FAO Modelling System for Agricultural Impacts of Climate Change

MOSAICC

# Modelling System for Agricultural Impacts of Climate Change

FAO-MOSAICC is developed in the framework of the EU/FAO Programme on "*Improved Global Governance for Hunger Reduction*".


MOSAICC

(for *MOdelling System for Agricultural Impacts of Climate Change*)

is a **system of models and utilities** designed

to carry out inter-disciplinary climate change impact assessment

on agriculture through simulations.

There are numerous climate change impact studies, **but**

most of them are disconnected from decision-making processes of stakeholders.

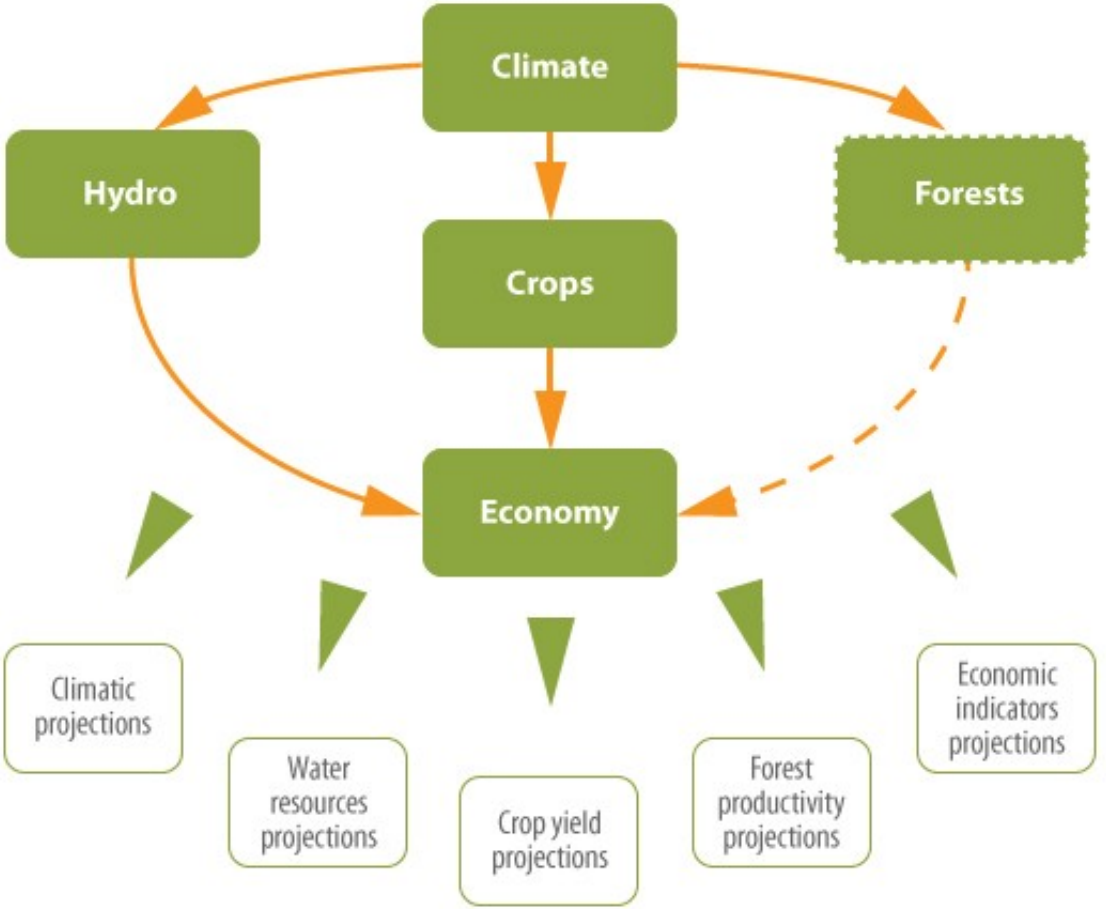
others lack a solid evidence-base about current and future climate impacts as well as vulnerabilities at different spatial and temporal scales.

MOSAICC employs an interdisciplinary assessment approach to addressing climate change impacts and adaptation planning in the agriculture and food security sectors.

An innovative software design supports participatory and integrated modelling environment in an interdisciplinary working group.

The **models** integrated in MOSAICC are organized in five main components:

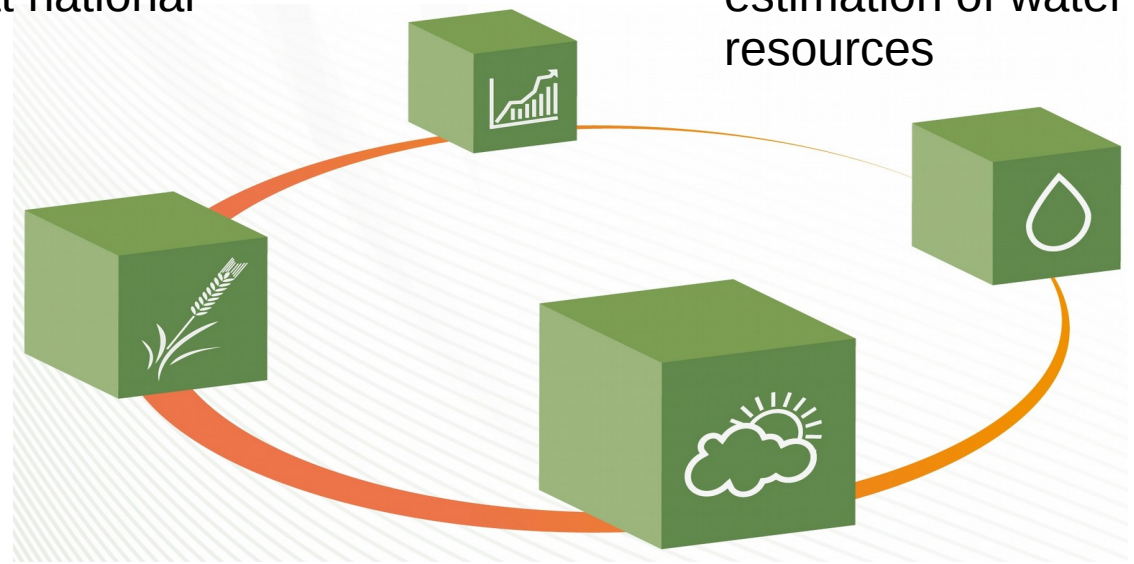
- Climate
- Hydrology
- Crop
- Forestry
- Economy



# MOSAICC MOdelling System for Agricultural Impacts of Climate Change

**Economic impact** and analysis of policy response at national level

Simulation of the country's **hydrology** and estimation of water resources

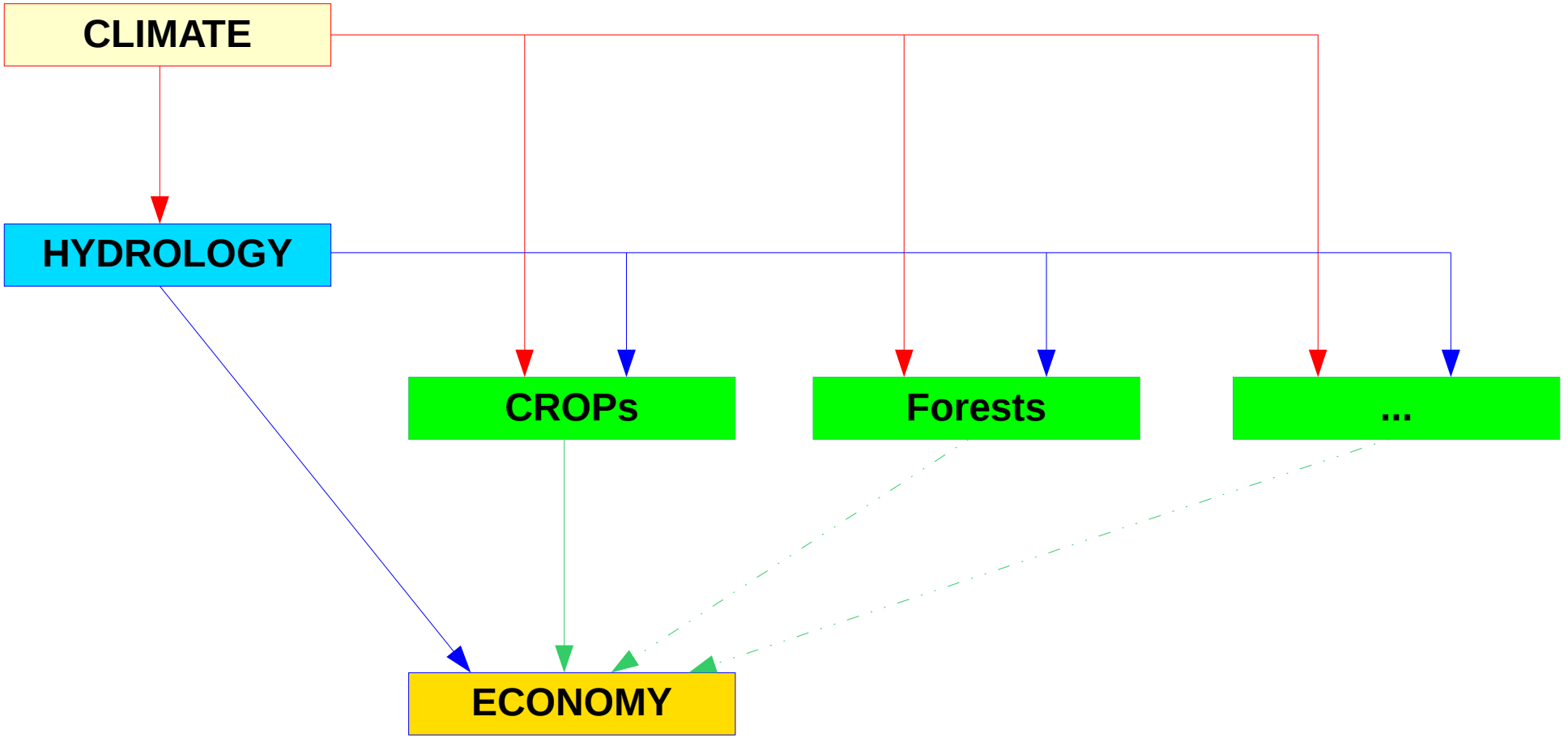


**Crop yield** projections under climate scenarios

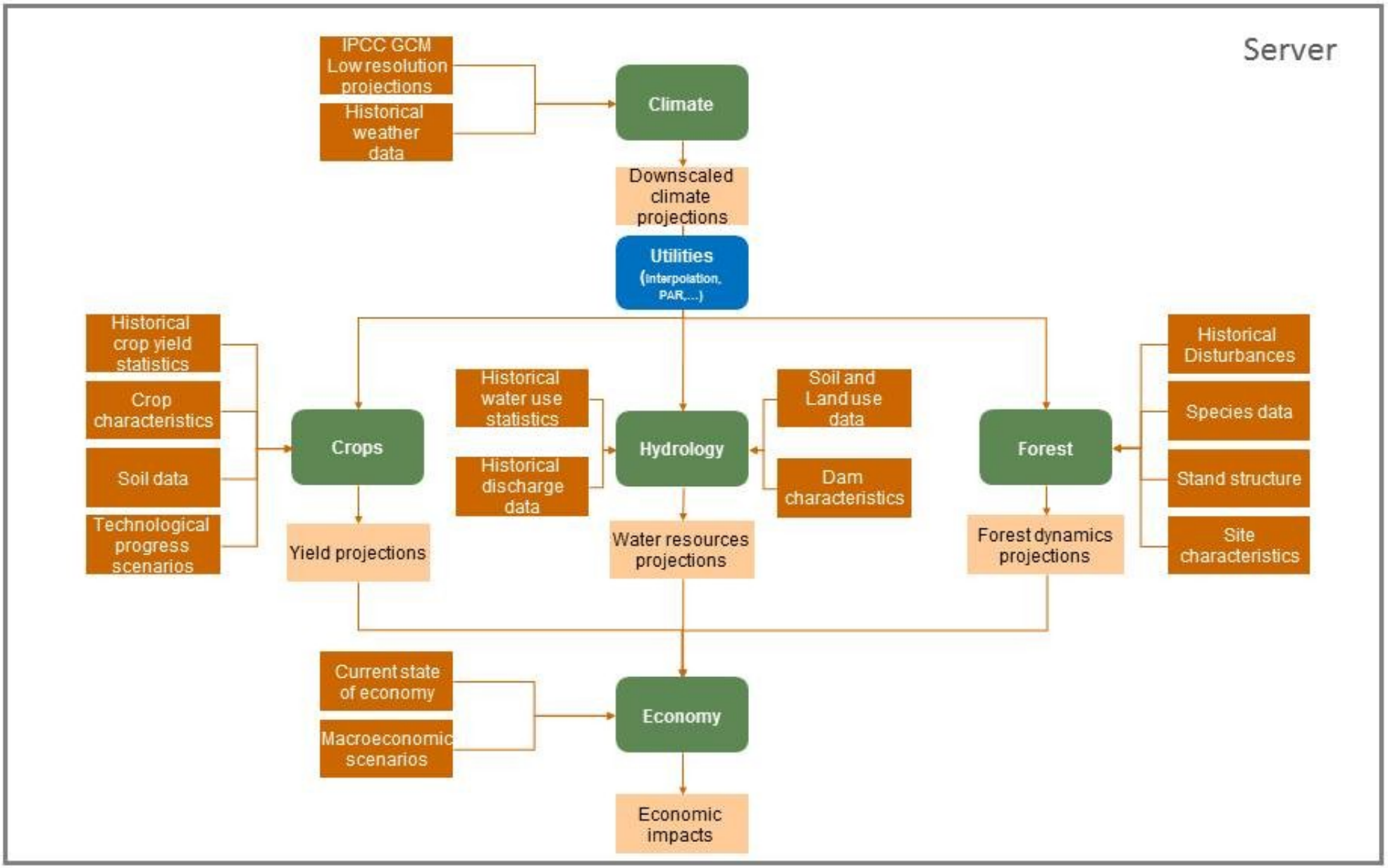
Downscaled climate projections under various **climate scenarios**

Robustness rather than sophistication
flexibility, wide application, open source
(minimum input data required, simple)

