LCLUC Synthesis: Forested Land-Cover and Land-Use Change in the Far East of Northern Eurasia Under the Combined Drivers Of Climate and Socio-Economic Transformation

Multi-Institution Synthesis Team

- Kathleen Bergen, Dan Brown, Josh Newell, Stephanie Hitztaler: *University of Michigan*
- Tatiana Loboda, Guoqing Sun: *University of Maryland*
- Hank Shugart, Jacqueline Shuman: *University of Virginia*
- Olga Krankina: *Oregon State University*
- Yuri Blam: *Russian Academy of Sciences, Siberian Branch*
Outline

Past research and synthesis of past work for NASA Siberia book

Leads to....

New NASA LCLUC integrated synthesis project
Human Dimensions of Environmental Change chapter in NEESPI Siberia Book

Approach: ‘a posteriori’ synthesis of relevant social-science literature and of completed remote sensing LCLUC case studies illustrating main environmental change themes

Synthesis Region
Soviet Era 1922-1991

Demographics
- Large influxes of population through migration
- Growth of large urban centers

Land-Use Trends
- Conversion of steppe and southern taiga to industrial agriculture
- Expansion of mining, oil, gas sectors
- Harnessing of hydropower to supply industrialization
- The extension of railways

Institutions and Resource Management
- The beginning & height of industrial forestry
Demographics
- Population loss in Siberia
- Deep economic hardship
- Transformation of people’s livelihoods and their relationship to natural resources

Land-Use Trends
- Production from large industrial enterprises (esp. forestry) were brought nearly to a halt
- Collective agriculture partially dissolved
- Extractive industries least impacted

Institutions and Resource Management
- Forestry decentralization and liberalization
- Unwittingly fostered the emergence of local oligarchies and illegal logging operations.
Synthesis Remote Sensing Case Study Sites Illustrate these LCLUC Themes
Some Observations Leading to Focus on the Northern Eurasian Far East:

- Overall increasing ‘transnationalism’ especially between Russia and Asia
- Oil/Gas activities shifting from West Siberia to East Siberia and the Far East
- Logging and timber in Siberia/Far East shifting to “external” exports with China & Japan biggest importers
- Region of some greatest predicted influences of climate change
- Lack of integrated synthesis to date
- Opportunities for new kinds of synthesis
Russian Wood Products Exports to China 2008

Research Question and Goal

Synthesis Research Question: How have human-driven disturbances related to use of forest resources, combined with natural and other disturbances (fire, insects, agriculture), created the landscapes of the region over the past 35 years? How might they change in the future?

Goal: Be able to quantify and attribute changes in land-use and land-cover due to climatic variability and due to changing anthropogenic socio-economic drivers in this large region. Build on and extend existing diverse research into synthesis in an approach that integrates remote sensing, socio-economic data & models.
Three Characteristics of this LCLUC Synthesis Project

- ‘A Priori’ Integrative Approach: explicitly designed to integrate remote sensing, socio-economic data and several types of models (forest, climate, systems) to answer research question/s

- Scaled Approach: Combines both Landsat-scale case study sites plus wall-to-wall MODIS over a large regional extent in East Siberia/Russian Far East

- Broader Context: focus on East Siberia/Russian Far East
- AND incorporation of external contexts
Integrated Synthesis Approach

Synthesis Output 1: Long-term moderate resolution forest and LCLUC characterization and rates for region

Synthesis Output 2: Regional wall-to-wall MODIS-derived LCLUC characterization and rates 1975-2010

Synthesis Output 3: Regional forest composition & structure scenarios under different climate and climate + disturbance scenarios; validation

Forest and socio-economic data by sub-region and era

Forest and socio-economic data by sub-region and era

Climate Models

Extend to ~2010 and extract forest and LCLUC data; analyze statistical relationships

Landsat Case Studies ~1975-2010

MODIS for region 2000-2010

Apply regional back-casting & on-going disturbance mapping algorithms; extract statistics

Validation & Adjustment

Apply forest IBM model parameterized & tested for region

IBM Model

Integrate within a systems dynamics model

Capstone Synthesis Output: Forest & land-cover scenarios analyzed across a) eras, b) countries, c) regions and d) under different climate regimes

Forest and socio-economic data by sub-region and era

Tuesday, April 09, 2013
Synthesis Output 1: Long-term LCLUC from Multiple Landsat Case Study Sites


Extend to ~2010 and extract forest and LCLUC data; analyze statistical relationships

Forest and socio-economic data by sub-region and era

Synthesis Output 1: Long-term moderate resolution forest and LCLUC characterization and rates for case sites
Landsat Case Study Sites

- **Existing Siberia/RFE NELDA Sites:** Chita, Amur, Sikhote-Alin

- **Add U. Mich. Case Sites:** Tomsk, Krasnoyarsk, Irkutsk, Primorsky, Kamchatka
Landscape change continues... a Landsat case study site in 2010
Synthesis Challenges

Merging two different classification schemes to integrate for synthesis

Data availability and quality for 2003-2010

Future synthesis projects may benefit from “Landsat-8”
Synthesis Output 2: Long-Term Regional Disturbance Patterns from MODIS

Synthesis Output 1:
Long-term moderate resolution forest and LCLUC characterization and rates for region

MODIS Data for region 2000-2010

Apply regional back-casting & on-going disturbance mapping algorithms; extract statistics

