



# CGMS-Maroc: National System for Agrometeorological monitoring

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  - Objectives of the system
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- Part 2: Operational cereal yield forecasting in Morocco.
  - Material and methods
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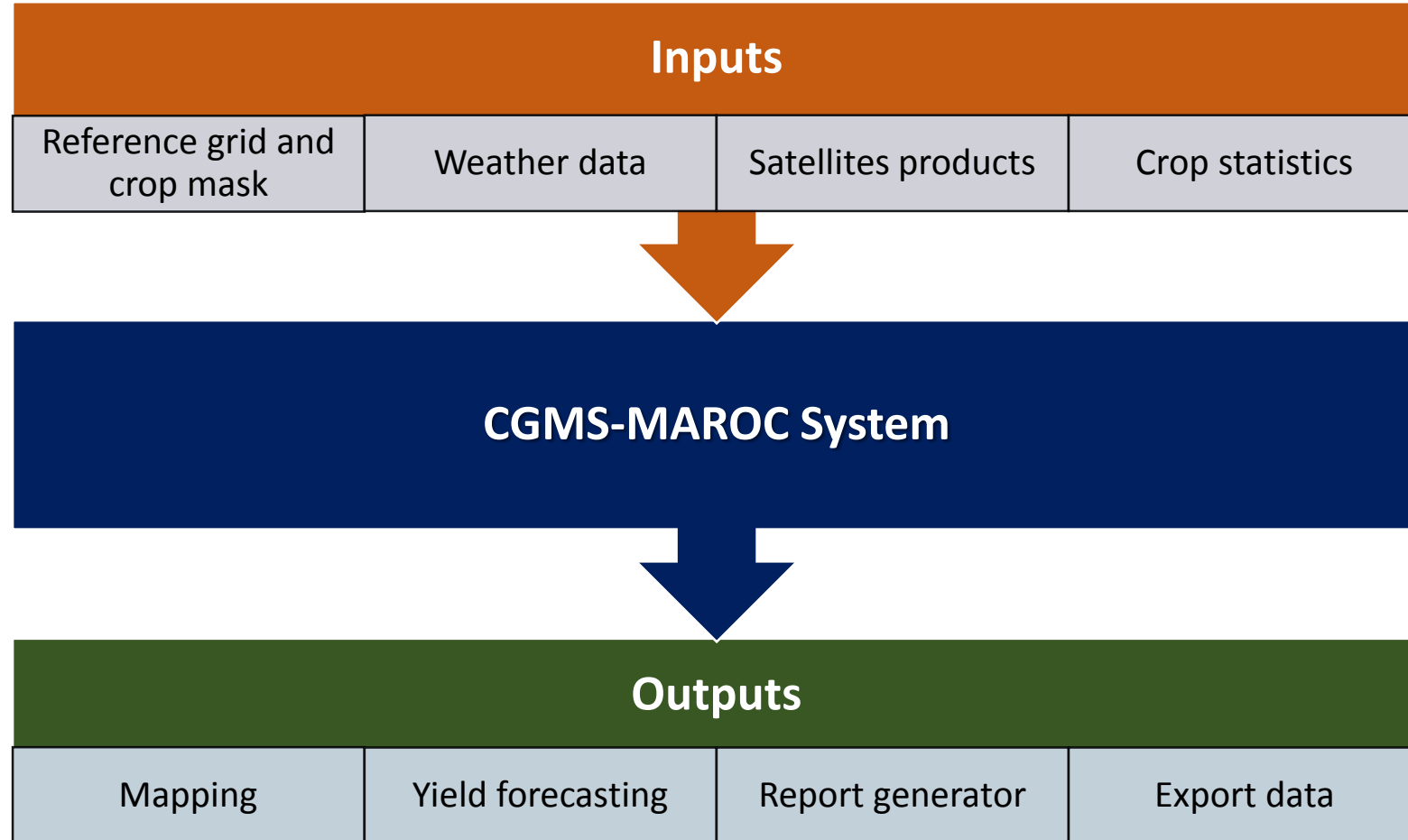
**CGMS-Maroc ([www.cgms-maroc.ma](http://www.cgms-maroc.ma))**

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



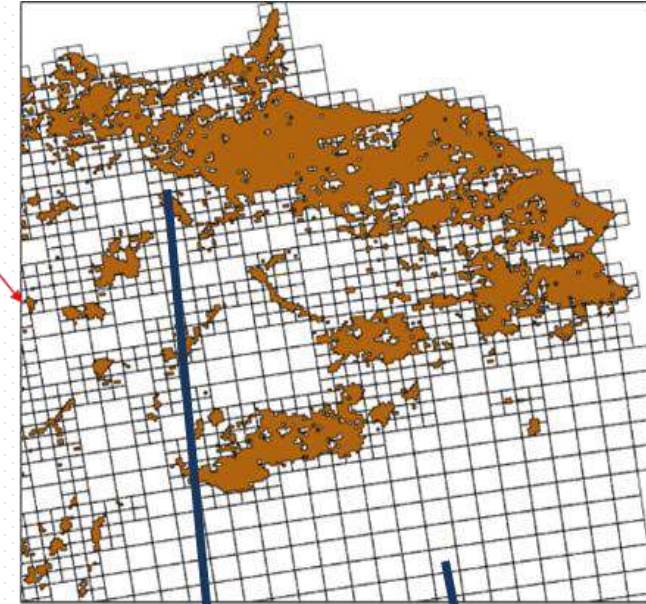
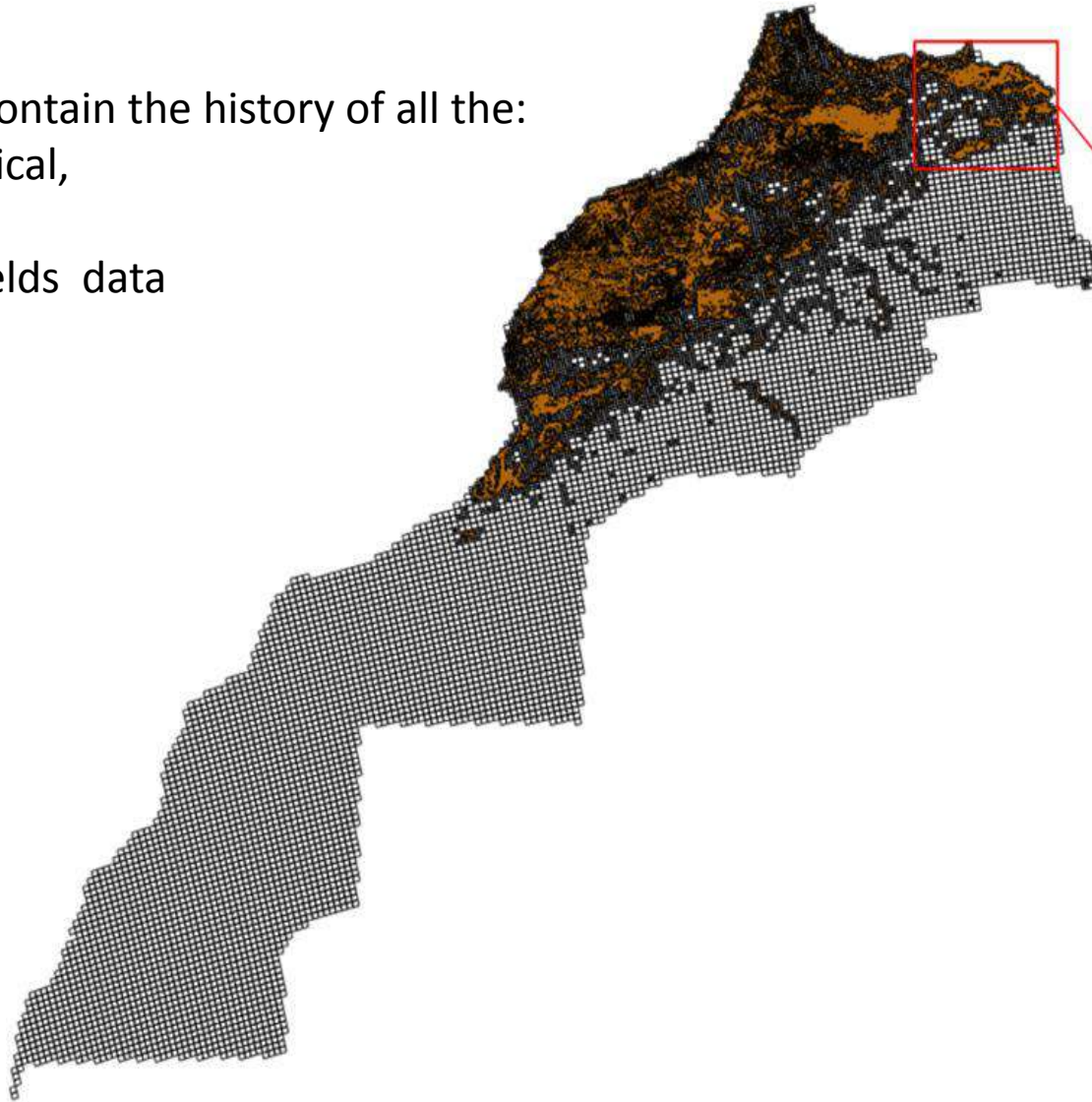
# CGMS-Maroc

Data storage

# Data grid and agricultural mask

Each grid will contain the history of all the:

