Land cover change:

PRESENT

Bart van den Hurk[1], S.I. Seneviratne[2] and L. Batlle-Bayer[3]

[1]Royal Netherlands Meteorological Institute, De Bilt, Netherlands; bart.van.den.hurk@knmi.nl
[2]Department of Environmental Systems Science, Swiss Federal Institute of Technology Zürich, Switzerland; [3]Institute for Marine and Atmospheric research, University of Utrecht, Netherlands

Historic changes in land use have altered the land surface significantly. For example, since the early 19th century, there has been a substantial increase in the area of cropland in the middle latitudes of the Northern Hemisphere. The pronounced tropical deforestation during the 20th century has paralleled the large-scale development of urban settlements and irrigated agriculture. The land-cover changes have resulted in a number of alterations in the regional and global climate system, primarily by: 1) Changing the surface albedo; 2) Changing the surface evapotranspiration; 3) Modifying winds, heat wave resilience, vulnerability to floods and other such factors in the proximity of human settlements; and 4) Modifying atmospheric CO_2 uptake.

Changes in the albedo and evaporation have likely had a discernible effect on global mean temperatures since the late 19th century, although models show varying results of the net effects on climate (Pitman et al. 2009). Decreased forest cover has generally increased the surface albedo, thereby reducing the net energy available at the surface. This has possibly led to a downward modulation of the global mean warming rate (approximately 0.7°C since instrumental measurements began; IPCC 2007) by 0–0.1°C (de Noblet-Ducoudré et al., in press). Local land-atmosphere feedbacks generate large spatial variability of the land-use effects. In general, land-use-induced temperature changes are relatively small in the tropics, but increase significantly while moving to the equator. In areas with large deforestation (e.g. USA, central Eurasia) the local cooling has likely more than compensated for the global mean warming induced by elevated greenhouse gas concentrations (de Noblet-Ducoudré et al., in press; Fig. 1), although this finding needs to be balanced with the fact that deforestation itself has significantly contributed to the increase in CO_2 (Pongratz et al. 2010). Net effects of land use on evaporation are more uncertain than those on albedo. Higher evaporation may be alternatively found over forests or grassland depending on the local conditions (Teuling et al. 2010).

Apart from the direct impacts on the physical climate system, large-scale deforestation has resulted in a significant release of carbon to the atmosphere, adding to the CO_2-perturbation caused by fossil fuel burning. On top of the estimated 9.1±0.5 Gt carbon released from fossil resources in 2010, another estimated 0.9±0.7 Gt carbon was released by land-use change (Peters et al. 2011). Through the combination of CO_2 and biophysical effects, deforestation is expected to lead to a net climate warming in tropical regions, but possibly to a net cooling in boreal regions (Betts et al. 2007, Bonan 2008). However, human management could also play a role, because areas that are deforested tend to have higher carbon content and less snow cover (Pongratz et al. 2011). Another marked effect of land-use change on climate is an increase in vulnerability to climate extremes, both because of the potential inability of forest areas to dampen temperature extremes during the early heatwave stages, and because of the increased exposure to extreme events like floods.

In the context of the 5th Coupled Model Intercomparison Project (CMIP5), many Global Circulation Model projections have been carried out for a number of future socio-economic scenarios, including land-use change. Early results indicate that the overall magnitude of projected land-use change (that is, the conversion of natural vegetation to cropland) is generally smaller than observed during the 20th century in all future scenarios. The regional differences, however, are pronounced. Sub-Saharan Africa is projected to experience a significant increase of agricultural area in most of the scenarios, even in the low-emission scenario targeted to meet the 2-degree global warming criterion. The local expression of land-use interaction with climate and the large spatial variability of the nature and degree of land-use change calls for an increasing focus on assessing impacts of land-cover change at a regional level.

