Some modifications to the simulation of Irrigation practices in rice paddy using SWAT

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Water Use

www.unesdoc.unesco.org
Annual Renewable Water

Annual renewable water (m$^3$/person/year)

Ref. 5: “Will there be enough water?”
Revena, C., EarthTrends, October 2000,
www.earthtrends.wri.org
## Irrigated Agriculture

<table>
<thead>
<tr>
<th>Rank</th>
<th>Countries</th>
<th>Amount</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1</td>
<td>India</td>
<td>558,080 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 2</td>
<td>China</td>
<td>545,960 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 3</td>
<td>United States</td>
<td>223,850 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 4</td>
<td>Pakistan</td>
<td>182,300 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 5</td>
<td>Iran</td>
<td>76,500 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 6</td>
<td>Mexico</td>
<td>63,200 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 7</td>
<td>Turkey</td>
<td>52,150 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 8</td>
<td>Thailand</td>
<td>49,860 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 9</td>
<td>Bangladesh</td>
<td>47,250 sq km</td>
<td>2003</td>
</tr>
<tr>
<td># 10</td>
<td>Russia</td>
<td>46,000 sq km</td>
<td>2003</td>
</tr>
</tbody>
</table>

Source: [http://www.nationmaster.com](http://www.nationmaster.com)
Chart 9 Arable/Irrigated Area in Selected Countries during 2003 (M.Ha.)

- China: Arable Land 142.6, Irrigated Area 54.6
- India: Arable Land 160.6, Irrigated Area 55.8
- Pakistan: Arable Land 19.5, Irrigated Area 18.2
- UK: Arable Land 5.7, Irrigated Area 0.2
- USA: Arable Land 173.5, Irrigated Area 22.4
- Bangladesh: Arable Land 8.0, Irrigated Area 4.7
- Nepal: Arable Land 2.4, Irrigated Area 1.2
Chart 13 Area Sown and Irrigated (Million Hectares)

Source: http://www.nationmaster.com
Chart 17 Planwise Irrigation Potential Created and Utilised (Cumulative)
Chart 12 Decadal Changes in Cropping Pattern According to Land Use Statistics - All India
Chart 28 Comparative Yield of Important Crops during 2005 (Kg./Ha.)

- Wheat: India 2738, Asia 2898, World 3000
- Paddy: India 2752, Asia 4099, World 4004
- Total Cereals: India 2367, Asia 3315, World 3256
- Total Pulses: India 612, Asia 780, World 843
Chart 8 Per Capita Water Availability in Selected Countries ('000 CU.M)

<table>
<thead>
<tr>
<th>Country</th>
<th>1975</th>
<th>2000</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>3</td>
<td>2.2</td>
<td>1.9</td>
</tr>
<tr>
<td>India</td>
<td>3.1</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2.7</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>UK</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>USA</td>
<td>11.3</td>
<td>8.9</td>
<td>7.6</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>15.8</td>
<td>9.4</td>
<td>6.8</td>
</tr>
<tr>
<td>Nepal</td>
<td>16.4</td>
<td>16.4</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Per Capita Water Availability ('000 CU.M)
Significance

- Paddy is a major consumer of irrigation water
- Tamil Nadu
- Uses about 63% of total available water resources for cultivating paddy
Field water balance lowland rice

Source: IRRI
Irrigation efficiency \( \approx (\text{conveyance efficiency} \times \text{field application efficiency}) = 40\% \)

Water diverted from source = Irrigation requirement / Irrigation Efficiency

Water applied in the field = Water diverted from source \times \text{Conveyance Efficiency}

Water lost in conveyance = Water diverted – water applied
### Irrigation methods

<table>
<thead>
<tr>
<th>Irrigation methods</th>
<th>Field application efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface irrigation (border, furrow, basin)</td>
<td>60%</td>
</tr>
<tr>
<td>Sprinkler irrigation</td>
<td>75%</td>
</tr>
<tr>
<td>Drip irrigation</td>
<td>90%</td>
</tr>
</tbody>
</table>

**Formula**

\[
e = \frac{ec \times ea}{100}
\]

with

- \(e\) = scheme irrigation efficiency (%) 
- \(ec\) = conveyance efficiency (%) 
- \(ea\) = field application efficiency (%) 

A scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme Irrigation efficiency of 20-30% is poor.