- meteorological,
- satellite
- and crop yields data



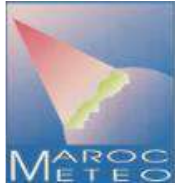
**4,5x4,5 km**

In agricultural  
area

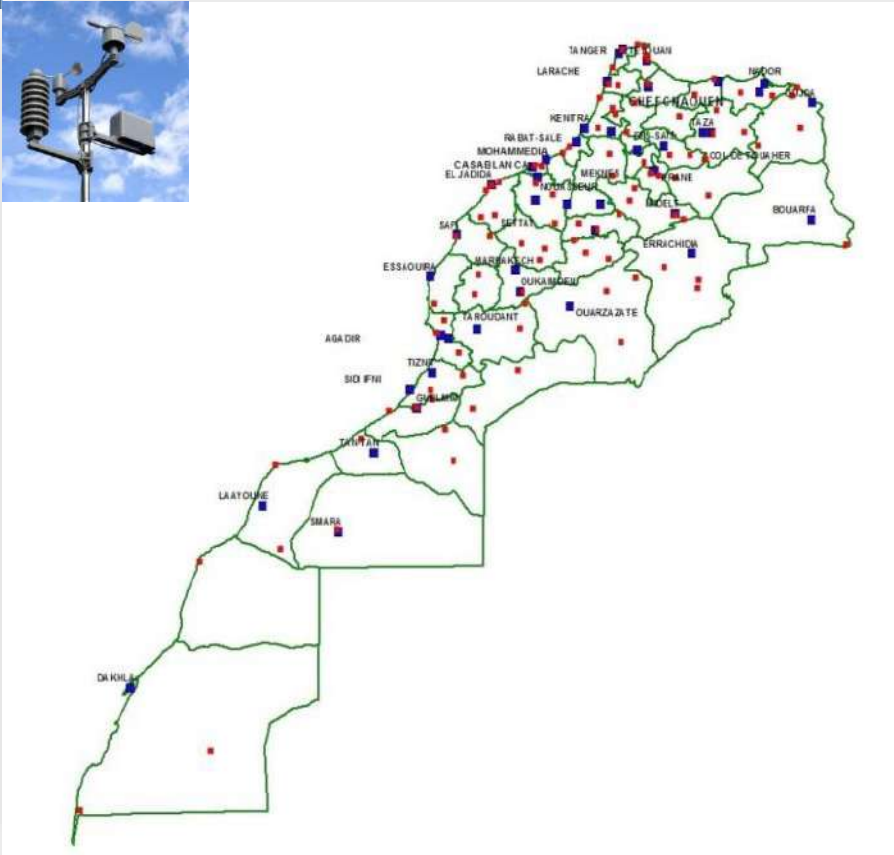
**9x9 km**

In non agricultural  
area

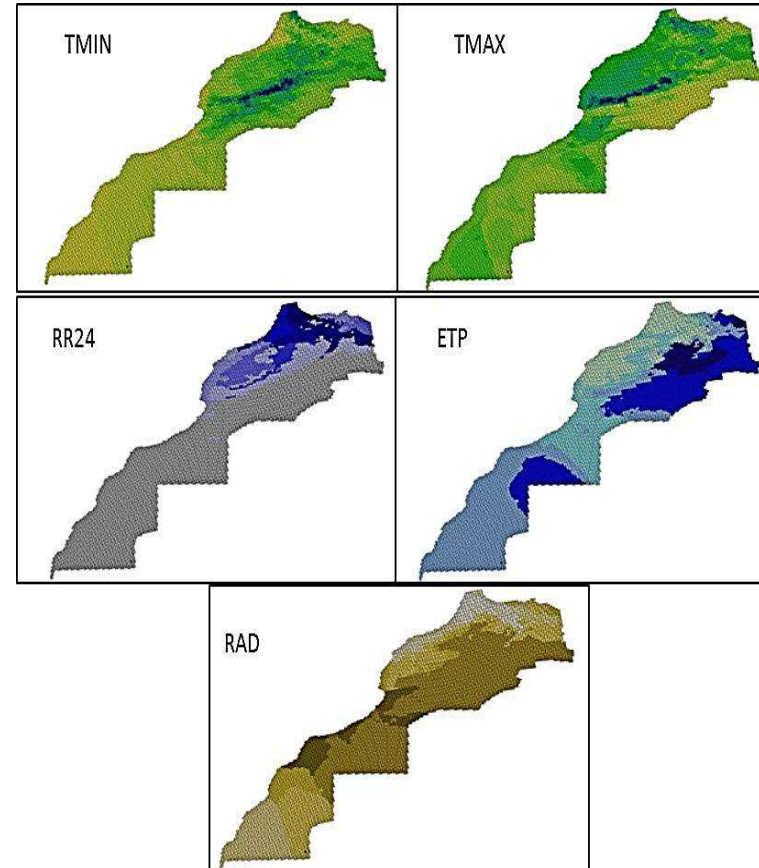
# Meteorological Data: **Daily** Interpolated Data.



50 Synoptics stations  
150 Vigiobs stations



Weather station network

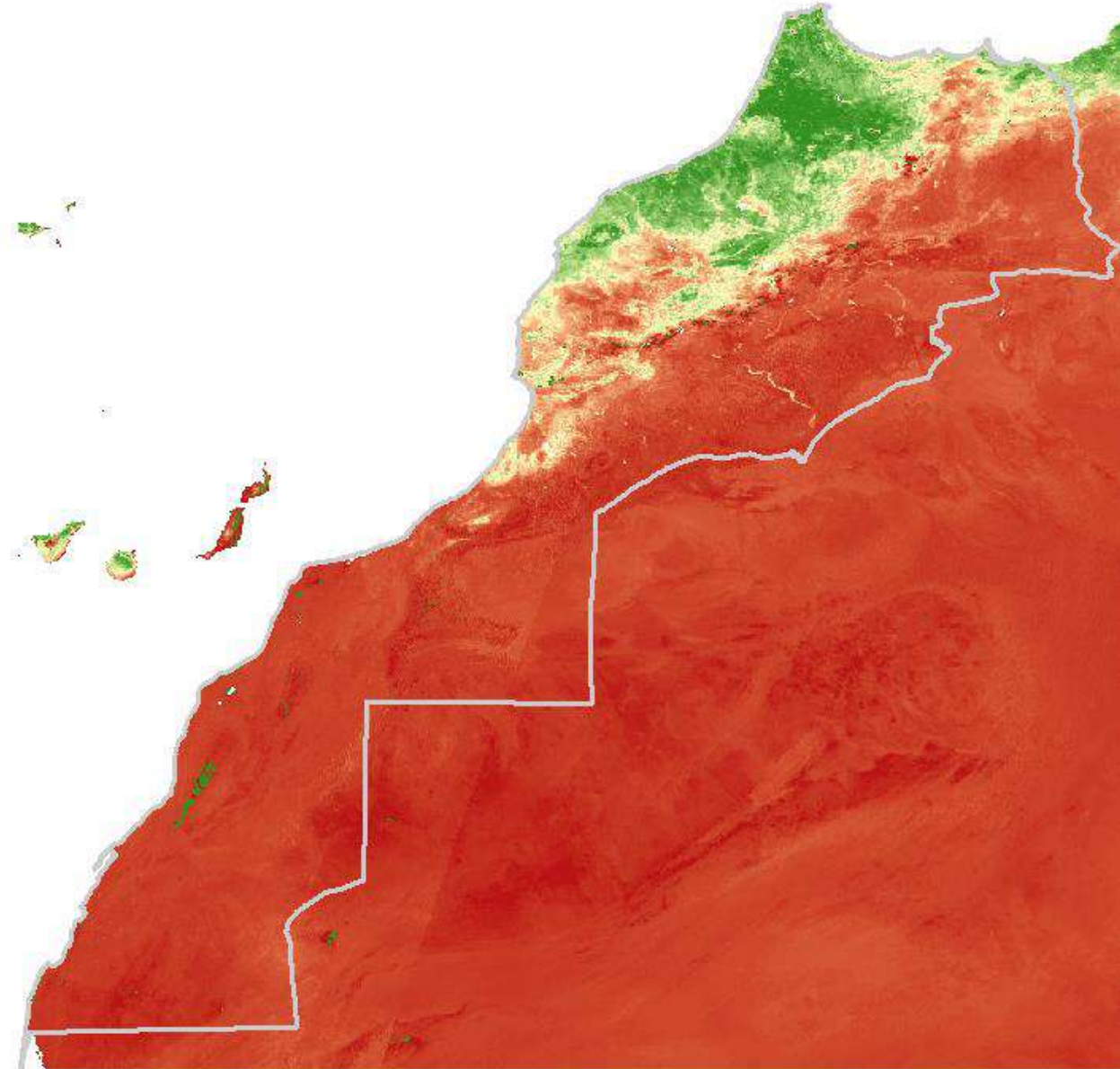


Ex: Grid for 09/02/2014



# Satellite **decadal** data

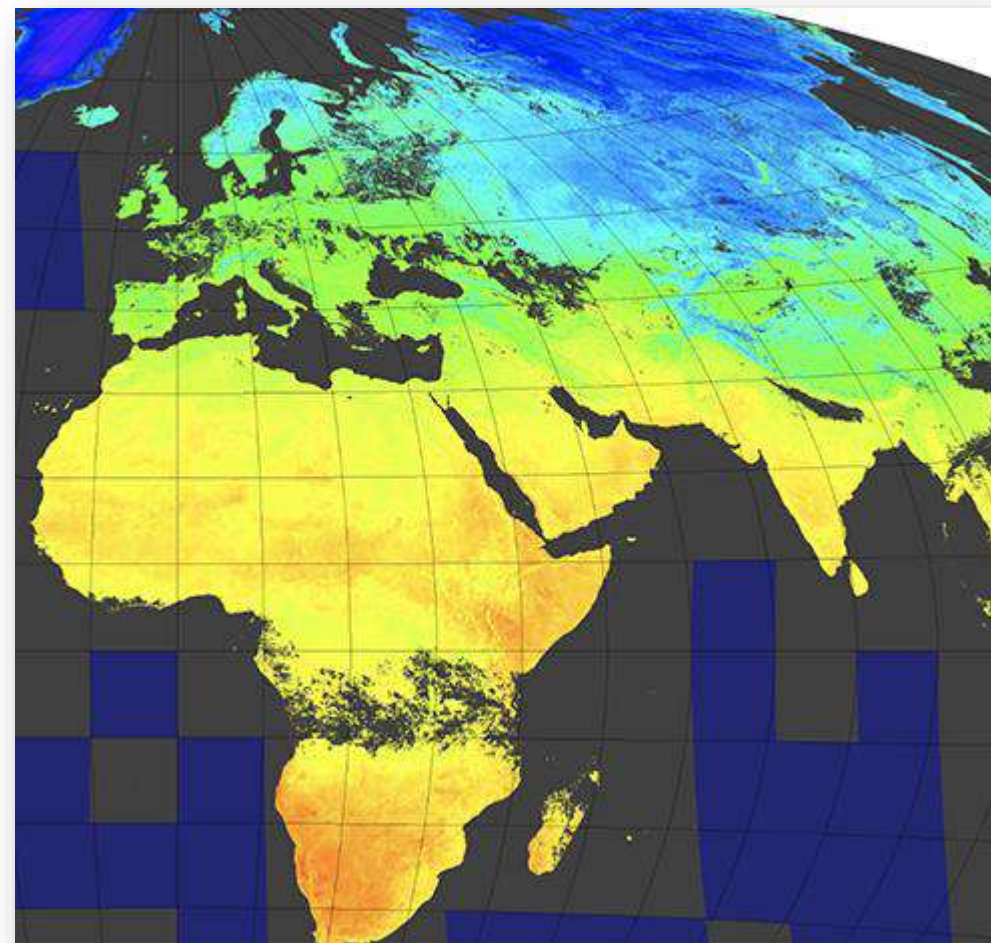
- Vegetation indices derived from satellite images available for free in **Copernicus** Global Land Service (1 km Grid) :
  - NDVI
  - FAPAR
  - LAI



