AquaCrop
A new model for crop prediction under water deficit conditions
- Calibration for potato -

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Objectives

• General framework
• Description of AquaCrop
• Main issues related to AquaCrop calibration for potato
• AquaCrop performances
• Discussion, feed-backs, & contacts
Background

• Revision of the 1979 FAO I & D Paper no.33, “Yield Response to Water”

\[
\frac{Y_a}{Y_m} = Ky \left(1 - \frac{ET_a}{ET_c}\right)
\]

• Consultative process

• Separation herbaceous-crops and trees: AquaCrop & Guidelines
Why another model?

- Uncertainty
- Complexity
- Structure
- Parameters
- Total
• **AquaCrop** differs from other models for its relatively small number of parameters

• **AquaCrop** is explicit and mostly intuitive, and maintains an optimum balance between simplicity, accuracy and robustness

• **AquaCrop** is aimed at practical end-users: farmers and irrigation associations, extension services, governmental agencies, NGOs, planners, economists, as well as researchers and students.

• **AquaCrop** as unique crop response to water model with crop-specific parameters
Evolution from Paper 33

Water-driven model

Solar Radiation

Canopy Transpiration

Evapotranspiration

Biomass

Yield

Canopy

Daily time-steps

Long-term sums

AquaCrop

Paper 33

HI

WP

E
AquaCrop Conceptual Framework

Atmosphere

Crop

Soil

Management
AquaCrop Conceptual Framework

CLIMATE

Rain

R_s, T, RH, u

E_T_0

T (°C)

CO_2
Data needed for calibration

| Rainfall | ETo | Tmin & Tmax |

![Graphs showing data for Rainfall, ETo, and Tmin & Tmax](image)

Food and Agriculture Organization of the United Nations

www.fao.org/nr/water
AquaCrop Conceptual Framework

- Phenology
- Leaf expansion
- Canopy Cover
- Senescence
- Rooting depth
Canopy Cover (CC) follows the exponential growth during the first half of the full development (Eq. 1) and an exponential decay during the second half of the full development (Eq. 2).

\[ CC = CC_o e^{CGC \cdot t} \]  

\[ CC = CC_x - (CC_x - CC_o) \cdot e^{-CGC \cdot t} \]
Data needed for calibration

Density

<table>
<thead>
<tr>
<th>Canopy development</th>
<th>Flowering period</th>
<th>Rooting depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial canopy cover</td>
<td>high plant density</td>
<td>3.75%</td>
</tr>
<tr>
<td>maximum canopy cover</td>
<td>almost entirely covered</td>
<td>95%</td>
</tr>
<tr>
<td>green canopy decline</td>
<td>very slow decline</td>
<td>65%</td>
</tr>
</tbody>
</table>

In-season CC

Phenology

From transplanting to:
- recovered
- max canopy
- senescence
- maturity

Duration yield formation:
- yield formation
- maturity end
- ripening [days] 57

From transplanting to:
- tuber formation
- maturity [days] 87

www.fao.org/nr/water
AquaCrop Conceptual Framework

- Phenology
- Canopy Cover
- Leaf expansion
- Senescence
- Biomass
- Rooting depth

- T (°C)
- $ET_o$
- $E_s$
- $T_a$
- WP

WWW.FAO.ORG/NR/WATER
WP = \frac{\text{Biomass}}{\sum T_C} (g \ m^{-2} \ mm^{-1})

WP^* = \left[ \frac{\text{Biomass}}{\sum \left( \frac{T_C}{ET_o} \right)} \right]_{\text{CO}_2(2000)} (g \ m^{-2})

\begin{align*}
\text{Biomass} &: \\
\sum T_C: & (\text{mm} \times 1000)
\end{align*}
In-season dry biomass

Data needed for calibration | Crop
In-season yield

Reference Harvest Index (HI)

50 [%]

Harvest Index

60%
45%
30%
15%
0%
tuber formation
lag phase
yield formation
maturity
opening

Canopy Cover (CC)

100%
80%
60%
40%
20%
0%

63 days to maturity

data needed for calibration
Water stress coefficients
AquaCrop conceptual framework

Water stress coefficients

Adjustment of Harvest Index (HI) to water stress

<table>
<thead>
<tr>
<th>Before tuber formation</th>
<th>During yield formation</th>
<th>Combined effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>65% (Reference HI)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**combined effect of water stress before and during yield formation**

- Water stress before tuber formation
  - Positive effect on Harvest Index as a result of water stress affecting leaf expansion
  - Negative effect on Harvest Index as a result of water stress inducing stomatal closure

- Water stress during yield formation
  - Maximum possible increase of HI: + 20%
Data needed for calibration | Crop

Different water regimes
Soil water (and salt) balance

Infiltration
Redistribution

Runoff

Rain

Irrig.

Ks

Texture 1
Texture 2
Texture ...

