The Role of Climate Change and Human Activities in Changes of Land Cover and Land Use and Greenhouse Gas Emissions in Northern Eurasia

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Introduction

Northern Eurasia accounts for about 20% of the Earth's land surface and 60% of the terrestrial land cover north of 40°N. It contains 70% of the Earth's boreal forests and more than two-thirds of the Earth's land that is underlain by permafrost. The region is covered by vast areas of peatland, complex tundra in the north and semi-deserts and deserts in the south, including the Mongolia plateau. The surface air temperature has increased in the last half century and this increase will continue during this century. To date, studies have generally focused on analyzing climate change effects on biogeochemical processes and mechanisms governing the carbon and water dynamics in the region or potential changes in the distribution of natural vegetation. While we will also examine such issues, here we propose to investigate how patterns of land use in Northern Eurasia may change in the future due to: 1) Economic pressures for providing food, fiber and fuel to a growing global population; 2) Opportunities for expanding managed ecosystems into areas that experience a more favorable climate in the future; and 3) Abandonment of managed ecosystems in other areas that experience a less favorable climate. In our investigation, we will examine how these future changes in land use and land cover influence the exchange of CO_2 and CH_4 between terrestrial ecosystems and the atmosphere, terrestrial carbon storage and primary productivity, water supply and radiative forcing of the atmosphere through changes in surface albedo. We will also assess how human adaptation and quality of life may be impacted by these changes.

Research Goals

The research goals of this project are:

1. *Using satellite and remote sensing data and a general modeling framework, we will link socio--economic factors, land-use and land-cover change, ecosystem and biogeochemical dynamics, and climate models with observational data to understand the large-scale processes and thresholds in determining the feedbacks between the human dimension, the atmosphere, and ecosystem dynamics over the Northern Eurasia.*

2. *Using our modeling framework to conduct integrated assessment of economic, environmental, and climate impacts for next 50 to 100 years, we will provide information, which will help society and decision-makers to plan for the future to lessen the negative consequences of environmental changes over the Northern Eurasia and to benefit from the positive consequences*

To achieve these goals, the project designed the following studies with an integrated modeling consortium of terrestrial biogeochemistry, human dimension, and climate combining *in situ* and satellite ecosystem data:

Task 1: Refine land-cover and land-use data in the region using satellite and remote sensing products.

Task 2: Evaluate how climate change and human activities may influence land-cover and land-use change in Northern Eurasia over the next 50 to 100 years.

Task 3: Evaluate how CO_2 and CH_4 fluxes and carbon pools in Northern Eurasia have changed over the last three decades.

Task 4: Evaluate how CO_2 and CH_4 fluxes in Northern Eurasia may change over the next 50 to 100 years in response to changes of climate, atmospheric chemistry, land cover, and land use.

In addition, this project will also (1) evaluates the impacts of changes in terrestrial biogeochemistry and land-use and land-cover on regional and global climate and (2) assesses human adaptation and quality of life to changes in climate, atmospheric chemistry, land cover and land use in Northern Eurasia.

Data Development

To date, we have acquired all the available Landsat data over the Western Siberia region, and towards finishing acquiring data for the Eastern Siberia and Mongolia Plateau from 1973 to 2006 (http://glovis.usgs.gov/). We have also worked out the technical details to process the imageries and to detect changes of land cover and land use with the data. The techniques were applied to process the Landsat data for the Alaskan Yukon River Basin as a test-bed (Figure 1). Using the same techniques, we have been processing the data for the Western Siberian region. We have also acquired various land-cover and land-use data sets in this region such as the digital version of wetland distribution and classification data derived based on various existing satellite products and Russian ecoregions digital maps. These existing land-use and land-cover data will help us further develop land-cover and land-use data augmented by using Landsat data for the last 30 years in the region.

