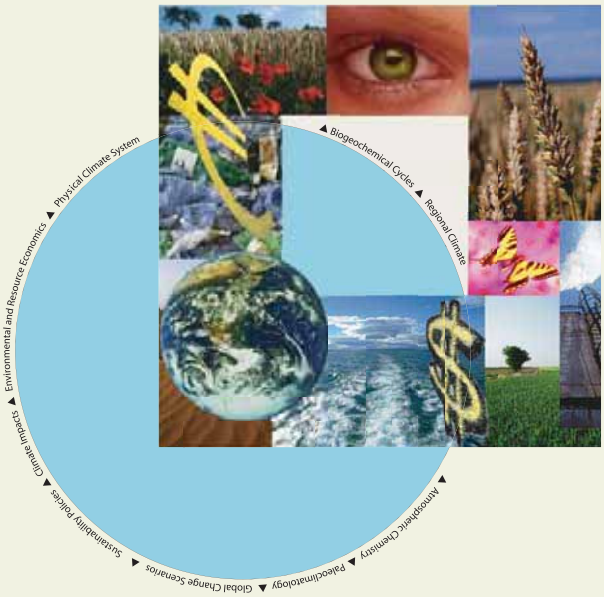
International Max Planck Research School on
EARTH SYSTEM MODELLING

A model estimate on the effect of anthropogenic land cover change on the climate of the last millennium

Julia Pongratz

PhD Thesis prepared within the
International Max Planck Research School on
Earth System Modelling



Abstract

Anthropogenic land cover change (ALCC) represents one of the most substantial human impacts on the Earth system, altering land surface properties and carbon fluxes. In this study, the role of ALCC for climate and the carbon cycle are assessed using a complex climate model. A special focus is placed on the preindustrial period, for which only few studies exist.

First, a method is developed to reconstruct spatially explicit changes in global agricultural areas and the resulting ALCC over the last millennium. Published maps for the last 300 years are extended into the past using country-level population data as a proxy for agricultural activity. This reconstruction is applied to calculate radiative forcing (RF) from ALCC-induced surface albedo changes. RF is found to be small throughout the preindustrial period on the global scale (negative with a magnitude less than 0.05 W/m^2) and not strong enough to explain the Northern Hemisphere cooling reconstructed from climate proxies between AD 1000 and 1900. An early anthropogenic impact on the energy balance, however, is found for the regional scale.

In transient coupled climate simulations the effects of ALCC are isolated by applying ALCC as the only climate forcing. The terrestrial biosphere releases 96 Gt C during AD 800–2000 in the simulations, increasing atmospheric CO_2 by 20 ppm. Primary emissions are quantified to 53–61 Gt C and 108 Gt C over the preindustrial and the industrial period, respectively. A high restorage of carbon by the biosphere due to the coupling to climate and atmospheric CO_2 occurs over the preindustrial period (48% of the primary emission). Nevertheless, the atmospheric CO_2 concentration is significantly increased by ALCC by 5–6 ppm prior to the Industrial Revolution. Historic events such as epidemics and warfare are found unlikely to be the cause for drops in ice-core CO_2. Global mean temperature increase due to ALCC amounts to 0.13–0.15 K in the 20th century, but remains within natural variability in the preindustrial era.

A simulation is performed to quantify the contribution from only the biogeophysical effects of ALCC in addition to the full climate response. Biogeophysical effects are found to contribute a weak cooling (−0.03 K in the 20th century). The rise in CO_2 from ALCC emissions is therefore the driving force of the simulated global warming. A comparison of biogeophysical temperature change and RF from albedo changes indicates that RF is not a comprehensive measure for the climatic importance of ALCC, especially in the tropical regions. Finally, the mitigation potential of reversing past ALCC is assessed: When reversing ALCC of the last millennium, most regions, including the northern mid- to high latitudes, would contribute a cooling effect.