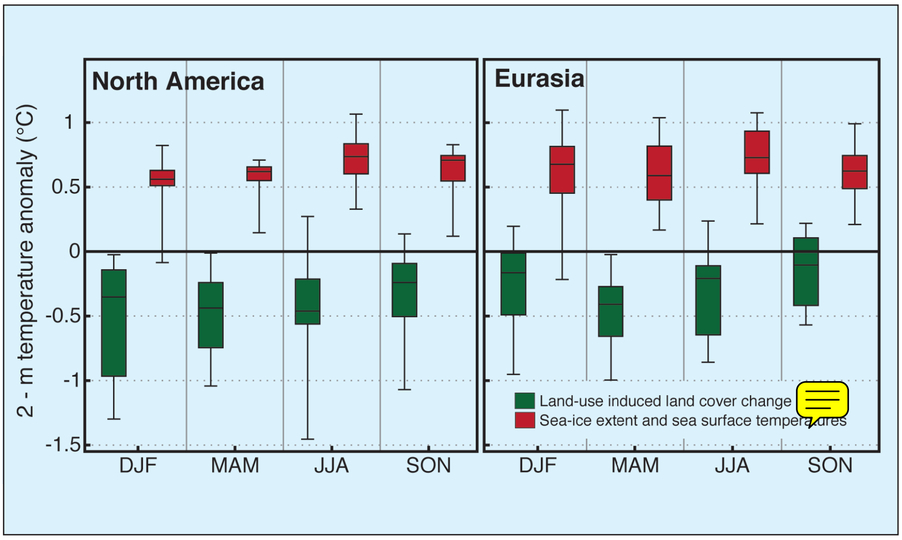

Figure 1: Effects of land use and CO_2 forcings on temperature change from pre-industrial to present-day in two heavily deforested areas (Central North America and Central Eurasia) as simulated with seven atmosphere-land models (de Noblet-Ducoudre et al., in press). Most simulations suggest that the propagating land use resulted in significant regional cooling, which approximately counteracted the concurrent CO_2-related warming in these regions.

References

Bonan GB (2008) *Science* 320: 1444

de Noblet-Ducoudré N et al. (in press) *Journal of Climate*, doi: 10.1175/JCLI-D-11-00338.1

Peters GP et al. (2011) *Nature Climate Change* 2: 2-4

Pitman AJ et al. (2009) Geophysical Research Letters 36, doi:10.1029/2009GL039076

Pongratz J et al. (2011) *Geophysical Research Letters* 38, doi: 10.1029/2011GL047848

Teuling AJ et al. (2010) *Nature Geoscience* 3: 722-727

For full references please consult:
http://www.pages-igbp.org/products/newsletters/ref2012_1.pdf

To what degree do human land cover dynamics affect climate change?

PAST

Jed O. Kaplan
ARVE Group, Swiss Federal Institute of Technology Lausanne, Switzerland; jed.kaplan@epfl.ch

During the 12,000 years preceding the Industrial Revolution, melting ice sheets, stabilizing sea level, and changes in temperature and precipitation patterns influenced global land cover. Over the same period, humans adopted agriculture, domesticated animals, developed metallurgy and other technologies, and evolved in their social and cultural systems. These changes led to exponential growth in human populations, urbanization, and the expansion of human settlements to the entire ice-free area of the world. Both human-induced and natural environmental change over the Holocene resulted in the transformation of the Earth's system by modifying land cover and through emissions of greenhouse gases and aerosols.

Preindustrial anthropogenic activities, mainly deforestation, rice cultivation, and domestication of ruminants, resulted in substantial emissions of CO_2 and CH_4 to the atmosphere. This change in greenhouse gas concentrations could have affected global climate to the point of precluding the inception of a new glacial period (Ruddiman 2003; Ruddiman et al. 2011). Ruddiman based his analysis on orbital forcing, thought to be the ultimate cause of ice age inception, and atmospheric CO_2 and CH_4 concentrations measured in ice cores. He concluded that greenhouse gas concentrations in the Holocene showed anomalous trends when compared to previous interglacials. Ruddiman's analysis has been criticized on the alignment between orbital forcing and greenhouse gas records, and because most previous interglacials show a time trend in orbital forcing that is not completely analogous to the Holocene. There is one undisputed feature of the Holocene, however, that we know makes this epoch different from the rest of Earth history: the existence of behaviorally modern humans.

The earliest significant impact humans probably had on large-scale land cover is the application of fire for the improvement of hunting and gathering opportunities. Even extremely low population densities can radically change land cover using fire (Bowman 1998; McWethy et al. 2009). Where an obvious anthropogenic trend is not identified in synthesis of charcoal records from sedimentary archives (Marlon et al. 2008) this may be a result of the fact that we have no appropriate baseline without human influence with which to assess the data, e.g. from previous interglacials.