# 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)

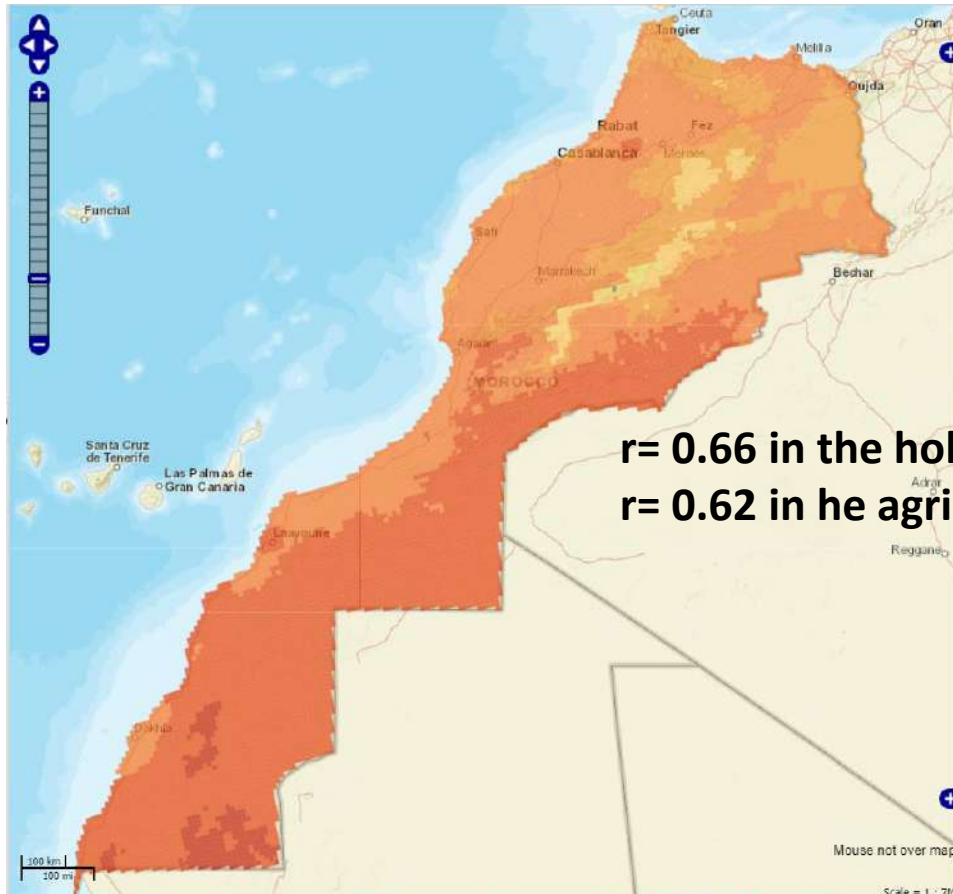
**All data are automatically download and processed using Python Script**



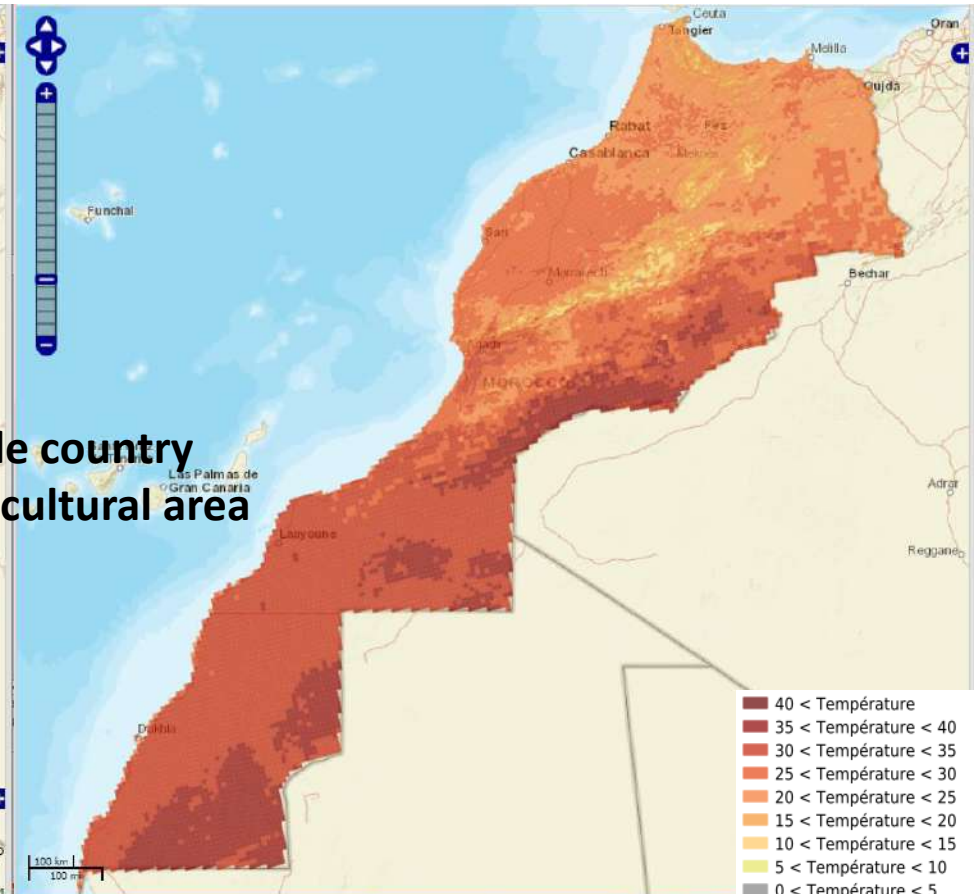
# Temperature comparison

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

Stations terrestres



Satellite



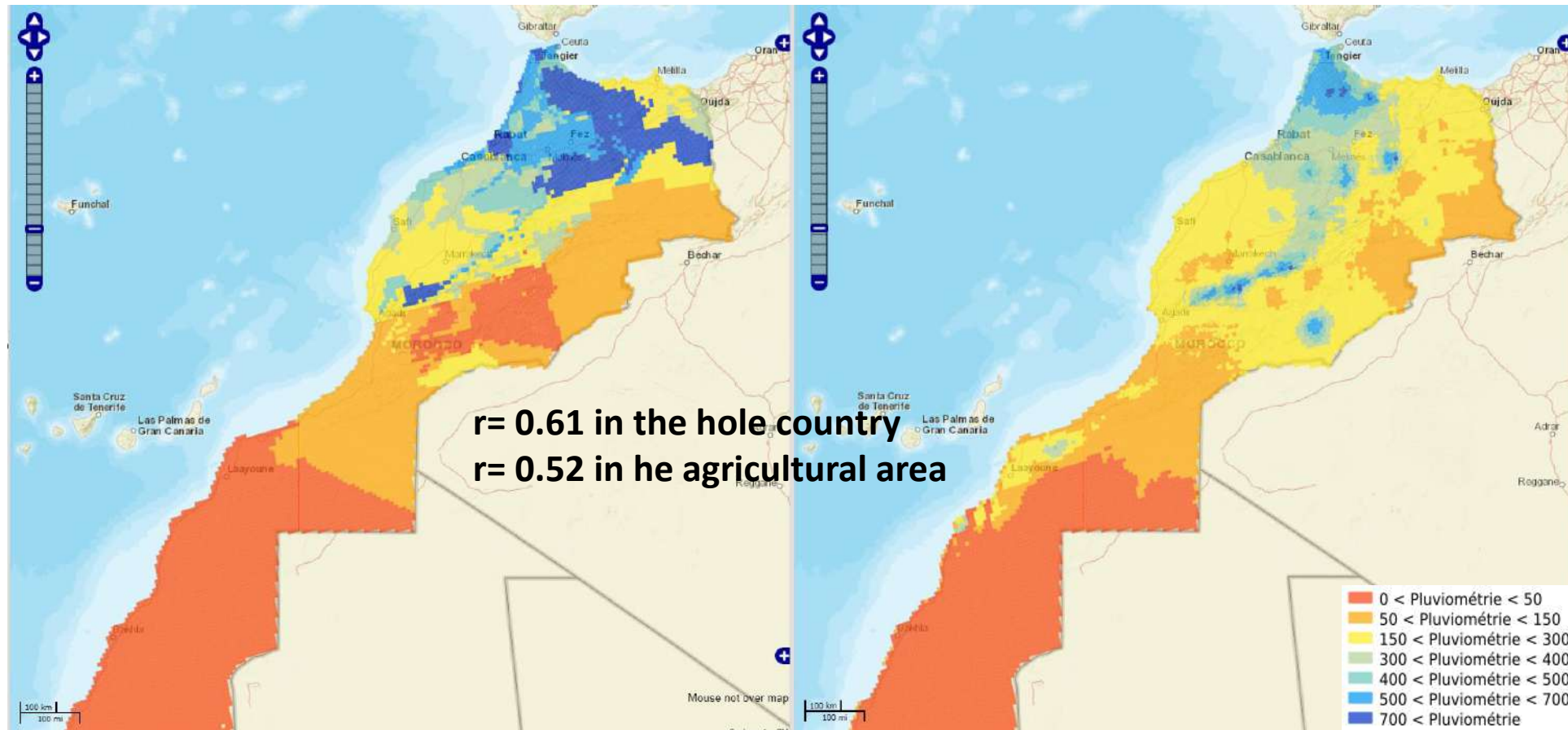
**r= 0.66 in the hole country**  
**r= 0.62 in he agricultural area**

