Relationship between Land-use, climate and the hydrologic cycle in Central Asia

Mutlu Ozdogan
University of Wisconsin-Madison

Chen Xi and Alishir Kurban
Xinjiang Institute of Ecology and Geography, PRC
Why Central Asia?

• Water is a vital natural resource in the region
• Mismatch between the sources and users
• Large institutional changes that affect the use of resources
• Changing land-use practices (that are unsustainable)
• Ecological systems sensitive to change
• Climate change wildcard
A new project

- Joint between UWisc and CAS (Xinjiang Institute of Ecology and Geography)
- Focussed on 3 intensive study sites (Xinjiang, SE Kazakhstan, E Uzbekistan)
- Investigate the relationship between land-use, climate, and hydrologic cycle
- Remote sensing, hydrologic modeling, ecosystem modeling
- Apply lessons learned to a larger region
Conceptual framework

- Remote Sensing data:
  - Landsat
  - CBERS
  - MODIS
  - AVHRR
  - ASTER

- Climate spatial data:
  - precipitation
  - temperature
  - humidity

- In-situ data:
  - meteorological
  - LUCC
  - LAI
  - Soil moisture
  - ET

- LUCC spatial data:
  - Land-use/cover
  - Land cover change
  - Vegetation distribution

- Groundwater model:
  - Evapotranspiration
  - Recharge/runoff

- Simulation results:
  - evapotranspiration
  - runoff
  - LAI
  - yield

- Basic data on typical:
  - Groundwater information
  - Vegetation information
  - Lake information

- Groundwater change
- Vegetation change
- Lake change
Field sizes

- Average field size in the region determines remote sensing of crops and irrigation status.
Changes in landscape

1975

1990

2000
Changes in landscape
Fine-scale surface features
Landsat vs. CBERS

A

Landsat 7

B

CBERS CCD
Landsat vs. CBERS

Experimental variogram

Landsat

CBERS

CCD
Fig 17. The IBIS Model and Capabilities for Carbon Cycle Science Research. Schematic of IBIS (Kucharik, 2003; Foley et al. 1996).
Kazakhstan spring wheat yields

Source: US Dept. of Agriculture FAS
Agro-IBIS simulations show failed crop starts in certain years but for those years for which we can simulate crops there is a strong correspondence between modeled and observed LAI.
Conceptual framework

Remote Sensing data
- Landsat
- CBERS
- MODIS
- AVHRR
- ASTER

Climate spatial data
- precipitation
- temperature
- humidity

In-situ data
- meteorological
- LUCC
- LAI
- Soil moisture
- ET

LUCC spatial data
- Land-use/cover
- Land cover change
- Vegetation distribution

Agro-IBIS

Groundwater model
- Evapotranspiration
- Recharge/runoff

Simulation results
- evapotranspiration
- runoff
- LAI
- yield

Basic data on typical
- Groundwater information
- Vegetation information
- Lake information

Groundwater change
Vegetation change
Lake change
AgroIBIS - Groundwater linkage

- Crop yields
- Hydrologic fluxes
- Agricultural runoff (nitrate)

AgroIBIS  
MODFLOW  
LUT  
water table elevation  
vadose zone water movement  
soil/water quality  
salt accumulation  
vadose zone water movement
Prediction of recharge/discharge

An Example from Canadian Prairie

AgroIBIS-MODFLOW predicted recharge (RED) and discharge (BLUE) zones. Discharge zones are also locations susceptible to salt accumulation. It is also possible to calibrate the model with ASTER LST observations.

Levine and Salvucci (1999)
Climate change wildcard

• The region is expected to experience dramatic changes in climate
• Directly linked to water resources (e.g. glacier retreat, decreased surface flow, decreased lake levels, increased ET)
• What is the role of these changes on crop productivity, rate of water depletion, salt accumulation and so on?
• Answer some of these questions with our modeling framework
Climate change wildcard

Global (latitudinal zone from 60°S to 90°N) and Northern Eurasia (north of 40° N) surface air temperature anomalies, 1881-2008

<table>
<thead>
<tr>
<th>Temperature anomalies</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5</td>
<td>1860</td>
</tr>
<tr>
<td>2.5</td>
<td>1880</td>
</tr>
<tr>
<td>1.5</td>
<td>1900</td>
</tr>
<tr>
<td>0.5</td>
<td>1920</td>
</tr>
<tr>
<td>-1.5</td>
<td>1940</td>
</tr>
<tr>
<td>-2.5</td>
<td>1960</td>
</tr>
<tr>
<td>-3.5</td>
<td>1800</td>
</tr>
</tbody>
</table>

Linear trends, 0.86K/128yrs and 1.47K/128yrs respectively, are statistically significant at the 0.001 level

(Archive of Lugina et al. 2007 updated).

Northern Asia, north of 40°N. 1881-2008. Surface air temperature anomalies from the 1951-1975 reference period

<table>
<thead>
<tr>
<th>Temperature anomalies, K</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5</td>
<td>1860</td>
</tr>
<tr>
<td>2.5</td>
<td>1880</td>
</tr>
<tr>
<td>1.5</td>
<td>1900</td>
</tr>
<tr>
<td>0.5</td>
<td>1920</td>
</tr>
<tr>
<td>-1.5</td>
<td>1940</td>
</tr>
<tr>
<td>-2.5</td>
<td>1960</td>
</tr>
<tr>
<td>-3.5</td>
<td>1800</td>
</tr>
</tbody>
</table>

During the past twenty years, all anomalies were above 0.5K and eight of them were above 1.5K. Year 2007 showed a record anomaly of 2.5K.

Linear trend: 1.65K/128 yrs; $R^2 = 0.40$
Projected changes in glacier volumes in Tajikistan (2050)

Different emitters

Changes in annual GHG emissions in Central Asia (1990-2004)

Per-capita greenhouse gas emissions in Central Asia (tons)

Source: UNDP
Thank you

ozdogan@wisc.edu