SAT-IRR
SATELLITE
FOR
IRRIGATION
SCHEDULLING

Le Page Michel, S. Khabba, L. Jarlan, S. Er Raki, H. Kharrou, O. Hagolle, A.Tavernier, M. Huc, M. Kasbani, J. Toumi, M. Yousfi
1. An introduction to Current Irrigation Scheduling Tools
2. Update to the results of the Irrigation scheduling experiment with SPOT4-Take5
3. Limits to the FAO-56 model constrained by Remote Sensing and Objectives of Sat-Irr
4. Implementation of a prototype Web Service based on Landsat 8
IRRIGATION SCHEDULING?

- Aims
  - Maximize yield while minimizing water stress (but other things too...)
  - Minimize water losses by evaporation, percolation or run-off

- Four principal components
  - Crop Water Needs
  - Soil Texture
  - Soil Water Content
  - Available Water Capacity
ESTIMATE/MEASURE WATER NEEDS AT THE PLOT LEVEL

- Touching and feeling the soil
- Measure the soil water amount
  - Tensiometry (watermark)
  - Electric resistency (gypsum)
  - Capacitive sensor (Sentek..)
- Plant health
  - Température de la canopée (IRT)
  - Turgidité de la plante
- Hydric Budget
- Other techniques are less used

Farmer’s equation = (Time + Money + Precision) vs Gain
# Irrigation Methods

<table>
<thead>
<tr>
<th>Family</th>
<th>Techniques</th>
<th>Efficacy</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>• Basin</td>
<td>40-70%</td>
<td>• Low investment</td>
<td>• Low efficacy</td>
</tr>
<tr>
<td></td>
<td>• Furrow</td>
<td></td>
<td>• Easy</td>
<td>• Leveling</td>
</tr>
<tr>
<td></td>
<td>• Border</td>
<td></td>
<td>• Low handling</td>
<td>• Human resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Low energy</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Leveling</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>• Human resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Low energy</td>
<td></td>
</tr>
</tbody>
</table>

| Sprinkler| • Rotative sprinkler              | 60-80%   | • All terrains                  | • Investment                         |
|          | • Water cannon                    |          | • Low human resources           | • Available pressure                 |
|          | • Pivot                           |          |                                 | • Wind                               |
|          |                                  |          |                                 |                                      |
| Localized| • Drip                            | 80-95%   | • Efficacy                      | • Investment                         |
|          | • Porous canal                    |          | • All terrains                  | • Water filtering                    |
|          | • Micro-sprinkler                 |          | • Low human resources           |                                      |
|          |                                  |          | • Fertirrigation                |                                      |
|          |                                  |          |                                 |                                      |

- Reduction of evaporation with natural or artificial mulches
THE LOCALIZED METHODS ARE STILL NOT VERY USED AND ALREADY OPTIMALS

France:
- Flooding: 5%
- Sprinkler: 10%
- Localized: 85%
- ~1.5 Millions Ha

Africa:
- Flooding: 5%
- Sprinkler: 17%
- Localized: 78%
- ~12.5 Millions Ha

Margat, 2000 and FAO Aquastat
PART 2.

UPDATE ON

THE LIFE-SIZE AND NEAR REAL-TIME TEST OF IRRIGATION SCHEDULING WITH SPOT4-TAKE5 IN MOROCCO

Le Page et al, Remote Sensing, 2014
WHEAT IRRIGATION IN AN OPEN CANAL NETWORK

High ET
Low Rainfall
HYDRIC BUDGET IN SAMIR

\[ E = K_e \times ET_0 \]

\[ K_e = \min(K_r \times (K_{cmax} - K_{cb}), (1 - f_c) \times K_{cmax}) \]

\[ K_r = \frac{(T_{EW} - D_e)}{(T_{EW} - R_{EW})} \]

\[ T_{EW} = (q_{fc} - q_{wp}) \times Z_r \]

\[ R_{TW} = T_{TW} \times (0.55 + 0.04 \times (5 - ET_c)) \]

\[ f_c \]

\[ 1 - f_c \]

\[ T \]

\[ E \]

\[ Kcb \]

\[ fc \]

Ze : fixed

Zr : varies with LU and fc

Zd : Tot-Zr
2 PLOTS OF ~4HA

- Same Soil Texture (Clay: 36%, Sand 20%)
- Durum Wheat sowed 23/12/12
- Reference: Irrigation as usual
- Test: «Sat» Irrigation
ON SITE MEASUREMENTS

**METEO (forcing)**
- Alfalfa maintained to 15cm
- Installed January 3rd, 2013
- ETO very comparable to the meteo station of Marrakech

**FLUX (validation)**
- South installed on Dec, 24th 2012
- Nord installed on Dec, 25th, 2012

- Soil Texture (Parametrization)
- Cropscan Measurements and LAI (Validation)
- Areal Biomass (Yields estimates)
- Technical itinerary and irrigations inputs
18 CLEAR IMAGES (64%)

- **SPOT5 (ISIS #691)**
  + 6 imgs
  + Orthorectified

- **SPOT4 (Project Take5)**
  + 12 imgs (until 21/04)
  + Orthorectified

- **PHOTOMETER SAADA**
  + Down from Jan, 27th to Feb, 26th, grrrrr
RESULTS

- NDVI of the two plots
- Kcb extrapolations
- ETa results
RESULTS ON E-T

<table>
<thead>
<tr>
<th></th>
<th>RMSE</th>
<th>Sum_diffs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.84 mm/d</td>
<td>11 mm</td>
</tr>
</tbody>
</table>

On the 62 dates, RMSE is 0.84 mm/day compared to Eddy cov Measurements.