# Rainfall comparison

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

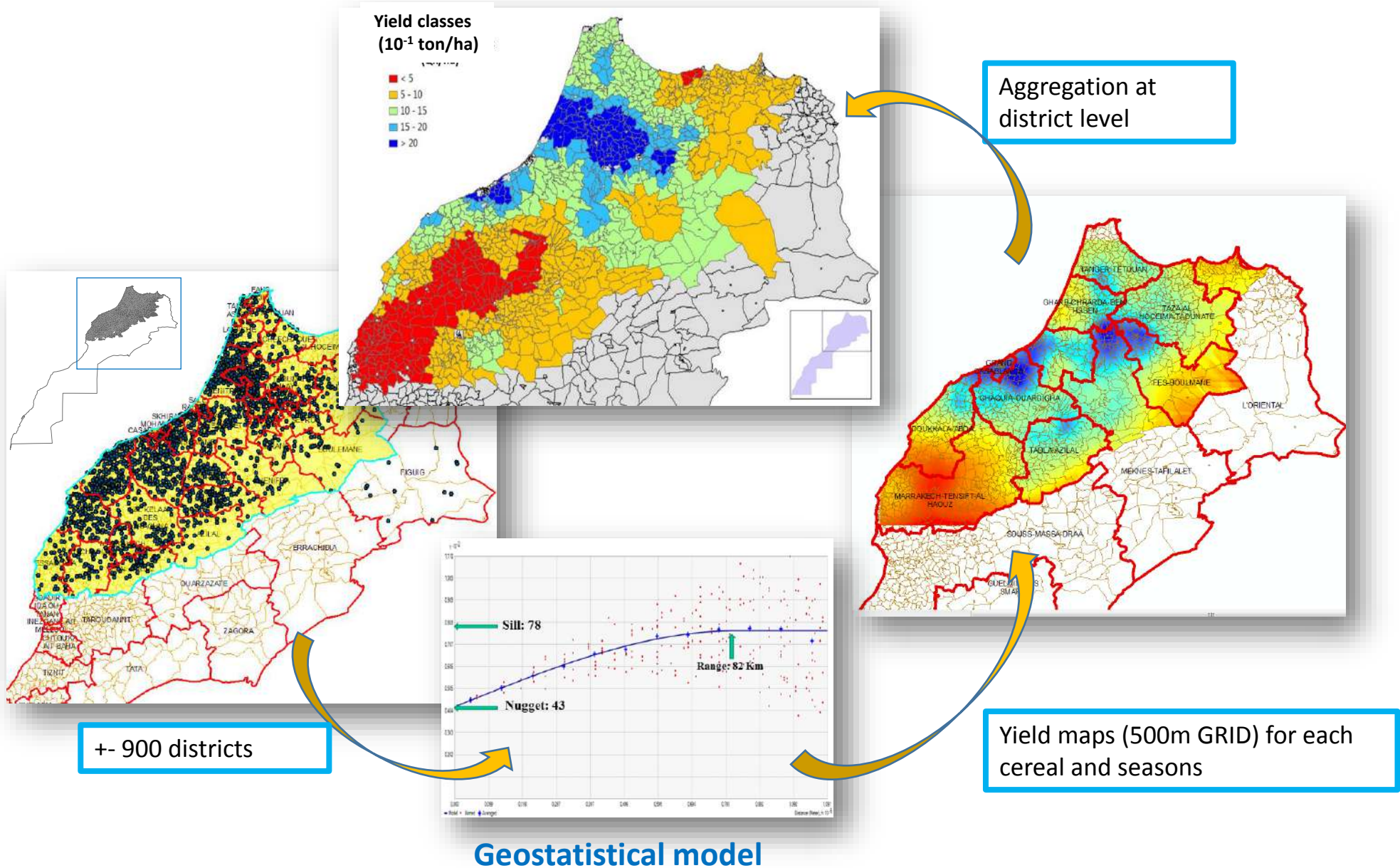
Stations terrestres

Satellite



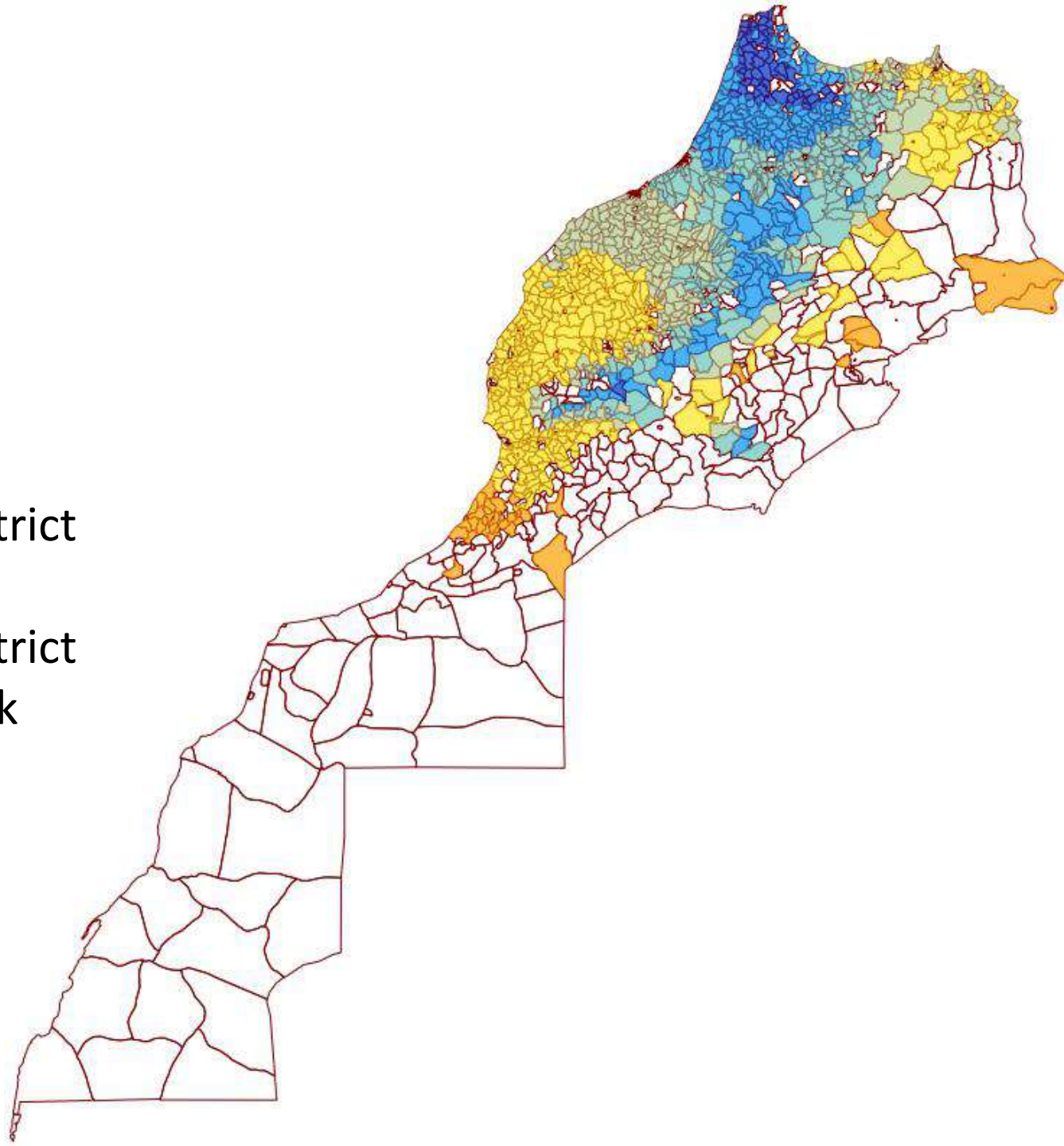
# Spatial yield interpolation from sample frames

Area Frame Sampling



# Data storage

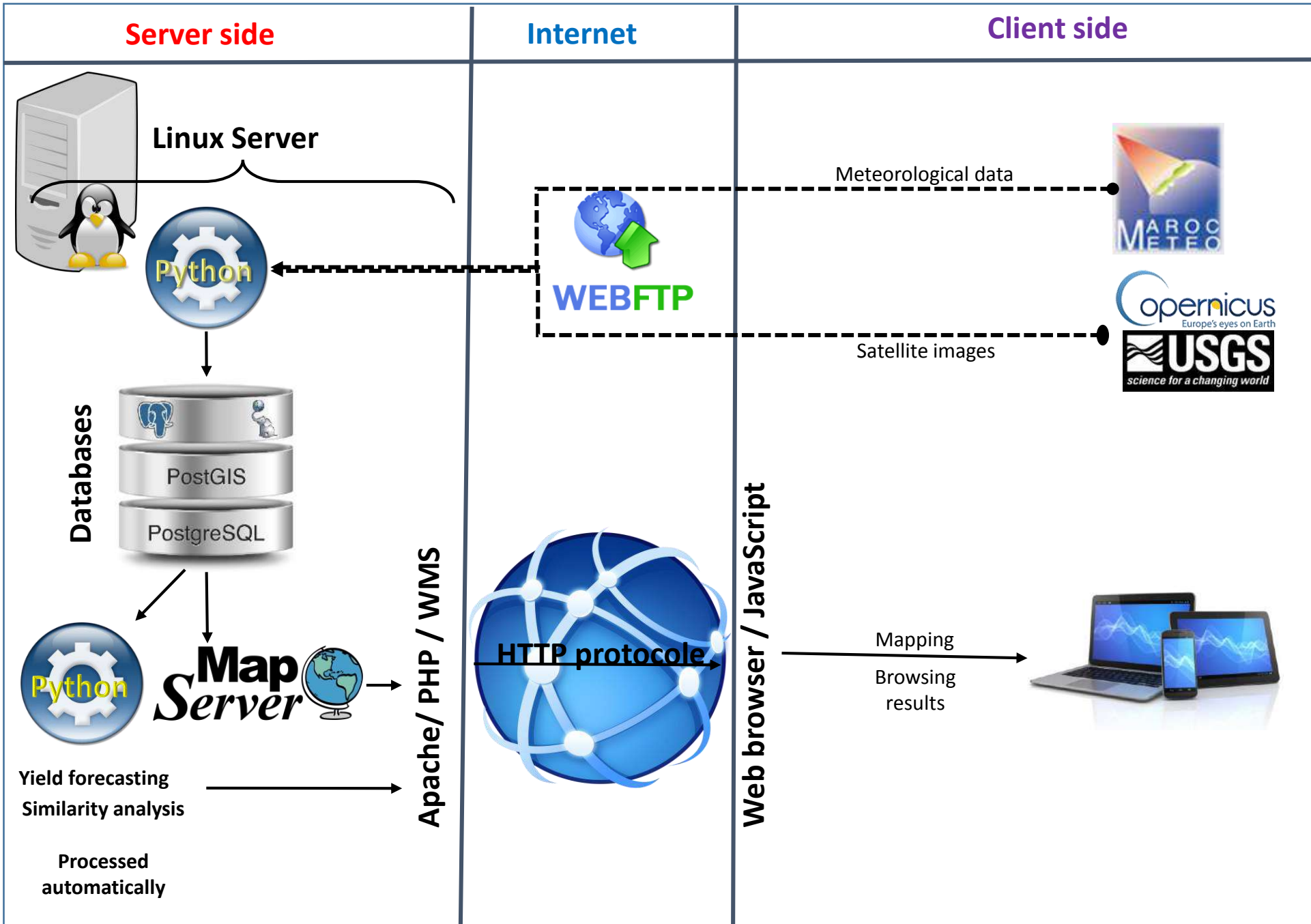
- Data grid
- Data by grid
- District division
- Aggregated data by district
- Agricultural mask
- Aggregated data by district within agricultural mask