# Processing Flow



# MOdelling System for Agricultural Impacts of Climate Change



# Climate Models and Scenarios (a)

***Coupled Model Intercomparison Project*** (**CMIP5**)
28 institutions involved and 61 models available

Models selected in MOSAICC depending on features and terms of use:

| Name | Description | Institution | Terms of use | XR | YR |
|---|---|---|---|---|---|
| CanESM2 | Canadian Earth System Model, 2nd generation | Canadian Centre for Climate Modelling and Analysis | unrestricted | 2.8 | 2.8 |
| MIROC-ESM | Model for Interdisciplinary Research on Climate - Earth System Model | Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies | non-commercial only | 2.8 | 2.8 |
| MPI-ESM-MR | Max Planck Institute for Meteorology – Earth System Model – Mixed Resolution | Max Planck Institute for Meteorology (MPI-M) | unrestricted | 1.9 | 1.9 |

CMIP5 model availability: http://cmip-pcmdi.llnl.gov/cmip5/availability.html

# Climate Models and Scenarios (b)

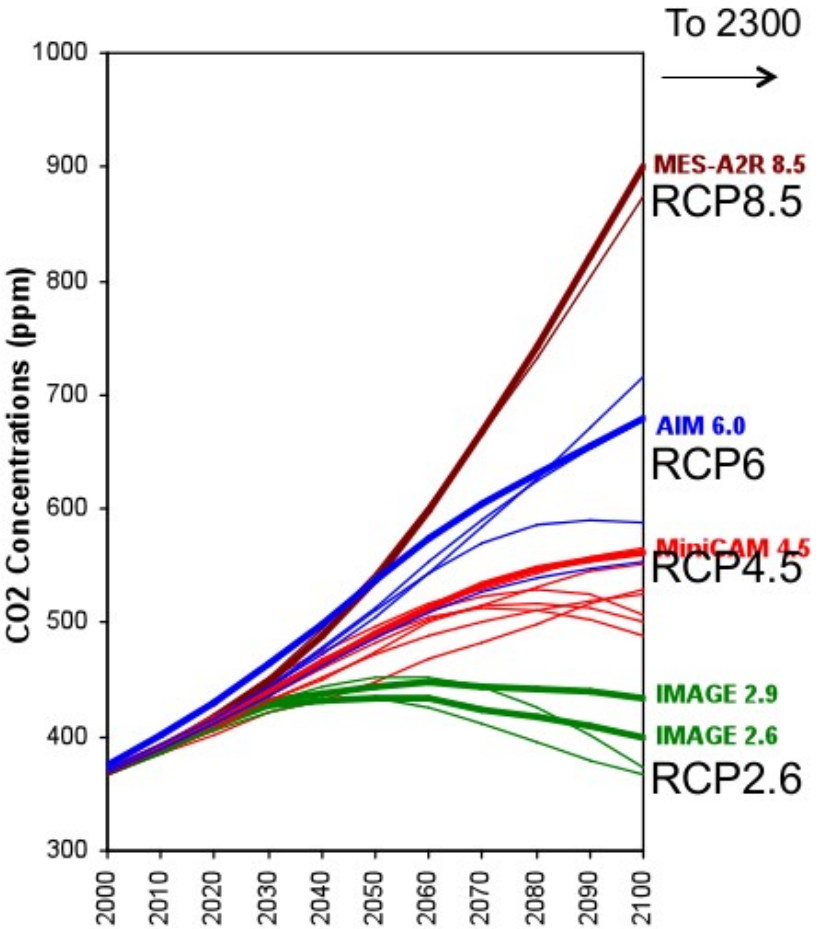
Emissions scenarios describe future releases into the atmosphere of greenhouse gases, aerosols, and other pollutants and, along with information on land use and land cover, provide inputs to climate models. There are 40 different scenarios, each making different assumptions for future greenhouse gas pollution, land-use and other driving forces. These emissions scenarios are organized into families A1, A2, B1 and B2.

The ***Representative Concentration Pathways*** (**RCP**) are based on selected scenarios from four modelling teams/models working on integrated assessment modelling, climate modelling, and modelling and analysis of impacts.

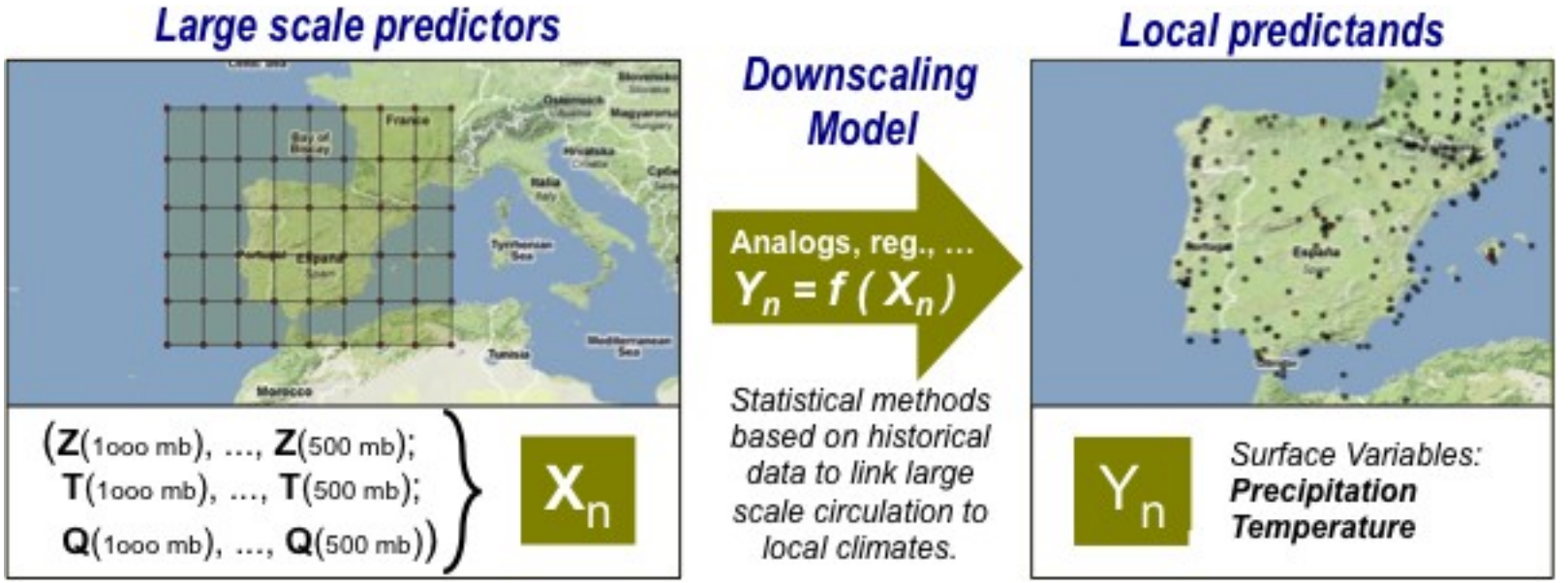
RCP used in MOSAICC:

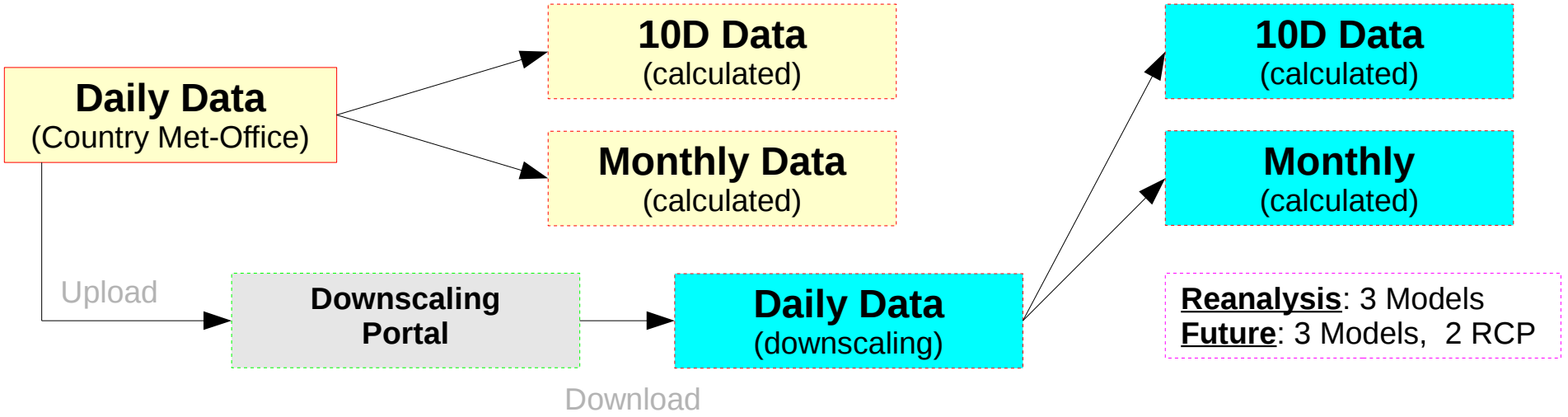
- **RCP 4.5**: Stabilization without overshoot pathway to 4.5 W/m² at stabilization after 2100
- **RCP 8.5**: Rising radiative forcing pathway leading to 8.5 W/m² in 2100.

| RCP 4.5<br>Optimistic | RCP 8.5<br>Pessimistic |
|---|---|



# Climate Data Processing (a)



# Climate Data Processing (b)

**Climate Variables**:
- Precipitation
- Min Temperature
- Max Temperatute
- PET (Et0)

**3 Periods**:
- 1980 – 2010: Real Data
- 1971 – 2000: Reanalysis Data
- 2010 – 2099: Future Data

**3 Uses**:
- Model Calibration
- Reference Time Sim.
- Future Time Simulation

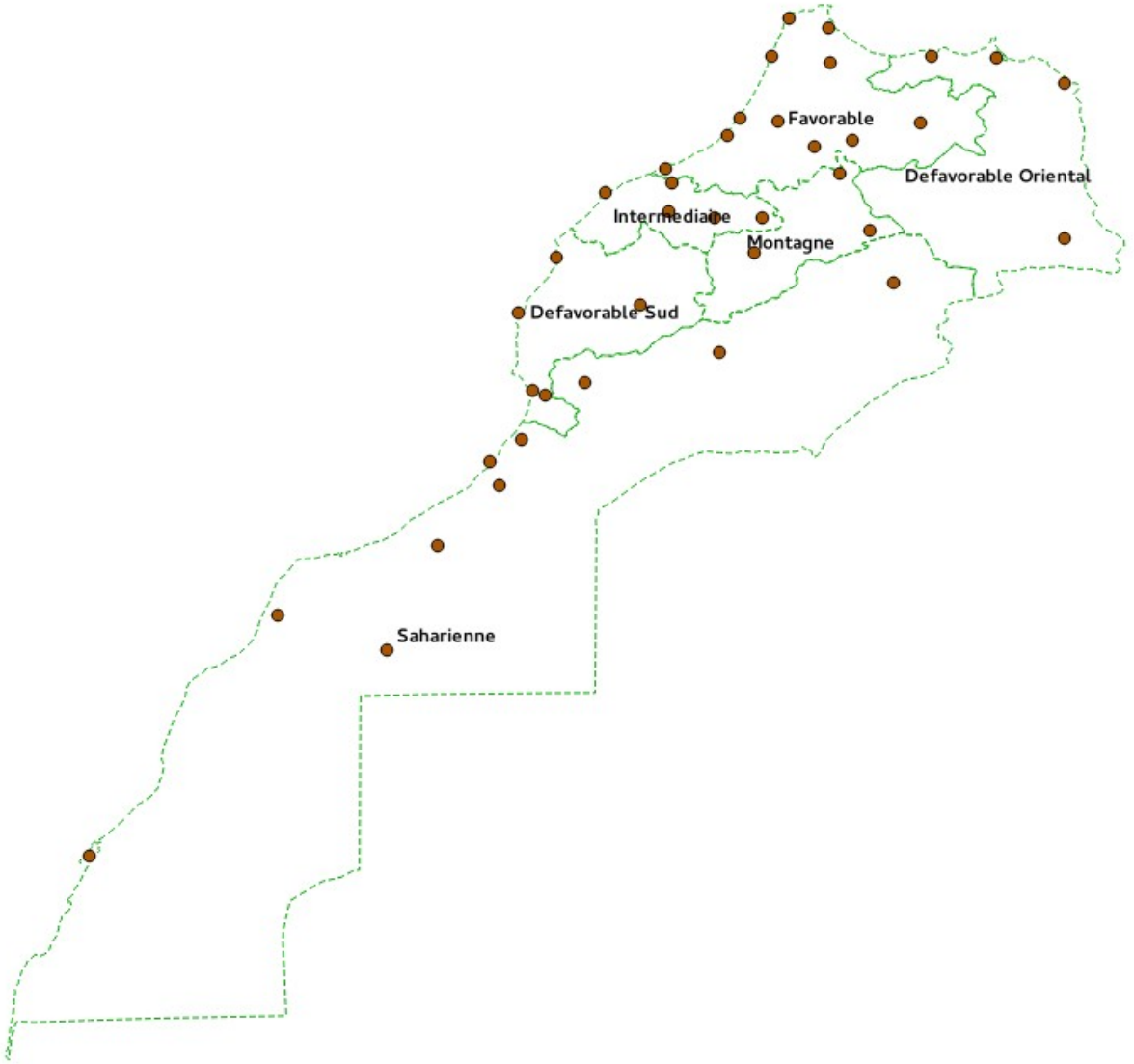
**3 Selected Models**:
- CanESM2
- MIROC-ESM
- MPI-ESM MR

More than 20 models available in **CMIP5** (*Coupled Model Intercomparison Project*)

