The Role of Climate Change and Human Activities of Northern Eurasia in the Global Changes of Land Cover and Land Use and Carbon Biogeochemistry

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Introduction and Research Objectives

In recent decades, the largest increase of surface air temperature and related climate extremes have occurred in northern Eurasia. This temperature increase and extreme climate are projected to continue during the 21st century according to climate models. The changing climate could affect land cover and the biogeochemical cycles in the region. These changes in biogeography and biogeochemistry, in turn, will affect how land use evolves in the future as humans attempt to mitigate and adapt to future climate change. Regional land-use changes, however, also depend on pressures imposed by the global economy. Feedbacks from future land-use change will further modify regional and global biogeochemistry and climate. Using a suite of linked biogeography, biogeochemical, economic, and climate models, we explore how future climate projections may influence regional vegetation distributions, carbon stocks and fluxes, and economic activity in northern Eurasia, and the impacts of these changes on land use and carbon cycling at the global scale during the 21st century.

Methods

We use a suite of models of climate, vegetation dynamics, biogeochemistry, and economy to evaluate (1) how climate change and human activities may influence land-use and land-cover change in Northern Eurasia over the next 100 years; (2) how these changes affect carbon cycling and productivity at the regional and global scale; and (3) how the consequences of carbon and productivity affect the global land use change. The climate change influence on the distribution of natural vegetation in the region is simulated with SiBCliM model. The integrative effects of climate change, vegetation redistribution, and global economy on land-use change is then projected with the MIT Integrated Global System Model (MIT-IGSM) (Figure 1).

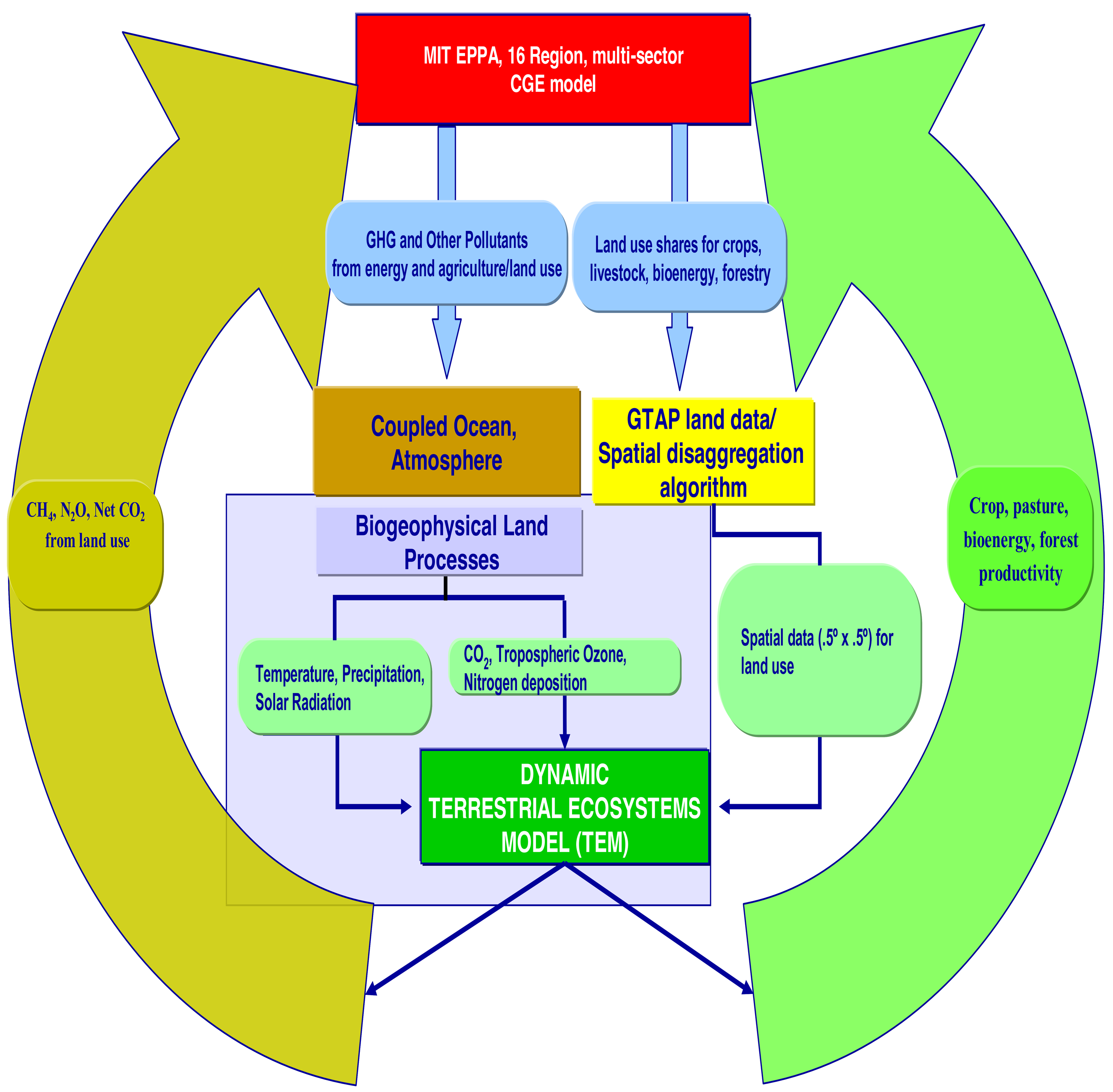
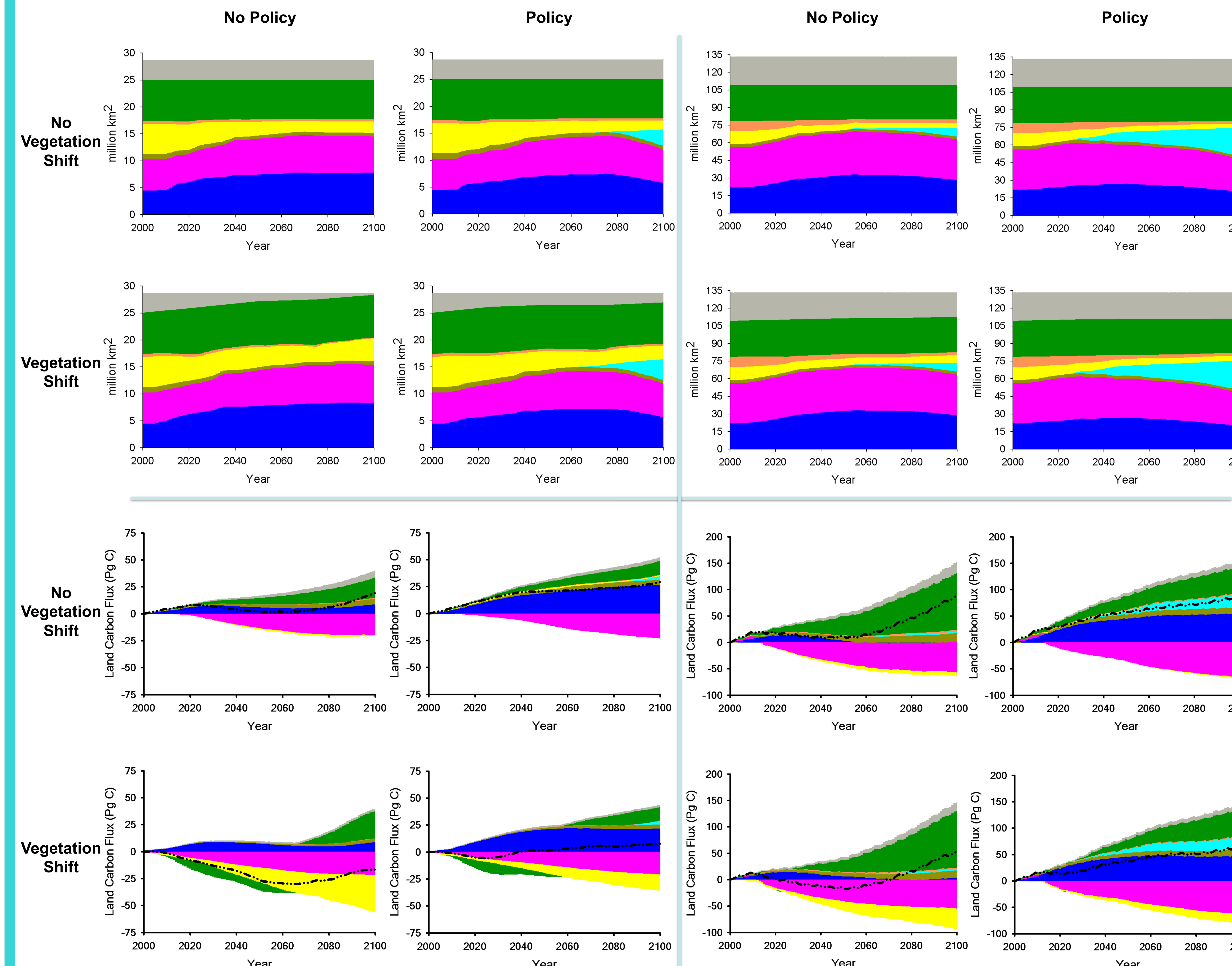