# CGMS-Maroc

System operation

# System architecture (Only open Source tools were used)





# CGMS-Maroc

Interface

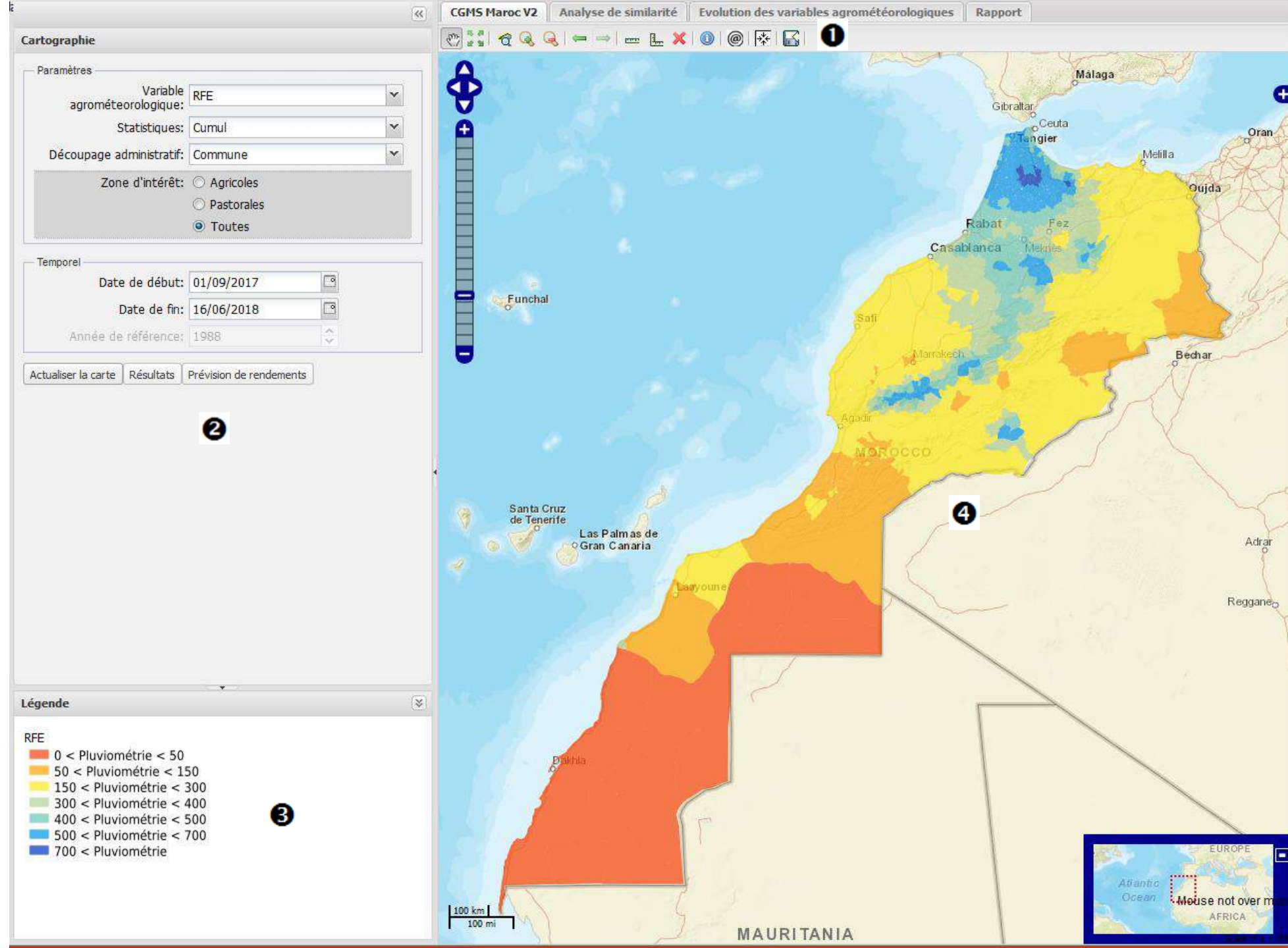
# Main interface CGMS-Maroc

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

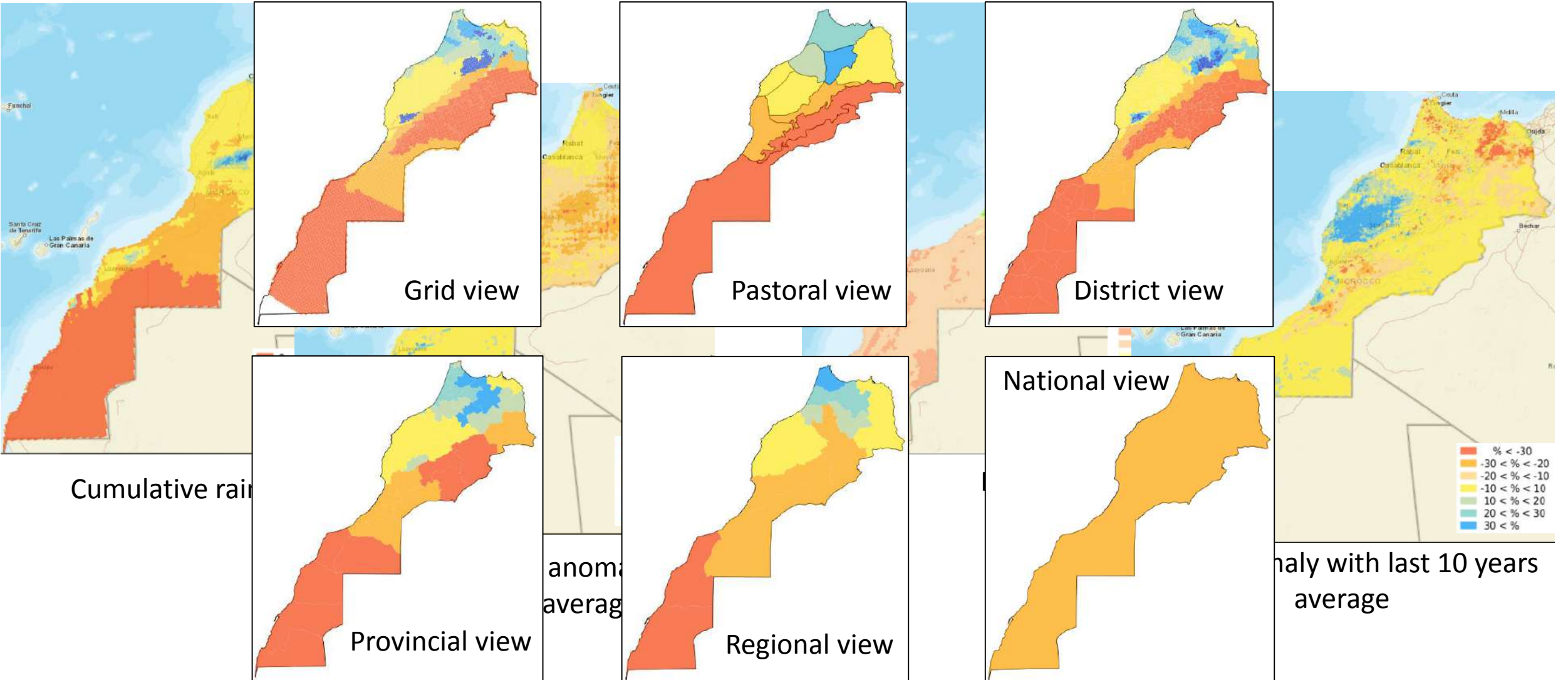
&

## 4 Applications

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



# Mapping



# 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

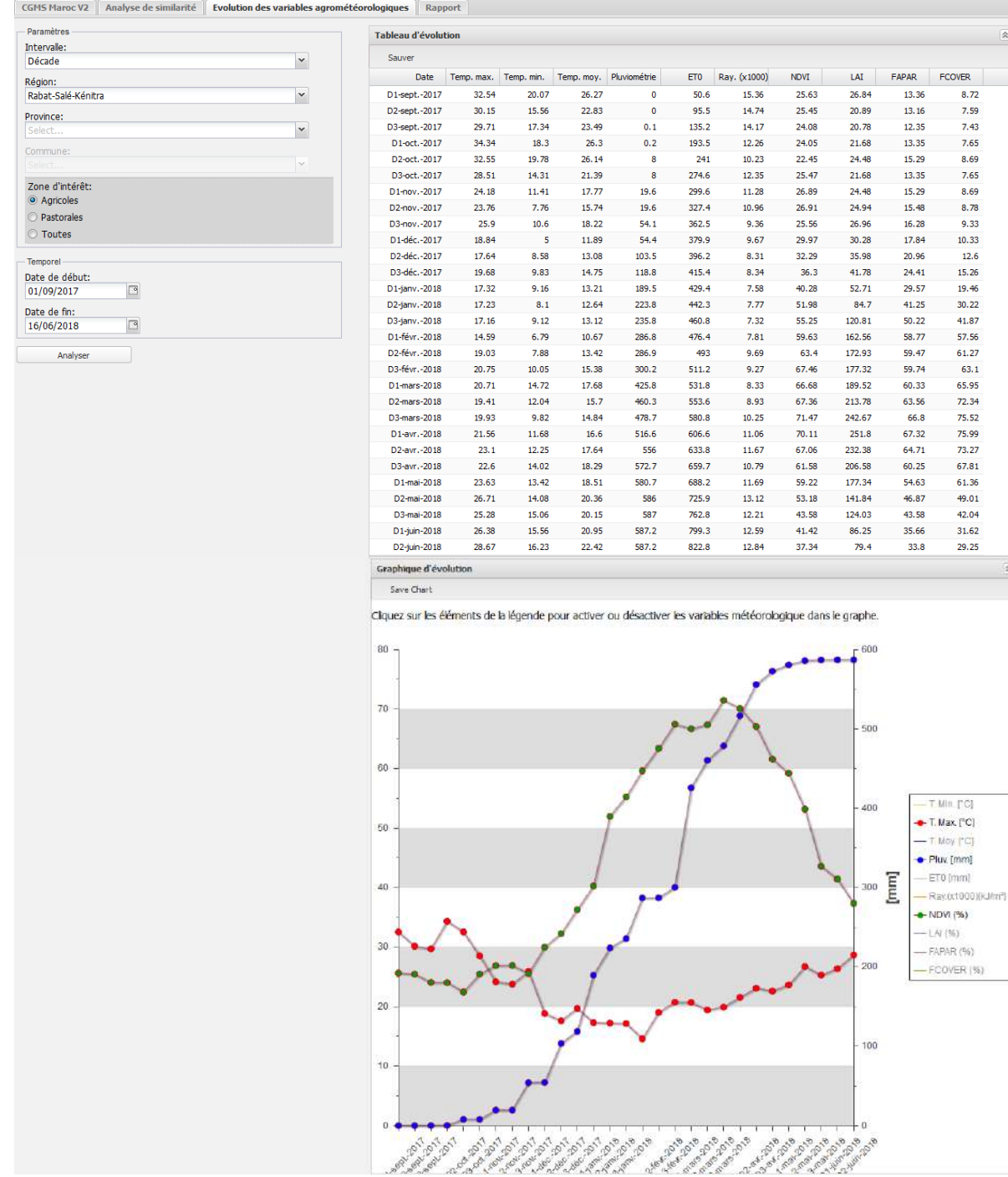
# Similarity analysis

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.



**CGMS-Maroc**

Système national de suivi agro-météorologique de la campagne agricole et de prévision des rendements céréalières

Région : Fès-Meknès

**Bulletin de suivi agrométéorologique de la campagne agricole 2018-2019**  
Situation arrêtée au 16/10/2018

Ce bulletin a été réalisé grâce au système national de suivi de la campagne agricole CGMS-Maroc, réalisé par l'Institut National de la Recherche Agronomique, en collaboration avec la Direction de la Météorologie Nationale, le Département de la Stratégie et des Statistiques et l'Institut Agronomique et Vétérinaire Hassan II. Ce bulletin concerne les zones agricoles du Maroc uniquement. Il présente l'état de la situation climatique et de végétation sur ces zones, depuis le début de la saison agricole.

