Application of the FIGARO platform for improving irrigation water management in Southern Portugal

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Objective

To present results of the application of the FIGARO platform for improving irrigation water management in the Sorraia Valley region (southern Portugal).

• Brief context about irrigation in Portugal
• Description of the test site
• Description of the FIGARO platform
• Tools used - Model calibration and validation
• Irrigation scheduling
• Water productivity
Brief context: The climate

Aridity Index (P/ETp) 1980-2010

- Semi-arid
- Dry sub-humid
- Wet sub-humid
- Wet
Brief context: Irrigation area

- Total irrigated area: 540 000 ha
- Actual irrigated area: 469 000 ha
- Public irrigation districts: 194 000 ha
  - Located mostly in the south of Portugal
  - 100 000 ha in the Alqueva project (under construction)
  - 41% built between 1938-1974

Source: INE (2009), DGADR (2015)
Brief context: Irrigation methods

- **Pressurized systems:** 68% of the area
  - Sprinkler irrigation (pivots);
  - Micro-sprinkler irrigation;
  - Drip irrigation (surface and sub-surface irrigation)
  - Fruit trees, Olive trees, horticulture

- **Surface Irrigation**
  - Flood irrigation;
  - Furrow irrigation;
  - Rice, irrigated pastures ("Lameiros")

Source: INE (2009), DGADR (2015)
Brief context: **Water use efficiency**

- **Water use efficiency (globally):** 60-65%

Source: INE (2009), DGADR (2015)
Policy instruments

Portugal has established Portaria nº 50/2015 that mandates:

- the adoption of pressurized irrigation systems;
- the periodic inspection of irrigation systems;
- the precise quantification of irrigation pulses;
- the definition of improved irrigation schedules based on the soil-water balance;
- the total irrigation amount cannot exceed a threshold limit defined for each region, crop, and irrigation system.
Brief context: DSS in irrigation

Two main approaches:

• Provide recommendations only to fulfil weekly ETc values
  (soil-water status is neglected)

• Provide recommendations based on soil moisture sensors
  (usually 1 probe per 40 ha)
The FIGARO platform

Weather forecast

Soil-Vegetation-Atmosphere (SVAT) models

Soil water balance and Irrigation scheduling

Sensors:
- Soil moisture
- Crop growth
- Water table
- Weather

AQUACROP

MOHID

Water Modelling System

REPORT
Experimental site

- Tested in the Sorraia Valley region
- Between 2014-2015
Experimental site

- Fluvisol with silty-loam texture
- Maize crop
- Irrigated by sprinklers

Sorraia River

Maize

Rice fields
Experimental site

- Shallow GWD
- Two contrasting years:
  - Temperatures
    - 2014: 163 mm
    - 2015: 12 mm
  - Precipitation
    - 2014: 365 mm
    - 2015: 620 mm
  - Irrigation
Sensors

- Soil moisture capacitance probes at different depths and locations;
- Weather sensors from the Meteoagri network;
- Level sensors for monitoring GWD;
- Water applied (rain gauges, water meters);
- Crop parameters (manually);
Weather forecast

- Regional models
  - MM5 (meteo.tecnico.ulisboa.pt/)
  - WRF (www.meteogalicia.es/)

- Resolution: 5-12 km

- 4-7 days forecast
Soil-Vegetation-Atmosphere models

**Aquacrop** is developed and supported by FAO.
- Water balance model;
- Soil water dynamics is computed based on the canopy cover (transpiration) and soil water storage;
- Percolation and capillary rise are computed empirically.

**MOHID** is developed at IST.
- Mechanistic model;
- Soil water dynamics is computed with the Richards equation;
- Potential transpiration is reduced locally based on the soil pressure heads (Feddes macroscopic approach);
- Crop growth is computed from solar radiation and temperatures (EPIC model - heat units theory).
**SVAT models – Calibration/Validation**

**Soil moisture**

- **Measurements**
- **MOHID**
  - RMSE = 7.92 – 9.37 mm
  - EF = 0.08 – 0.73
- **AQUACROP**
  - RMSE = 12.02 – 24.80 mm
  - EF = 0.23 – 0.52

2014 (calibration)

2015 (validation)
SOIL WATER CONTENT (cm$^3$ cm$^{-3}$)

MOHID computes soil moisture at different depths

RMSE = 0.018-0.019 cm$^3$ cm$^{-3}$
EF = 0.11-0.70
SVAT models – Calibration/Validation

Canopy Cover (or LAI)

Measurements

- **MOHID**
  - RMSE = 14.25 – 17.02 %
  - EF = 0.78 – 0.84

- **AQUACROP**
  - RMSE = 3.46 – 14.48 %
  - EF = 0.84 – 0.99

2014 (calibration)

2015 (validation)
SVAT models – Calibration/Validation

Dry Biomass

- **Measurements**
- **MOHID**
  - RMSE = 4.62 – 5.13 ton/ha
  - EF = 0.87 – 0.89
- **AQUACROP**
  - RMSE = 3.72 – 3.83 ton/ha
  - EF = 0.93

2014 (calibration)

2015 (validation)
SVAT models – Calibration/Validation

Maize Yield

Yield (ton/ha)

<table>
<thead>
<tr>
<th>Year</th>
<th>Measurements</th>
<th>MOHID</th>
<th>AQUACROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>15</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>2015</td>
<td>20</td>
<td>19</td>
<td>21</td>
</tr>
</tbody>
</table>
Irrigation scheduling: AQUACROP

- AQUACROP computes the irrigation scheduling based on soil water storage and irrigation needs.

