Policy Shifts Influence the Functional Changes of the CNH Systems on Mongolian Plateau

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The LCLUC Spring Science Team Meeting
April 18-19, 2016, Maryland
In the very beginning, we were interested in Spatiotemporal changes (trends) and regulations of CO$_2$, H$_2$O, and energy fluxes in a changing climate on the Mongolia Plateau.
Two contrasting macro-systems on Mongolia Plateau
Inner Mongolia (China) & Mongolia

• High latitude (>40 °N), high elevation (>1,000 m)
• Nomadic culture, with Mongols dominating the landscape
• Two contrasting societies (IM & MG): after WWII
• The center of atmospheric activities in East Asia for the monsoons
• How do policy shift alter the function of human and natural systems on Mongolia Plateau?
Spatiotemporal changes and regulations of C, H₂O, and energy fluxes in a changing climate on Mongolia Plateau

(1) Gross Primary Production (GPP)

<table>
<thead>
<tr>
<th>Type</th>
<th>SSE</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.8924</td>
<td>64.3</td>
</tr>
<tr>
<td>Year</td>
<td>1.20423</td>
<td>26.8</td>
</tr>
<tr>
<td>Year*type</td>
<td>0.40085</td>
<td>8.9</td>
</tr>
<tr>
<td>total</td>
<td>4.49748</td>
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(2) Evapotranspiration (ET)

<table>
<thead>
<tr>
<th>Type</th>
<th>SSE</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>11425.4</td>
<td>83.6</td>
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<tr>
<td>Year</td>
<td>1981.1</td>
<td>14.5</td>
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<tr>
<td>Year*type</td>
<td>257.1</td>
<td>1.9</td>
</tr>
<tr>
<td>total</td>
<td>13663.6</td>
<td></td>
</tr>
</tbody>
</table>

Chen et al. 2013
In sum, it seems that

- The systems, **not ecosystems**, are very complex.
- Almost **no knowledge** on the interactive feedbacks of human and physical drivers; but it is clear that the system is not driven by climate alone—as ecologists traditionally believe (e.g. temperature, precipitation).
- Feedbacks and interactions among HS/NS elements are **unknown**.
- The underlying mechanisms are virtually **unknown**.
Divergence of IM & MG as Coupled Human and Natural Systems

Chen et al. Bioscience, 2015
Spatial mismatches among the elements of human systems (HS) and natural systems (NS)

Δtemperature (60 yrs)

Chen et al 2015
Spatiotemporal changes in precipitation and drought on the Mongolian Plateau

John et al. 2013
Mann–Kendall spatial and temporal slope trends of a) total livestock density, b) goat livestock density, c) sheep livestock density, and d) total population density

John et al 2016
Mining licenses (in ha) normalized by Soum area (ha)

Amartuvshin et al. in prep
Changes in livestock, policy, and climate in IM & MG: Policy Dimension

Qi et al. (2012)
Abandoned village in Inner Mongolia: jobs
Policy-Driven Migration in Mongolia: Atar
Population migration in Mongolia

1990-2010

- < -0.50
- -0.5- 0
- > 1
Population migration in Mongolia

1990-2010

< -0.50
-0.5- 0
>1
Population migration in Mongolia

1990-2010

< -0.50
-0.5- 0
>1

Km 1,000 500 0

Map showing population migration in Mongolia from 1990 to 2010.
Connecting the dots representing social, economic, ecosystem functions, and land use

The three foundational pillars in sustainable science!

POP: population
GDP: gross domestic production
NPP: net primary production
LSK: livestock

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GDP: gross domestic production
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Chen et al. Bioscience, 2015
Major Policy/Institution Shifts

**Inner Mongolia**

WTO 2001: China became a member of the World Trade Organization

GFG 2008: Grain for Green program

**Mongolia**

CSU 1991: Collapse of the Soviet Union

Atar 1995: Several shifts
Hypothesis tests using Structural Equation Modeling (SEM)

Mongolian Plateau
The Structural Equation Modeling of the CNH system

The Plateau

Mongolian Plateau
The Structural Equation Modeling of the CNH system

Inner Mongolia

\[ \text{NPP} \rightarrow \text{EVI} \]
\[ \text{GDPP} \rightarrow \text{LSKD} \]
\[ \text{POPD} \rightarrow \text{LCC} \]
\[ \text{WTO} \rightarrow \text{GFG} \]

Mongolian Plateau
The Structural Equation Modeling of the CNH system

Mongolia

Urbanization in six different cities in the Mongolian Plateau for 1990-2015
Preliminary results (local scale)

**PLS-SEM in IM and MG**
for the relationship of urban expansion, economy, social goods and environmental conditions in cities of IM and MG (1990-2015). The collinearity statistics of latent variables of two models are high (VIF > 0.2), and the latent variables of two models have higher convergent validity (average variance extracted, AVE > 0.5).

*Park et al., in prep (see poster)*
Preliminary results (regional scale)

Dynamics of macrosystems (Sustainability Index, SI) over a 20-year period along the Silk Road. Light color indicates a more sustainable system.

- Largest dryland on the Earth
- 22 juristic units (countries/Provinces)
- 3 clusters: East Asia, Central Asia, and the Middle East

Chen et al, in prep
Take-home Messages

- **Institution** (e.g., policy) plays a critical role in maintaining the sustainability of a system: How?

  Douglas North (1991): Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights).

- **Resource-rich region**: tower clusters (LEES Lab), multi-teams on paleoecology (*Amy Hessl*), cross-scale RS modeling (*Martin Kappas*, Germany), livestock (*Maria Fernandez-Gimenez*), urbanization (*Peilei Fan*), modeling (*Qianlai Zhuang*), synthesis (*Dan Brown; Dennis Ojima*), other unknowns.

- **Others**? Our synthesis workshop in Ann Arbor (May 12–13, 2016)
In the end, there remains much work to do, with a central focus on the role of institution through syntheses of data, models, and knowledge (Chen & Brown, LCLUC Synthesis Project, 2015-2017).
Thank You!

Data, publications, updates, contacts, questions, etc. can be accessed through project webpage at
http://lees.geo.msu.edu/research/cnh_mongolia.html