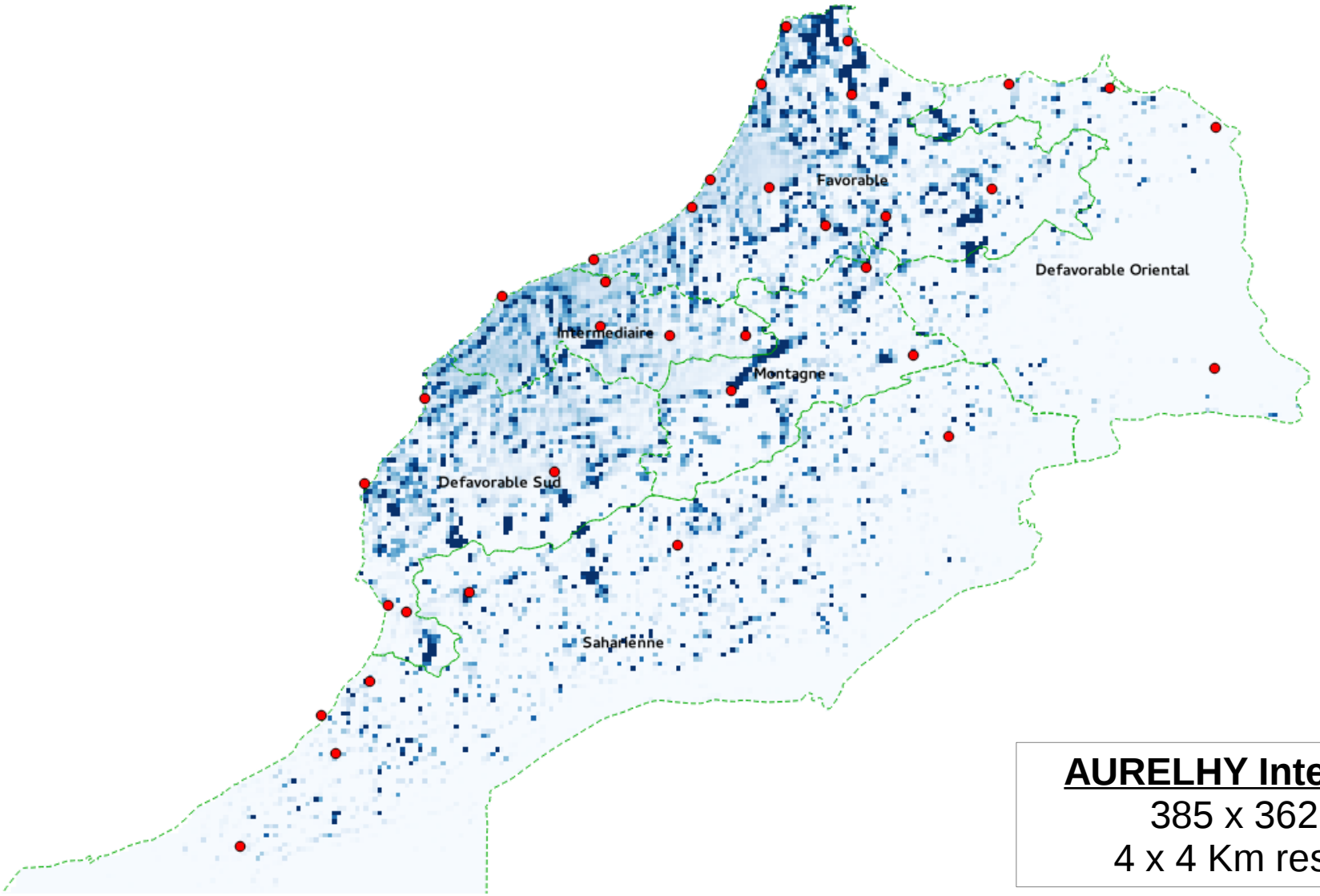
**2 Scenarios**
- RCP 4.5 (optimistic)
- RCP 8.5 (pessimistic)

**Spatial Interpolation**:
- **Method = AURELHY** (*Analyse Utilisant le RELief pour les besoins de l'Hydrométéorologie*)
- **Resolution** = 4 Km
- **Grid Size** = 385 x 362
- **Extent** = 16° x 15° (Lat = 21-36°N)

# Climate Data: weather stations (38)



# Climate Data: interpolated precipitation




**AURELHY Interpolation**
385 x 362 cells
4 x 4 Km resolution

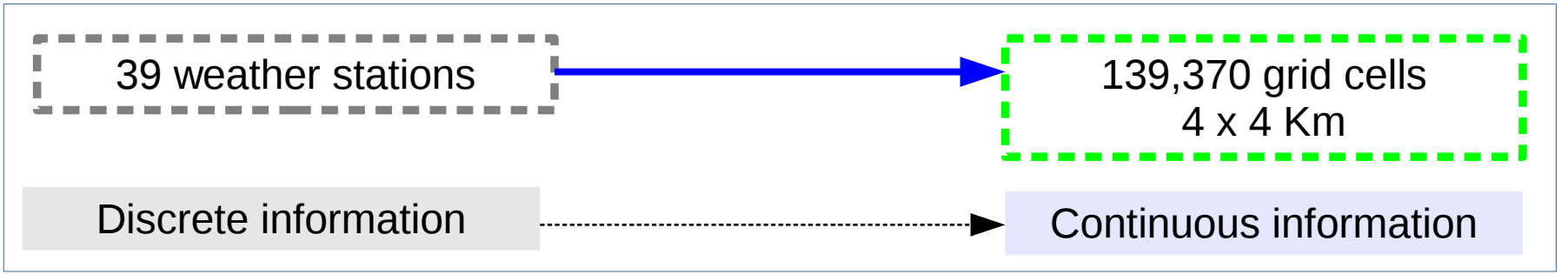
# AURELHY Interpolation

*Analyse Utilisant le RELief pour les besoins de l'Hydrométéorologie*

**Basic Idea**: Use of topography to guide the spatial interpolation of climatic variables (precipitation and others)

Steps:

1) Terrain analysis
   - ✔ Mapping relative altitude differences of smoothed local topographies
   - ✔ PCA of local topography variables
2) Regression of climate variable against terrain
   - ✔ Surface predicted by regression
3) Spatial interpolation of residuals by Kriging
4) Adding surface of interpolated residuals to surface predicted by regression



# Climate Data Processing in numbers

| | Real Data | Reference Time | Future Time |
|---|---|---|---|
| Stations | 38 | 38 | 38 |
| Variables | 4 | 4 | 4 |
| Models | 1 | 3 | 3 |
| Scenarios | 0 | 0 | 2 |
| Begin Year | 1980 | 1971 | 2010 |
| Final Year | 2010 | 2000 | 2099 |
| Records | 1,719,880 | 4,993,200 | 29,959,200 |
| Grids | 4,464 | 12,960 | 77,760 |
| Cells | 622,147,680 | 1,806,235,200 | 10,837,411,200 |

# Climate Data-Set Table

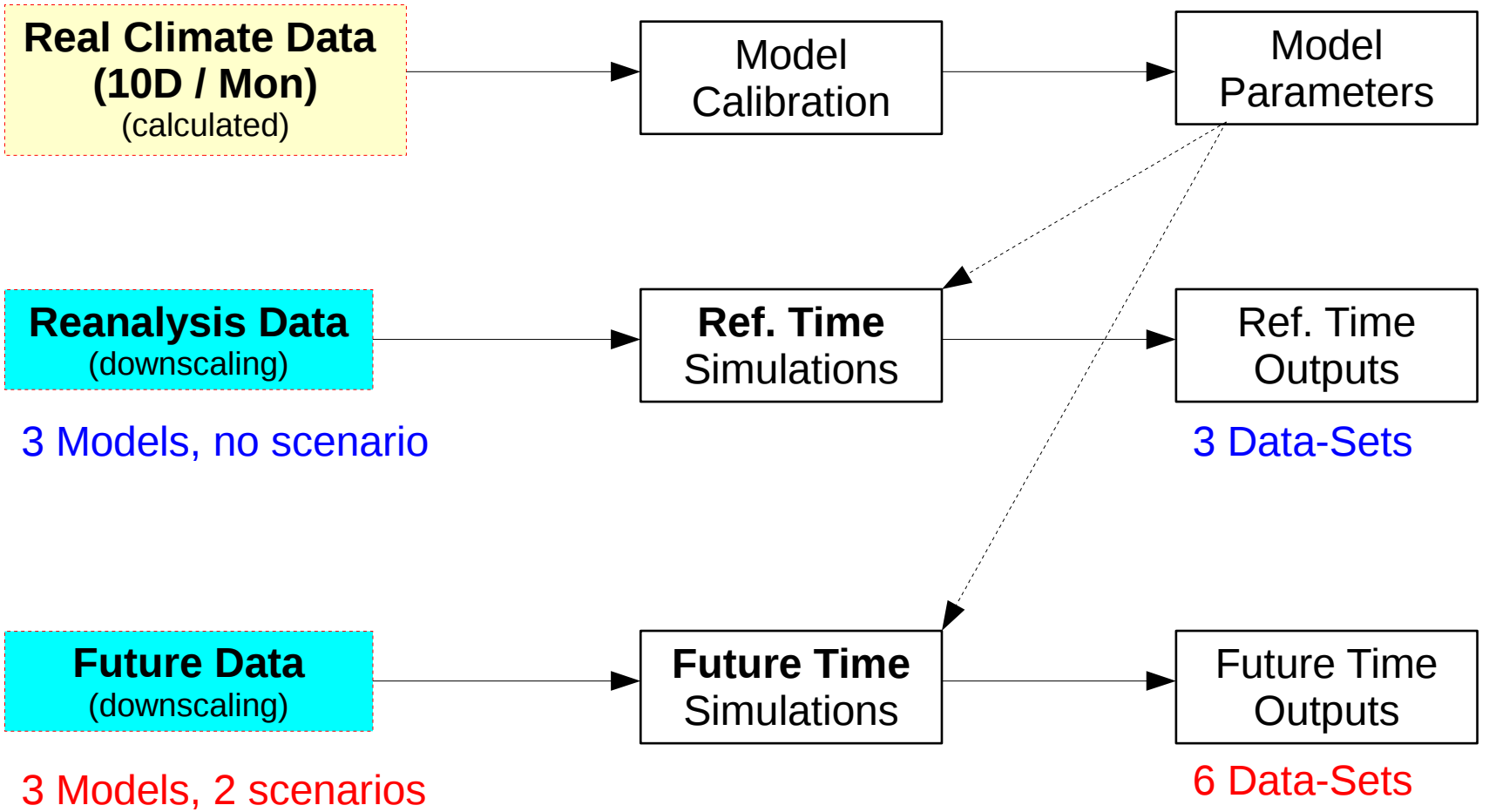
Climatologies start from the daily data at weather station level and provide to the other experts all the variables as dekadal and monthly data for each model and scenario

| PREC | TMIN | TMAX | PET | Time Step | Period | Scenario | Model |
|---|---|---|---|---|---|---|---|
| 2650 | 2664 | 2663 | 2682 | Monthly | 1980-2010 | | |
| 3009 | 3014 | 3013 | 3025 | Monthly | 1971-2000 | | CanESM2 |
| 3101 | 3108 | 3109 | 3114 | Monthly | 1971-2000 | | MIROC-ESM |
| 3139 | 3142 | 3143 | 3148 | Monthly | 1971-2000 | | MPI-ESM MR |
| 3011 | 3015 | 3017 | 3027 | Monthly | 2010-2099 | RCP 4.5 | CanESM2 |
| 3102 | 3110 | 3113 | 3115 | Monthly | 2010-2099 | RCP 4.5 | MIROC-ESM |
| 3140 | 3144 | 3146 | 3149 | Monthly | 2010-2099 | RCP 4.5 | MPI-ESM MR |
| 3012 | 3016 | 3018 | 3028 | Monthly | 2010-2099 | RCP 8.5 | CanESM2 |
| 3103 | 3112 | 3111 | 3116 | Monthly | 2010-2099 | RCP 8.5 | MIROC-ESM |
| 3141 | 3145 | 3147 | 3150 | Monthly | 2010-2099 | RCP 8.5 | MPI-ESM MR |
| 2651 | 2665 | 2667 | 2678 | Dekadal | 1980-2010 | | |
| 2990 | 3004 | 2999 | 3006 | Dekadal | 1971-2000 | | CanESM2 |
| 3050 | 3078 | 3079 | 3084 | Dekadal | 1971-2000 | | MIROC-ESM |
| 3117 | 3120 | 3121 | 3136 | Dekadal | 1971-2000 | | MPI-ESM MR |
| 2991 | 3005 | 3002 | 3008 | Dekadal | 2010-2099 | RCP 4.5 | CanESM2 |
| 3051 | 3081 | 3082 | 3098 | Dekadal | 2010-2099 | RCP 4.5 | MIROC-ESM |
| 3118 | 3122 | 3124 | 3137 | Dekadal | 2010-2099 | RCP 4.5 | 2 |
| 2996 | 3007 | 3003 | 3010 | Dekadal | 2010-2099 | RCP 8.5 | CanESM2 |
| 3052 | 3080 | 3083 | 3100 | Dekadal | 2010-2099 | RCP 8.5 | 1 |
| 3119 | 3123 | 3125 | 3138 | Dekadal | 2010-2099 | RCP 8.5 | 2 |

4 VAR *
3 MOD *
(2 SCEN + 1 REF) *
2 AGGR
=
72 Experiments

in 18 coherent data sets

# Modeling Methodology



# Parameters to evaluate the climate change impacts

**Climate Variables**:
- Precipitation
- Min Temperature
- Max Temperatute
- PET (Et0)

**Water availability per basin:**
- Tensift
- Sebou
- Moulouya
- Souss Massa Draa
- Loukkos
- Bouregreg
- Oum Er Rbia
- Sakia Alhamra Oued Eddahab
- Ziz Guir Rheriss

**Yield on crops:**
- Wheat
- Barley
- Olive
- Sugar beet
- Sugar canr
- Early tomato
- Seasonal tomato

**Forestry Variables**:
- Biomass
- Biologic diversity
- Establishments
- Forestry evolution
- Non forest products

**Economic Parameters:**
- Macro Indicators
  - GDP
- Domestic Market
  - Consumption
  - Production
  - Selfsufficiency
- External Trade:
  - Export
  - Import
  - Exchange Rate
- Price
  - Composite price
  - Output price
  - Aggregated producer price
- Factors
  - Water

Experiments by component executed in MOSAICC: **2562**

| component | experiments | models |
|---|---|---|
| Climate | 484 | Climate Downscaling<br>PET Hargreaves |
| Data Interpolation | 420 | PCA<br>Preliminary Interpolation<br>AURELHY Interpolation |
| Hydrology | 867 | DEM Processing<br>STREAM Calibration<br>STREAM Simulation |
| Crop | 565 | PLD<br>WABAL<br>AQUACROP |
| Forestry | 143 | LANDIS II |
| Economy | 83 | DCGE |

Experiment count including the deleted ones: 4328

## Data Sets by format in MOSAICC: **2891**

| Data Format | Data Sets |
|---|---|
| Raster | 1238 |
| Polygon | 703 |
| Point | 189 |
| Table | 761 |
| TOTAL | **2891** |