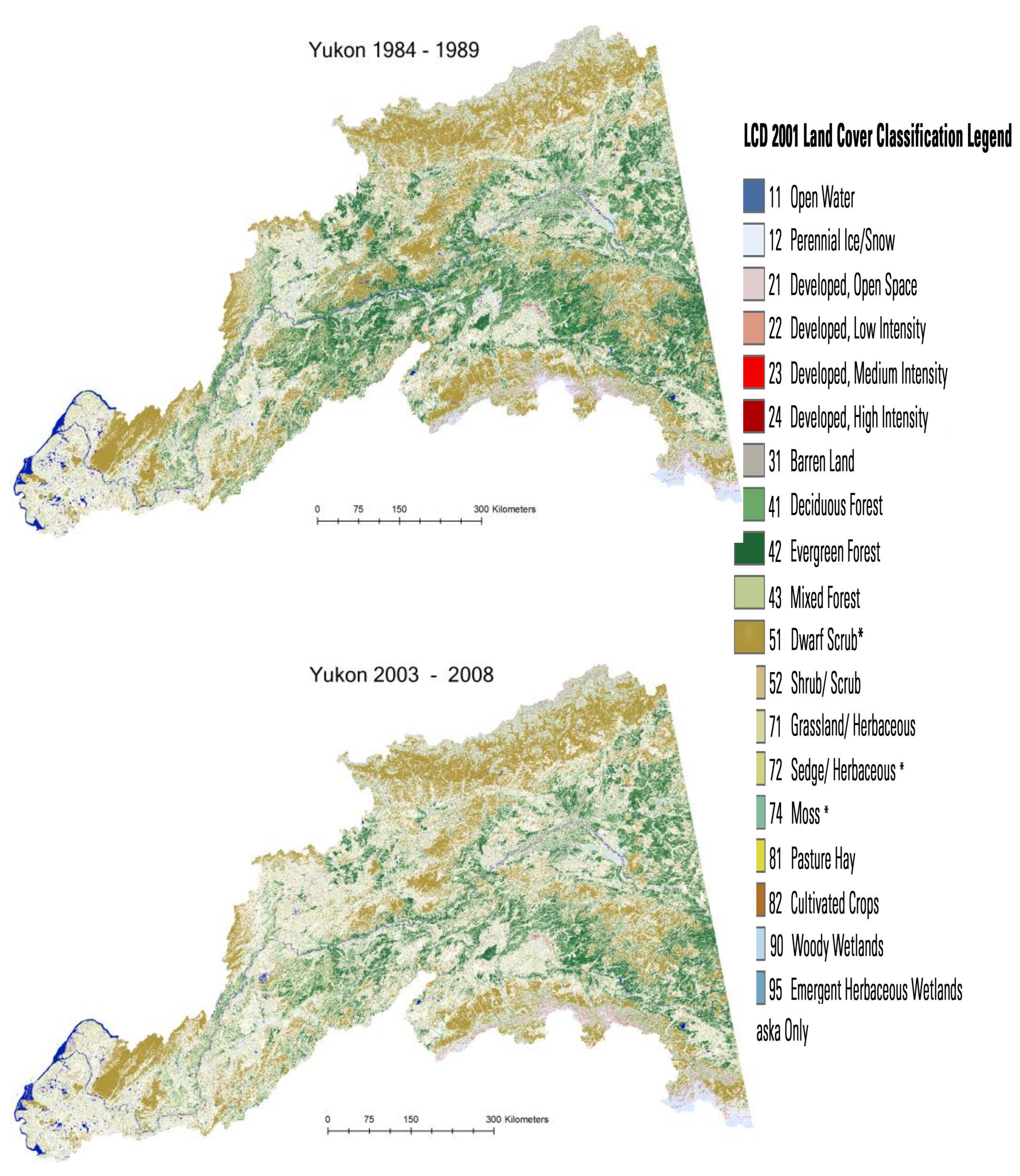

Figure 1. The land-use and land-cover change in Alaskan Yukon River Basin based on Landsat imageries. Top-left panel shows the land-cover composite during 1984-1989. Bottom-left panel shows the land-cover composite during 2003-2008. The classification was conducted based on 2001 National Land Cover Data land cover classification scheme (www.epa.gov/mrlc/nlcd-2001.html).

An integrated Global System Model and Preliminary Results

To evaluate how climate change and human activities may influence land-use and land-cover change in Northern Eurasia over the next 50 to 100 years**,** we first examine how climate change may influence the distribution of natural vegetation in the region with SiBCliM model and then examine the integrative effects of climate change, vegetation redistribution, and global economy on land-use change with the MIT Integrated Global System Model (MIT-IGSM) i (Figure 2). To date, we have conducted the MIT-IGSM to produce six climate scenarios for the 21st century. The vegetation simulations with SiBCliM driven with these climate scenarios have been ongoing.

