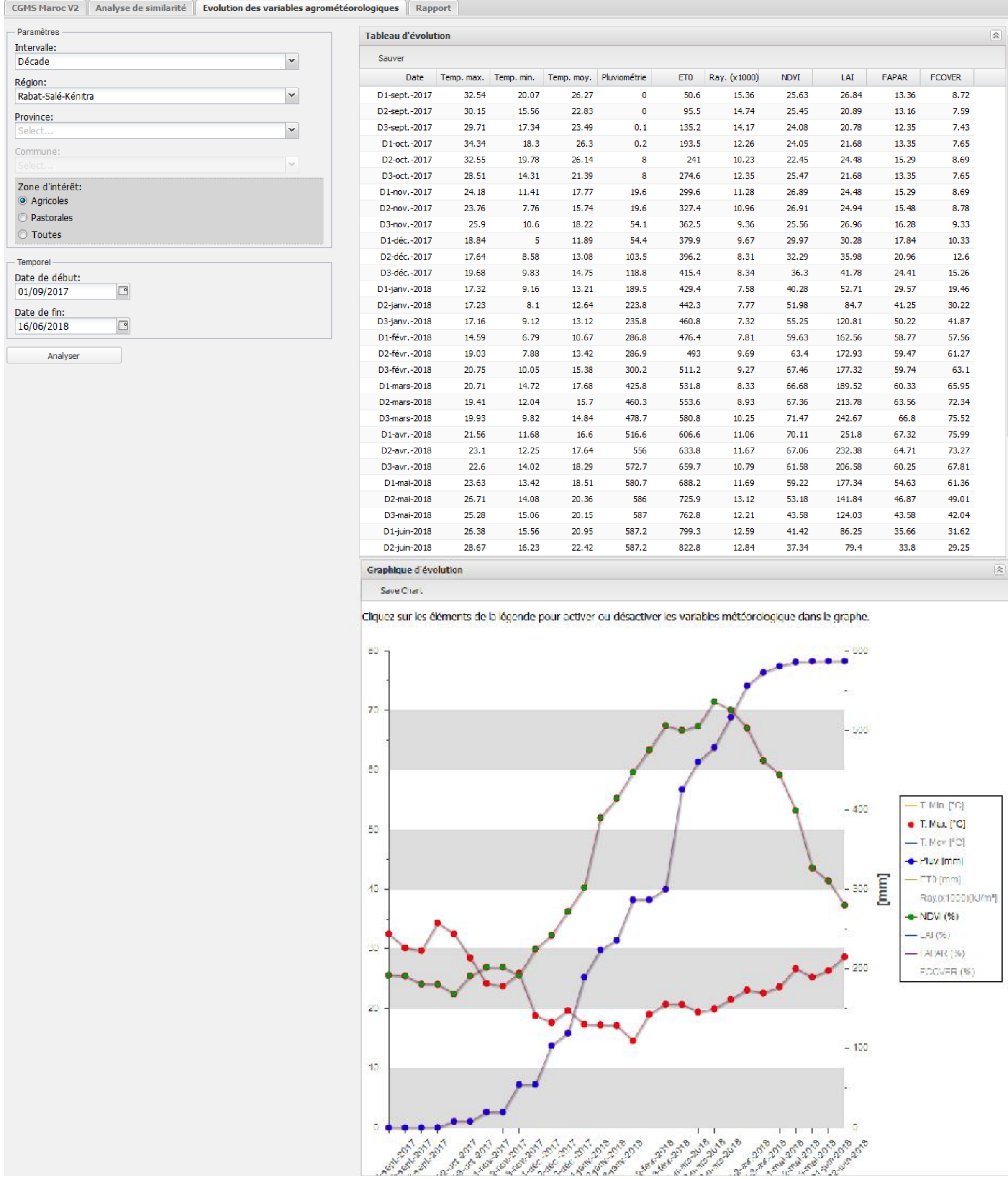
Province	Modèle	N	Prévision rendement LI	Prévision rendement Qx/Ha	Prévision rendement LS	S... Mo... x ...	... ... x 1...	Similarité pluviométrie		Similarité Taux de satisfaction		Similarité NDVI	
								An	Prévision (Qx/Ha)	An	Prévision (Qx/Ha)	An	Prévision (Qx/Ha)
04.-Province:Salé	rdt = -14.7304 + 27.1718*NDVI_Fev_2-42.3041*NDVI_Fev_3 + 65.7886*NDVI_Mar_2,...	16	14.58	19.28	23.98			2010	16	2010	16	2010	16
04.-Province:Sidi Kacem	rdt = -28.5621 + 0.0375*Taux_Satisfaction_P2-0.0164*Regular_S_Pluv + 70.0084*ND...	16	15.66	23.54	31.41			1998	24.23	1998	24.23	1998	24.23
04.-Province:Sidi Slimane	rdt = -25.2765 + 0.032*Taux_Satisfaction_P2 + 59.0402*NDVI_Mar, R^2adj=70%	16	11.09	20.48	29.87			1998	25.12	1998	25.12	2003	16.6
04.-Province:Skhirate- Témara	rdt = -10.9404 + 42.5935*NDVI_Mar_2, R^2adj=73%	16	12.61	19.28	25.95			2010	15.55	2010	15.55	2013	25.42
05.-Province:Azilal	rdt = -21.7741 + 0.054*Pluv_P2 + 0.1486*Taux_Satisfaction_P1 + 59.6013*NDVI_Moy...	16	0	10.36	20.73			2011	6.71	2011	6.71	2015	12.14
05.-Province:Béni Mellal	rdt = -23.731-0.078*Pluv_P3 + 0.5929*Taux_Satisfaction + 42.8201*NDVI_Avr_3, R^2a...	16	2.93	17.86	32.78			2010	12.51	2011	16.69	2013	16.41
05.-Province:Fquih Ben Salah	rdt = -7.0272 + 0.17*Taux_Satisfaction_P1-0.0009*Rayonnement + 37.6271*NDVI_Av...	16	0	12.09	35.8			2011	3.61	2002	6.1	2003	17.48
05.-Province:Khouribga	rdt = 53.219-3.4991*Temp + 42.7219*NDVI_Mar_2-0.1001*Amplitude_NDVI, R^2adj=8...	16	12.45	19.91	27.37			2009	20.79	1998	18.54	2003	14.69
05.-Province:Khénifra	rdt = 29.8304-2.6147*Temp-69.9083*NDVI_Fev_2 + 98.1863*NDVI_Mar, R^2adj=82%	16	14.3	19.83	25.35			2010	10.67	2011	17.23	2003	12.76
06.-Province:Benslimane	rdt = -20.4685 + 59.6707*NDVI_Mar_2, R^2adj=75%	16	11.03	23.96	36.89			2002	11.52	2017	30.56	2010	17.04
06.-Province:Berrechid	rdt = 12.3679-0.0022*Rayonnement + 94.2882*NDVI_Mar_2-56.0388*NDVI_Avr_3, R^2...	16	1.91	22.08	42.25			2002	10.86	1998	18.13	2010	16.44
06.-Province:El Jadida	rdt = -55.9091-0.1802*Pluv_P3 + 126.9766*NDVI_Avr_2 + 0.3428*Amplitude_NDVI, R...	16	0	24.44	82.49			2010	13.72	1998	16.69	2010	13.72
06.-Province:Mohammadia	rdt = -35.8422 + 28.7929*NDVI_Fev_2 + 57.4195*NDVI_Mar_2, R^2adj=81%	16	15.11	23.1	31.1			2013	25.76	2013	25.76	2010	18.32
06.-Province:Médiouna	rdt = -21.0328 + 540.8807*PNDVI_P3 + 49.1571*NDVI_Fev_2 + 65.3733*NDVI_Mar_...	16	13.92	27.64	41.37			2017	31.19	1998	20.98	2002	12.02
06.-Province:Nouaceur	rdt = -47.5017 + 29.315*NDVI_Fev_2 + 73.7897*NDVI_Mar_2, R^2adj=86%	16	15.61	24.06	32.51			2009	30.04	1998	18.58	2002	16.23
06.-Province:Settat	rdt = 32.5382-0.0026*Rayonnement + 80.4171*NDVI_Mar_2-43.5697*NDVI_Avr_1, R^2...	16	13.53	23.91	34.29			1998	18.7	1998	18.7	2010	13.33
06.-Province:Sidi Bennour	rdt = 170.5952-0.0018*Rayonnement-9.7392*Temp + 68.7976*NDVI_Mar, R^2adj=79%	16	8.45	29.94	51.42			1998	15.78	1998	15.78	2011	21.46
07.-Province:Al Haouz	rdt = -13.9018 + 54.7101*NDVI_Avr_1, R^2adj=82%	16	7.39	11.39	15.39			2011	1.72	2011	1.72	2009	16.73
07.-Province:Chichaoua	rdt = -1.9543 + 0.0251*Pluv_P3 + 62.8803*NDVI_Mar_2-54.0399*NDVI_Avr_3, R^2adj...	16	6.47	7.81	9.15			2011	4.39	2011	4.39	1998	6.92
07.-Province:El Kelâa des Sraghna	rdt = 21.1396 + 0.0762*Taux_Satisfaction_P1-2.0809*Temp_P3 + 42.1885*NDVI_Mar...	16	7.06	20.32	33.58			1998	11.16	2002	5.22	2010	9.23
07.-Province:Essaouira	rdt = -5.9056 + 0.137*Taux_Satisfaction_P1-19.867*NDVI_Mar_3 + 34.3314*NDVI_Av...	16	1.87	3.65	5.43			2003	7.41	1998	9.13	2011	9.12
07.-Province:Marrakech	rdt = -12.4859 + 35.7884*NDVI_Fev_2 + 36.4922*NDVI_Mar-124.6901*NDVI_STD, R^2...	16	9.36	12.03	14.69			2011	4.78	2011	4.78	1998	6.57
07.-Province:Rehamna	rdt = 65.7033-0.0007*Rayonnement-3.5967*Temp + 38.6444*NDVI_Mar_2, R^2adj=89%	16	13.46	18.91	24.36			1998	10.32	2011	7.36	1998	10.32
07.-Province:Safi	rdt = 27.3208 + 0.0247*Regular_S_Pluv-2.0514*Temp_P2, R^2adj=67%	16	0	6.11	14.27			1998	12.51	1998	12.51	1998	12.51
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Similarity analysis

