Harmonizing Human and Nature for the Changing Globe

Jiquan Chen
Department of Environmental Sciences
University of Toledo

Lake Erie Center Public Lecture
April 18, 2013
Increasing in emission of GHG and air pollution
Pressing Issues facing the globe

- Cultural, religion, and other conflicts: wars
- Population increase & living standards: natural resources
- Pollution (water, air, soil): life and health
- Climate change (warming, extreme events, variable climate, etc.): life quality
- Energy crisis & renewable energy: land use, life quality
- Biodiversity & Species invasions: economy, ecosystem services
- Inflectional diseases and may others: healthy/economy
Growing islands (120/year) were measured because of large amount of sediments carried down from >2000 km polluted Yangtze River.
Spartina plantation and expansion

(a) *Spartina* plantation

(b) Mosaics of *Spartina* invasion

(c) *Spartina* domination

(d) Natural gradients

Chen et al. 2008. JPE
• Invasive *Spartina* on coastal islands of eastern China.

• It provides a powerful filtering function clean water from heavily polluted Yangtze River and higher carbon sequestration;

• High carbon sequestration

• But a disaster for the native species
Invasive *Phragmites australis* in North America
GLBRC: support the biomass-to-bioenergy pipeline by developing ecological, agricultural, & life cycle practices that are economically viable & environmentally responsive.

High Input, Low Diversity

Continuous Corn
Corn-Soybean-Canola

Low Input, High Diversity

Switchgrass
Miscanthus

Native grasses + Legumes

Poplars

Early successional

Restored prairie

Gelfand et al. 2011
Do we have the lands for these bioenergy systems?

Is it sound to convert forests or other types of land into biofuel systems?
Experimental design

**Baseline**

- **2010**
  - **CRP grassland**
    - Soybean
    - Soybean
    - Soybean
  - **Corn soybean rotation**
    - Soybean
    - Soybean
    - Soybean

**2009**

- **Baseline**
  - Soybean
  - Soybean
  - Soybean
  - **2010**
    - **CRP grassland reference site**
      - Corn
      - Mixed prairie
      - Switchgrass
    - **Corn soybean rotation**
      - Soybean
      - Soybean
      - Soybean

**Clean Energy: Biofuels**
GLBRC scale up fields: sustainability

A new conceptual model on multiple resource use (MRU) as

\[ NEP = \left( \varepsilon_1 \cdot \varepsilon_2 \cdots \varepsilon_n \right)^{\frac{1}{n}} \cdot \left( RUE_1 \cdot RUE_2 \cdots RUE_n \right)^{\frac{1}{n}} \cdot \left( R_{\text{avail}} \cdot R_{\text{avail2}} \cdots R_{\text{availn}} \right)^{\frac{1}{n}} \]
Carbon debt of a CRP grassland converted to bioenergy production. 76 yr would be required to repay a debt of 106±1 Mg CO$_2$e ha$^{-1}$ were the subsequent system continuous corn under permanent no-till. If tilled, repayment would require ~172 yr because of additional soil carbon loss that balloons total debt to 259±55 Mg CO$_2$e ha$^{-1}$. Were the subsequent system corn-soybean, repayment would require 88 (permanent no-till) or 196 (tilled) yr.

(Gelfant et al. 2011. PNAS)
CURRENT THRUST II FOCUS
The Coupling Effects
Land Use Change and Hotspots in Inner Mongolia

Chen et al.
Repeated ANOVA tests: Coupled Effects of Climate and Landuse on GPP & ET

(1) Gross Primary Production (GPP)

<table>
<thead>
<tr>
<th>Type</th>
<th>SSE</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</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>
<td></td>
</tr>
</tbody>
</table>

(2) Evapotranspiration (ET)

<table>
<thead>
<tr>
<th>Type</th>
<th>SSE</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>11425.4</td>
<td>83.6</td>
</tr>
<tr>
<td>Year</td>
<td>1981.1</td>
<td>14.5</td>
</tr>
<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. in prep
Mongolia Plateau: interactive changes of natural and human under similar climate but different land-use conditions
Changes in livestock, policy, and climate in IM and MG

Qi et al. (2012)
The internal migration where the flow is oriented toward to Ulaanbaatar and the central region of MG has been a trend. Nearly 70% of the migrants is concentrated in such cities area as Ulaanbaatar, Darkhan, Orkhon and Selenge aimags or along the general roads and railway lines. Since 1990, 320 thousand have migrated from rural areas to Ulaanbaatar city and 34 thousands from cities to the countryside (J. Oyungerel, Mongolian Academy of Sciences, 2008).
One Thing in Common among These Examples

People ~ Nature

Coupled Human & Natural System (CHANS)
Coupled Human & Natural System (CHANS)

Drivers: technology advancement, policy, market, population, etc.