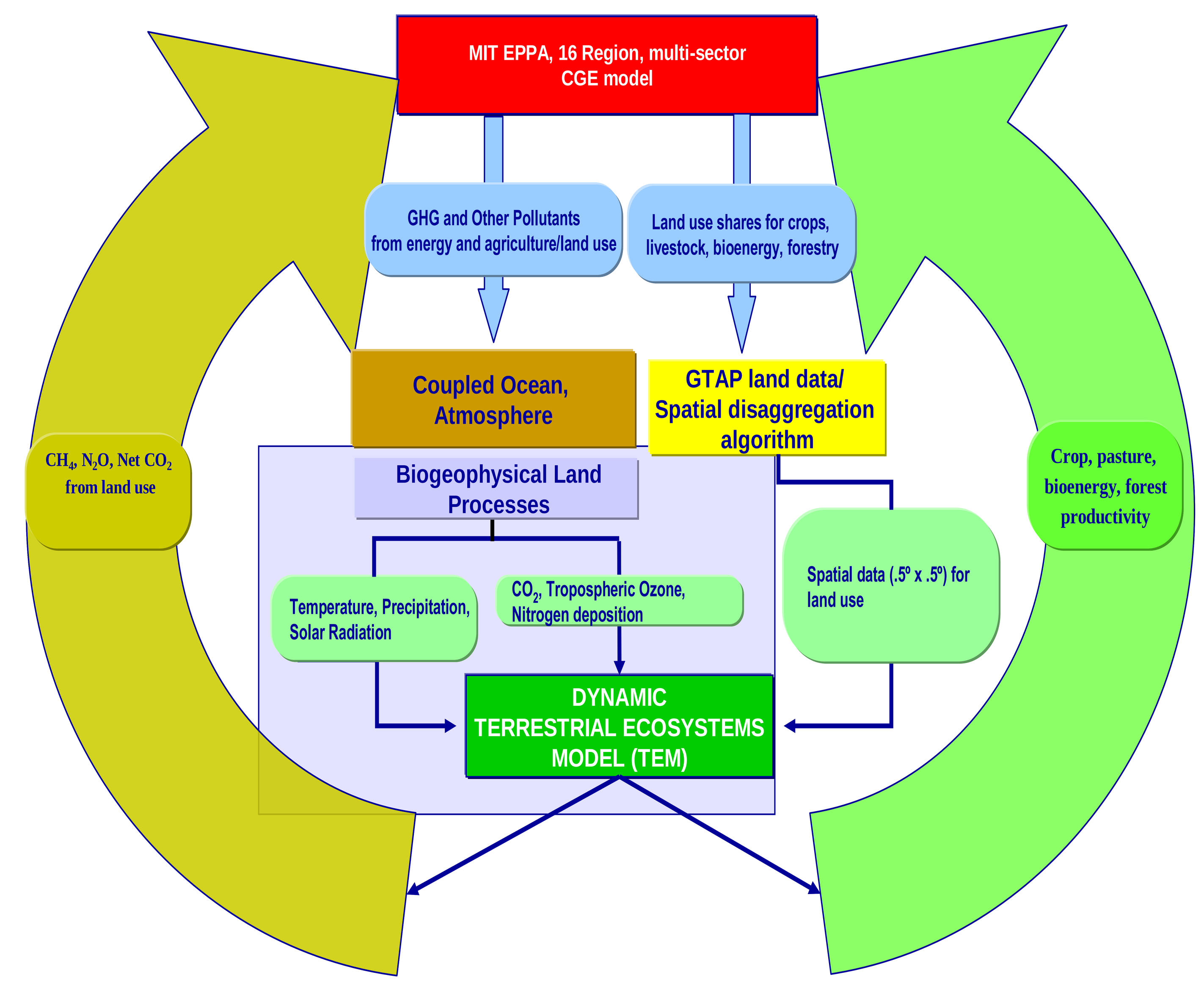

Figure 2. *The EPPA model produces policy and economic scenarios that lead to changes in economic activity in all sectors of the economy, leading to changes in emissions and land use. These changes drive the atmosphere-ocean general circulation model (AOGCM) and the Terrestrial Ecosystem Model (TEM). These change result, in turn, in feedbacks on the economic model. The linkages between the economic model, the AOGCM, and the TEM are simulated as a loosely coupled system, running EPPA to produce emissions scenarios, then the AOGCM with a reduced form version of TEM to produce climate scenarios, and then the TEM driven by climate and land use scenarios to produce productivity impacts. EPPA is then rerun with these productivity impacts, producing new scenarios of land use change, and TEM is rerun to estimate CO_2 and other trace gas impacts of the final land use scenarios.*