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Redouane ABREACH (MAPAGSDS)  
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CGMS Maroc

**Pluviométrie cumulée: valeurs observées**

Province	Pluviométrie (mm)
Bordj Bouja	181
El Djorf	92
Fes	127
Taza	164
Meknes	77
Meknes Yacoub	79
Sefrou	111
Tessalate	91
Taza	91

Evolution de la pluviométrie cumulée par décade (mm)

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CGMS Maroc

**Pluviométrie cumulée: Ecart vs Moyenne à long terme**

Province	Ecart (%)
Bordj Bouja	128
El Djorf	171
Fes	300
Taza	121
Meknes	121
Meknes Yacoub	179
Sefrou	91
Tessalate	141
Taza	141

Pluviométrie cumulée: Analyse de similarité

Décade	En cours	Année de référence				
		2009	2002	2011	2007	1998
D1-Sept.	8	9	4	0	11	1
D2-Sept.	2	19	8	21	0	0
D3-Sept.	48	69	25	43	43	-4
D1-Oct.	77	65	71	63	43	94
D2-Oct.	88	58	164	59	72	84

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CGMS Maroc

**Température moyenne: valeurs observées**

Province	Température (°C)
Bordj Bouja	19
El Djorf	24
Fes	24
Taza	19
Meknes	26
Meknes Yacoub	21
Sefrou	17
Tessalate	14
Taza	21

Evolution de la température moyenne par décade (°C)

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# Reporting feature

Automatic generation of reports at different levels:

- National
- Regional
- And Provincial

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

CGMS Maroc

**Température moyenne: Ecart vs Moyenne à long terme**

Province	Ecart (%)
Bordj Bouja	11
El Djorf	30
Fes	38
Taza	22
Meknes	27
Meknes Yacoub	21
Sefrou	26
Tessalate	26
Taza	38

Température moyenne: Analyse de similarité

Décade	En cours	Année de référence				
		2018	2009	2002	2011	2007
D1-Sept.	25	24	24	23	21	22
D2-Sept.	24	24	24	24	24	24
D3-Sept.	21	21	21	21	21	21
D1-Oct.	22	22	22	22	22	22
D2-Oct.	19	19	19	19	19	19

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CGMS Maroc

**Indice de végétation (NDVI): situation arrêtée à la décade 3 de sept.**

Province	NDVI (%)
Bordj Bouja	26
El Djorf	30
Fes	33
Taza	21
Meknes	21
Meknes Yacoub	21
Sefrou	24
Tessalate	31
Taza	31

Evolution du NDVI par décade

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CGMS Maroc

**Indice de végétation (NDVI): Ecart vs Moyenne à long terme**

Province	Ecart (%)
Bordj Bouja	11
El Djorf	26
Fes	12
Taza	21
Meknes	21
Meknes Yacoub	21
Sefrou	21
Tessalate	13
Taza	13

Indice de végétation (NDVI): Analyse de similarité

Décade	En cours	Année de référence				
		2018	2009	2002	2011	2007
D1-Sept.	21	21	21	21	21	19
D2-Sept.	21	21	21	21	21	21
D3-Sept.	21	21	21	21	21	21

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# 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

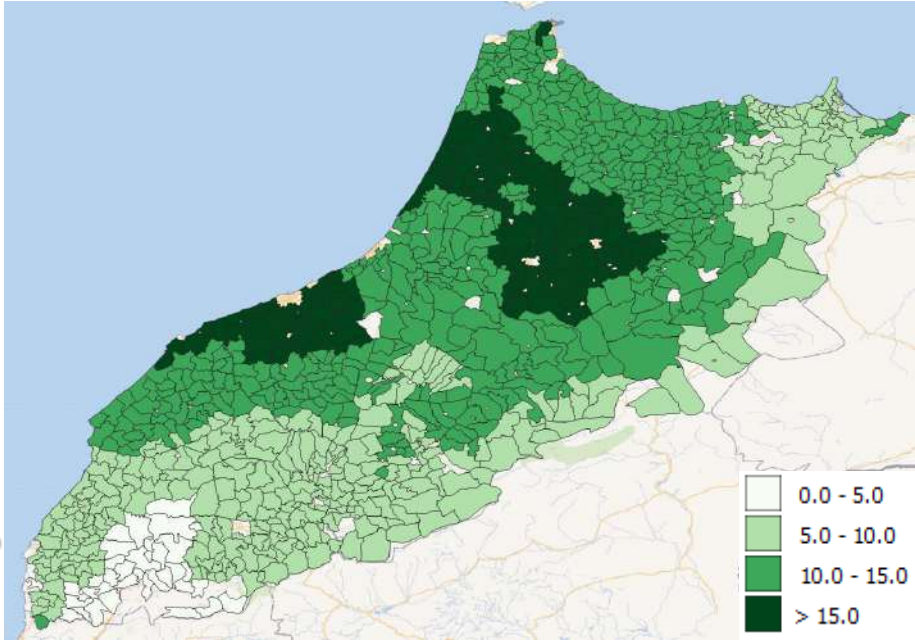
- **1** dependent variable : yield
- **140** predictors
  - **4** geographical information
  - **58** meteorological
  - **42** vegetation indices
  - **69** Estimated agro-climatic
- **35890** lines  
(14 years observation, 3 cereals and  $\approx$  900 districts)

# Simulation

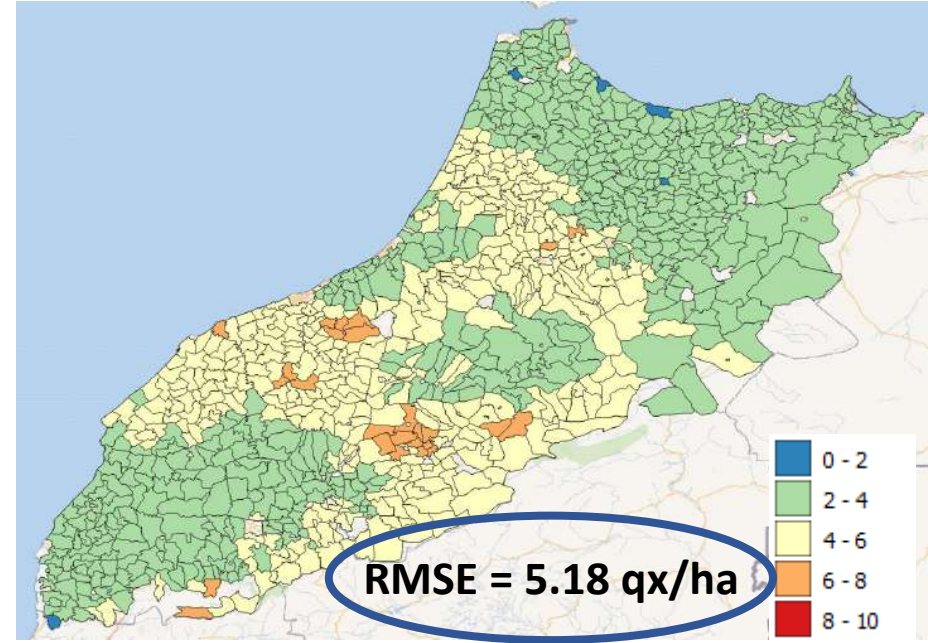
- Automation scripts have been developed for the three forecasting techniques selected for this study:
  - Multiple linear regression
  - Random Forest
  - Boosted Tree
- To perform calculations we
  - For each available growing season,
    - The data was separated into three different subsets to ensure 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