Rapid characteristics of the cropping season, by comparing the similarity of the past seasons to the current one, from an agro-climatic point of view.

Agro-climatic indicators evolution (data/graph)

This feature allows displaying in tables and graphs the evolution of agro-meteorological indicators.



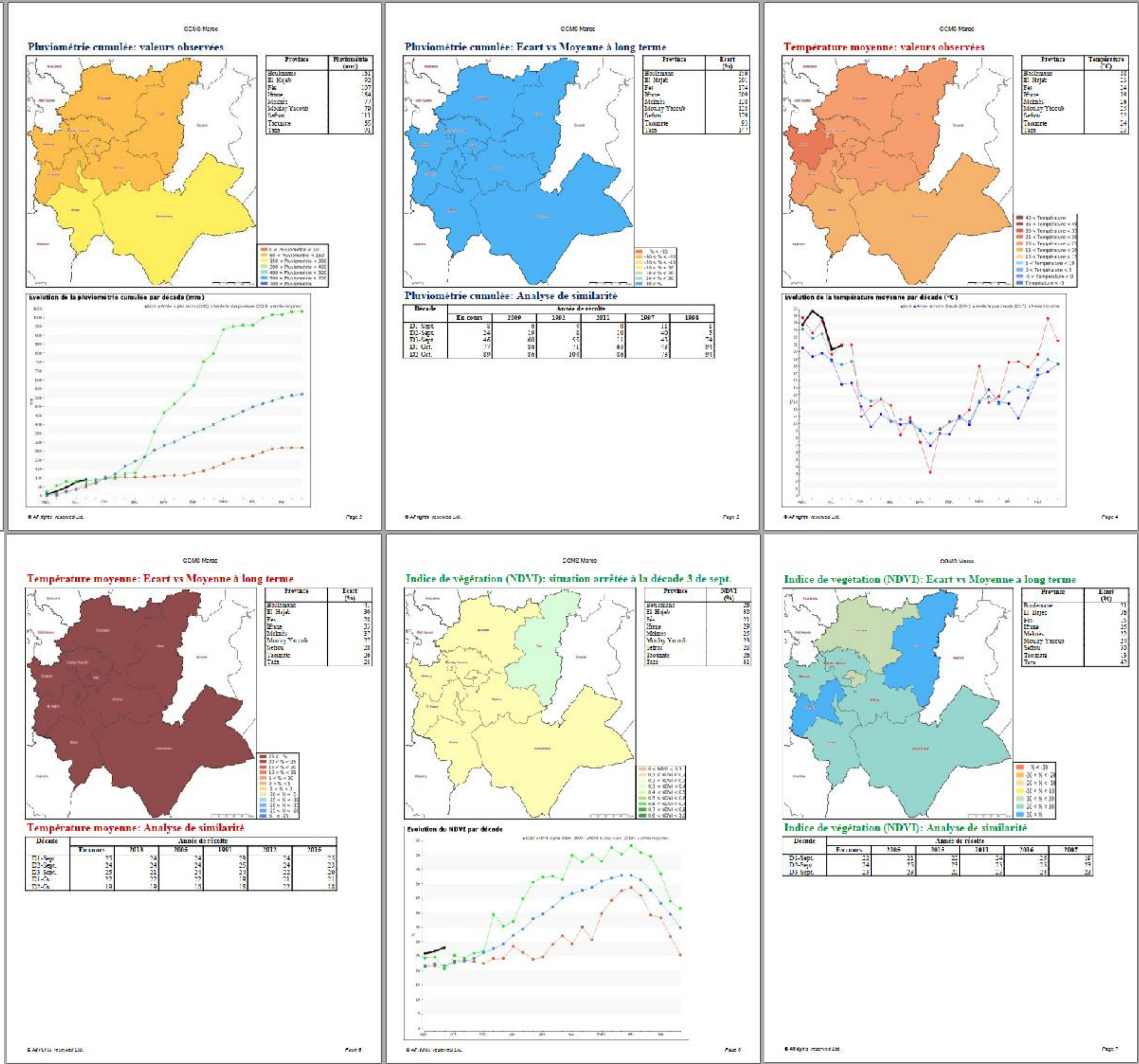
Date	Temp. max.	Temp. min.	Temp. moy.	Pluviométrie	ET0	Ray. (x1000)	NDVI	LAI	FAPAR	FCOVER
D1-sept.-2017	32.54	20.07	26.27	0	50.6	15.36	25.63	26.84	13.36	8.72
D2-sept.-2017	30.15	15.56	22.83	0	95.5	14.74	25.45	20.89	13.16	7.59
D3-sept.-2017	29.71	17.34	23.49	0.1	135.2	14.17	24.08	20.78	12.35	7.43
D1-oct.-2017	34.34	18.3	26.3	0.2	193.5	12.26	24.05	21.68	13.35	7.65
D2-oct.-2017	32.55	19.78	26.14	8	241	10.23	22.45	24.48	15.29	8.69
D3-oct.-2017	28.51	14.31	21.39	8	274.6	12.35	25.47	21.68	13.35	7.65
D1-nov.-2017	24.18	11.41	17.77	19.6	299.6	11.28	26.89	24.48	15.29	8.69
D2-nov.-2017	23.76	7.76	15.74	19.6	327.4	10.96	26.91	24.94	15.48	8.78
D3-nov.-2017	25.9	10.6	18.22	54.1	362.5	9.36	25.56	26.96	16.28	9.33
D1-déc.-2017	18.84	5	11.89	54.4	379.9	9.67	29.97	30.28	17.84	10.33
D2-déc.-2017	17.64	8.58	13.08	103.5	396.2	8.31	32.29	35.98	20.96	12.6
D3-déc.-2017	19.68	9.83	14.75	118.8	415.4	8.34	36.3	41.78	24.41	15.26
D1-janv.-2018	17.32	9.16	13.21	189.5	429.4	7.58	40.28	52.71	29.57	19.46
D2-janv.-2018	17.23	8.1	12.64	223.8	442.3	7.77	51.98	84.7	41.25	30.22
D3-janv.-2018	17.16	9.12	13.12	235.8	460.8	7.32	55.25	120.81	50.22	41.87
D1-févr.-2018	14.59	6.79	10.67	286.8	476.4	7.81	59.63	162.56	58.77	57.56
D2-févr.-2018	19.03	7.88	13.42	286.9	493	9.69	63.4	172.93	59.47	61.27
D3-févr.-2018	20.75	10.05	15.38	300.2	511.2	9.27	67.46	177.32	59.74	63.1
D1-mars-2018	20.71	14.72	17.68	425.8	531.8	8.33	66.68	189.52	60.33	65.95
D2-mars-2018	19.41	12.04	15.7	460.3	553.6	8.93	67.36	213.78	63.56	72.34
D3-mars-2018	19.93	9.82	14.84	478.7	580.8	10.25	71.47	242.67	66.8	75.52
D1-avr.-2018	21.56	11.68	16.6	516.6	606.6	11.06	70.11	251.8	67.32	75.99
D2-avr.-2018	23.1	12.25	17.64	556	633.8	11.67	67.06	232.38	64.71	73.27
D3-avr.-2018	22.6	14.02	18.29	572.7	659.7	10.79	61.58	206.58	60.25	67.81
D1-mai-2018	23.63	13.42	18.51	580.7	688.2	11.69	59.22	177.34	54.63	61.36
D2-mai-2018	26.71	14.08	20.36	586	725.9	13.12	53.18	141.84	46.87	49.01
D3-mai-2018	25.28	15.06	20.15	587	762.8	12.21	43.58	124.03	43.58	42.04
D1-juin-2018	26.38	15.56	20.95	587.2	799.3	12.59	41.42	86.25	35.66	31.62
D2-juin-2018	28.67	16.23	22.42	587.2	822.8	12.84	37.34	79.4	33.8	29.25

