Guiding adaptation to climate change by crop modeling: Parameterizing for irrigated agroecosystems in Central Asia

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Uzbekistan Agriculture Sector: 2030 Vision

Environmental protection and sustainable use of natural resources

<table>
<thead>
<tr>
<th>Goals</th>
<th>Baseline 2017</th>
<th>Vision 2030</th>
<th>Possible Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved agriculture and environmental practices</td>
<td>5% of farmers adopting good agricultural practices</td>
<td>20% of farmers adopting good agricultural practices</td>
<td>Recognized GAP / Organic Certification</td>
</tr>
<tr>
<td>Improved efficiency in use of water resources</td>
<td>0.2 million ha farmland with water-saving technologies</td>
<td>1.0 million ha farmland with water-saving technologies</td>
<td>Irrigation technology investment</td>
</tr>
<tr>
<td>Reduced land salinity</td>
<td>42% of land with high salinity</td>
<td>25% of land with high salinity</td>
<td>Irrigation renovation / water user groups</td>
</tr>
</tbody>
</table>

# Uzbekistan Agriculture Sector: 2030 Vision

## Food Security

<table>
<thead>
<tr>
<th>Goals</th>
<th>Baseline 2017</th>
<th>Target 2030</th>
<th>Possible Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased wheat yields</td>
<td>4.2 tons/ha</td>
<td>5.0 tons/ha</td>
<td>Research / Liberalization</td>
</tr>
<tr>
<td></td>
<td>Average yield</td>
<td>Average yield</td>
<td></td>
</tr>
<tr>
<td>Achieved zero hunger</td>
<td>6.3% Food insecure people</td>
<td>0% Food insecure people</td>
<td>Income Support / Social Safety nets</td>
</tr>
<tr>
<td>Reduced malnutrition</td>
<td>10% Children under 5 years old stunned</td>
<td>5% Children under 5 years old stunned</td>
<td>Nutrition education / Farm-school programs</td>
</tr>
</tbody>
</table>

Steps

1. Collect dataset of weather parameters for selected sites in 3 countries
2. Collect information on soil properties and agro-technology
3. Collect phenology of irrigated crops for conditions of sites in 3 countries
4. Parameterize the crop model
Study sites

- **Kyrgyzstan** – Chuy region (Lat 42.85°N; Lon 74.53°E). Elevation ranges 400-760 m above sea level.

- **Tajikistan** – Sughd region (Lat 38.77°N; Lon 68.8°E). Elevation around 1455 m above sea level.

- **Uzbekistan** – Khorezm region located in northwest (Lat 60.05°- 61.39°N; Lon 41.13°- 42.02°E). Elevation ranges 90-138 m above sea level.
Weather data

Daily data spanning from 1951 to 2018 for

- Air temperature maximum and minimum (°C);
- Relative air humidity maximum and minimum (%);
- Wind speed (m/sec);
- Short-wave radiation (Mj);
- Precipitation (mm)

<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>Precipitation Temperature</th>
<th>Solar radiation</th>
<th>Relative air humidity</th>
<th>Wind speed</th>
</tr>
</thead>
</table>
Historical weather data 1951–2018

Khorezm, Uzbekistan

Chuy, Kyrgyzstan

Sughd, Tadjikistan
Crop model

- CropSyst model (Stockle et al., 2003);
- Version 4.19.06 under the irrigated agro-ecological conditions;
- Data was drawn from previous studies (Axmatbekov M. 2000; Sommer et al., 2008; Djumaniyazova et al., 2010; Babadjanova et. al., 2012; Devkota et. al., 2013b; FAO, 2015; TajStat, 2017a,b; Husenov, 2018; Haitbayeva, 2019).
Considered crops