- This is the usual error range of our previous FAO modelling of ET

- A small delay is visible at irrigation time. It is mainly due to the duration of the water turn (20 to 30h).
### TECHNICAL ITINERARIES

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>23/12/2012</td>
<td>Soil preparation (Schezell)</td>
</tr>
<tr>
<td>24/12/2012</td>
<td>Soil preparation (Cover croup  2 times)</td>
</tr>
<tr>
<td></td>
<td>Sowing: Durum Wheat ( V /SARAGOLA 200 Kg /ha)</td>
</tr>
<tr>
<td></td>
<td>Fertilizing (DAP) 200KG /Ha</td>
</tr>
<tr>
<td>12/02/2013</td>
<td>Weed treatment (TRAXOS 75cl /ha ; lintur 150 g/ha )</td>
</tr>
<tr>
<td>08/04/2013</td>
<td>Fertilizing M: amoniat 33,5 % 1 qx /ha</td>
</tr>
<tr>
<td>10/04/2013</td>
<td>Weed Treatment (PACT 1 L/ha )</td>
</tr>
</tbody>
</table>

- 9 irrigations versus 11 irrigations
- 562mm against 640 mm
- Three big differences on Irrigation
- Fertilization realized according to Ref Plot

![Graph showing NDVI and M3/ha over time](image)
**ET0:** 604 mm  
**Rain:** 99 mm  
**Irrigation:** *less total water* (562mm against 640 mm) and *less water turns* (9 against 11), but irrigation doses are not controllable.

**Fair results on Yields** in spite of the crust problem:  
+ Minus 20% on straw  
+ Equal grain yield  
+ Better Water productivity on grain (1.34 m³/kg against 1.52 m³/kg for the reference plot)

### Balance Sheet

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th></th>
<th></th>
<th>Experimental</th>
<th></th>
<th></th>
<th></th>
<th>Absolute Difference (WB-Exp)</th>
<th>Percentage (WB-Exp)</th>
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</thead>
<tbody>
<tr>
<td>#</td>
<td>Dates (DaS)</td>
<td>Quantity (mm)</td>
<td>#</td>
<td>Dates (DaS)</td>
<td>Quantity (mm)</td>
<td>Water Balance</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>9 January (17)</td>
<td>92</td>
<td>1</td>
<td>7 January (14)</td>
<td>91.8</td>
<td>-</td>
<td>-</td>
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<td></td>
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<tr>
<td>2</td>
<td>14 January (22)</td>
<td>62.1</td>
<td>2</td>
<td>26 January (34)</td>
<td>64.8</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>26 January (34)</td>
<td>30</td>
<td>3</td>
<td>14 February (53)</td>
<td>56</td>
<td>38</td>
<td>18</td>
<td>32</td>
<td></td>
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<tr>
<td>4</td>
<td>4 March (71)</td>
<td>46</td>
<td>4</td>
<td>12 March (79)</td>
<td>48.6</td>
<td>56</td>
<td>-7.4</td>
<td>-15</td>
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<tr>
<td>5</td>
<td>20 March (87)</td>
<td>48.6</td>
<td>5</td>
<td>28 March (95)</td>
<td>48.6</td>
<td>49</td>
<td>-0.4</td>
<td>-1</td>
<td></td>
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<tr>
<td>6</td>
<td>13 April (111)</td>
<td>70.2</td>
<td>6</td>
<td>10 April (108)</td>
<td>56</td>
<td>53</td>
<td>3</td>
<td>5</td>
<td></td>
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<tr>
<td>7</td>
<td>22 April (120)</td>
<td>72.9</td>
<td>7</td>
<td>19 April (117)</td>
<td>72.9</td>
<td>47</td>
<td>25.9</td>
<td>36</td>
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<tr>
<td>8</td>
<td>29 April (127)</td>
<td>55</td>
<td>8</td>
<td>27 April (125)</td>
<td>54</td>
<td>48.9</td>
<td>5.1</td>
<td>9</td>
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<tr>
<td>9</td>
<td>7 May (134)</td>
<td>67.5</td>
<td>9</td>
<td>10 May (137)</td>
<td>70.2</td>
<td>-</td>
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<tr>
<td></td>
<td>Total Irrigation</td>
<td>640.8</td>
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<td>Total Irrigation</td>
<td>640.8</td>
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<tr>
<td></td>
<td>Total with Rainfall</td>
<td>739.8</td>
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<td></td>
<td>Total with Rainfall</td>
<td>739.8</td>
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</tbody>
</table>
TOWARD A WEB SERVICE FOR IRRIGATION SCHEDULING