Reporting feature

Automatic generation of reports at different levels:

- National
- Regional
- And Provincial

Including **rainfall**, **temperature** and **NDVI** evolution and anomalies



Operational cereal yield forecasting in Morocco

Purpose of the study

1. Compare the two approaches of Machines Learning:
   - Statistic: Multiple linear regression
   - Learning: Random Forest and Boosted Tree
2. Quantify the contribution of satellite data in crop yield prediction by comparing models based on the use of:
   - Agro-climatic data from Earth observation
   - Vegetation indices from Copernicus Global Land Service
   - Estimated agro-climatic data derived from MODIS

Data characterization

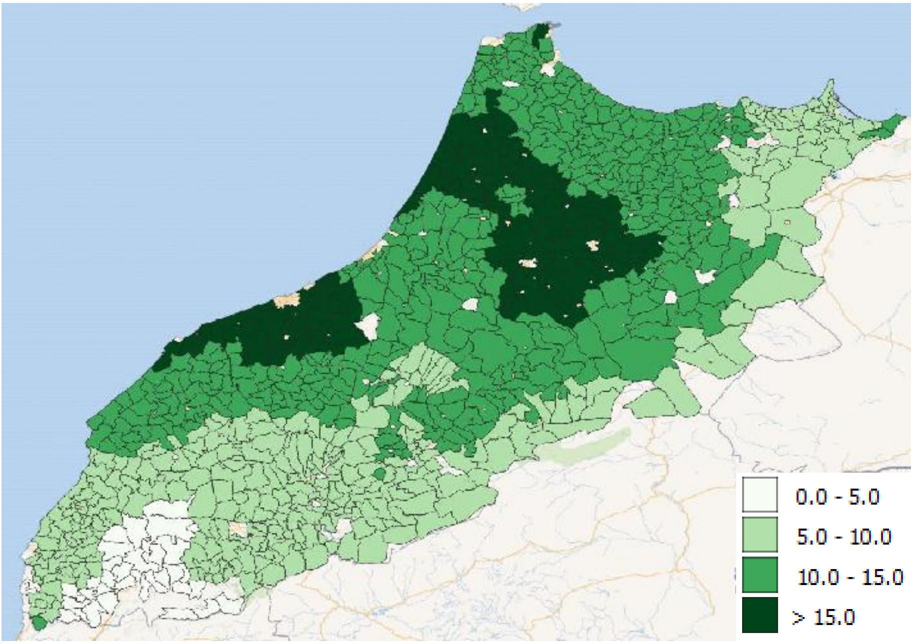
- **1** dependent variable : yield
- **140** predictors
  - **4** geographical information
  - **58** meteorological
  - **42** vegetation indices
  - **69** Estimated agro-climatic
- 35890 lines
  (14 years observation, 3 cereals and ≈ 900 districts)

Simulation

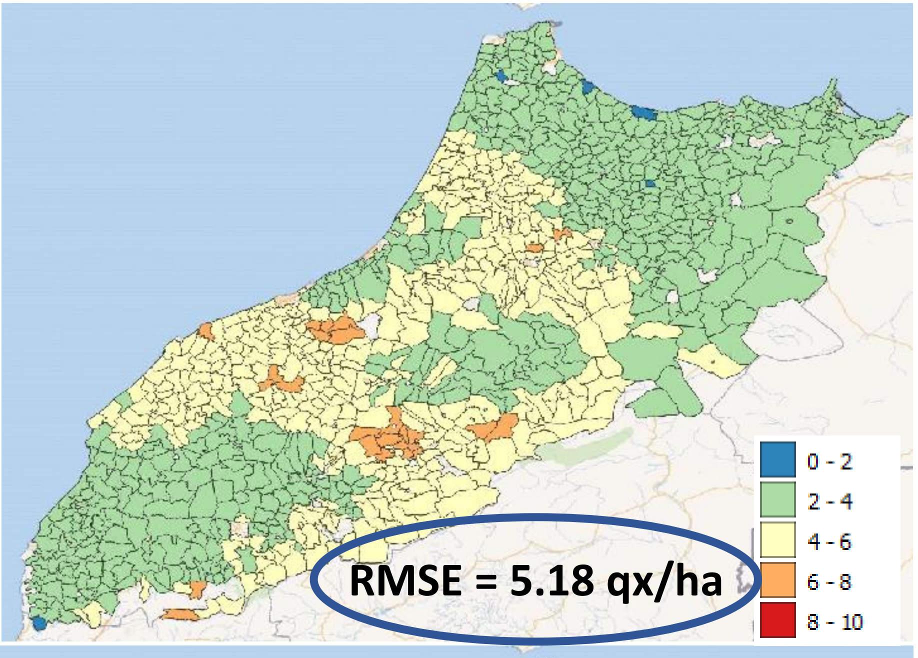
- Automation scripts have been developed for the three forecasting techniques selected for this study:
  - Multiple linear regression
  - Random Forest
  - Boosted Tree
- To perform calculations we
  - For each available growing season,
    - The data was separated into three different subsets to ensure model accuracy:
      1. Testing data that correspond to the growing season been analyzed,
      2. Validation data (fraction of 20%)
      3. Training data (remaining data).
    - The training data was used to build model. Once both the training and validation prediction results are similar to the observed, we use the model to predict the yield for the test data subset.