- Classical approach where soil-water is made to vary between FC and WP.

- Transpiration is computed from canopy cover.

- Water stress is defined with 3 Ks thresholds: Canopy expansion, Stomatal closure, Early senescence.
Water Productivity: AQUACROP

WP in the region: 1.48-3.15 kg m\(^{-3}\)
Source: Paredes et al. (2014)

<table>
<thead>
<tr>
<th>% of RAW</th>
<th>WP (kg m(^{-3}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer</td>
<td>1.92</td>
</tr>
<tr>
<td>20%RAW</td>
<td>2.06</td>
</tr>
<tr>
<td>50%RAW</td>
<td>2.21</td>
</tr>
<tr>
<td>80%RAW</td>
<td>2.53</td>
</tr>
</tbody>
</table>

2015

Trigger thresholds vs WP
Water Productivity: AQUACROP

2015

Fixed net applications vs WP

WP in the region:
1.48-3.15 kg m⁻³
Source: Paredes et al. (2014)
Water Productivity: AQUACROP

2015

WP in the region: 1.48-3.15 kg m$^{-3}$
Source: Paredes et al. (2014)

Irrigation interval vs WP

WP (kg m$^{-3}$)

<table>
<thead>
<tr>
<th>Irrigation interval</th>
<th>WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer</td>
<td>1.92</td>
</tr>
<tr>
<td>2 days</td>
<td>2.25</td>
</tr>
<tr>
<td>3 days</td>
<td>2.37</td>
</tr>
<tr>
<td>4 days</td>
<td>2.33</td>
</tr>
</tbody>
</table>
Irrigation scheduling: MOHID

- MOHID was upgraded to compute the irrigation scheduling
- MOHID uses a finite-volume approach to compute soil-water dynamics
- Irrigation starts whenever $h$ in the cells in the root zone drops below $h_t$
- The model applies enough water to increase $h$ from $h_t$ to $h_0$
- Constraints to avoid endless irrigation events (min and max pulses, minimum irrigation interval)
Irrigation scheduling: **MOHID**

Red cells: $h < h_t$

Green cells: $h > h_t$

Irrigation

$\theta$ increases ($h > h_t$)

Constraints need to be met
Irrigation scheduling: **MOHID**

![Soil pressure head (h)](image)

**Water stress**

- **Farmer**
Irrigation scheduling: **MOHID**

**Soil pressure head (h)**

Time (days)

16/04/15 10/06/15 04/08/15 28/09/15

-1500 to 1500

**Farmer**

-300 to 0

**$h_t = -500$ cm**
Irrigation scheduling: MOHID

Soil pressure head (h)

Water stress

Farmer

- $h_t = -500$ cm
- $h_t = -1000$ cm
Irrigation scheduling: MOHID

Soil pressure head (h)

Time (days)

10 cm
30 cm
50 cm

Water stress

Farmer

$h_t = -500$ cm

$h_t = -1000$ cm

$h_t = -1500$ cm
Irrigation scheduling: MOHID

**Soil pressure head (h)**

- $h_2 = -500$ cm
- $h_3 = -1000$ cm
- $h_4 = -1500$ cm
- $h_4 = -2000$ cm

**Water stress**

- Farmer
- $h_t$ ( differing values for different depths)
Irrigation scheduling: **MOHID**

**Water savings:**

- $h_t = -500 \text{ cm}$
  - $I = 499 \text{ mm}$
  - $T_a/T_p = 1.00$
- $h_t = -1000 \text{ cm}$
  - $I = 385 \text{ mm}$
  - $T_a/T_p = 0.94$
- $h_t = -1500 \text{ cm}$
  - $I = 317 \text{ mm}$
  - $T_a/T_p = 0.86$
- $h_t = -2000 \text{ cm}$
  - $I = 272 \text{ mm}$
  - $T_a/T_p = 0.77$

**FARMER**

$I = 620 \text{ mm}$
Irrigation scheduling: MOHID

Capillary rise:

2015

CR (mm)

Farmer

$h_t=-500$ cm

$h_t=-1000$ cm

$h_t=-1500$ cm

$h_t=-2000$ cm
Water Productivity: MOHID

2014

Farmer

-500 cm
-1000 cm
-1500 cm
-2000 cm

WP (kg m\(^{-3}\))

2015

Farmer

-500 cm
-1000 cm
-1500 cm
-2000 cm

WP (kg m\(^{-3}\))

GWD=1.08 m
GWD=1.50 m
Conclusions

• The FIGARO platform includes a series of modeling tools capable of improving the irrigation scheduling in the Sorraia Valley region;

• AQUACROP and MOHID can run in operational mode, estimating irrigation needs in real time;

• Both models were able to decrease irrigation needs by optimizing capillary rise from the shallow groundwater table;

• Model requirements are very different; MOHID as a mechanistic model is much more complex and difficult to calibrate than AQUACROP; The application of AQUACROP to similar GWD conditions will require further calibration;

• Results from Portugal showed that the FIGARO platform may become an important operational tool for irrigation water management as it is capable of integrating different set of data in real time and improve the decision making process.
Thank You