Drivers: climate, land use change, pollution, natural disturbances, etc.

Environmental knowledge on capabilities and responses of H-E sub-systems

Evolving human subsystem

Evolving environment subsystem
Global NPP decreased from 2000 to 2009, with NPP over North Hemisphere continued increasing (winner) and over South Hemisphere decreased; Recent drying trend caused the reduction in NPP in SH.

What are the consequences?

Zhao & Running (2010). Science
Carbon Sinks and Sources (Pg C yr\(^{-1}\)) in the World’s Forests

Pan et al. (2011) Science
FLUXNET for direct measurements of greenhouse gases (GHG). Several thousands site-year data are available.
Global annual evapotranspiration (ET) increased on average by 7.1 mm/yr per decade from 1982 to 1997. After that, coincident with the last major El Niño event in 1998, the global ET increase had ceased until 2008. This change was driven primarily by moisture limitation in the Southern Hemisphere, particularly Africa and Australia.
Forest fragmentation is one of the greatest environmental issues worldwide because of its significant impacts on biological diversity, disrupts the integrity of stream network (e.g., water quality), etc.
Degree of fragmentation of major river basins of the world
Fig. 2. (A) Earthrise (24 December 1968). Image of the rising Earth taken from the Apollo 8 spacecraft. (B) Earth taken on 7 December 1972 by the crew of the Apollo 17 spacecraft at a distance of about 29,000 km. This is the first time that the Apollo trajectory made it possible to photograph the south polar ice cap. (C) Earth’s cities at night. This image of Earth’s city lights at night shows the spatial distribution or arrangement of settlements. White areas of light show organized areas where population is typically large.
Urban heat island in 4 coastal cities in Southern China

Case Study From ShenZhen
Urban heat island in 4 coastal cities in Southern China

Annual mean $T_{\text{min}}$

$\text{Ratio} = \frac{1}{4} \times \frac{1}{n} \sum_{i=1}^{50} \sum_{n=1}^{4} T_{\text{min},i,n}$

Where $i$ is the cities (SEZ, ShT, ShW, YJ); $n$ is the time, from 1961 to 2010

Tian, Chen, Yu. (in press)
Connecting nature, land use change (LCC), economy, and population in Shenzhen (Tian et al. In preparation).

Chi-square = 4.98(4df)
P = 0.474
What to do?

Ecosystem Management for Maximizing the Services
Do differences among landscape-level disturbance regimes influence patterns of understory plant diversity or composition?
An agricultural landscape pattern
Each management option is accompanied with some expectations and many surprises.

Lacks of theoretical and empirical bases remain frustrations for landscape managers.

Managers need “cook books”: available information is too abstractive, not specific. Products need to be simple, straightforward.
Education holds the key for tomorrow

- Students decides the landscapes of future cities
- Explored students’ preferences toward natural and wild versus clean and neat residential landscapes.

Based on the rating scores of four housing landscape designs, we explore the potential influential factors on people’s preferences, especially the wildness or neatness of the home landscape.

Students in agricultural economics, horticulture, and social sciences are more inclined to choose a neat, well-kept environment around their homes.

In contrast, wildlife science students prefer more natural landscapes.

Senior students and students from large cities also prefer well-maintained and artificial landscapes.

Students who are members of an environmental group, and those whose parents have a better education, are more likely to choose a more natural landscape.
Environmental knowledge on capabilities and responses of H-E sub-systems

**Drivers:** technology advancement, policy, market, population, etc.

**Drivers:** climate, land use change, pollution, natural disturbances, etc.

- **Vulnerability**
- **Ecosystem Production,**
- **Water Supply,**
- **Air Quality,**
- **Food Production,**
- **Bioenergy,**
- **GHG Reduction,**
- **Forest/grassland cover,**
- **Green space per capita**
- ...

**Evolving human subsystem**

**Evolving environment subsystem**
Other applications

Brown et al. 2013. Land use and carbon cycle. Springer
Wu et al. in press. Landscape Ecology.
Chen et al. IceMe initiative at NUIST
Questions?