Absolute error: Comparison between prevision models

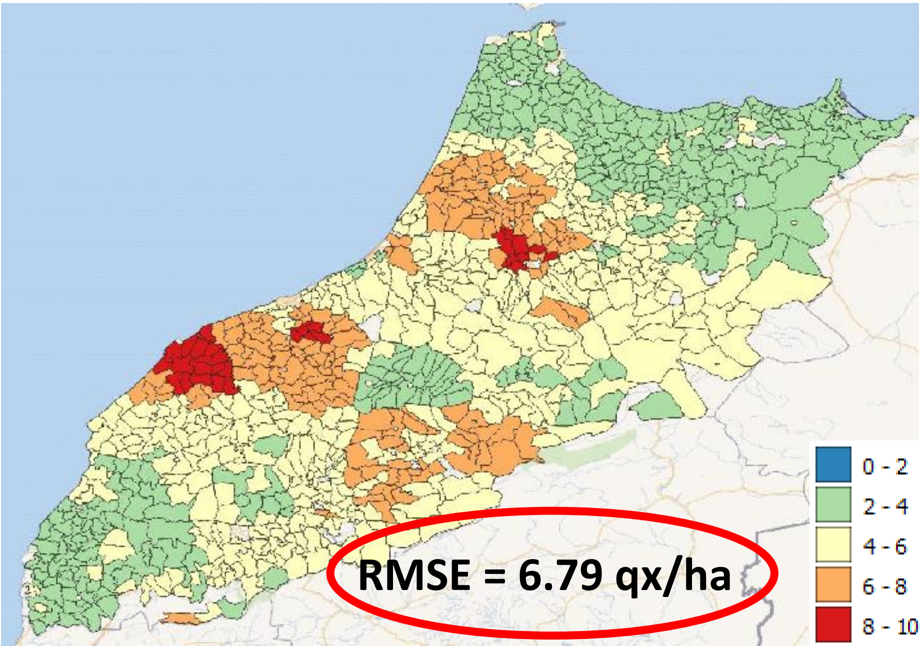
Average observed yield 2002-2017



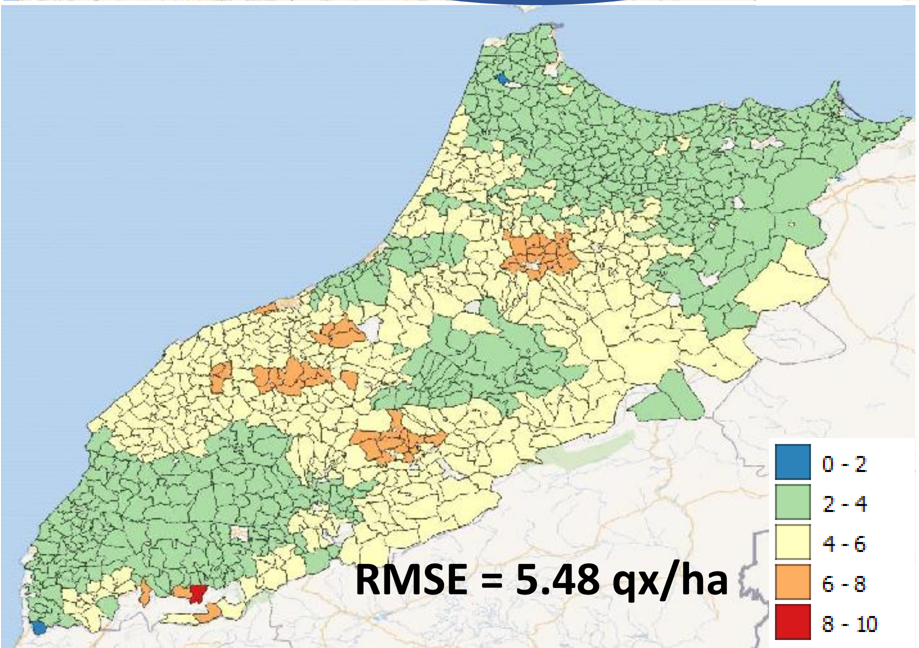
Random Forest



Linear Model

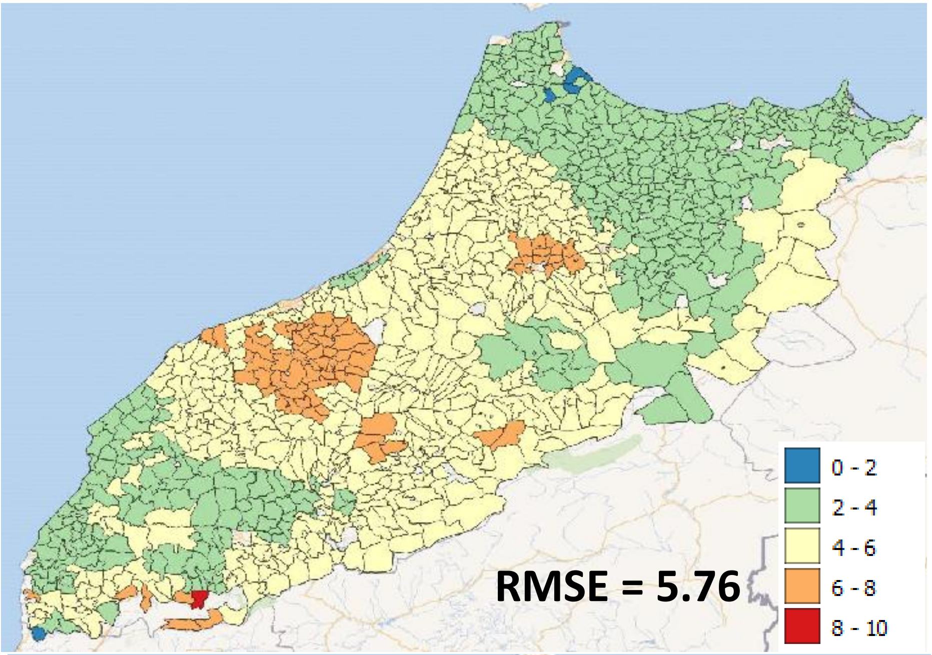


Boosted Tree

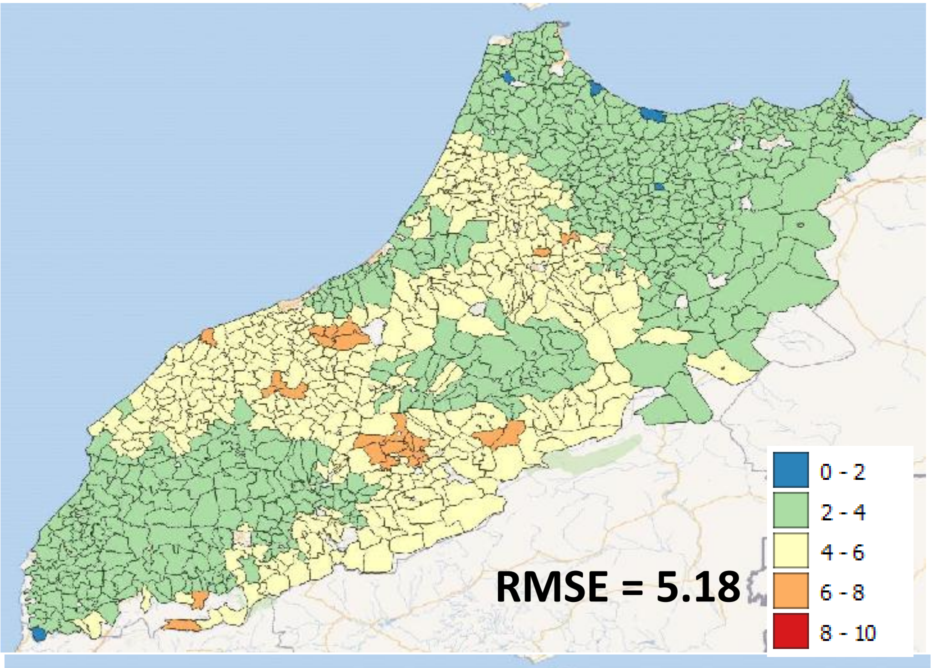


Absolute error: Comparison between data sources

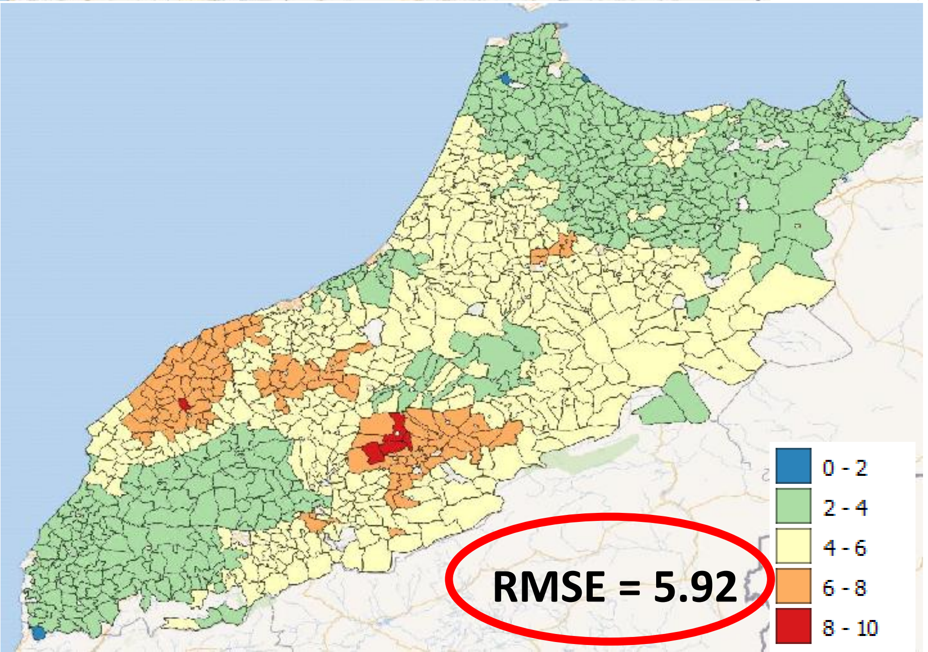
Weather data



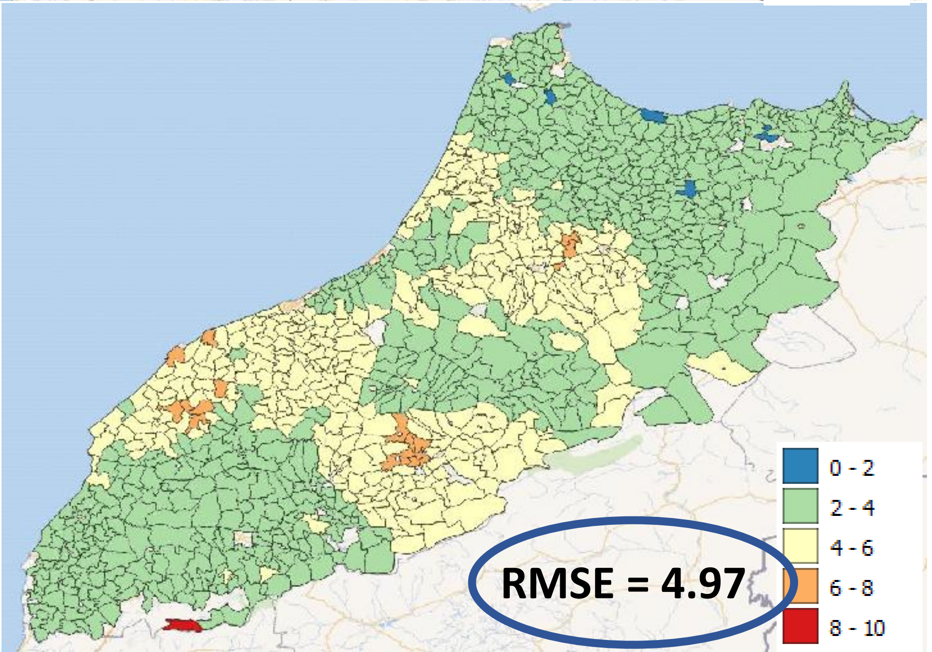
Weather & Satellite



Vegetation indices (Satellite)