Figure 1. The EPPA model produces policy and economic scenarios that lead to changes in economic activity in all sectors of the economy, leading to changes in emissions and land use. These changes drive the atmosphere-ocean general circulation model (AOGCM) and the Terrestrial Ecosystem Model (TEM). These changes 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. A set of six simulations are conducted considering two climate policy scenarios including a climate policy (stabilized greenhouse gas emissions at 550 ppm CO_2-equivalent) and no-climate policy (business as usual) and three land-use and land-cover change scenarios including land use only, vegetation shift only, and land use and vegetation shift in Northern Eurasia.

Results



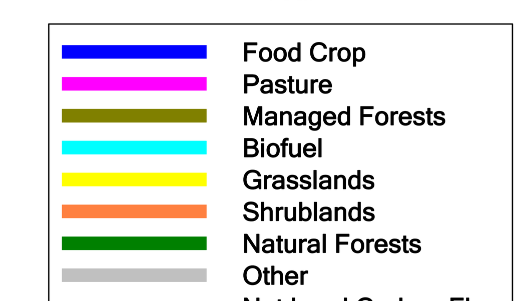


Figure 2. Land-cover and land-use change (upper panel) and land carbon flux (lower panel) in Northern Eurasia (left panel) and Global Land (right panel) over the 21st century.

Summary

By the end of the 21st century, the changing climate and global economy significantly changes the land use and land cover in Northern Eurasia. It appears that vegetation shift due to climate is a more important factor than the climate itself in driving land use change. At the global scale, however, the climate policy and climates significantly affect the land use at the global scale while the vegetation shift in Northern Eurasia has only a marginal effect. Under biogeography change conditions, Northern Eurasia will act as a cumulative carbon sink of 8 and source of 17 Pg C under the climate policy and non-policy scenarios, respectively, by the end of the 21st century. As consequences of changing climate and land cover and land use, the global land ecosystems will act as a cumulative carbon sink of 63 and 52 Pg C under the climate policy and non-policy scenarios, respectively. The vegetation shift in Northern Eurasia induced from changing climate affects both regional and global land use and decreases carbon sink activities at both regional and global scales.

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