PART 3.
A tool built on proprietary products
+ IDL language and ENVI software

A tool still too complicated
+ Satellite image handling
+ Large Parameterization
+ Multi-objective

An end-user tool for the Desktop
Observation about the Irrigator

- Trust into the FAO-56 method, but it remains rarely used (time, means)
- No competence in imagery
- Meteo Data rarely/not used (in Morocco)
- In flooding and sprinkle irrigation, a uniform dose of water is applied to the plot
- The irrigator is the only one to know the exact date and dose of irrigation applied on its plots
- In Morocco, low-speed 3G connexions is generally available
OBSERVATIONS ABOUT THE DATA

E = Ke * ET0
Ke = min(Kr * (Kcmax - Kcb), (1 - fc) * Kcmax)
Kr = (TEW - De) / (TEW -REW)
TEW = (qfc - qwp) * Ze
REW = fixed

E = Ke * ET0
Ke = min(Kr * (Kcmax - Kcb), (1 - fc) * Kcmax)
Kr = (TEW - De) / (TEW - REW)
TEW = (qfc - qwp) * 0.5 * Ze
REW = fixed

Zr: varies with LU and fc
Zd: Tot-Zr

Total Soil Depth

Surface compartment

Root compartment

Deep Compartment

Drainage
SAT-IRR GOALS

- Recommend dates and irrigation doses of a plot throughout the season ("irrigation scheduling")
- Make it simple
- Opensource based
- Thrifty in calculation, storage and internet outflow.
PART 4.

IMPLEMENTATION OF A PROTOTYPE WEB-APP BASED ON LANDSAT-8
DRAW MY PLOTS
### Mes Parcelles

<table>
<thead>
<tr>
<th>Nom</th>
<th>Description</th>
<th>Date de semi</th>
<th>Station Meteo</th>
<th>Modifier</th>
<th>Supprimer</th>
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<tr>
<td>parcelle 5</td>
<td>Coton</td>
<td>2013-11-22</td>
<td>BENI-MELLAL</td>
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<td>Parc 1</td>
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<td>aa</td>
<td>2013-12-02</td>
<td>SAFI</td>
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<td>parcelle 3</td>
<td>azazaza</td>
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<td>NOUASSEUR</td>
<td></td>
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<tr>
<td>michel</td>
<td>[ ]</td>
<td></td>
<td>null</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Description des Parcelles

Description parcelle

**Parcelle**

Choisissez une parcelle  
Ble2

**Culture**

Choisissez la culture  
Blé

**Sol**

Choisissez le type de sol  
Argile

**Mode d'irrigation**

Choissir le mode d'irrigation  
Irrigation gravitaire

**Date de semi**

Entrez la date de semi

Validez
Bonjour oulad sayad younes

Irrigation des parcelles

Irrigation parcelle

Choisissez une parcelle :
parcelle 5

Dose en Millimètres :
60

Date :
2014-01-23

Validez Annuler
The plot time series is fed every day

- Calculate $K_{cb}$, $F_c$
- Interpolate between dates
- Extrapolate
- Hydric Budget

- Look for nearest WMO SYNOP Station
- Retrieve weather data
- Calculate daily ET0 and Rainfall

- Download latest Landsat8
- Atmospheric correction
- Cloud screening
- Clip plot and do some calcs
- Drop image

- Weather (pe WMO)

- Insat. Imgs.

- Cloud
  - Unavailability of servers
  - Unavailability of data
  - Transfer problems
- Improve displays!
- Irrigation alert (Email, SMS?)
- Offer a temporal window for irrigation
CONCLUSION

- Potential clients
  - Irrigator under flood or sprinkler irrigation
  - Manager of an Irrigated Sector
- Evolutionary service

<table>
<thead>
<tr>
<th>Topic</th>
<th>Currently (Base Service)</th>
<th>Evolution (Advanced Service)</th>
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</thead>
<tbody>
<tr>
<td>Spatial Resolution</td>
<td>Landsat8 (ftp)</td>
<td>Sentinel2 (WCS)</td>
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<tr>
<td>Weather Forcing</td>
<td>WMO stations</td>
<td>Local Stations or Weather Model Reanalysis</td>
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<tr>
<td>Weather Forecasting</td>
<td>Climatologies FAO stations</td>
<td>Weather Model</td>
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<tr>
<td>Model</td>
<td>FAO-56 forced with NDVI</td>
<td>Assimilation T° (Tseb?)</td>
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<tr>
<td>Kcb Forecasting</td>
<td>FAO-56 standard curve</td>
<td>NDVI+GDD extrapolation</td>
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<tr>
<td>Yield Forecasting</td>
<td>---</td>
<td>Efficiency model under dev.</td>
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Toumi et al, Remote Sensing. Take5 Special issue, under preparation