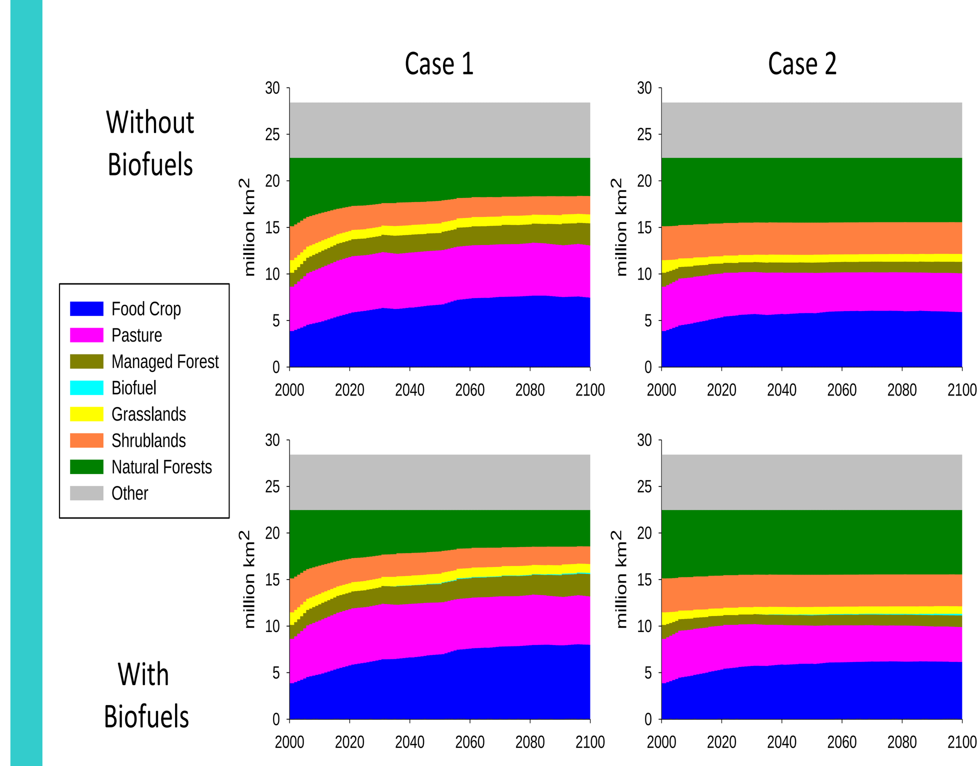

Figure 3. *Without considering detailed vegetation modeling, our integrated modeling framework has predicted the region will experience a significant land-use change due to global economic pressure. There are four scenarios created by two alternative characterizations of land use response and cases with and without a large second generation biofuels industry. All cases assume a greenhouse gas policy that is eventually operating globally and succeeds in keeping CO_2 concentrations to no more than about 550 ppm. The case 1 scenario land use allows unrestricted conversion of natural lands as dictated by economics. Case 2 creates a land supply elasticity based on land conversion response to rising land prices over the last decade. The greater willingness to convert in Case 1 generates a substantial conversion of forest and shrubland to other uses including crops, pasture and forest product production. Whether biofuels is produced globally or not does not have a particularly large effect. Little biofuels are projected to be produced in this region and it appears that global pressure through other markets is relatively limited. A more important driver of land use in this region may be the warming climate or other environmental change as it interacts with willingness to convert. To assess this we would need to construct scenarios without climate change. While in other parts of northern temperate regions, the observed willingness to convert land may reflect land use regulations and environmental valuation of natural systems, in this region less conversion in recent years may reflect unsuitable climate conditions that will not exist with climate change. Thus, the case 1 results may represent a more realistic land use scenario.*

Summary

Our preliminary results on land use and land cover show that there will be significant changes in land use in the region. Whether they occur or not depending on how land holders in the region will respond. Preliminarily it appears that climate change may be a more important factor in land use change than other forces, as with warming and increased CO_2 concentrations this region may become more productive. Further investigation is needed to confirm this hypothesis by including the simulated vegetation dynamics. We will also need to further investigate whether this land has other ecosystem values that may lead to its protection against conversion. The impacts of the land-use and land-cover changes on greenhouse gas emissions will then be evaluated. The human adaptation and quality of life in the region to changes in climate, atmospheric chemistry, land cover and land use will be assessed with the integrated system.

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