Validation & Adjustment

Synthesis Output 2:
Regional wall-to-wall MODIS-derived LCLUC characterization and rates 1975-2010
Objective 2: Reconstructing Forest Disturbances

Randomized sample of Landsat stacks

LEDAPS-based Landsat TM/ETM+ surface reflectance

Cloud/shadow/water masking

Mature forest masking

Disturbance Index

MODIS data sets:
MCD43A4 Nadir BRDF adjusted reflectance
MOD/MYD11A2 Land Surface Temperature

MODIS-based metrics:
yearly max, min, mean of Jun, Jul, Aug for surface reflectance Bands 1-6, NDVI, NBR, daytime & nighttime temperature)

MODIS Training Sample

Decision-tree classifier

Past disturbance map
Past Forest Disturbance map (Beta)

NELDA sites validation:
Overall accuracy – 63.8%
Synthesis Output 1: Long-term moderate resolution forest and LCLUC characterization and rates for region

Synthesis Output 2: Regional wall-to-wall MODIS-derived LCLUC characterization and rates 1975-2010

Synthesis Output 3: Local and Regional forest composition & structure scenarios under different climate and climate + disturbance scenarios; validation

Climate Model/s

Apply forest IBM model parameterized & tested for region

IBM Forest Model

Tuesday, April 09, 2013
Objective 3: Regional Climate and Climate Change Scenarios
The total is the sum of $\Delta$biomass between post-Soviet years 1990 and 2000 (Modified from Zhao, Bergen & Shugart 2009).

Disturbance and regrowth from Landsat analysis

Biomass/carbon from FAREAST model

<table>
<thead>
<tr>
<th></th>
<th>Tomsk</th>
<th>Krasnoyarsk</th>
<th>Irkutsk</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCLUC</td>
<td>Area (%)</td>
<td>Area-</td>
<td>Area (%)</td>
</tr>
<tr>
<td></td>
<td>weighted $\Delta$biomass</td>
<td>weighted $\Delta$biomass</td>
<td>weighted $\Delta$biomass</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>disturbance</td>
<td>4.82</td>
<td>-3.45</td>
<td>11.37</td>
</tr>
<tr>
<td></td>
<td>3.98</td>
<td>-3.59</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>regrowth</td>
<td>15.25</td>
<td>+6.46</td>
<td>20.91</td>
</tr>
<tr>
<td></td>
<td>9.00</td>
<td>+3.11</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+3.01</td>
<td>+6.37</td>
<td>-0.48</td>
</tr>
<tr>
<td>Constant</td>
<td>75.35</td>
<td>–</td>
<td>60.75</td>
</tr>
<tr>
<td></td>
<td>74.26</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>4.52</td>
<td>-0.34</td>
<td>6.97</td>
</tr>
<tr>
<td></td>
<td>12.76</td>
<td>-1.87</td>
<td></td>
</tr>
</tbody>
</table>
Capstone Synthesis

Synthesis Output 1: Landsat Case Studies LCLUC characterization and rates

Synthesis Output 2: Regional wall-to-wall MODIS-derived LCLUC characterization and rates

Synthesis Output 3: Regional forest composition & structure scenarios under different climate and climate + disturbance scenarios; validation

Forest and socio-economic data by sub-region and era

Integrate within a systems dynamics model

Capstone Synthesis Output: Forest & land-cover scenarios analyzed across a) eras, b) countries, c) regions and d) under different climate regimes
Capstone Challenges

Potential model types –

- what answers our objectives?
- what is feasible?

Proposed a systems dynamics model

- An aspatial model type
- Quantify stocks and flows
- Incorporate external considerations
  - e.g. external markets

Refine proposed approach as needed
Changing External Exports


- China
- Finland
- Japan
- Estonia
- Sweden
- Republic of Korea
Integrated Synthesis Approach

Synthesis Output 1: Long-term moderate resolution forest and LCLUC characterization and rates for region

Synthesis Output 2: Regional wall-to-wall MODIS-derived LCLUC characterization and rates 1975-2010

Synthesis Output 3: Regional forest composition & structure scenarios under different climate and climate + disturbance scenarios; validation

Landsat Case Studies ~1975-2010
Extend to ~2010 and extract forest and LCLUC data; analyze statistical relationships

MODIS for region 2000-2010
Apply regional back-casting & on-going disturbance mapping algorithms; extract statistics

Forest and socio-economic data by sub-region and era

Synthesis Output:
- Forest & land-cover scenarios analyzed across a) eras, b) countries, c) regions and d) under different climate regimes

Validation & Adjustment
Apply forest IBM model parameterized & tested for region

Climate Models
Application of regional back-casting & on-going disturbance mapping algorithms; extract statistics

Integrate within a systems dynamics model

Forest and socio-economic data by sub-region and era

IBM Model

Capstone Synthesis Output: Forest & land-cover scenarios analyzed across a) eras, b) countries, c) regions and d) under different climate regimes
Some thoughts on LCLUC Synthesis Requirements…..

- Identify important region/s WRT LCLUC
- Acquire very sound understanding of the key socio-economics and land-cover/land-use issues of the region or system under study
- Have a significant body of relevant previous and ongoing remote sensing-based research
- Have significant applicable methodologies to bring to synthesis
- Develop an ‘a priori’ integrative approach to synthesis
THANK YOU

Acknowledgments
- NASA LCLUC program
- Garik, Pasha, Chris
- Our team members
- Our Russian colleagues
- Our students