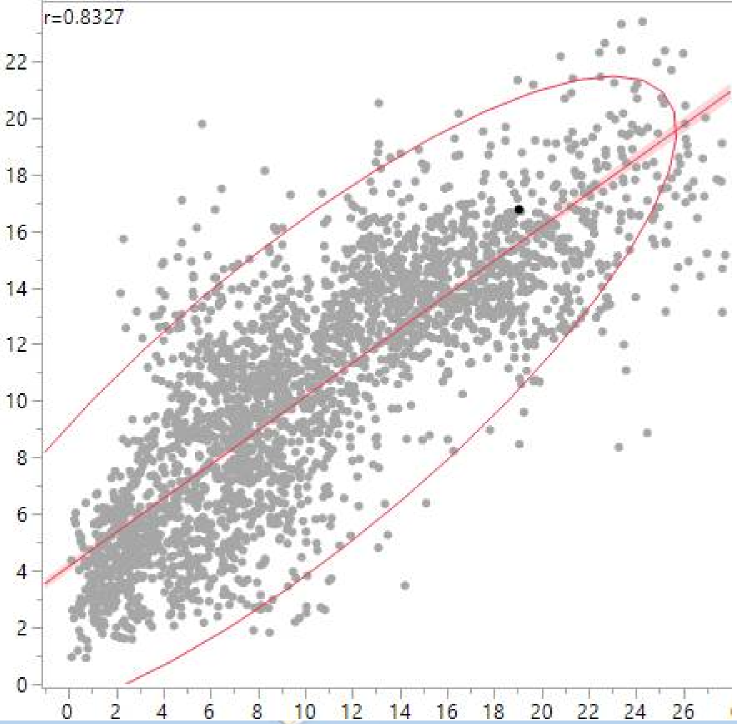


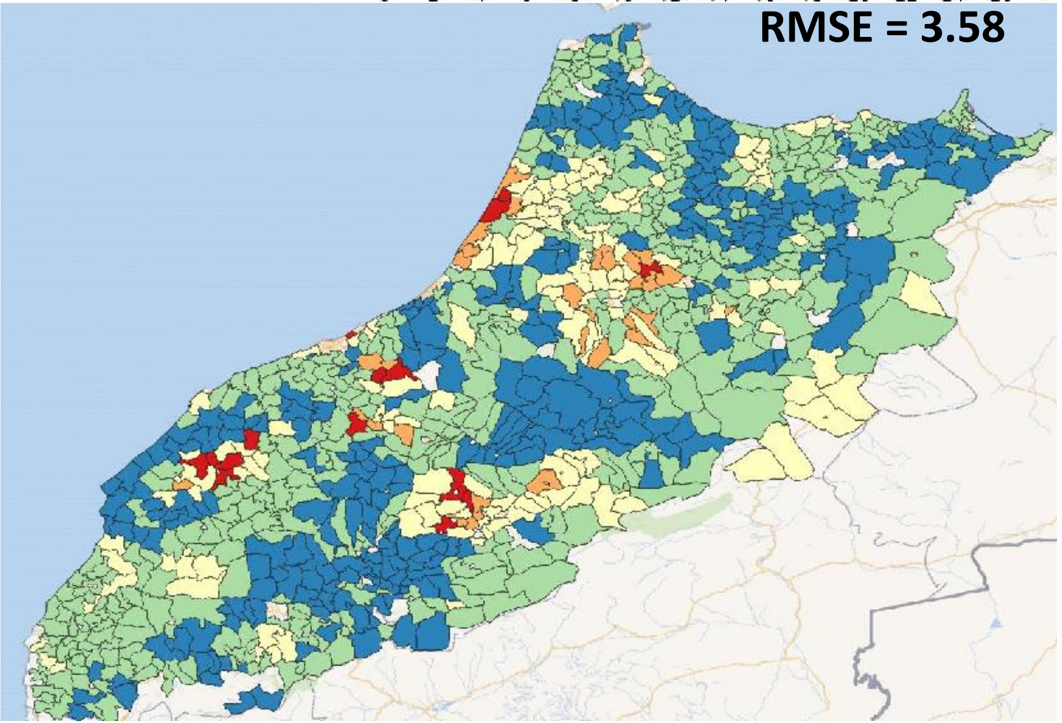
Satellite & Weather estimated from Sat



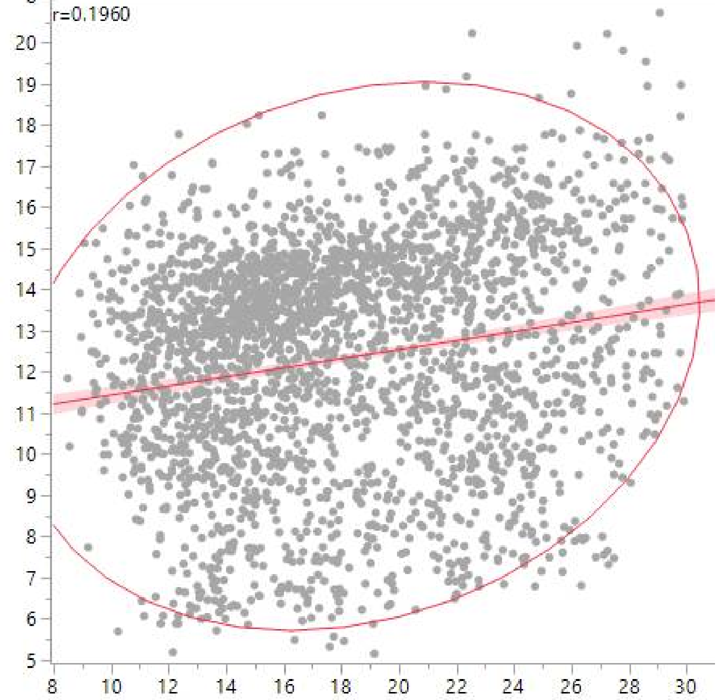
Case study

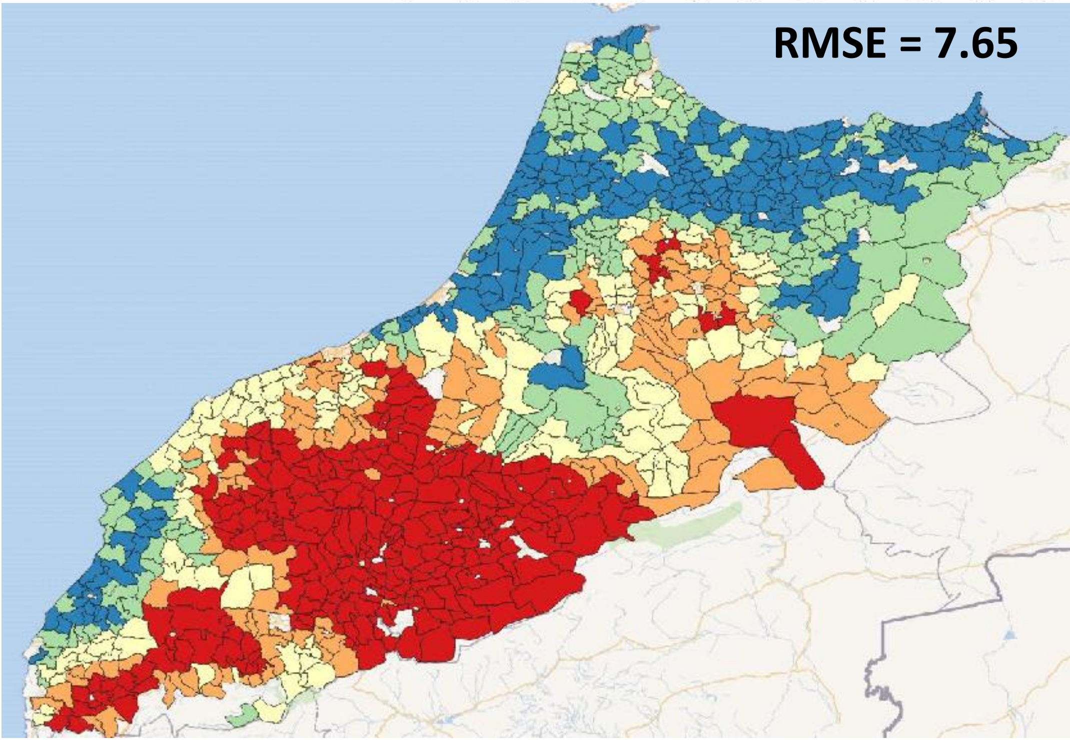
2014 year
Average production





2009 year
High production





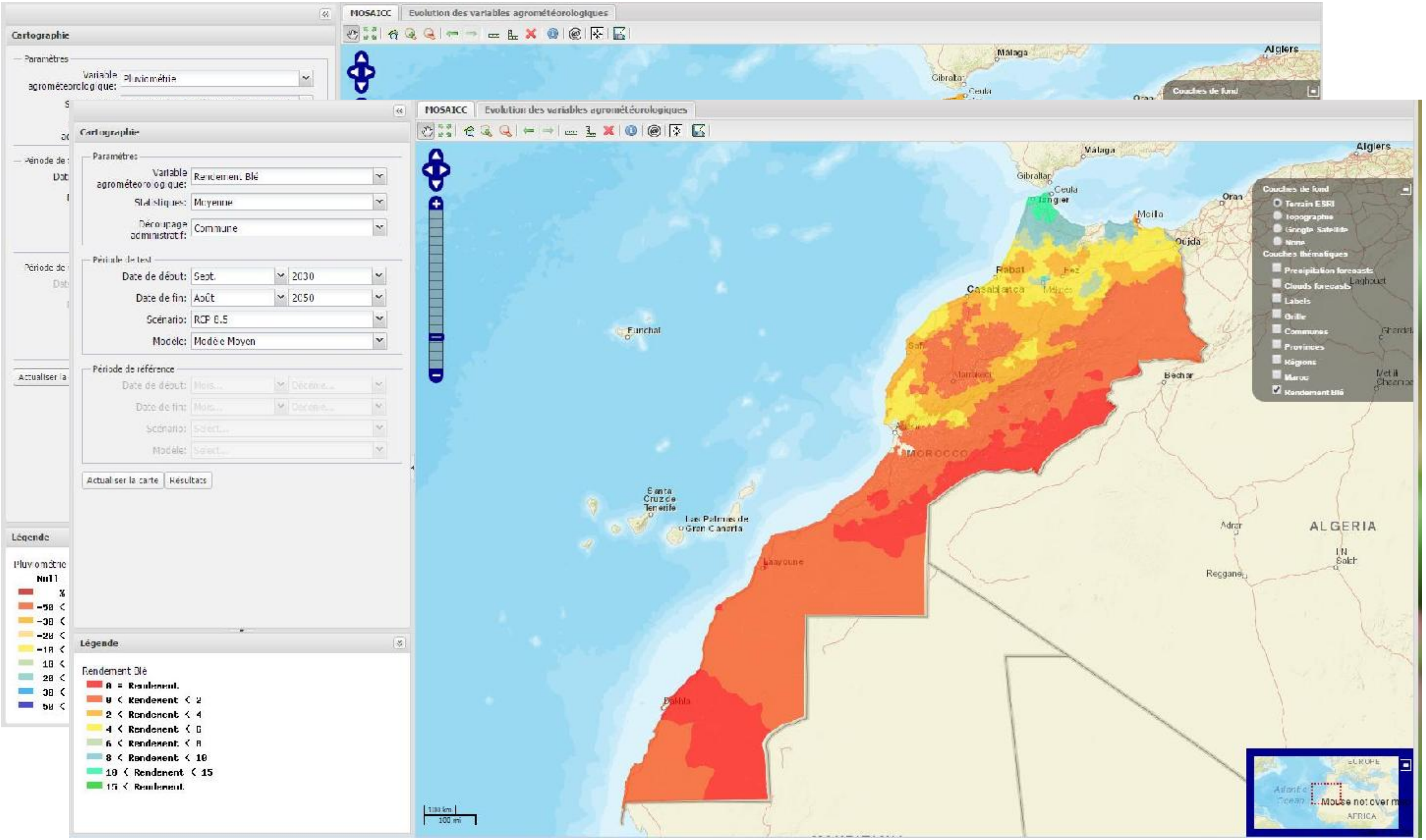
Future Improvement

- Land cover form last census (irrigated / rainfed)
- Land cover from Copernicus
- Move from 1 km to 300 m or 100 m with more accurate land cover
- Use phenology information derived from satellite images
- Use multi-model approach (like use AquaCrop output as predicator)