Source: FAO manual
Auto Irrigation trigger

- Plant growth
  - Fraction of potential plant growth reduced due to water stress
- Soil water stress
  - 1 – Depletion. Fac
  - Depletion factor
    - SW/TAWC
<table>
<thead>
<tr>
<th>Crop</th>
<th>Root zone depth (RZD)$^1$ (m)</th>
<th>Allowable soil moisture depletion (P)$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Small vegetables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>0.4-0.6</td>
<td>0.45</td>
</tr>
<tr>
<td>Brussels sprouts</td>
<td>0.4-0.6</td>
<td>0.45</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.5-0.8</td>
<td>0.45</td>
</tr>
<tr>
<td>Carrots</td>
<td>0.5-1.0</td>
<td>0.35</td>
</tr>
<tr>
<td>Cauliflowers</td>
<td>0.4-0.7</td>
<td>0.45</td>
</tr>
<tr>
<td>Celery</td>
<td>0.3-0.5</td>
<td>0.20</td>
</tr>
<tr>
<td>Garlic</td>
<td>0.3-0.5</td>
<td>0.30</td>
</tr>
<tr>
<td>Lettuce</td>
<td>0.3-0.5</td>
<td>0.30</td>
</tr>
<tr>
<td>Onions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– dry</td>
<td>0.3-0.6</td>
<td>0.30</td>
</tr>
<tr>
<td>– green</td>
<td>0.3-0.6</td>
<td>0.35</td>
</tr>
<tr>
<td>– seed</td>
<td>0.3-0.6</td>
<td>0.35</td>
</tr>
<tr>
<td>Spinach</td>
<td>0.3-0.5</td>
<td>0.20</td>
</tr>
<tr>
<td>Radishes</td>
<td>0.3-0.5</td>
<td>0.30</td>
</tr>
<tr>
<td>b. Vegetables – Solanum Family (Solanacea)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggplant</td>
<td>0.7-1.2</td>
<td>0.45</td>
</tr>
<tr>
<td>Sweet peppers (bell)</td>
<td>0.5-1.0</td>
<td>0.30</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.7-1.5</td>
<td>0.40</td>
</tr>
<tr>
<td>c. Vegetables – Cucumber Family (Cucurbitaceae)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cantaloupes</td>
<td>0.9-1.5</td>
<td>0.45</td>
</tr>
<tr>
<td>Cucumbers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– fresh market</td>
<td>0.7-1.2</td>
<td>0.50</td>
</tr>
<tr>
<td>– machine harvest</td>
<td>0.7-1.2</td>
<td>0.50</td>
</tr>
<tr>
<td>Pumpkin, winter squash</td>
<td>1.0-1.5</td>
<td>0.35</td>
</tr>
<tr>
<td>Squash, zucchini</td>
<td>0.6-1.0</td>
<td>0.50</td>
</tr>
<tr>
<td>Sweet melon</td>
<td>0.8-1.5</td>
<td>0.40</td>
</tr>
<tr>
<td>Watermelon</td>
<td>0.8-1.5</td>
<td>0.40</td>
</tr>
<tr>
<td>d. Roots and tubers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beet, table</td>
<td>0.6-1.0</td>
<td>0.50</td>
</tr>
<tr>
<td>Cassava</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– year 1</td>
<td>0.5-0.8</td>
<td>0.35</td>
</tr>
<tr>
<td>– year 2</td>
<td>0.7-1.0</td>
<td>0.40</td>
</tr>
<tr>
<td>Parsnips</td>
<td>0.5-1.0</td>
<td>0.40</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.4-0.8</td>
<td>0.35</td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td>1.0-1.5</td>
<td>0.65</td>
</tr>
<tr>
<td>Turnips (and Rutabaga)</td>
<td>0.5-1.0</td>
<td>0.50</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>0.7-1.2</td>
<td>0.553</td>
</tr>
</tbody>
</table>
 Significant quantum of water is used in the cultivation of paddy.
 Will there be enough water in the future to cultivate paddy?
Krishna Basin