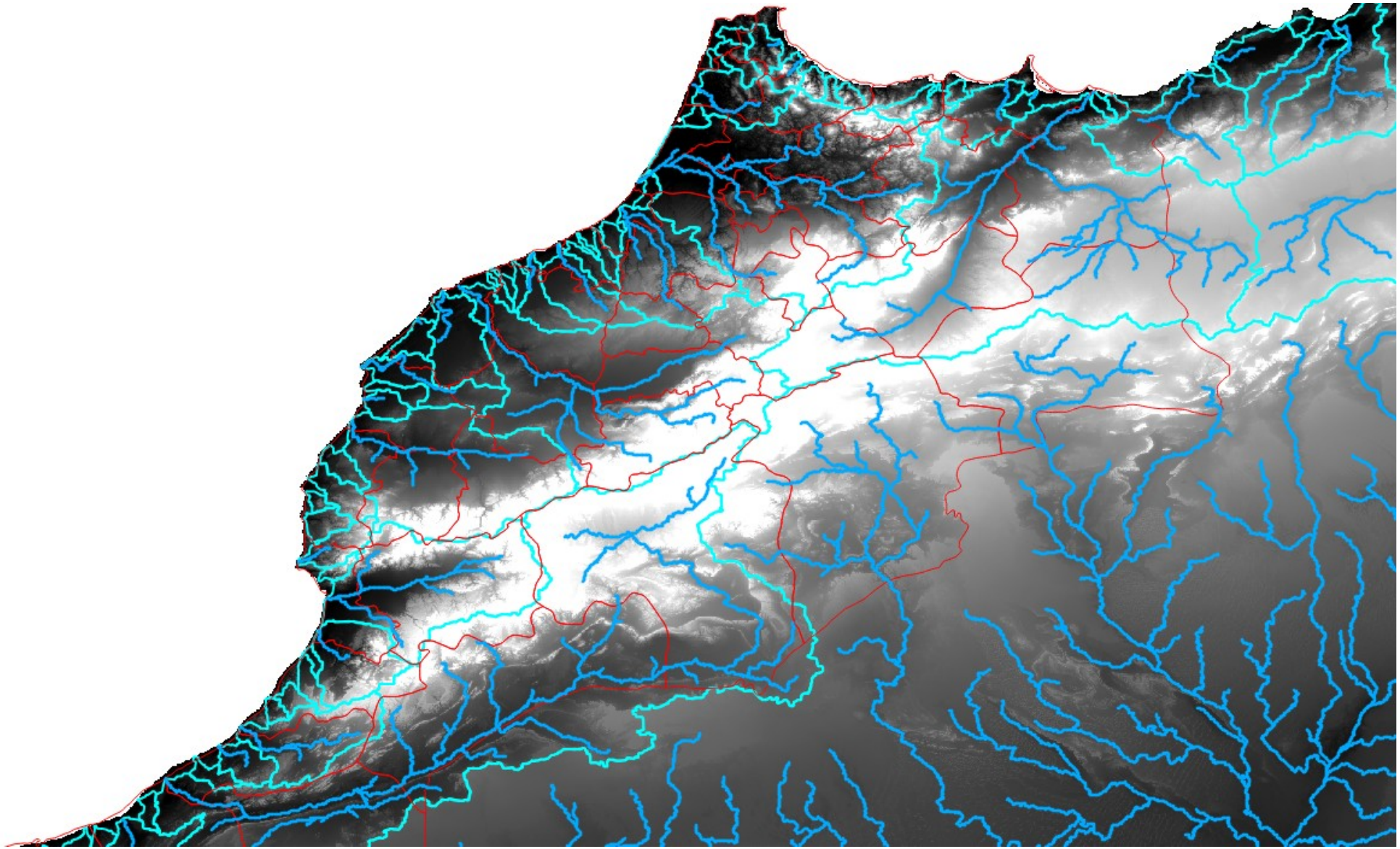
Raster Data Sets can be ***Gridded Time Series***, that actually means <u>many grids</u>

| Years | Dekadal | Monthly |
|---|---|---|
| 10 | 360 | 120 |
| 30 | 1080 | 360 |
| 90 | 3240 | 1080 |

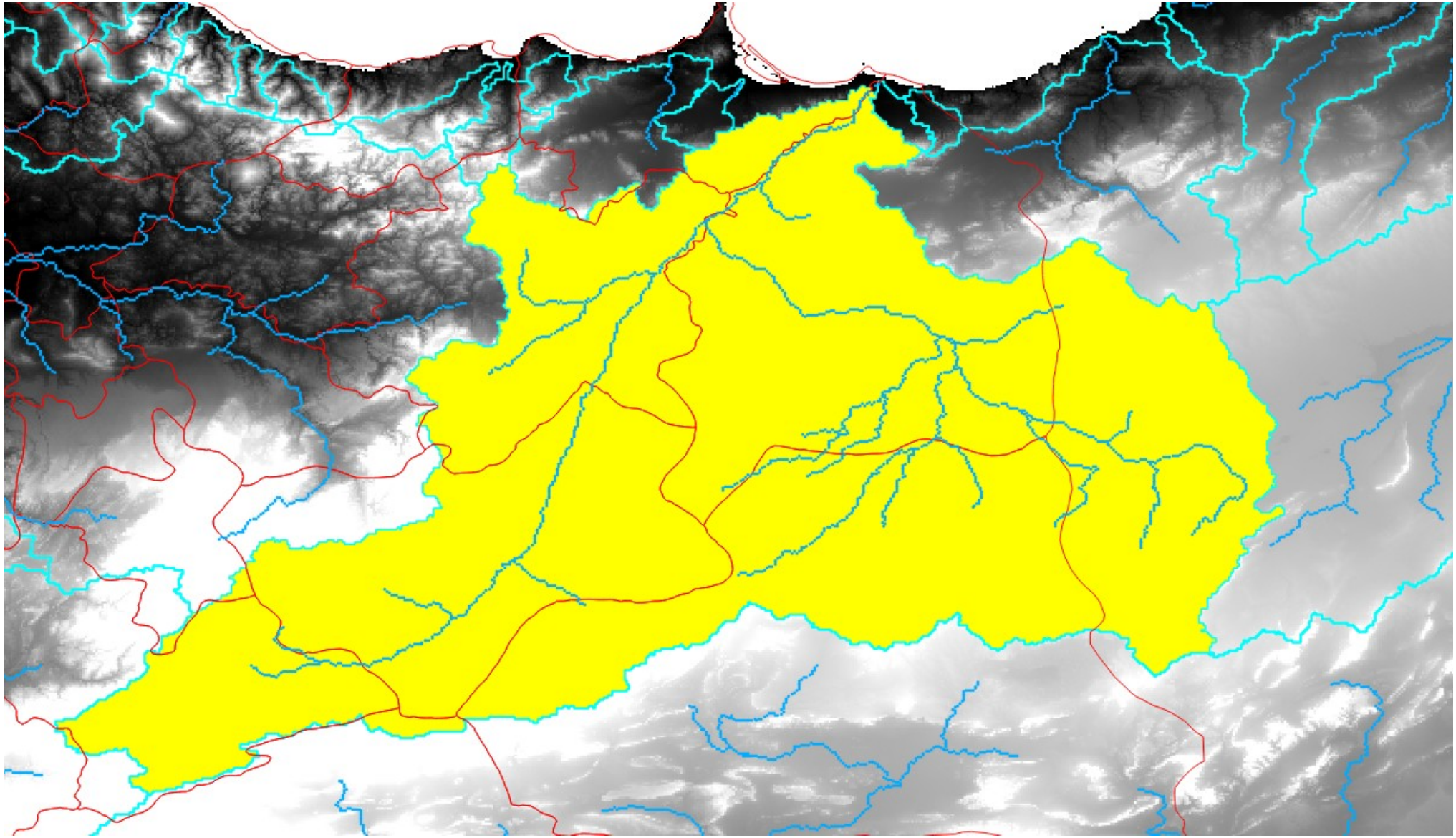
Grid Features:
- 16 x 17°
- resolution = 0.042° (~4 Km)
- 385 x 362 cells

| Climate Data | Main Usage |
|---|---|
| Dekadal (10 days) | Crop Modeling |
| Monthly | Hydrology, Forestry, Economy |

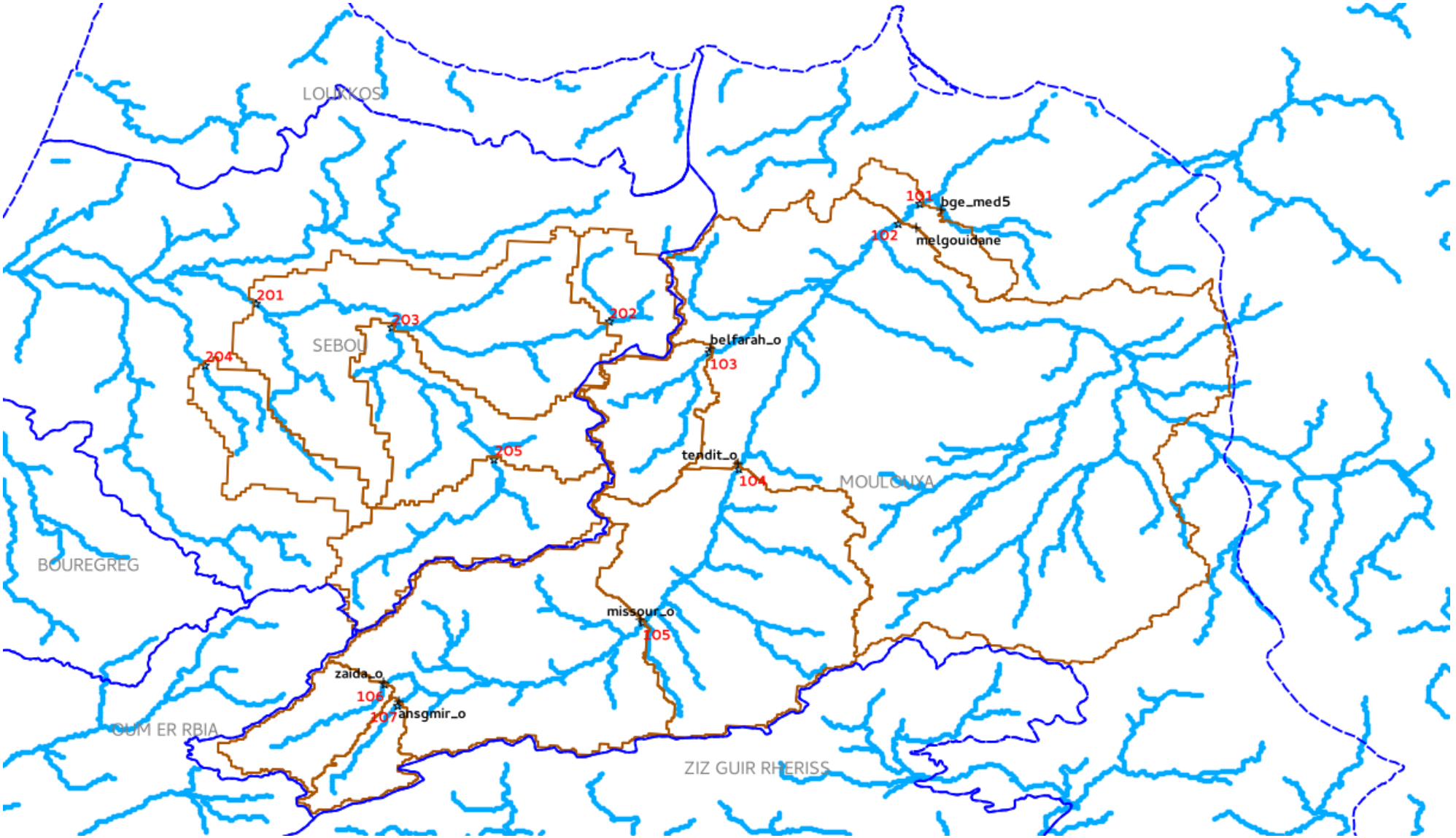
# DEM Processing: River Basins and Streamlines



