Comparative analysis and validation of remotely sensed estimation of actual evapotranspiration in cotton ecosystems of Middle Asia

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Outline

1. Introduction
2. ET Modelling
3. Results and validation
4. Outlook
   - Comparative analysis
   - Soil moisture implementation
1. Introduction: Aral sea development - Past

1. Introduction: Aral sea development - Present

false-color-composit (4-2-1)

black lines indicate the shore line in 1989

Khorezm

source: Landsat data (July 2009)
1. Introduction: Aral sea development - Present

false-color-composit (4-2-1)

black lines indicate the shore line in 1989

source: Landsat data (Jul-Sep 2010)
1. Introduction: Aral sea development

- More water reached the Aral Sea and the deltas of Syr Darya and Amu Darya than in the past 18 years

- The irrigated area in the deltas show higher vegetation intensity than 2009 (NDVI)

<table>
<thead>
<tr>
<th>Year</th>
<th>Plan [million m³]</th>
<th>Actual [million m³]</th>
<th>% (Plan – Actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>3990</td>
<td>972</td>
<td>25.3</td>
</tr>
<tr>
<td>2009</td>
<td>4200</td>
<td>2733</td>
<td>93.2</td>
</tr>
<tr>
<td>2010</td>
<td>4200</td>
<td>200000</td>
<td>476</td>
</tr>
<tr>
<td>2011</td>
<td>4200</td>
<td>1456</td>
<td>36.4</td>
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</tbody>
</table>

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>2008</td>
<td>4175</td>
<td>3193</td>
<td>76.5</td>
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<tr>
<td>2009</td>
<td>3939</td>
<td>4989</td>
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<tr>
<td>2010</td>
<td>4931</td>
<td>8294</td>
<td>168.2</td>
</tr>
<tr>
<td>2011</td>
<td>4279</td>
<td>4861</td>
<td>113.6</td>
</tr>
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</table>
1. Introduction – Study area
Irrigation agriculture in the aral sea basin is facing serious problems, like:

- unsustainable land and water usage,
- insufficient data about water user needs for water distribution,
- soil salinization due to high groundwater levels,
- glacier melting, and
- increasing population, etc.

Unpredictable water availability
Uncertainties for irrigation management and expected crop yield

Need for analysis and evaluation of water management system
here: remote sensing can provide large scale input data like potential and actual evapotranspiration, land use classification or yield estimations.
2. ET Modelling

SEBAL (Surface Energy Balance Algorithm for Land, [Bastiaanssen et al.1998])

- Approach to quantify actual evapotranspiration based on remote sensing data

- Solves the surface energy balance equation to estimate latent heat flux (ET)

- Originally developed for Landsat, in this study MODIS data is used.

Site specific adaptations:
- Semi-automated selection of anchor points
- Multi temporal approach.
2. ET Modelling

SEBAL (Surface Energy Balance Algorithm for Land, [Bastiaanssen et al.1998])

\[
R_n = (1 - \alpha)R_S + \varepsilon R_L - R_{Le}
\]

\[
\frac{G}{R_n} = \frac{LST}{\alpha} \left( 0.0038 + 0.0074\alpha \left( 1 - 0.978NDVI^4 \right) \right)
\]

\[
H = \frac{\rho_{air} \cdot c_p \cdot dT}{r_{ahl}}
\]

Actual evapotranspiration

Reference evapotranspiration

Meteorological data

Land use

NDVI

LAI

\(\alpha\)

\(\varepsilon\)

LST

\(R_n\)

\(G\)

\(H\)

\(\eta\)

\(ET\)
3. Results and validation

An eddy covariance station was build at the end of year 2008.

For this location the model validation was performed using the stations data.

The station is measuring the turbulent heat fluxes and meteorological information.

source: Landsat data (July 2009)
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3. Results and validation – Net radiation

Net radiation is showing strong correlation between measured and modelled values.
3. Results and validation - Footprint analysis

A footprint analysis was performed. In order to determine the days of valid measurements (where the fluxes came quite likely from the ecosystem of interest, in this case: cotton ecosystem)

Prevailing wind direction is SSW to WSW.
3. Results and validation - Footprint analysis

Performing a footprint analysis leads to lower RMSD compared to the RMSD of all days where a model run was performed.

Correlation of model results and measurements show weak correlation without footprint analysis.

After footprint analysis the correlation chances to be stronger correlated.
4. Outlook – Comparative analysis

LE

\[ y = 1.2254x - 114.75 \]
\[ R^2 = 0.587 \]
\[ n=8 \]

H

\[ y = 0.9231x + 44.48 \]
\[ R^2 = 0.7544 \]
\[ n=8 \]

MODIS

Landsat

Modelled latent heat flux [W/m²]

Measured latent heat flux [W/m²]

Modelled sensible heat flux [W/m²]

Measured sensible heat flux [W/m²]

Modelled latent heat flux [W/m²]

Measured latent heat flux [W/m²]

Modelled sensible heat flux [W/m²]

Measured sensible heat flux [W/m²]
4. Outlook - Soil heat flux validation

[W/m²]

- **G model (default SEBAL)**
- **G measured**
- **G modelled (with ASCAT SSM)**

May          June           July           August    September    October
3. Results and validation - Footprint analysis

**Daily actual evapotranspiration 2010 (cumulative curve)**

- **Modelled actual ET [mm/d]**
- **Measured actual ET [mm/d]**

*Start of measurement 19.04.2010*

**Daily actual evapotranspiration 2010 (seasonal)**

*After footprint analysis*

**Regression equations and R² values**

- Modelled vs. measured ET:
  - **ET Model interpolated**
  - **ET Measured**

- **April** - **November**

```plaintext
y = 0.9744x + 0.225
R² = 0.6075

y = 0.9427x + 0.1069
R² = 0.7612
```
4. Outlook - Soil moisture approach

Using the ASACT SSM information improves the estimation of the soil heat flux and increases the correlation from weak correlation to stronger correlation.
Summary

- Model results showing acceptable results for net radiation, sensible and latent heat flux after a footprint analysis.

- Implementation of soil moisture could improve the estimation of soil heat flux.

- Closer look on the comparative analysis between MODIS and Landsat.
Thank you for your attention