Other developped systems

Mosaicc

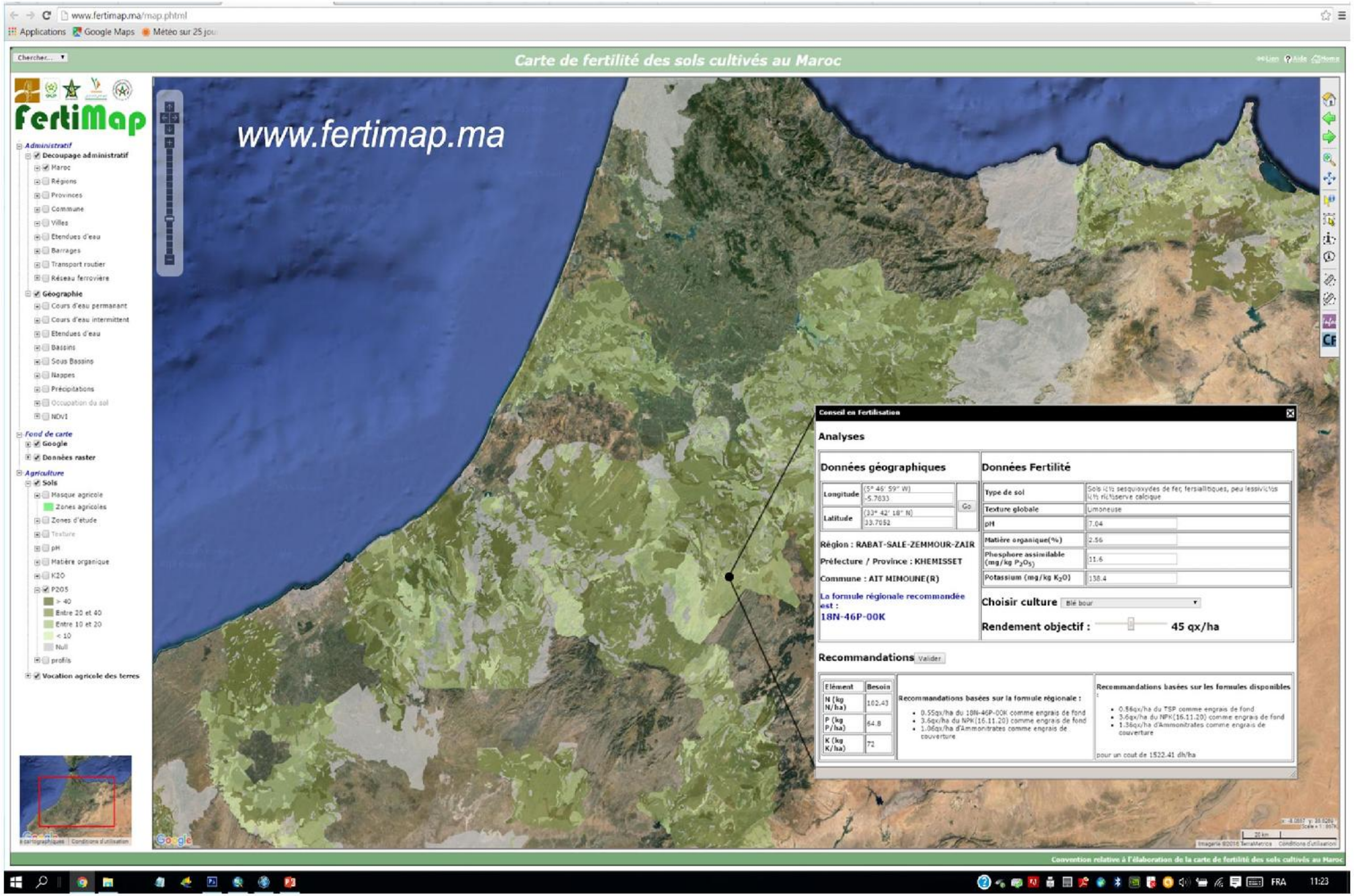
http://www.changementclimatique.ma/mosaicc/