# DEM Processing: Moulouya basin

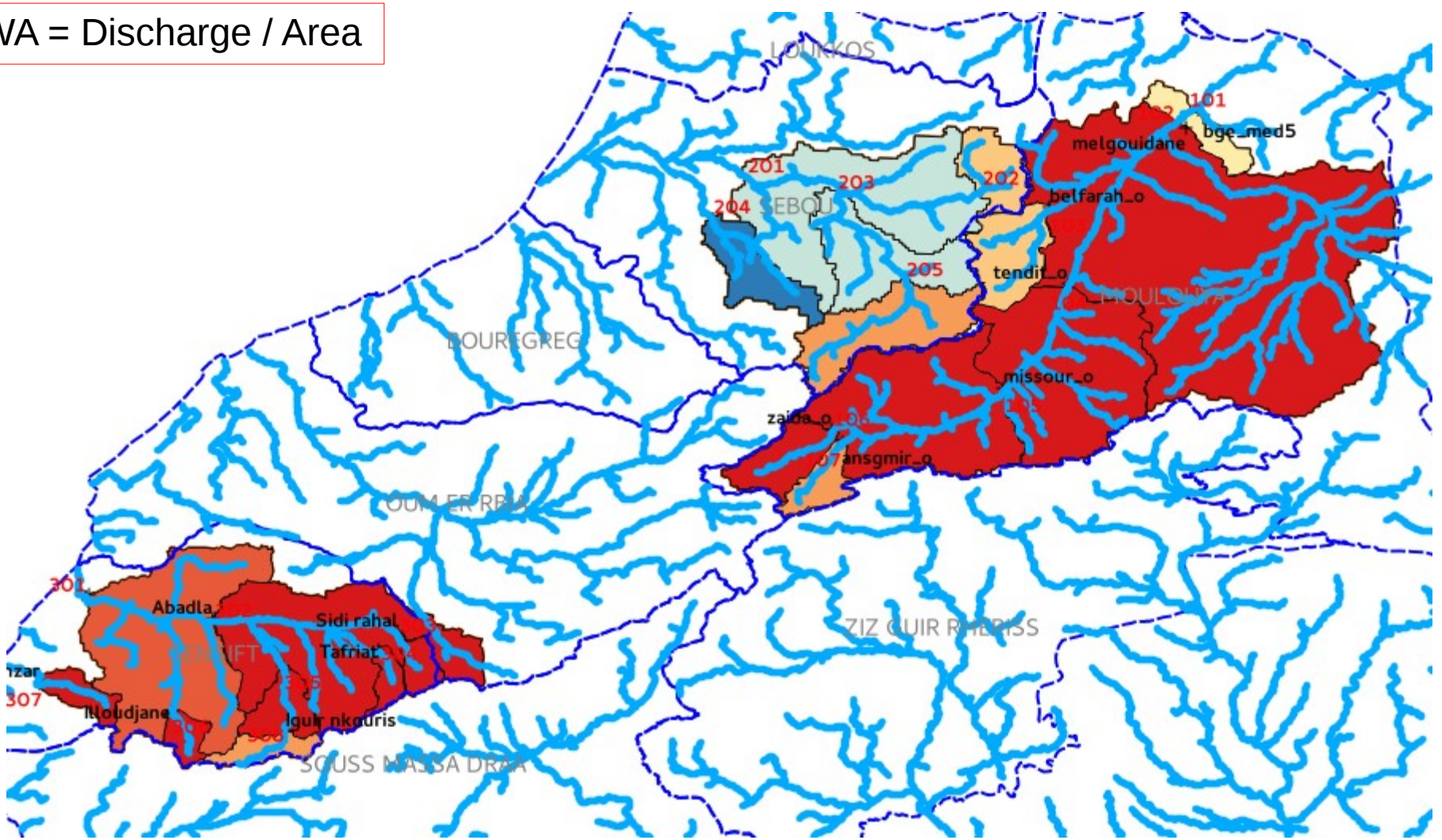


# Hydrology – Moulouya Water Availability



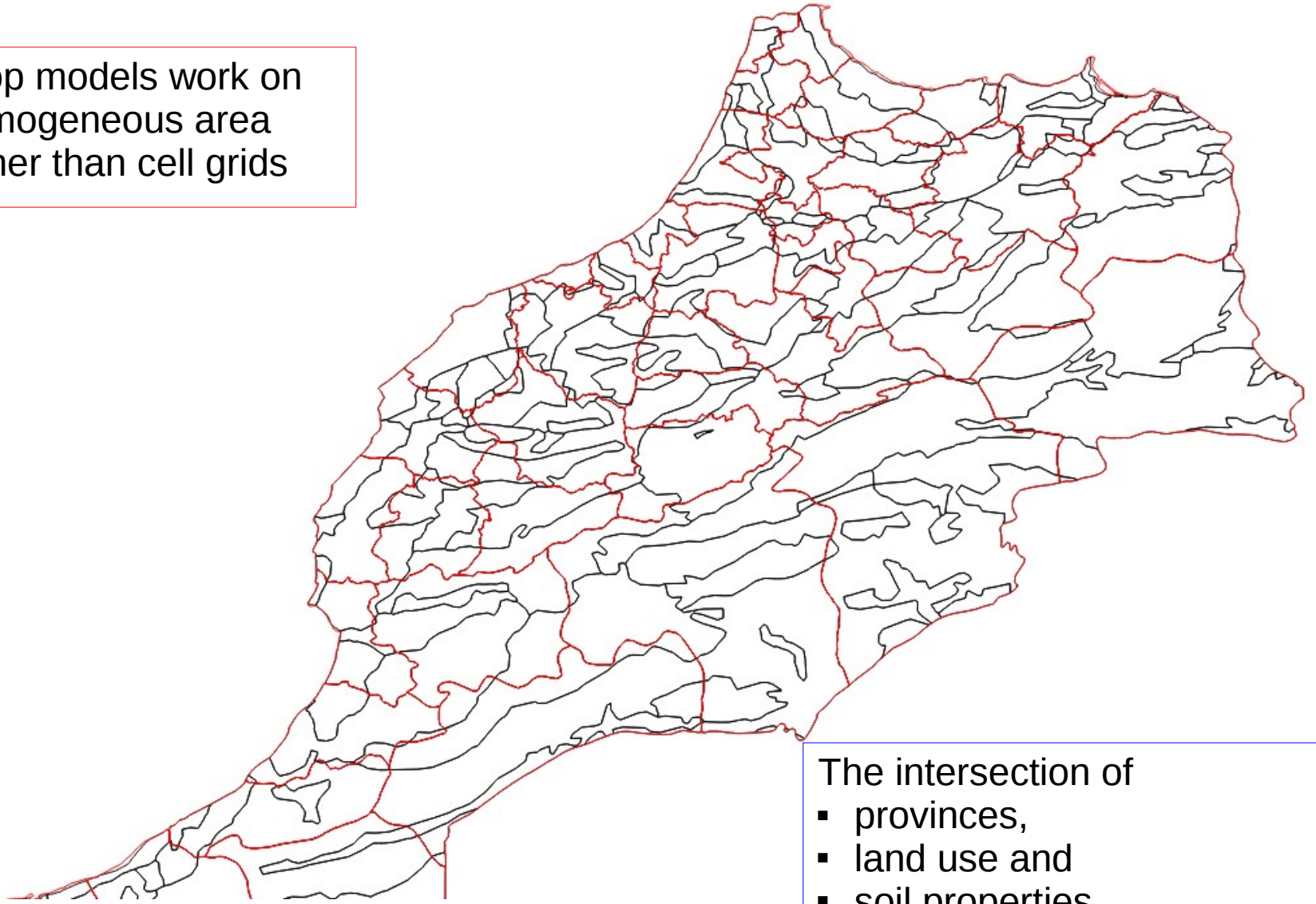
# Hydrology – Water Availability

WA = Discharge / Area



# Crop modeling

Crop models work on homogeneous area rather than cell grids



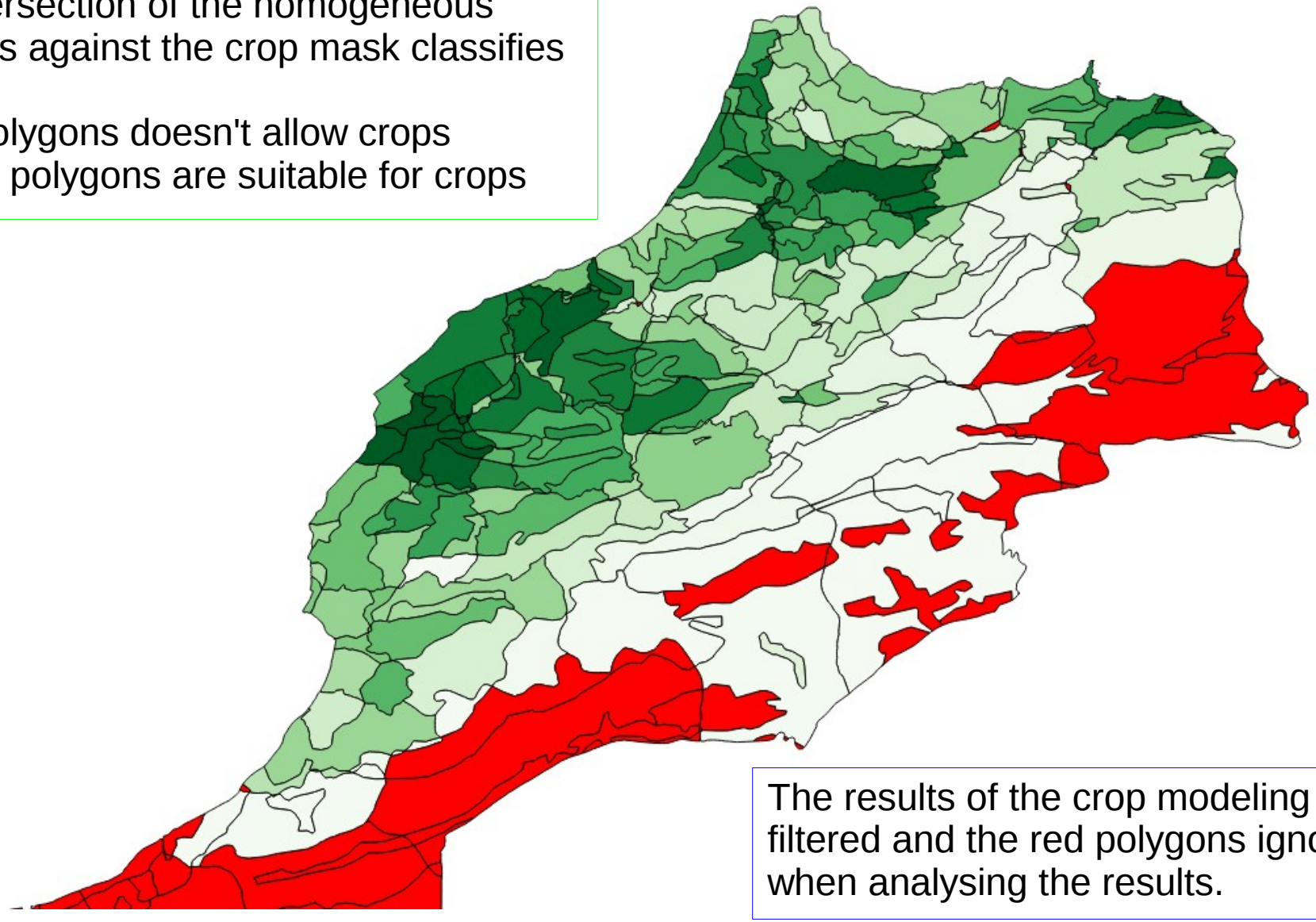
The intersection of
- provinces,
- land use and
- soil properties

generates 389 homogenewous polygons

# Crop modeling with crop mask

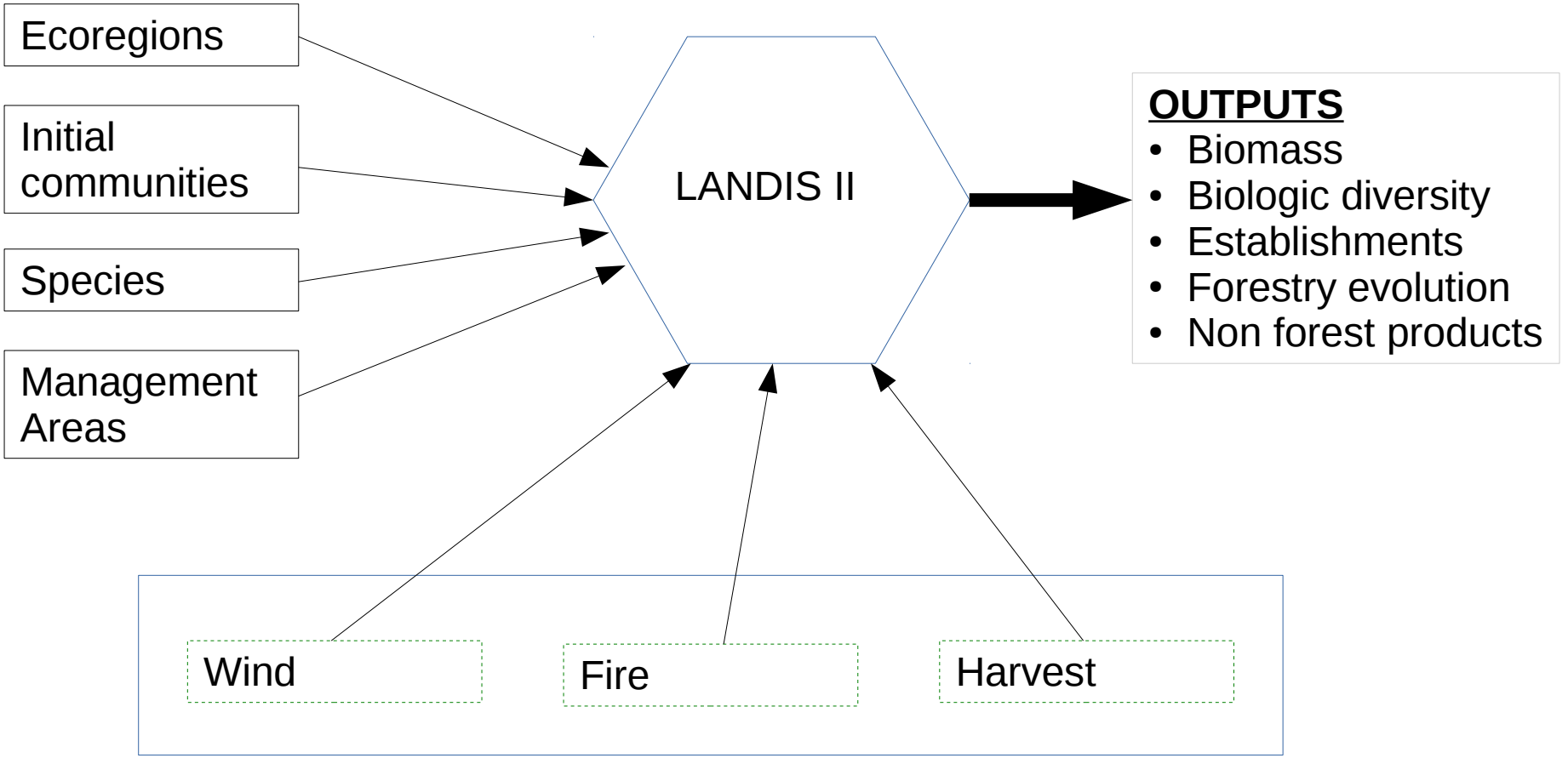
The intersection of the homogeneous polygons against the crop mask classifies them:

- red polygons doesn't allow crops
- green polygons are suitable for crops



The results of the crop modeling can be filtered and the red polygons ignored when analysing the results.

# Forestry (LANDIS II)



# Forestry (LANDIS II) - Maamora Forest (Rabat)

**Ecoregions**

Area: 70 x 40 Km

# Forestry (LANDIS II) - Maamora Forest (Rabat)

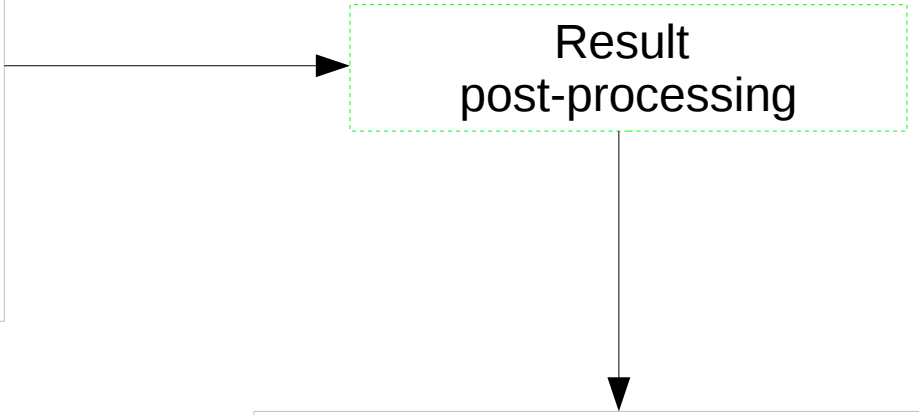
**Initial communities**

Area: 70 x 40 Km

# Forestry (LANDIS II) - Outputs

**Direct outputs**:

- Establishment of species
- Biomass of species
- Soil water
- Wind Disturbance
- Fire Disturbance
- Harvest Disturbance




**Calculated outputs**:

- Leaf Area Index (LAI)
- Distribution of species
- Max biomass above ground
- Mean biomass above ground
- Non-wood forest products (NWFP)

# Economic Model (DCGE)

*Dynamic Computable General Equilibrium*

Equilibrium relates to the condition that supply equals demand in all markets

Basic Idea: the economists describe the current situation in the "*Social Accounting Matrix*" and then provide information about the shocks they imagine activities and commodities can have in the future.