- Winter Wheat
- Mungbean
- Cotton
## Input characteristics

<table>
<thead>
<tr>
<th>Crop</th>
<th>Uzbekistan</th>
<th>Tajikistan</th>
<th>Kyrgyzstan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter wheat</strong></td>
<td>Variety: Kupava</td>
<td>Variety: Krasnodarskaya-99</td>
<td>Variety: Intensivnaya</td>
</tr>
<tr>
<td><strong>Triticum aestivum</strong></td>
<td>Fertilization: N&lt;sub&gt;240&lt;/sub&gt;P&lt;sub&gt;130&lt;/sub&gt;K&lt;sub&gt;90&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Fertilization: N&lt;sub&gt;150&lt;/sub&gt;P&lt;sub&gt;80&lt;/sub&gt;K&lt;sub&gt;60&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Fertilization: N&lt;sub&gt;80&lt;/sub&gt;P&lt;sub&gt;90&lt;/sub&gt;K&lt;sub&gt;30&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td>L.)</td>
<td>Irrigation: 624 mm</td>
<td>Irrigation: 405 mm</td>
<td>Irrigation: 130 mm</td>
</tr>
<tr>
<td><strong>Mungbean</strong></td>
<td>Variety: Radost</td>
<td>Variety: Marjon</td>
<td>Variety: Radost</td>
</tr>
<tr>
<td><strong>(Vigna radiate [L.]</strong></td>
<td>Fertilization: N&lt;sub&gt;30&lt;/sub&gt;P&lt;sub&gt;120&lt;/sub&gt;K&lt;sub&gt;100&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Fertilization: N&lt;sub&gt;30&lt;/sub&gt;P&lt;sub&gt;60&lt;/sub&gt;K&lt;sub&gt;60&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Fertilization: N&lt;sub&gt;30&lt;/sub&gt;P&lt;sub&gt;120&lt;/sub&gt;K&lt;sub&gt;100&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Wilcz.</strong></td>
<td>Irrigation: 200 mm</td>
<td>Irrigation: 150 mm</td>
<td>Irrigation: 200 mm</td>
</tr>
<tr>
<td><strong>Cotton</strong></td>
<td>Variety: Khorezm-127</td>
<td>Variety: Hujand-67</td>
<td></td>
</tr>
<tr>
<td><strong>(Gossypium</strong></td>
<td>Fertilization: N&lt;sub&gt;240&lt;/sub&gt;P&lt;sub&gt;140&lt;/sub&gt;K&lt;sub&gt;100&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Fertilization: N&lt;sub&gt;200&lt;/sub&gt;P&lt;sub&gt;100&lt;/sub&gt;K&lt;sub&gt;60&lt;/sub&gt; kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>hirsutum L.)</td>
<td>Irrigation: 570 mm</td>
<td>Irrigation: 570 mm</td>
<td></td>
</tr>
</tbody>
</table>
Parameterization of crop model for Cotton

A-Cotton 2016

Leaf area index, m² m⁻²

DAP

Khorezm 127

Observed

Hujand 67

B-Cotton 2016

Above ground biomass kg ha⁻¹

DAP

Khorezm 127

Observed

Hujand 67
Parameterization of crop model for Winter wheat

A-Winter wheat 2015/16

- **Kupava**
- **Observed**
- **Krasnodar 99**
- **Intensivnaya**

B-Winter wheat 2015/16

- **Kupava**
- **Observed**
- **Krasnodar 99**
- **Intensivnaya**

Leaf area index, m² m⁻²

Above ground biomass kg ha⁻¹

DAP
Parameterization of crop model for Mungbean

A-Mungbean 2016

B-Mungbean 2016

Leaf area index, m² m⁻²

Above ground biomass kg ha⁻¹
Simulated grain yield and aboveground biomass (AGB) vs. observed grain yield and AGB for all sites and years
The calculation of the root mean square error in %

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Uzbekistan</th>
<th>Tajikistan</th>
<th>Kyrgyzstan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter wheat (Triticum aestivum L.)</td>
<td>AGB</td>
<td>2</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Mungbean (Vigna radiate [L.] Wilcz.)</td>
<td>AGB</td>
<td>11</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>32</td>
<td>9</td>
</tr>
<tr>
<td>Cotton (Gossypium hirsutum L.)</td>
<td>AGB</td>
<td>7</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• The CropSyst model performed well to simulate productivity of 3 crops in irrigated conditions in 3 countries;

• Simulation of yield and above ground biomass:
  o Winter wheat:
    ❖ Excellent in Tajikistan and Uzbekistan (RRMSE 2-11%);
    ❖ Good in Kyrgyzstan (RRMSE 17-18%).
  o Cotton
    ❖ Excellent in Tajikistan and Uzbekistan (RRMSE 6–9%);
  o Mungbean
    ❖ Excellent in Kyrgyzstan and Uzbekistan (RRMSE 0-11%);
    ❖ Fair in Tajikistan (RRMSE 13-32%).

• Model results offer the possibility of specifying management options and they can be used to investigate a wide range of management strategies at low costs.