Fertimap

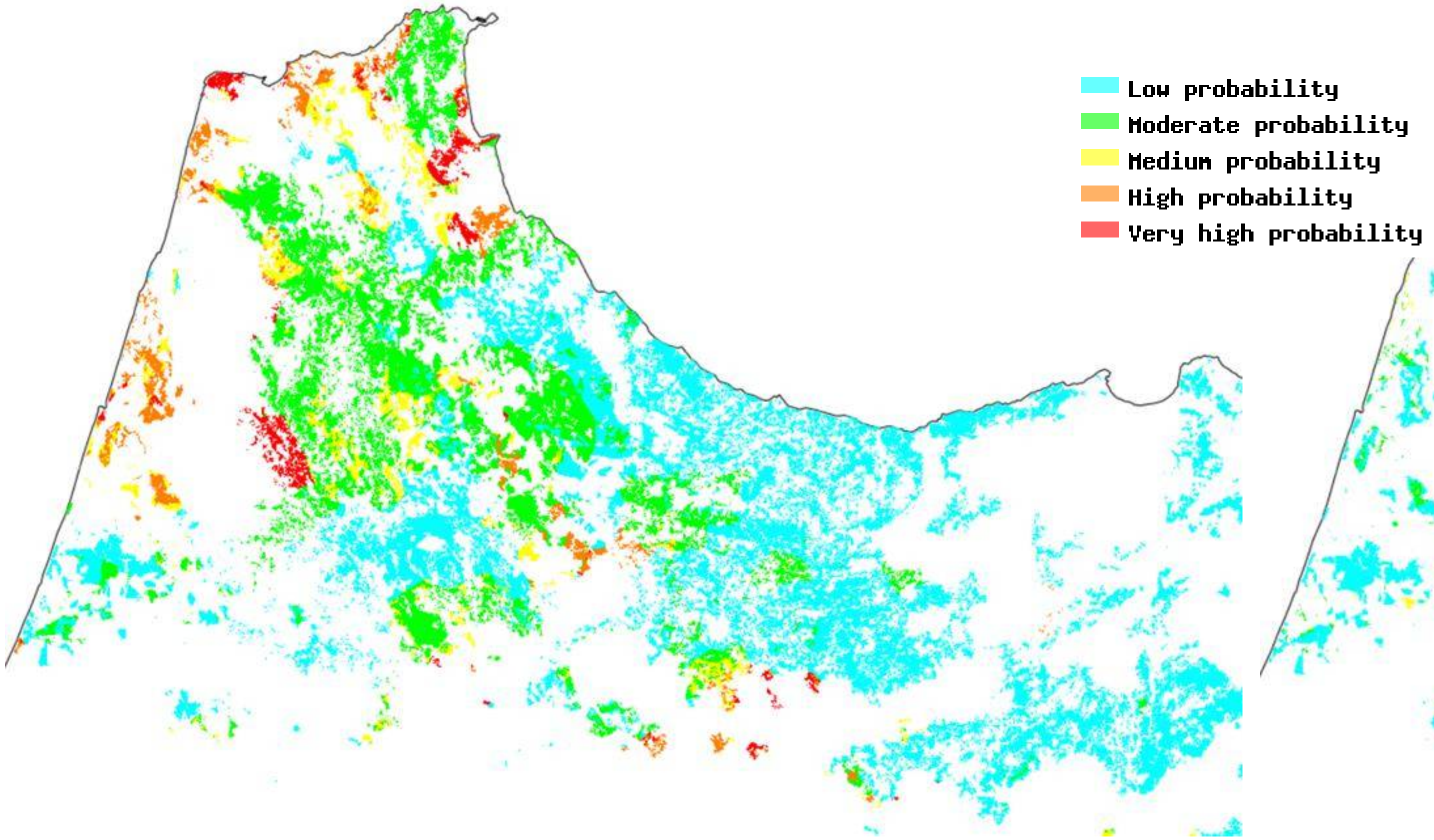
www.fertimap.ma

Web-GIS
Soil fertility &
fertilizer recommendation

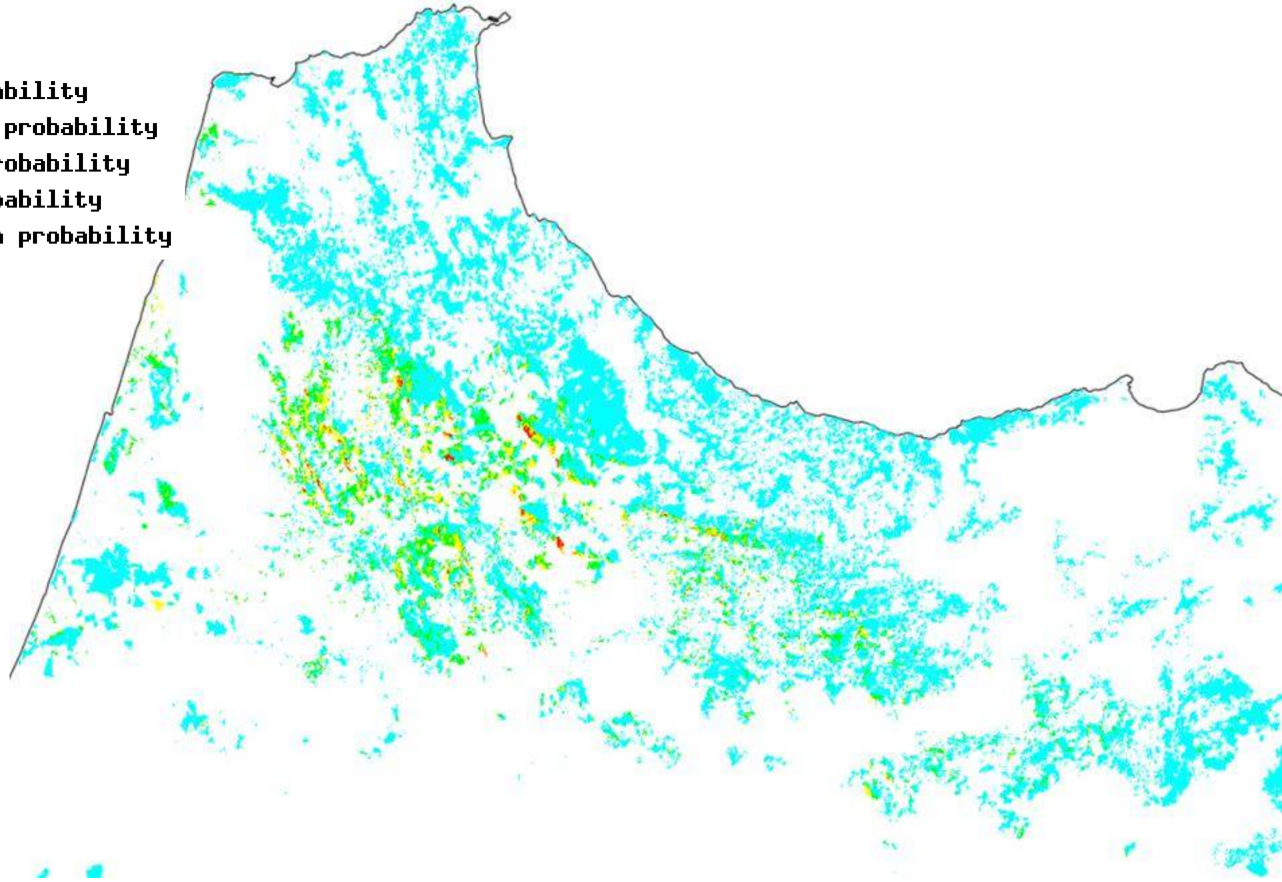


Forest Fire Risk Maps at (day-1 and day-2)

By combining statics (Land & Forest) and dynamics (Satellite & meteorological) maps.

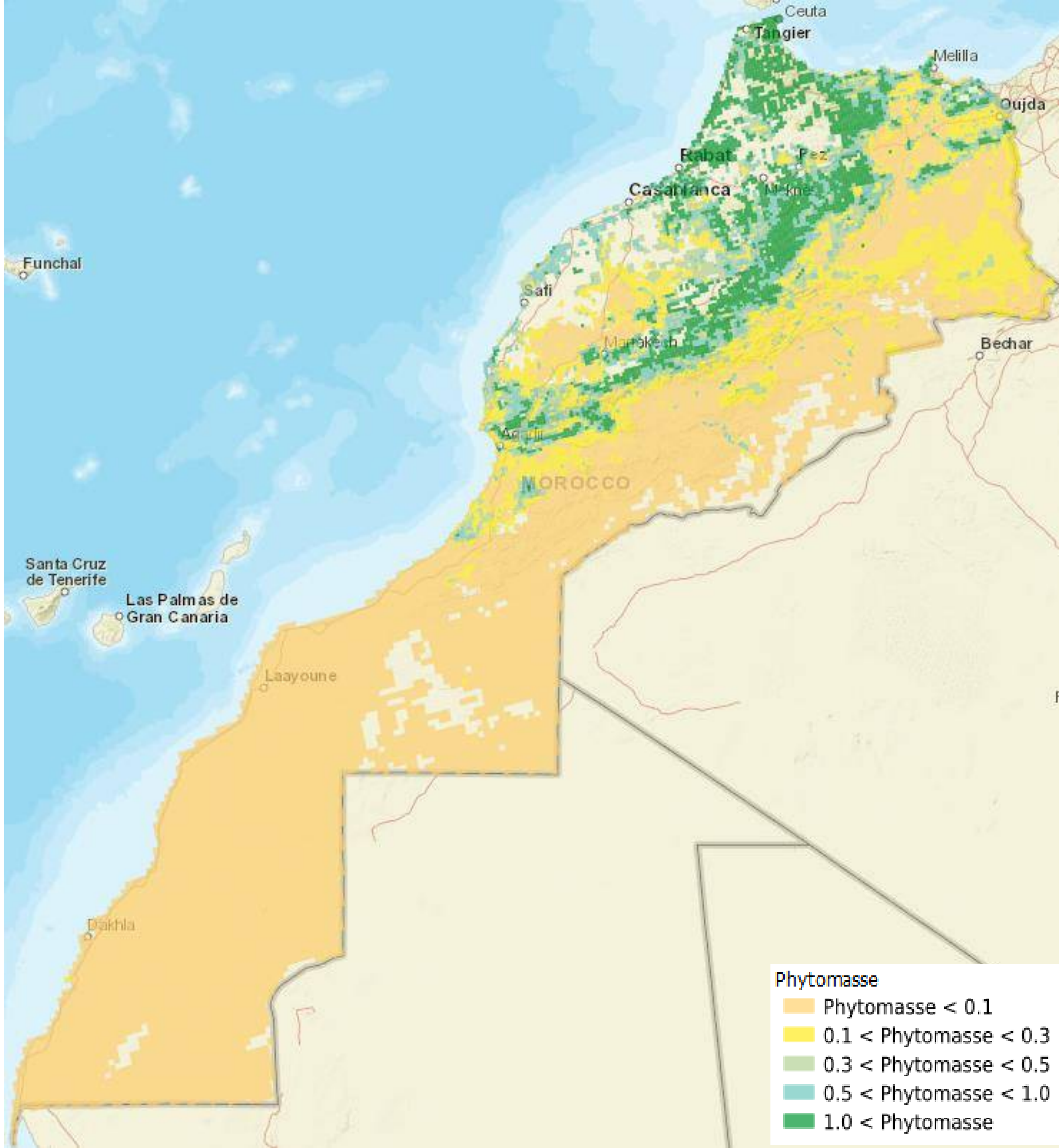


Ignition risk map



Propagation risk map

Phytomass production estimation in Rangelands.



Thank you