MOSAICC provides the crop yield and water availability, that are calculated from the experts

Shocks are generated comparing the calculated values for a future scenario with they reference values:

- SHOCK = 1: no changes
- SHOCK < 1: negative evolution
- SHOCK > 1: positive evolution

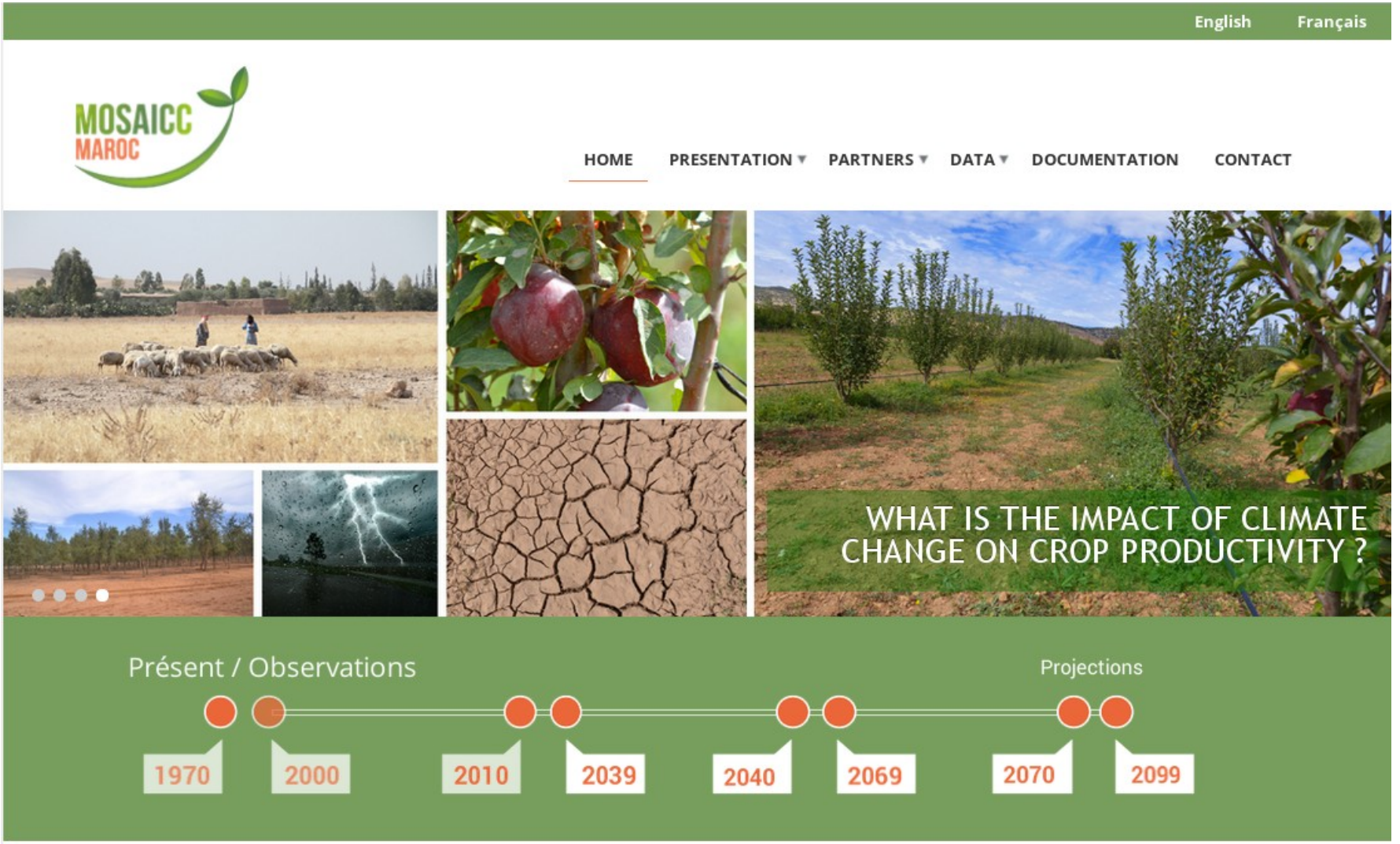
**Economic Parameters:**

- Macro Indicators
  - GDP
- Domestic Market
  - Consumption
  - Production
  - Selfsufficiency
- External Trade:
  - Export
  - Import
  - Exchange Rate
- Price
  - Composite price
  - Output price
  - Aggregated producer price
- Factors
  - Water

MOSAICC MOdelling System for Agricultural Impacts of Climate Change

# www.changementclimatique.ma

*the new web portal to publish the results of MOSAICC*



# www.changementclimatique.ma

*the new web portal to publish the results of MOSAICC*

**Menu**

- Home
- Presentation
  - MOSAICC
  - Climate Change
  - Technical Architecture
  - Exchange Workshops
  - Resources
- Partners
  - National
  - International
- Data
  - CC Impact
  - Simulator
- Documentation
- Contacts

**CC Impact**

Simple point-and-click interface designed for decision makers with three views on the data:

- Variable Overview
- Single Variable Mode
- Comparison Mode

Built-in PDF generation facility.

**Simulator**

WEB-GIS based interface for advanced users that offers highly configurable query system for detailed analysis

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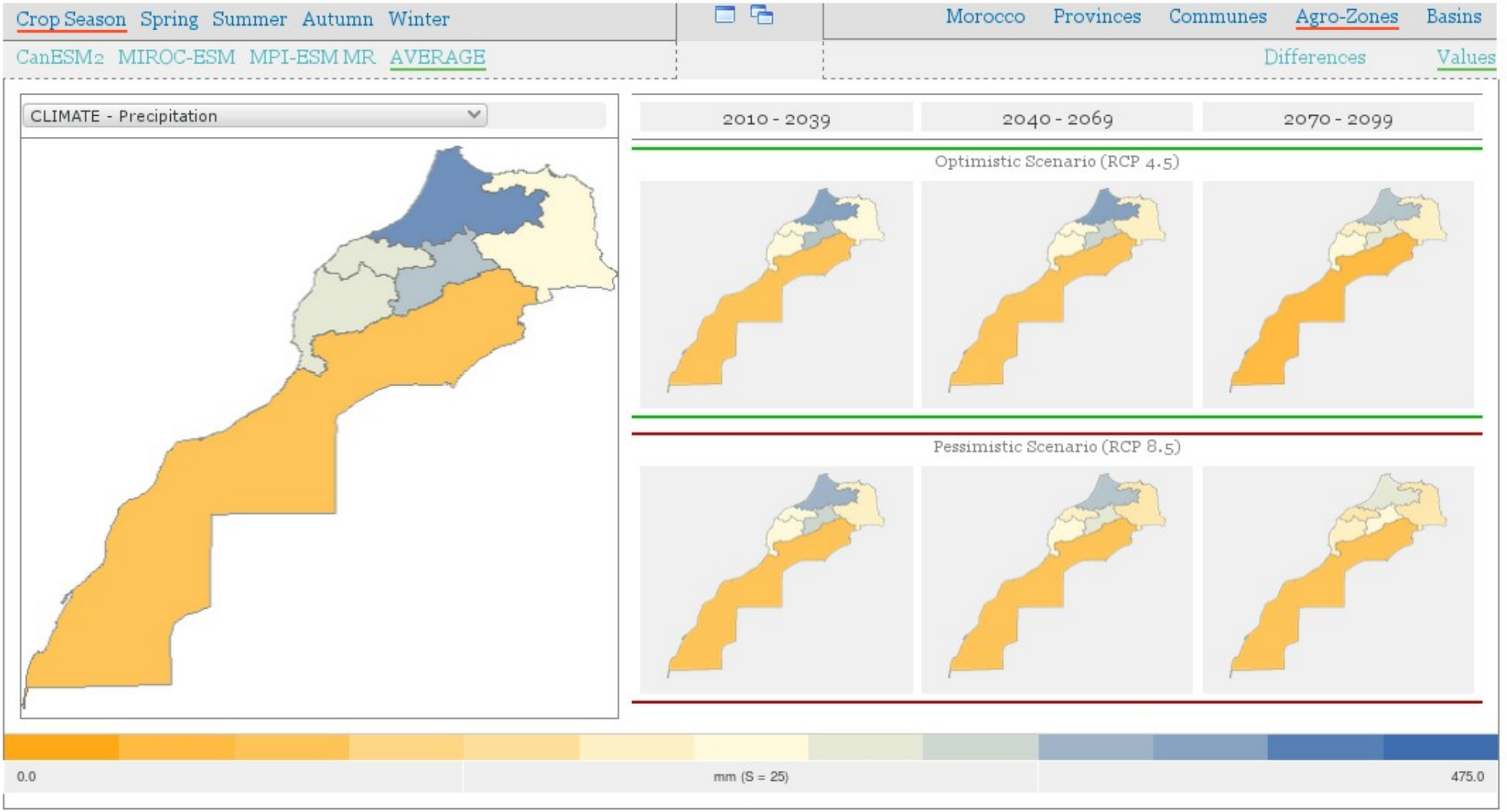
# CC Impact :: Landing page



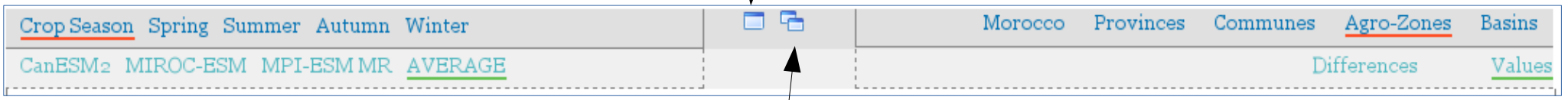

Get printable version (PDF)

# CC Impact :: Top Bar

**Period Selector**
It allows the user to select the period to display with a simple click on one of them:
- Crop Season (September-August)
- Spring
- Summer
- Autumn
- Winter

Single Variable Mode Icon

**Aggregation Level Selector**
It allows the user to select the level of aggregation of the data with a simple click on one of them:
- Morocco
- Provinces
- Communes
- Agro-zones
- Basins




**Model Selector**
It allows the user to select the model to display with a simple click on one of them:
- CanESM2
- MIROC-ESM
- MPI-ESM-MR
- AVERAGE

Compare Mode Icon

**Data Visualization Mode Selector**
It allows the user to select the mode to display the data with a simple click on one of them:
- Difference
- Values

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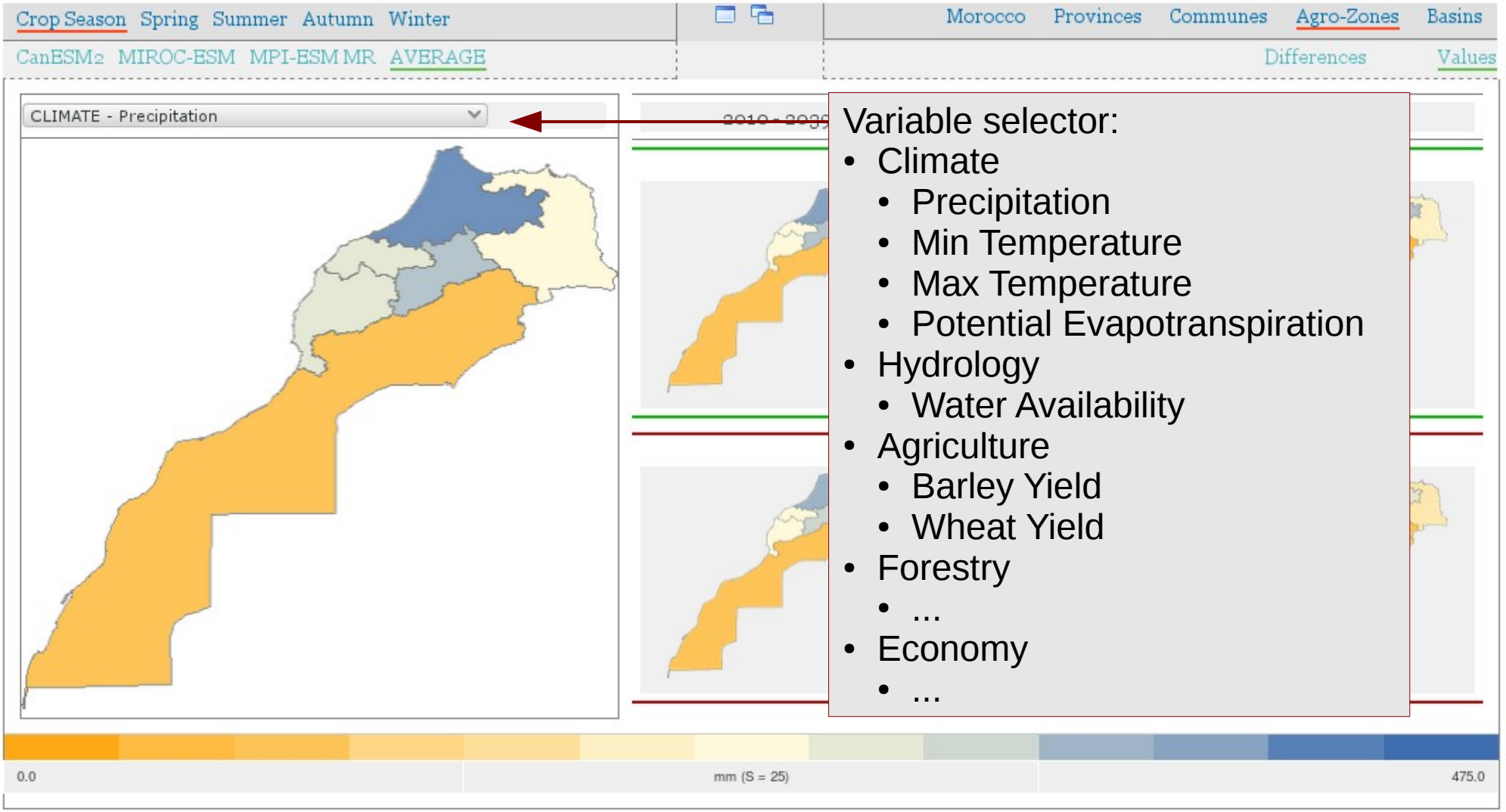
# CC Impact :: Variable selector




Variable selector:

- Climate
  - Precipitation
  - Min Temperature
  - Max Temperature
  - Potential Evapotranspiration
- Hydrology
  - Water Availability
- Agriculture
  - Barley Yield
  - Wheat Yield
- Forestry
  - ...
- Economy
  - ...