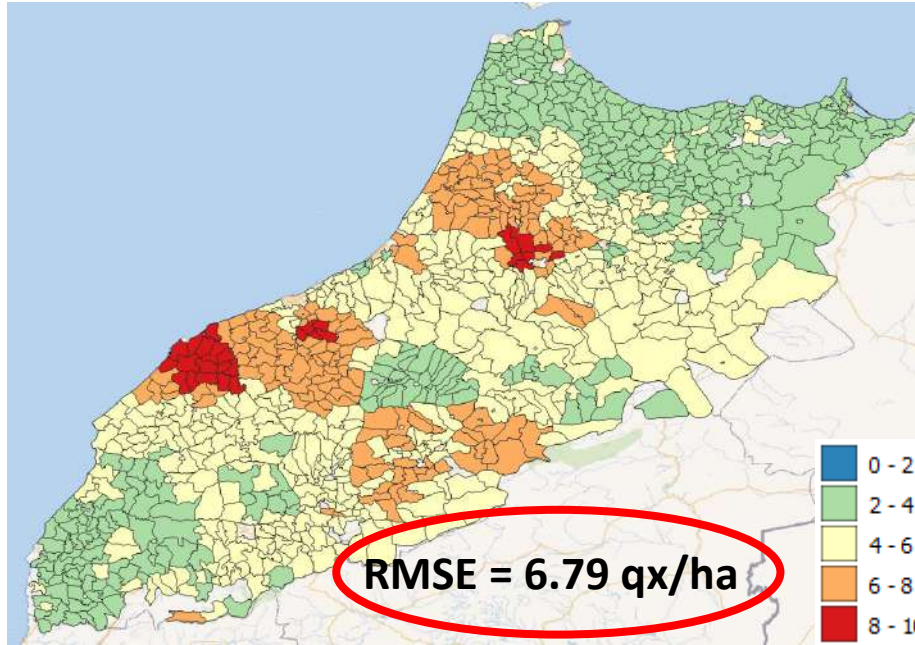
Average observed  
yield 2002-2017



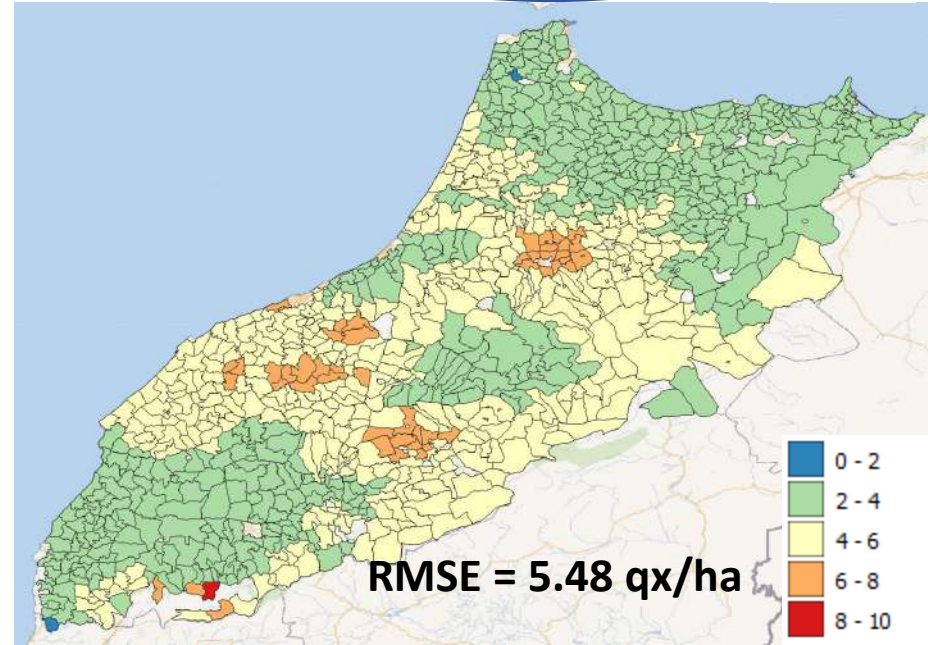
Random Forest



Linear Model

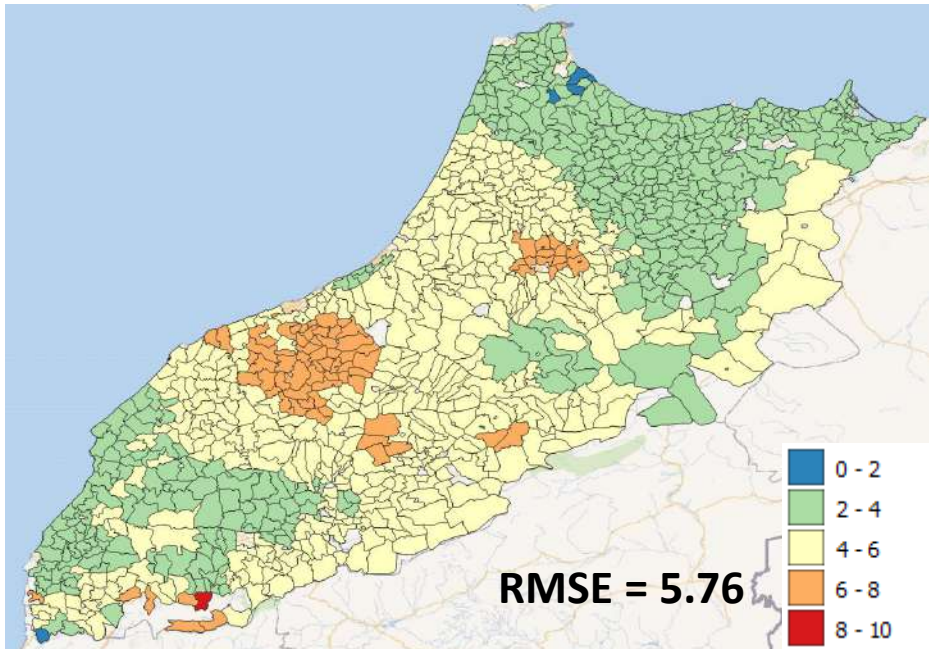


Boosted Tree

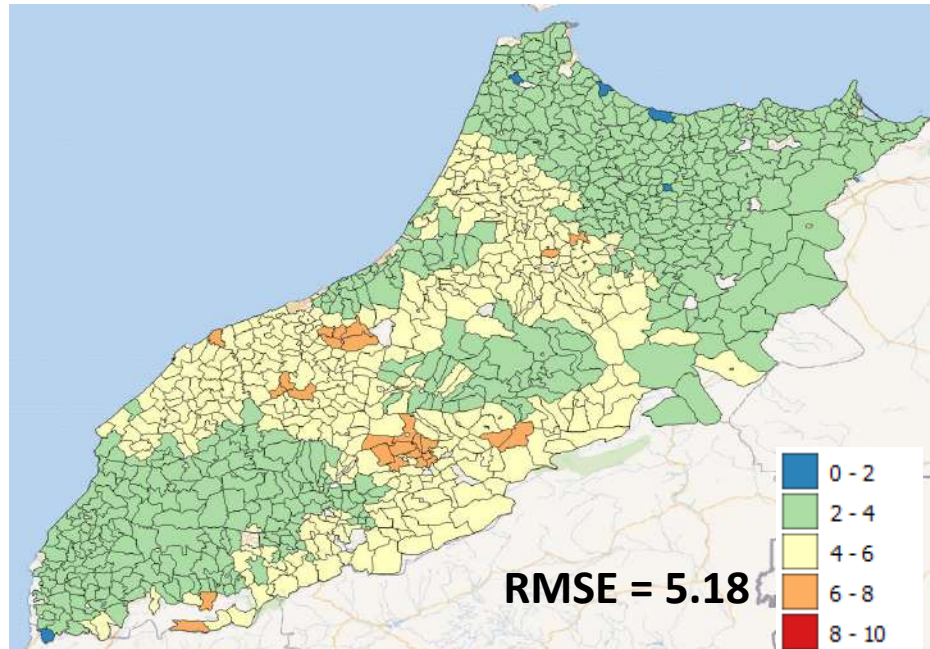


# Absolute error: Comparison between data sources

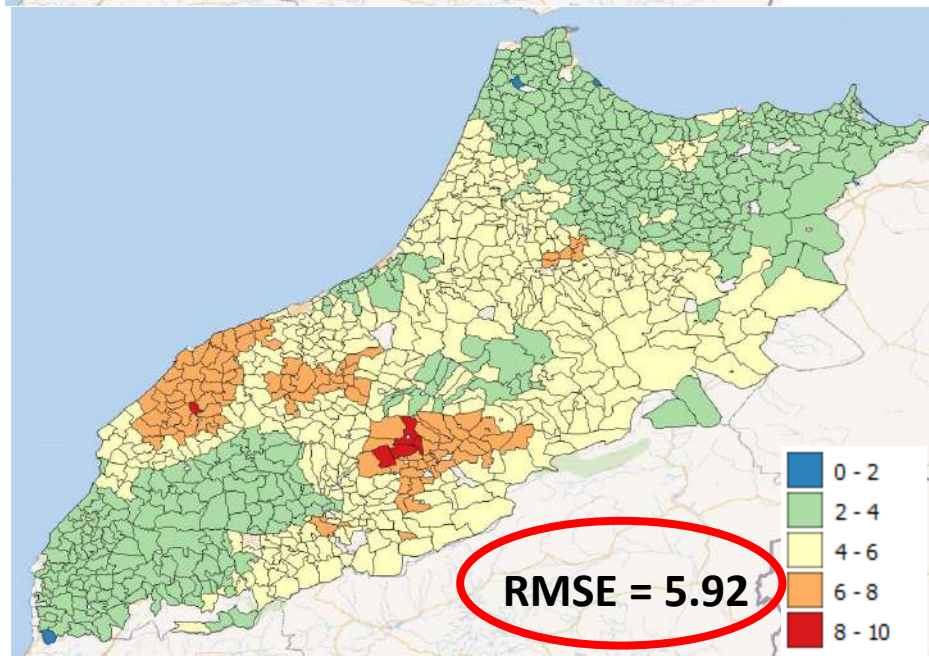
Weather data



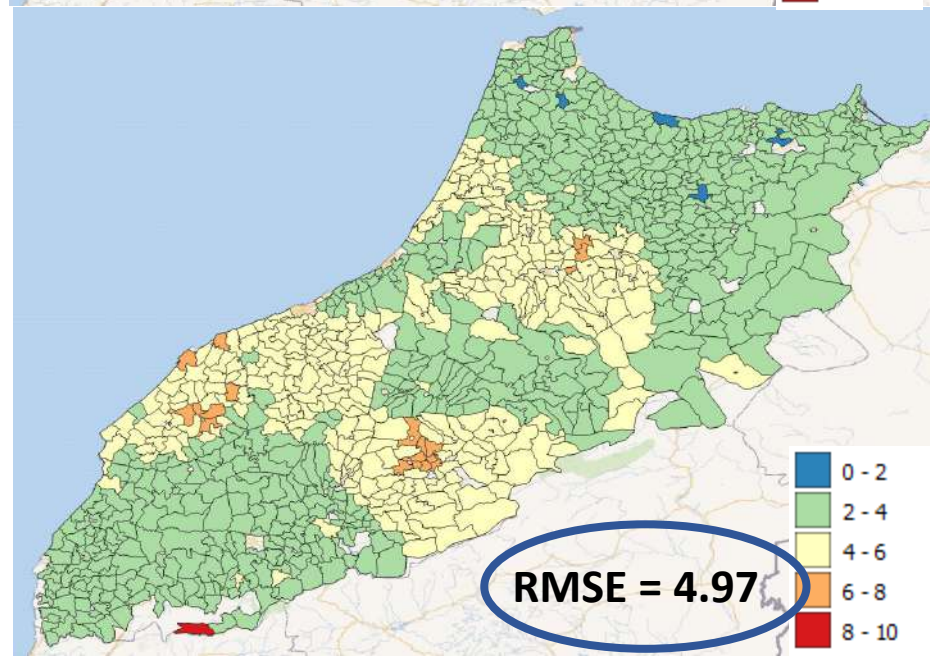
Weather & Satellite



Vegetation indices  
(Satellite)