Salient features

- Length: 1,400 km
- Drainage area: 258,948 sq.km
- Population: 76.5 million
  - Density: 287/sq.km
- Climate: Semi-arid
- Rainfall: 800mm
  - 300 – 2000mm
Surface Water potential 78.1 km³
Ground Water potential 26.41 km³
Close basin: All the water resources are allocated

Agriculture: 78%
Irrigated Agriculture: 40%
Modeling Process

- Analysis of weather data inputs from climate model
  - Bias correction of precipitation
- Simulation of water availability at important control points
  - Major reservoir locations and diversions
- Irrigation water demand
Climate Model

GFDL

- Baseline, A1B and Y1B
  - IPRC-RegCM
    - $0.25^\circ \times 0.25^\circ$
Slope Values of the regression fit for JJAS
(Ordered series of original baseline data with IMD 0.5 deg gridded data)

Slope Values of the regression fit for ONDJ
(Ordered series of original baseline data with IMD 0.5 deg gridded data)

Slope Values of the regression fit for FMAM
(Ordered series of original baseline data with IMD 0.5 deg gridded data)
Reason for Bias in RCM

- **Systematic model errors**
  - Imperfect conceptualization
    - Model physics is quite complicated
  - Discretization and spatial averaging within grid cells
## Downscaling Models – An Overview

### Dynamic downscaling

- Involves nesting of Regional Climate Model (RCM) in GCM

Source: VVS, IISc
Need for Bias correction

- Rainfall underestimated
  - May not have enough water for irrigation
  - Irrigation demand cannot be predicted correctly

- Rainfall overestimated
  - May indicated more water is available
  - Irrigation demand cannot be predicted correctly

- Flood and drought assessment
Bias adjustment

Baseline scenario

Equi-probability transformation

- The simulated rainfall of a given probability of exceedance was made equivalent to the IMD rainfall of same exceedance
Distribution transfer

Probability mapping or quantile-quantile mapping

Figure 2. Equi-probability transformation of precipitation amounts obtained from the weather station of Campinas (22°54′S, 47°05′W; Instituto Agronómico).
Weibull Distribution

Parameters
\( \lambda > 0 \) scale (real)
\( k > 0 \) shape (real)

Support
\( x \in [0; +\infty) \)

PDF
\[
f(x) = \begin{cases} 
\frac{k}{\lambda} \left( \frac{x}{\lambda} \right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^k} & x \geq 0 \\
0 & x < 0 
\end{cases}
\]

CDF
\[
1 - e^{-\left(\frac{x}{\lambda}\right)^k}
\]

Slope Values of the regression fit for JJAS
(Ordered series of corrected baseline data with IMD 0.5 deg gridded data)

Slope Values of the regression fit for ONDJ
(Ordered series of corrected baseline data with IMD 0.5 deg gridded data)

Slope Values of the regression fit for FMAM
(Ordered series of corrected baseline data with IMD 0.5 deg gridded data)

Slope values:
- < 0.50
- 0.501 - 0.750
- 0.751 - 1.00
- 1.01 - 1.25
- 1.26 - 2.00
- > 2.00
Percentage Change in Irrigation Demand for Rice crop from Baseline to End Century A1B Scenario

Percent Change
-41 -20
0 - 20
-20 - 0
> 20

Kilometers
ONGOING STUDIES
Field Instrumentation
Record daily measurements in the field water tube and percolation tube in order to estimate the field water balance based evapotranspiration.
Aquacrop – water productivity based crop growth model

FAO 33 Yield response to water
(Doorenbos & Kassam, 1979)

SolarRadiation → CropEvapotranspiration → Ky → CropYield

FAO AquaCrop

SolarRadiation → CropEvapotranspiration → CanopyTranspiration → Biomass → HI → WP → WP* → B = WP* \times \sum \left( \frac{Tr}{ETo} \right) → HI → Yield → Zr

Source: Raes et al., 2009
ET maps (mm/day) at different resolutions (through resampling)

ET_60m
- High: 4.67517
- Low: 3.31744

ET_250m
- High: 4.6411
- Low: 3.3105

ET_1000m
- High: 4.6352
- Low: 3.3298
Improve the rice paddy irrigation routine within SWAT

- AQUACROP, ORYZA, and field observations

Improve SWAT parameterization using thermal remote sensing based ET