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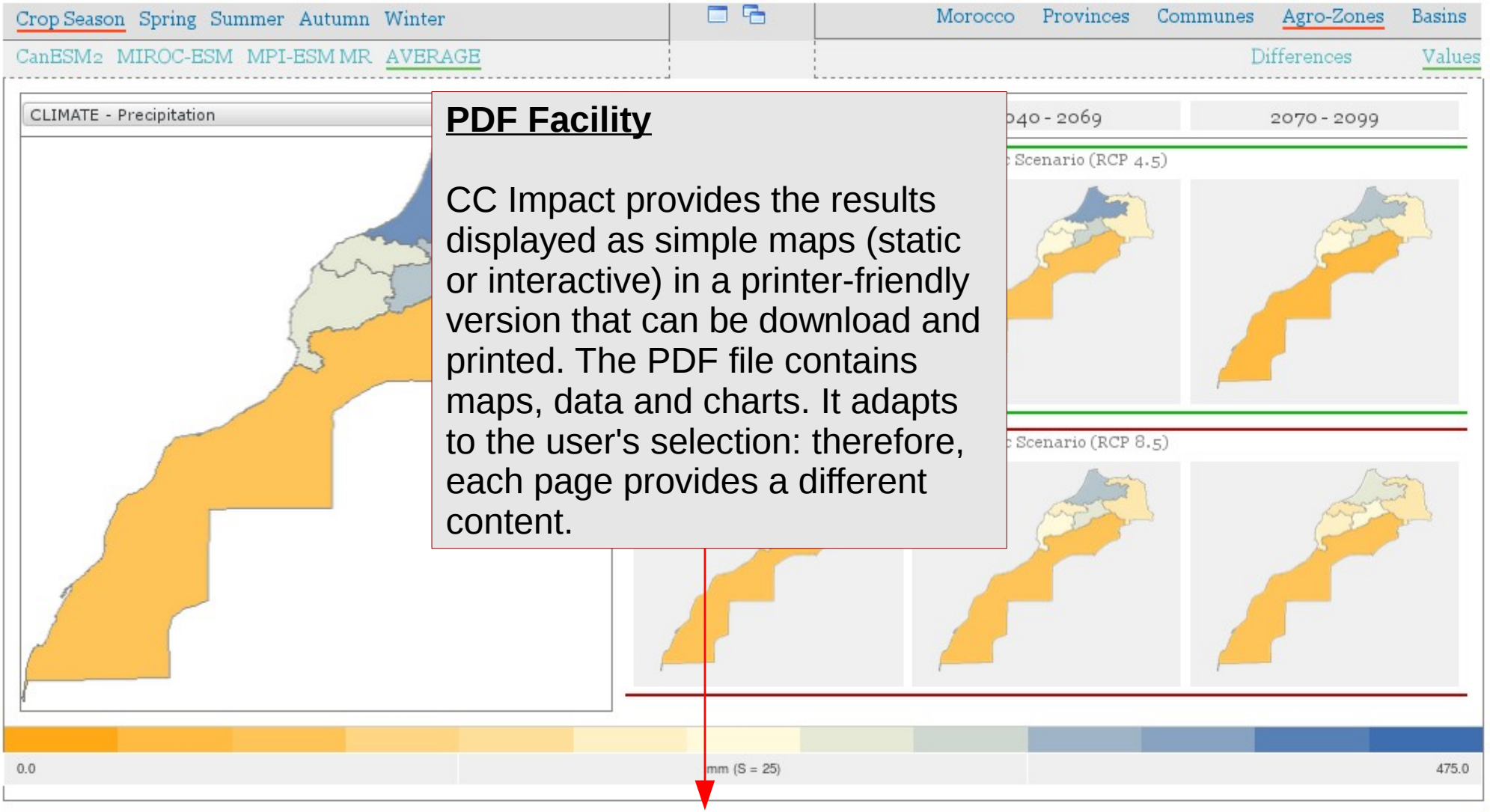
# CC Impact :: PDF Facility




## PDF Facility

CC Impact provides the results displayed as simple maps (static or interactive) in a printer-friendly version that can be download and printed. The PDF file contains maps, data and charts. It adapts to the user's selection: therefore, each page provides a different content.

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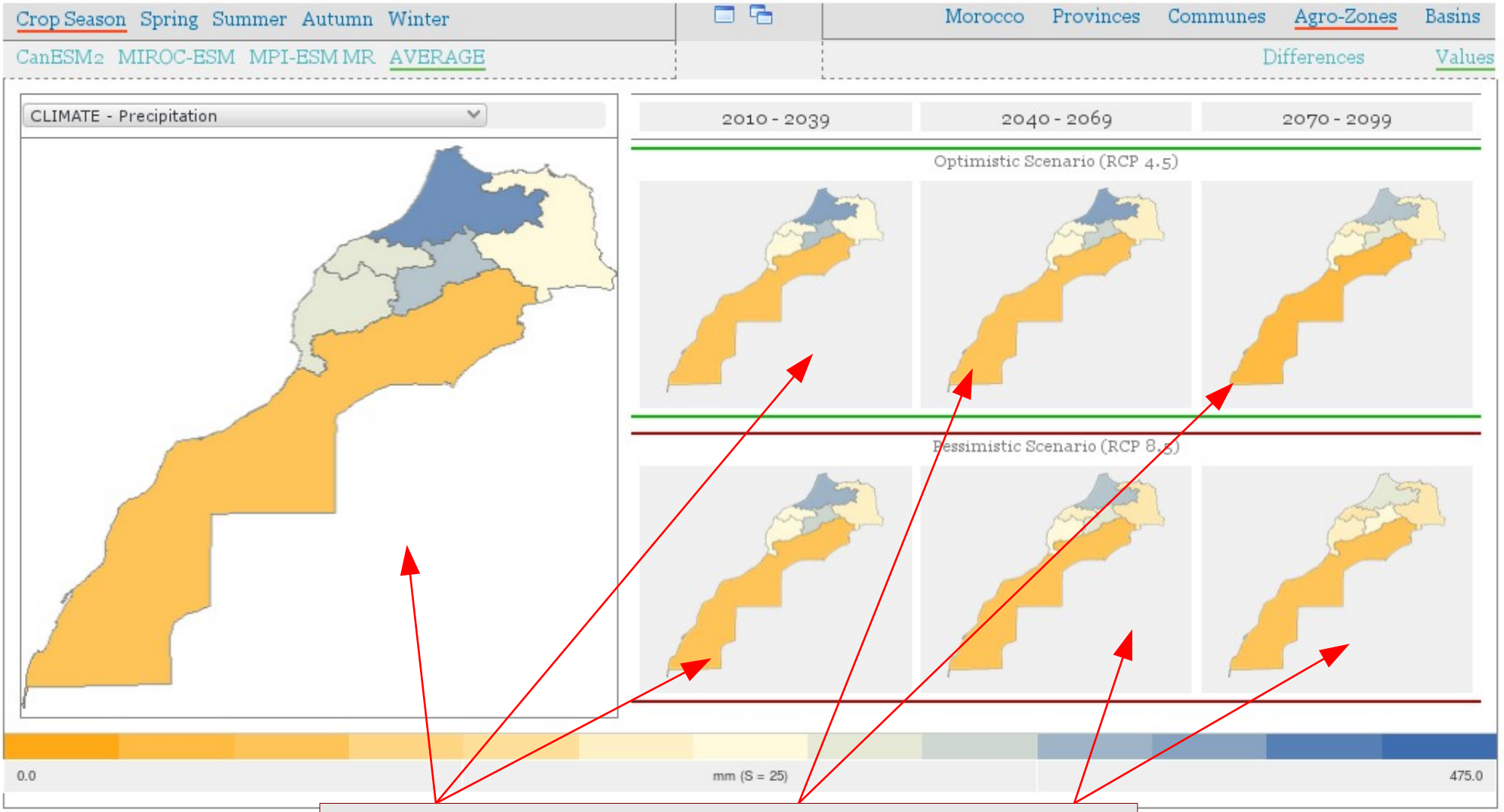
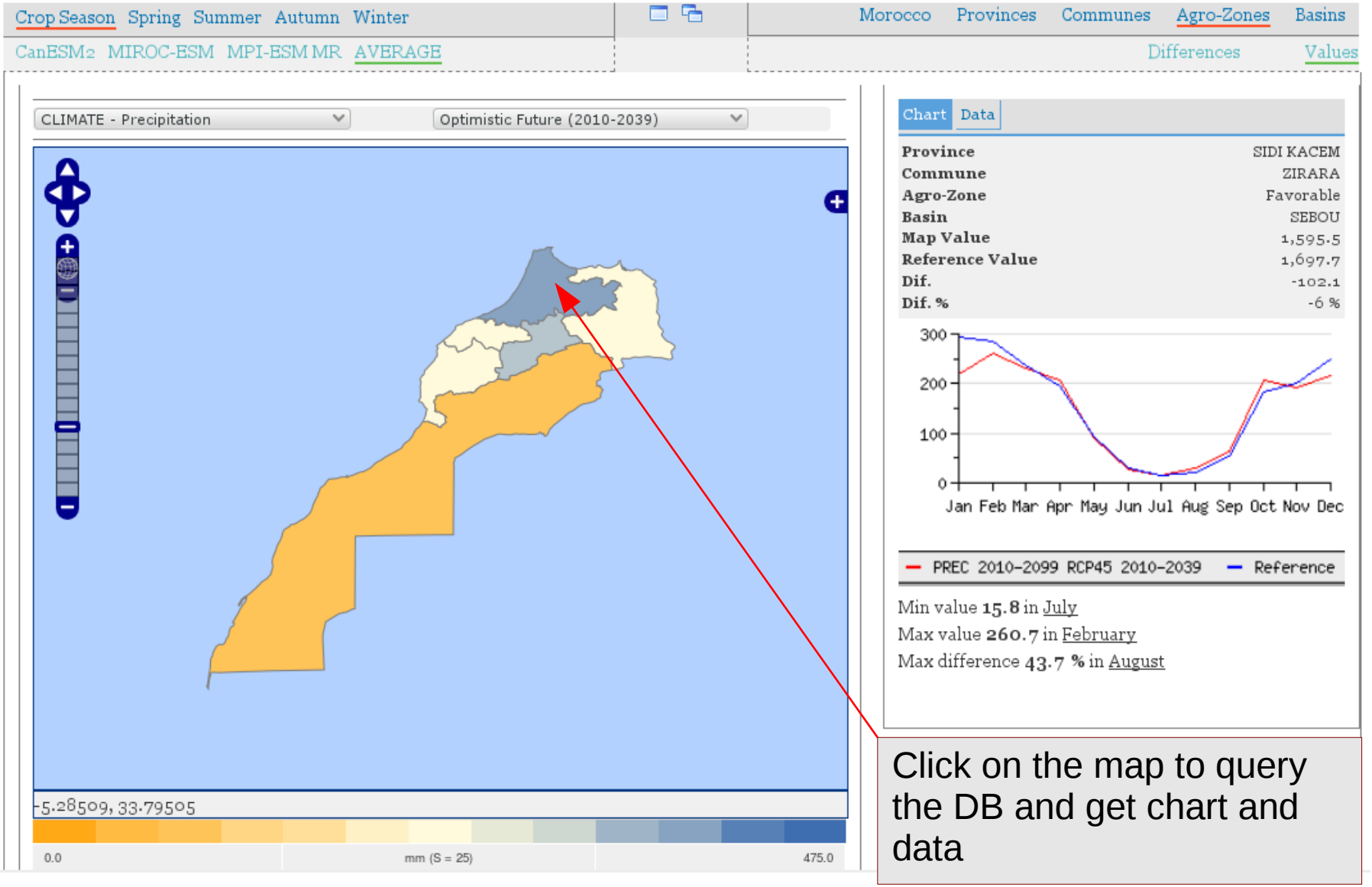
# CC Impact :: Overview to Details