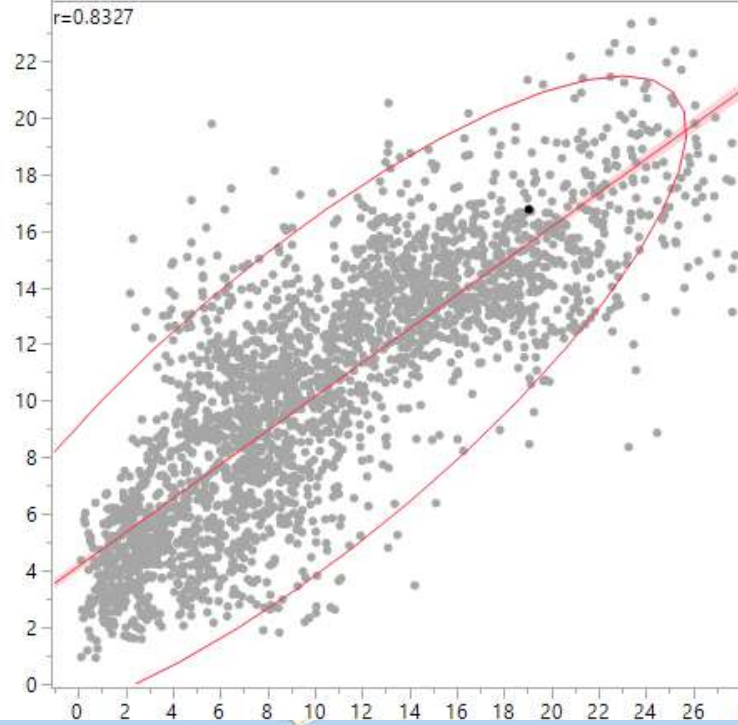


Satellite & Weather  
estimated from Sat

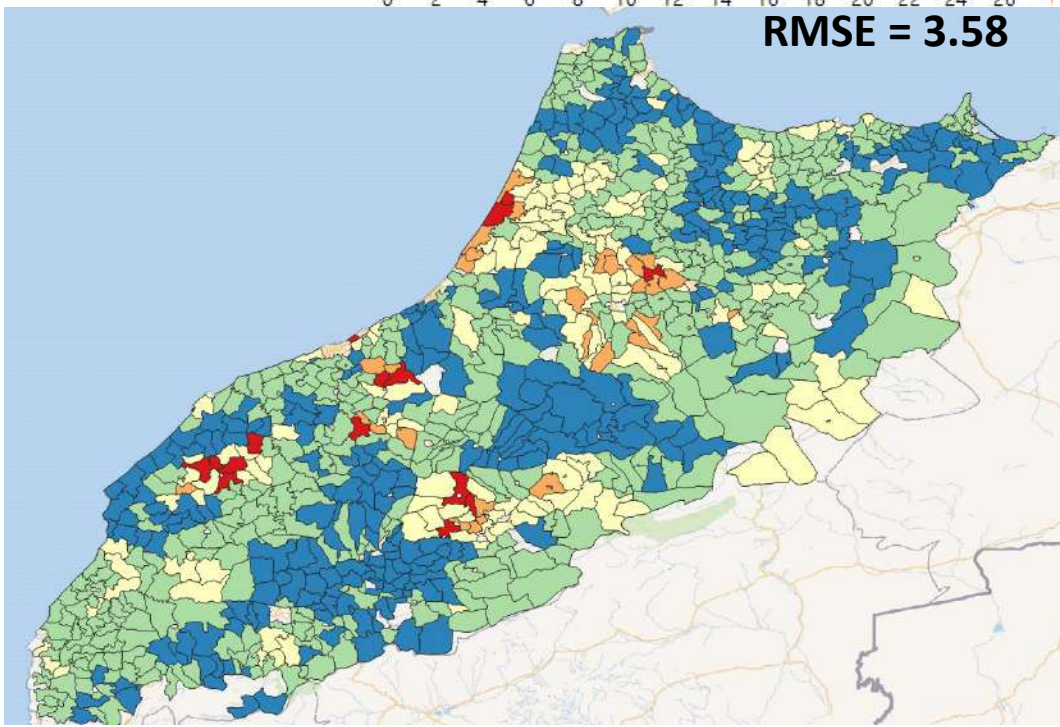


# Case study

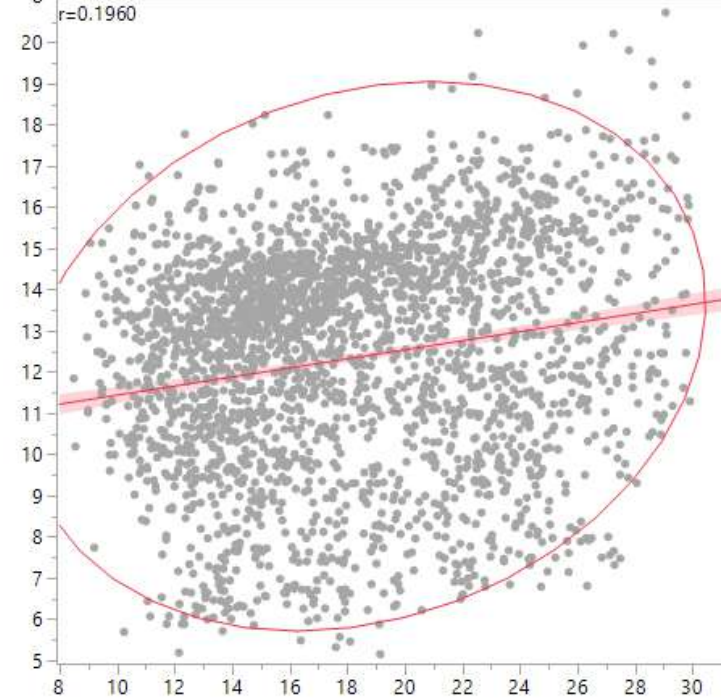
2014 year  
Average production



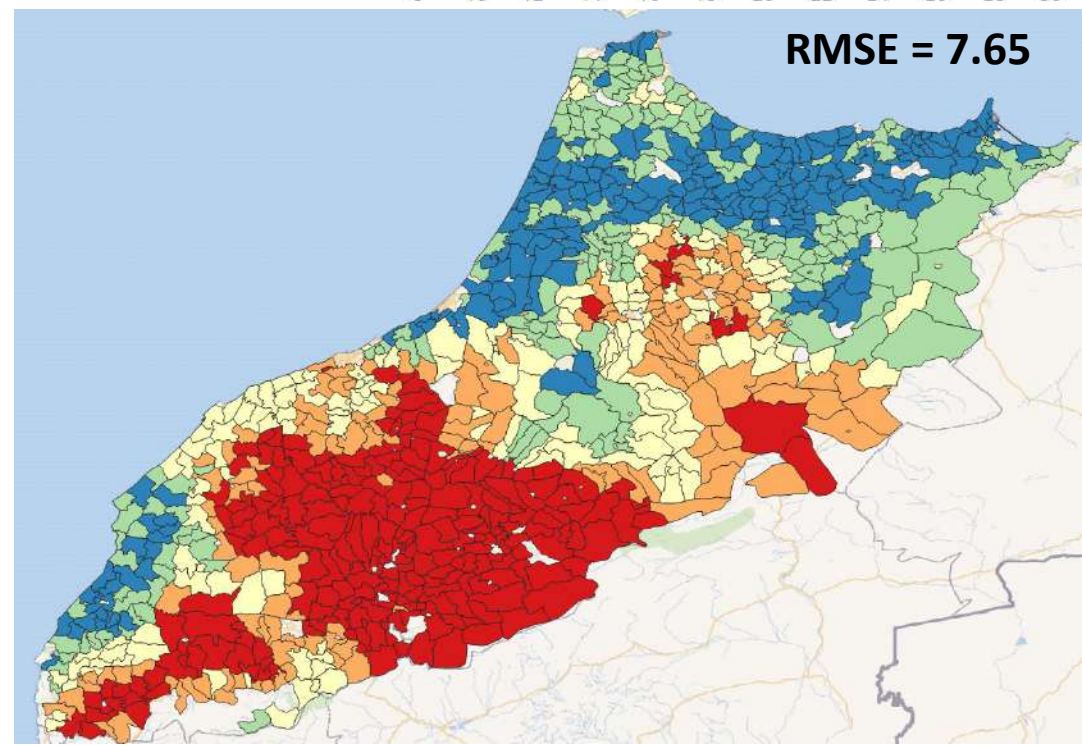
RMSE = 3.58



2009 year  
High production



RMSE = 7.65

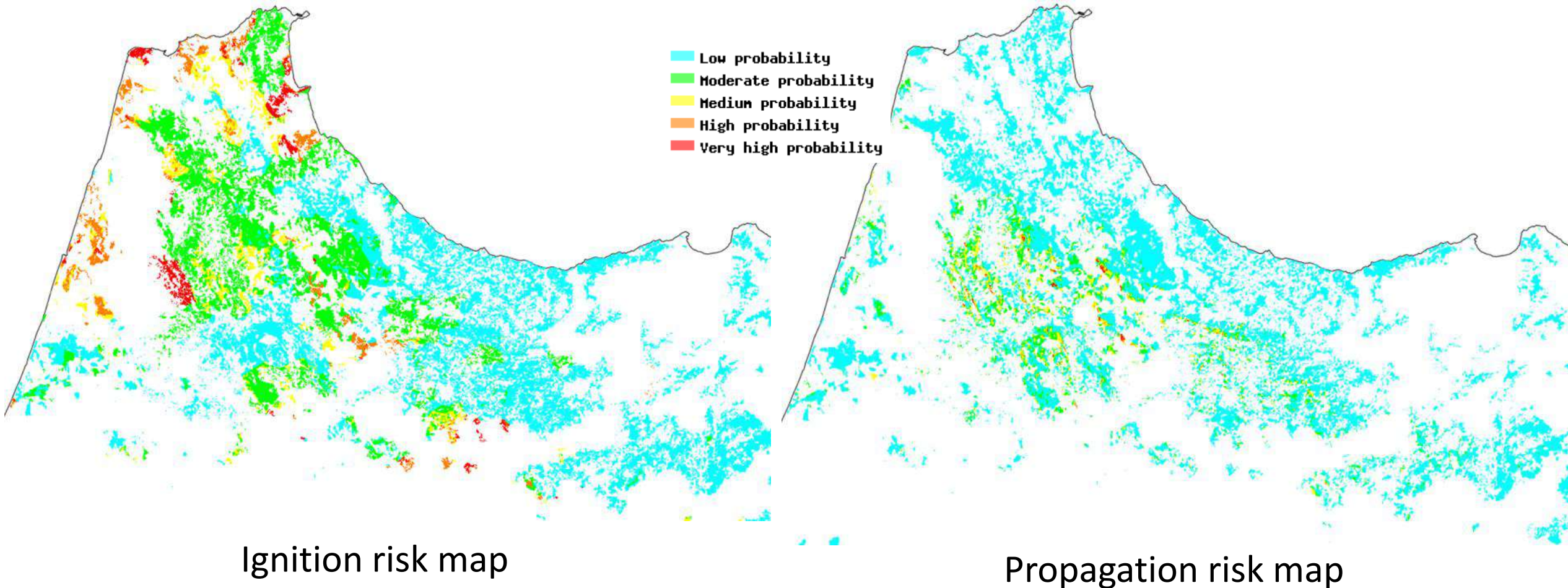


# Future Improvement

- Land cover from 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 predictor)

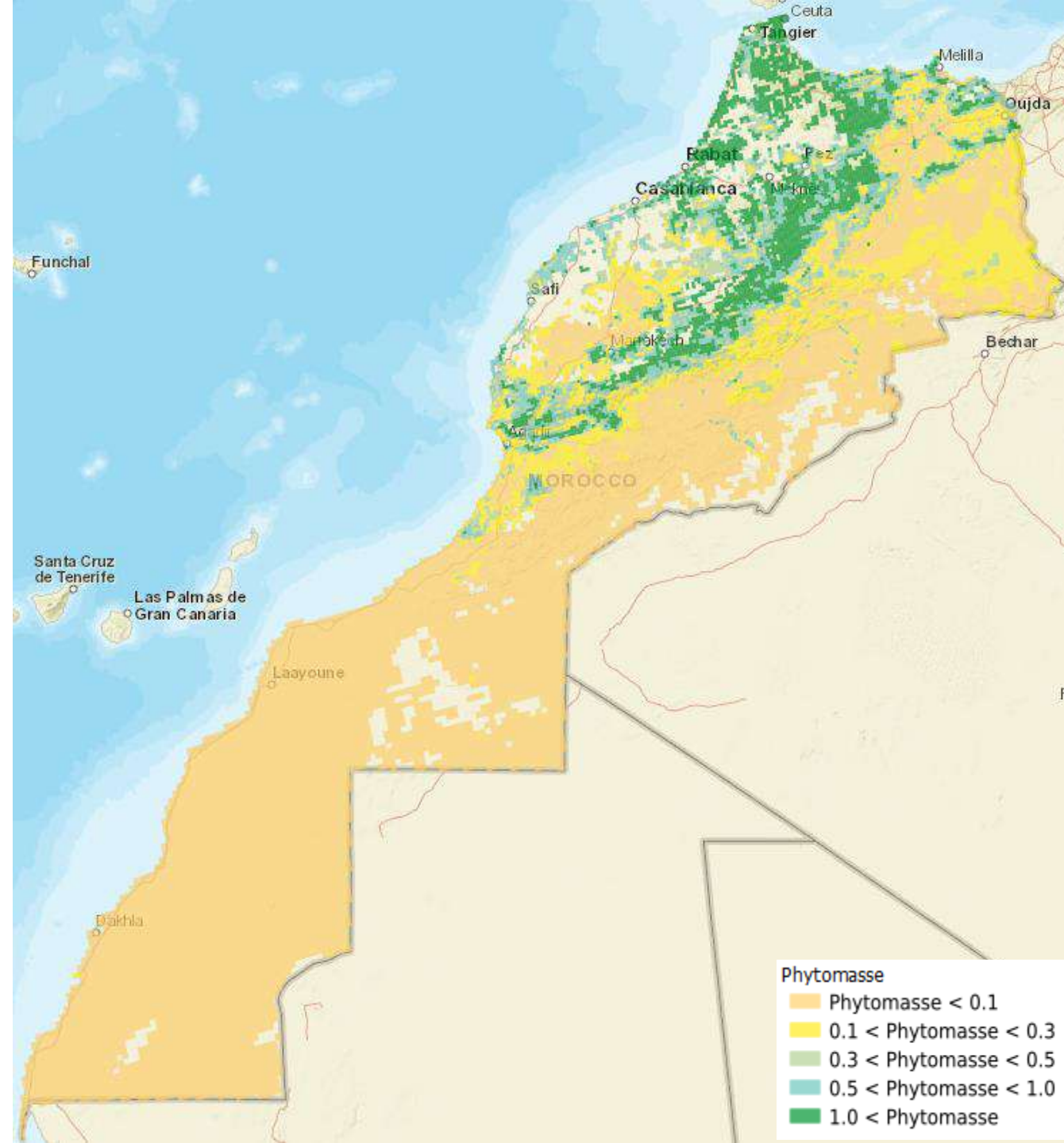
# Producing Forest Fire Risk Maps at (day-1 and day-2)

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





# Estimation of Phytomass production in Rangelands.



**Thank you**