Ksat

FC
PWP

E_s
T_a

deep percolation

AquaCrop Conceptual Framework | Soil
Data needed for calibration

Soil layers

FC, PWP, Ksat

<table>
<thead>
<tr>
<th>Description</th>
<th>Soil horizons</th>
<th>Soil surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Physical characteristics</td>
<td></td>
</tr>
<tr>
<td>soil porosity</td>
<td>soil depth</td>
<td>hydraulic conductivity</td>
</tr>
</tbody>
</table>

- 0 meter
- 4.00 meter

<table>
<thead>
<tr>
<th>soil layer</th>
<th>thickness [m]</th>
<th>wilting point</th>
<th>field capacity</th>
<th>saturation</th>
<th>Ksat (mm/day)</th>
<th>Total Available soil Water [mm/m]</th>
<th>saturated hydraulic conductivity [mm/day]</th>
<th>tau</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 silty clay loam</td>
<td>4.00</td>
<td>23.0</td>
<td>44.0</td>
<td>52.0</td>
<td>210</td>
<td>20.0</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>
Water Management

- **Irrigation**
  - User defined schedule (timing and depth)
  - Model-generated schedule (fixed interval; fixed depth; % of RAW)
  - Irrigation method (drip; sprinkler; surface » basin; border; furrow)

Field Management

- Fertility level (non-limiting; high; moderate; poor)
- Field-surface practices (mulching; soil bunds)
### Data needed for calibration

**Management**

#### Irrigation date

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>DayNumber</th>
<th>Application depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21 January 2001</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>2</td>
<td>24 January 2001</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>25 January 2001</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>27 January 2001</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>31 January 2001</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>6</td>
<td>2 February 2001</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>4 February 2001</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>8</td>
<td>7 February 2001</td>
<td>21</td>
<td>37</td>
</tr>
</tbody>
</table>

**Manual irrigation schedule**

- 1 mm = 10 m3/ha
- DayNumber 1 = 18 January 2001
- DayNumber 95 = 22 April 2001

**Clear All Events**
Fertility level

Soil fertility:
- User defined

Crop parameters:
- Soil Fertility Class
  - Non limiting: maximum canopy: 50 days
  - User defined: maximum canopy: 63 days

Effect of soil fertility:
- CGC reduction: 25%
- CCx reduction: 19%
- Decline Canopy Cover: 0.4
- WP reduction: 0%

Canopy Cover (CC)

Day:
- 1
- 19
- 2
- 50
- 3
- 110
AquaCrop performances
Maize

Texas

California

Florida

Spain

Quzhou
Treatments:
- Full Irrigation (I)
- Rainfed (NI)
- Irrig. day 55 onward (I55)

<table>
<thead>
<tr>
<th></th>
<th>Measured</th>
<th>Simulated</th>
<th>Measured</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>24.3</td>
<td>22.7</td>
<td>11.4</td>
<td>10.8</td>
</tr>
<tr>
<td>NI</td>
<td>16.8</td>
<td>16.8</td>
<td>5.2</td>
<td>6.2</td>
</tr>
<tr>
<td>I55</td>
<td>21.2</td>
<td>22.4</td>
<td>10.3</td>
<td>10.6</td>
</tr>
</tbody>
</table>

**Biomass Yield**
- Measured: 24.3, 16.8, 21.2
- Simulated: 22.7, 16.8, 22.4

**Ground Cover (GC) and Cumulative Dry Matter (DM)**

**I55 (IRR on Day55) treatment Ground Cover**

- GC (%): 0, 20, 40, 60, 80, 100, 120, 140

**I55 treatment biomass**

- Cum DM (g/m²): 0, 20, 40, 60, 80, 120, 140
Spain

Treatments:
- Full Irrigation
- Deficit Irrigation

The graph shows the comparison of observed and simulated yields and biomass. The treatments are compared against a 1:1 line, indicating a close correlation between observed and simulated values.
Cotton Treatments:
- Full Irrigation
- Deficit Irrigation

Syria
## China

### Treatments:
- 98-99 - Full Irr.
- 99-00 - Full Irr.

<table>
<thead>
<tr>
<th>Yield</th>
<th>Measured</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.72</td>
<td>6.50</td>
</tr>
<tr>
<td></td>
<td>6.22</td>
<td>7.09</td>
</tr>
</tbody>
</table>

### Graphs:
- **Canopy Cover (%)**
- **Biomass (t/ha)**
- **Min and Max Temperature (°C)**
- **DAP**
Quinoa

Bolivia
Bolivia

Treatments:
- Full Irrigation
- Deficit Irrigation

Graphs showing relationships between measured and simulated yields with regression equations and coefficients.
Conclusions

- **AquaCrop** shows first encouraging results, under full, deficit and rainfed conditions.

- **AquaCrop** needs to be calibrated for potato.

- **AquaCrop** calibration and validation need solid datasets, under a variety of agro-climatic, water and fertilization conditions.
Thank You