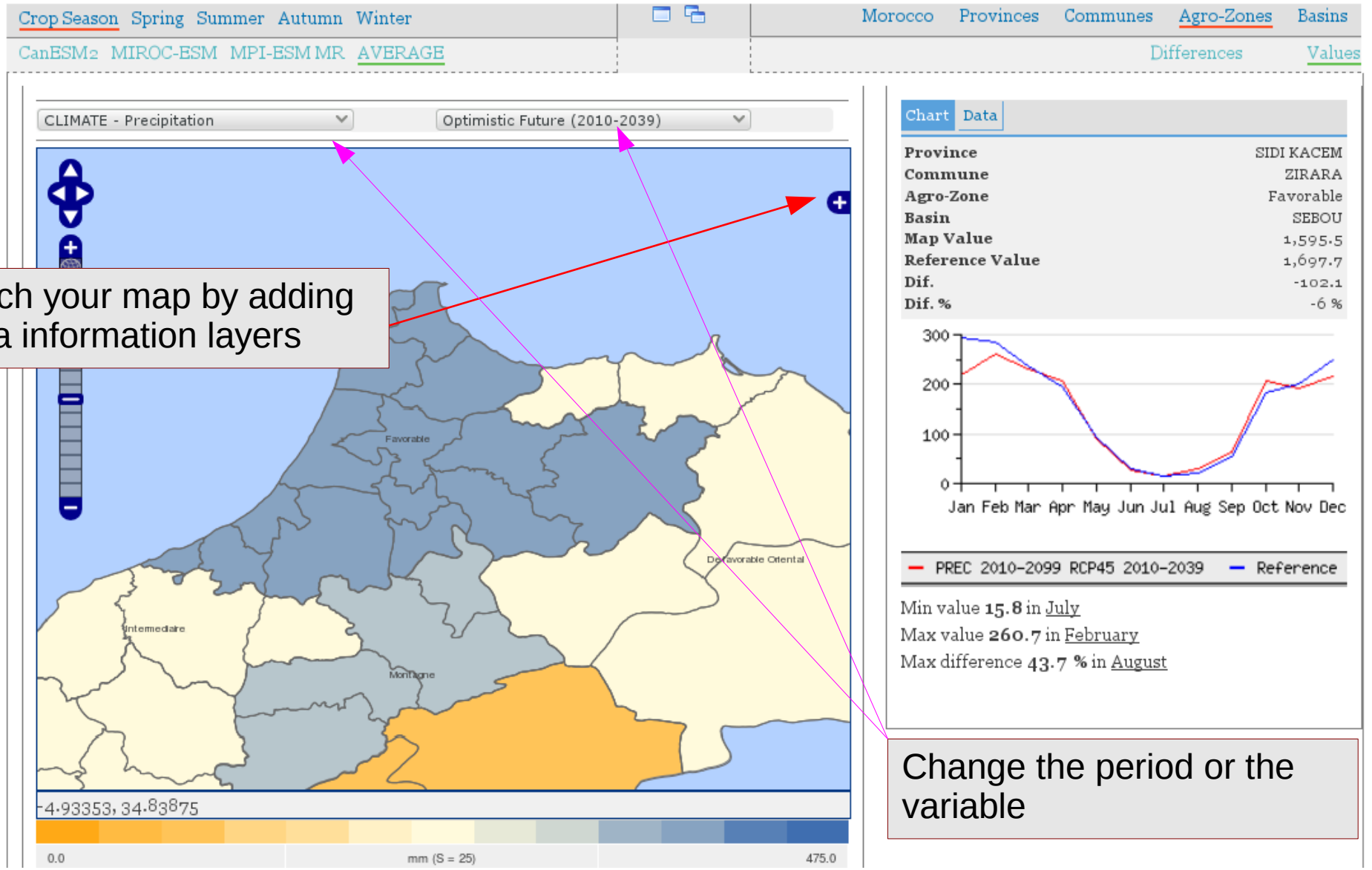

Click on the maps to access the **detailed view**

# CC Impact :: Detailed View




Click on the map to query the DB and get chart and data

# CC Impact :: Detailed View




Enrich your map by adding extra information layers

Change the period or the variable

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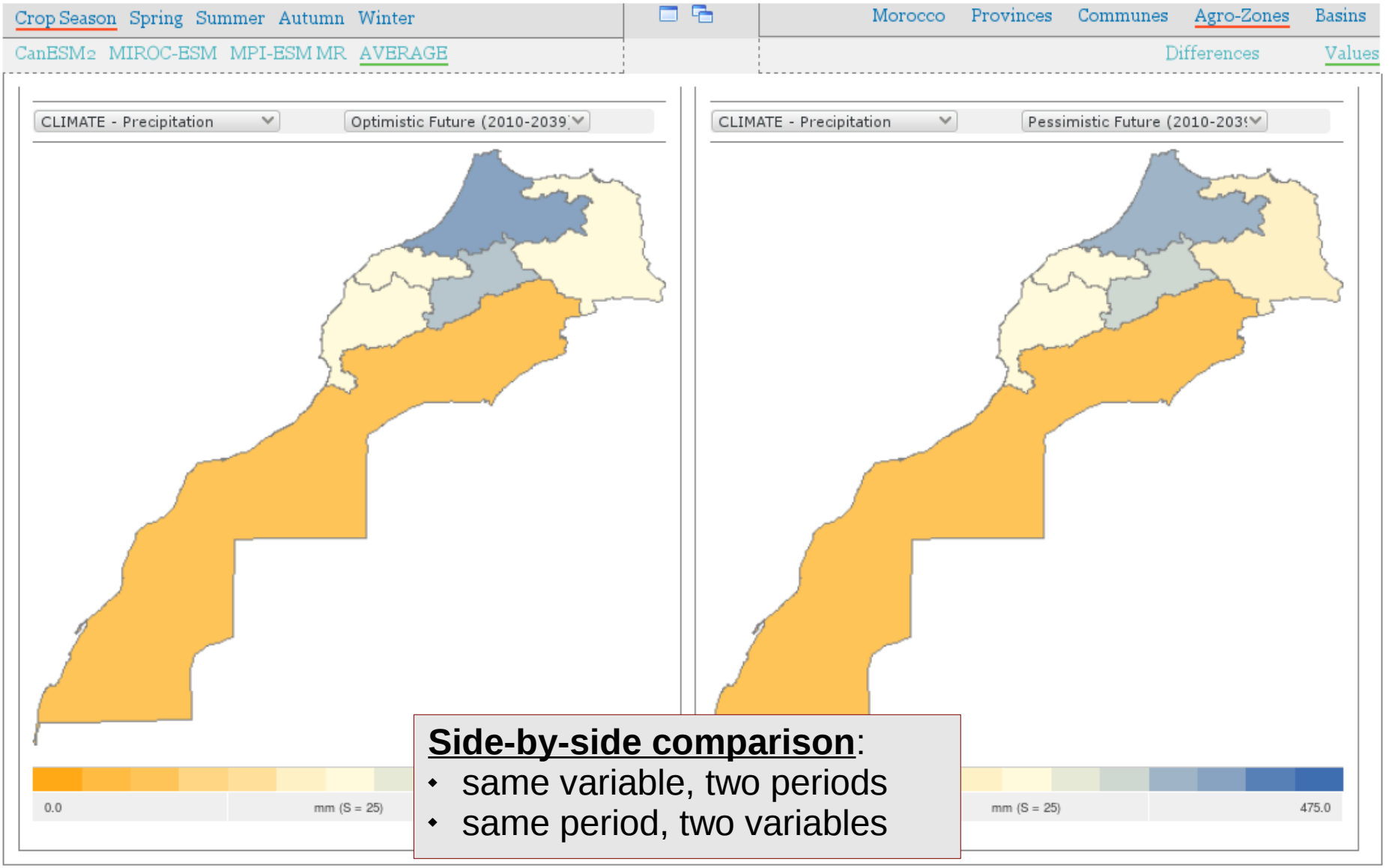
# CC Impact :: Compare View (a)




**Side-by-side comparison**:

- same variable, two periods
- same period, two variables

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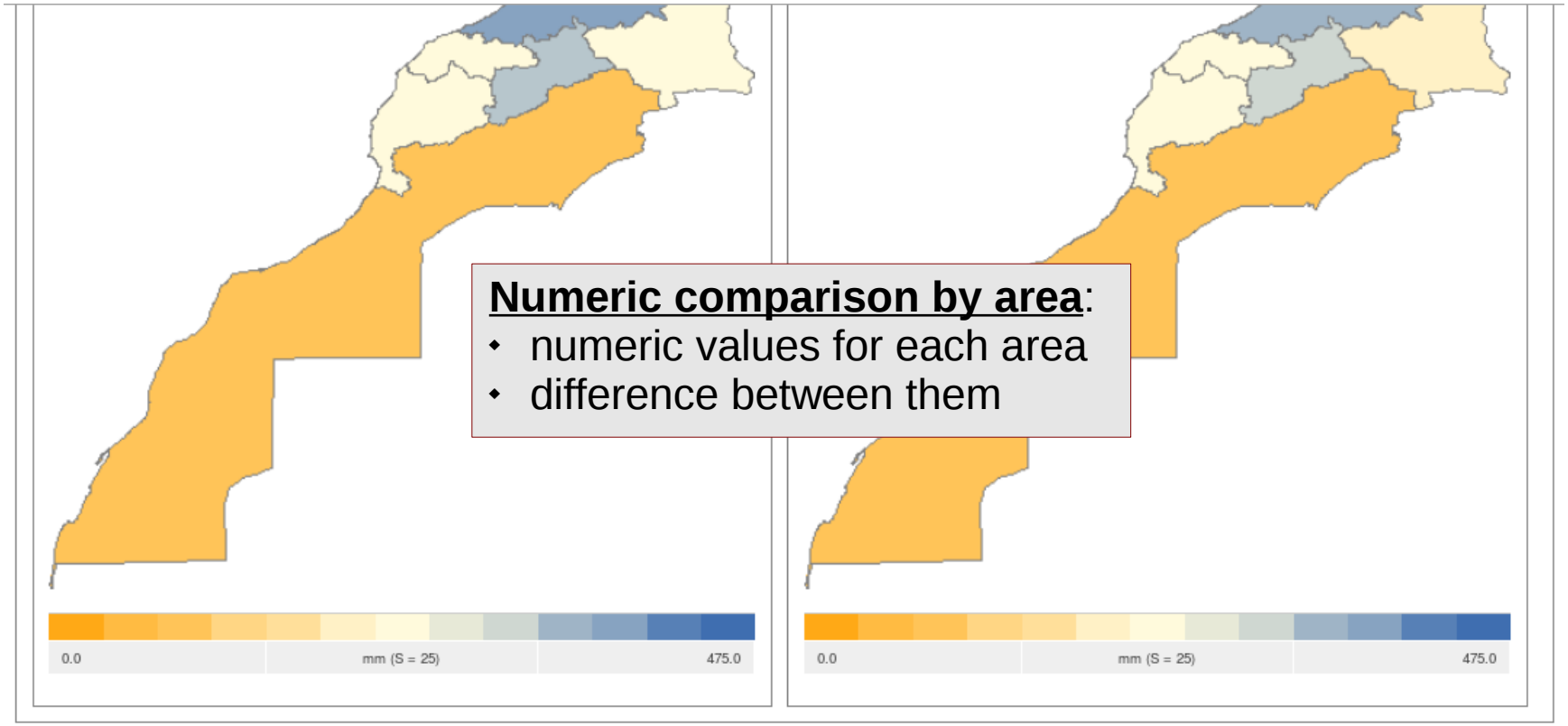
# CC Impact :: Compare View (b)




**Numeric comparison by area**:
- numeric values for each area
- difference between them

| NAME | VALUE | REFERENCE | DIF | % DIF |
|---|---|---|---|---|
| Defavorable Oriental | 225.9 | 220.5 | 5.4 | 2.4 % |
| Defavorable Sud | 274.9 | 260.2 | 14.7 | 5.4 % |
| Favorable | 399.1 | 372.8 | 26.3 | 6.6 % |
| Intermediaire | 274.1 | 252.3 | 21.8 | 7.9 % |
| Montagne | 326.1 | 311.5 | 14.6 | 4.5 % |
| Saharienne | 80.9 | 79.0 | 1.9 | 2.4 % |

MOSAICC MAROC

# CC Impact :: Compare View (b)

Monthly average comparison

| Name | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Defavorable Oriental | 26.9 | 36.4 | 33.6 | 30.4 | 17.1 | 7.3 | 4.7 | 10.1 | 16.1 | 28.9 | 23.8 | 29.8 |
| | 32.4 | 31.8 | 30.6 | 26.3 | 16.5 | 7.3 | 4.4 | 9.5 | 18.3 | 24.2 | 26.1 | 30.9 |
| | 5.5 | -4.6 | -3.0 | -4.1 | -0.6 | 0.0 | -0.3 | -0.6 | 2.2 | -4.7 | 2.3 | 1.1 |
| | 20.4 % | -12.6 % | -8.9 % | -13.5 % | -3.5 % | 0.0 % | -6.4 % | -5.9 % | 13.7 % | -16.3 % | 9.7 % | 3.7 % |
| Defavorable Sud | 38.9 | 44.7 | 41.1 | 36.0 | 15.0 | 5.4 | 4.3 | 8.5 | 12.9 | 33.6 | 33.1 | 34.6 |
| | 41.5 | 39.6 | 36.4 | 30.4 | 14.2 | 5.3 | 3.8 | 8.1 | 13.8 | 26.6 | 33.9 | 38.1 |
| | 2.6 | -5.1 | -4.7 | -5.6 | -0.8 | -0.1 | -0.5 | -0.4 | 0.9 | -7.0 | 0.8 | 3.5 |
| | 6.7 % | -11.4 % | -11.4 % | -15.6 % | -5.3 % | -1.9 % | -11.6 % | -4.7 % | 7.0 % | -20.8 % | 2.4 % | 10.1 % |
| Favorable | 54.9 | 65.2 | 57.9 | 51.6 | 22.7 | 6.9 | 4.0 | 7.6 | 15.6 | 51.9 | 47.9 | 54.1 |
| | 62.7 | 58.0 | 49.6 | 45.0 | 21.0 | 6.7 | 3.6 | 7.3 | 15.5 | 39.4 | 47.6 | 55.0 |
| | 7.8 | | | | | | | | | -12.5 | -0.3 | 0.9 |
| | 14.2 % | | | | | | | | | -24.1 % | -0.6 % | 1.7 % |
| Intermediaire | 41.0 | | | | | | | | | 33.0 | 35.1 | 34.4 |
| | 44.0 | | | | | | | | | 25.1 | 32.9 | 38.0 |
| | 3.0 | | | | | | | | | -7.9 | -2.2 | 3.6 |
| | 7.3 % | | | | | | | | | -23.9 % | -6.3 % | 10.5 % |
| Montagne | 43.4 | | | | | | | | | 39.5 | 35.6 | 41.4 |
| | 47.3 | | | | | | | | | 31.6 | 38.5 | 43.9 |
| | 3.9 | | | | | | | | | -7.9 | 2.9 | 2.5 |
| | 9.0 % | -11.7 % | -11.5 % | -15.2 % | -0.5 % | 2.2 % | -12.5 % | 1.4 % | 12.6 % | -20.0 % | 8.1 % | 6.0 % |
| Saharienne | 9.5 | 11.9 | 11.6 | 10.0 | 5.2 | 3.3 | 2.7 | 6.6 | 9.4 | 10.3 | 7.9 | 10.2 |
| | 10.6 | 10.3 | 10.1 | 8.8 | 5.6 | 3.1 | 2.5 | 6.6 | 11.3 | 8.9 | 8.8 | 10.2 |
| | 1.1 | -1.6 | -1.5 | -1.2 | 0.4 | -0.2 | -0.2 | 0.0 | 1.9 | -1.4 | 0.9 | 0.0 |
| | 11.6 % | -13.4 % | -12.9 % | -12.0 % | 7.7 % | -6.1 % | -7.4 % | 0.0 % | 20.2 % | -13.6 % | 11.4 % | 0.0 % |

**Time series comparison by area**:

- numeric values for each area in each month
- difference between them

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