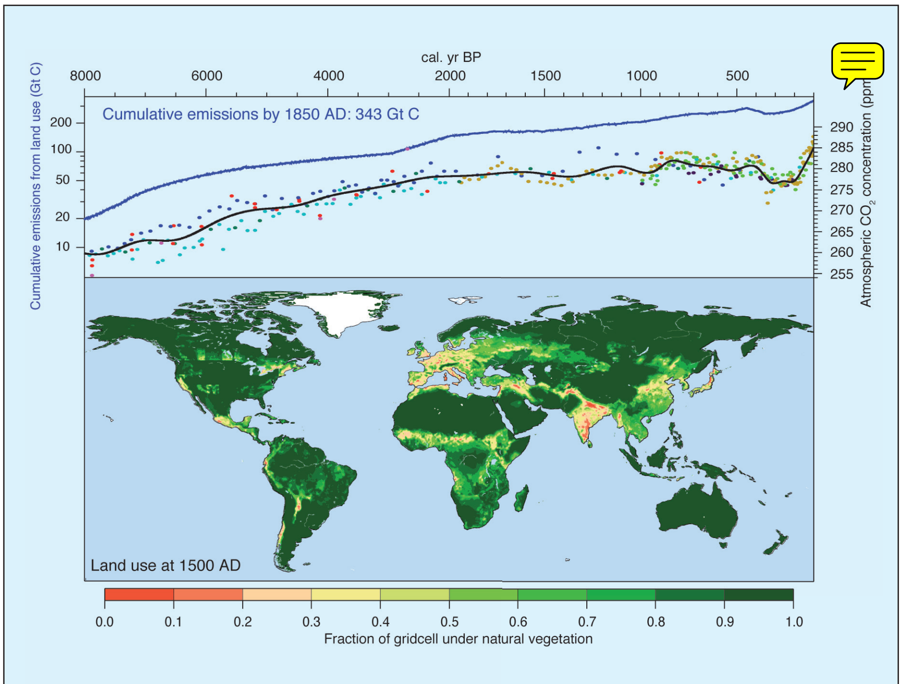

*Figure 1: **Top:** Preindustrial Holocene atmospheric CO_2 concentrations measured in Antarctic ice cores (dots, black line), and carbon emissions as a result of anthropogenic land cover change (blue line). **Bottom:** Global land use at 1500 AD, before the collapse of the indigenous populations of the Americas following European contact. For details and data sources, see Kaplan et al. 2011.*

With the Neolithic revolution, the human interaction with the landscape changed completely, with large areas of natural vegetation converted to cropland and pasture. Outside of river floodplains, early agriculture was inefficient, and meant that early farmers used much more land per capita than observed even in late preindustrial societies. Deforestation for agricultural land use and exploitation of forest resources for fuel, construction materials, and nutrients meant that human impact on the global carbon cycle could have been substantial (Fig. 1; Kaplan et al. 2011). Metal smelting began in the mid-Holocene and entailed large-scale deforestation as a result of the demand for fuelwood. Expansion of rice cultivation across East and South Asia accelerated beginning at about 6 ka and concomitant CH_4 emissions would have increased proportionally (Fuller et al. 2011).

While anthropogenic activities may have stabilized or increased greenhouse gas concentrations leading to a warmer global climate than would have occurred otherwise, the biogeophysical impact of deforestation and increases in aerosols could have had contrasting effects. Cooling could have occurred as a result of increased surface and atmospheric albedo, though climate-modeling experiments have shown that these effects are limited to the region where land cover change occurred. Furthermore, preindustrial human activities affected the global hydrological balance: deforestation leads to reductions in evapotranspiration and increases in runoff; these alterations could also have led to seasonally contrasting changes in regional climate. Thus, preindustrial human activities may have had an influence on regional and global climate over the Holocene, long before the Industrial Revolution.

References

Fuller DQ et al. (2011) *The Holocene* 21(5): 743-759

Kaplan JO et al. (2011) *The Holocene* 21(5): 775-791

McWethy DB et al. (2010) *PNAS* 107(50): 21343-21348

Marlon JR et al. (2008) *Nature Geoscience* 1: 697-702

Ruddiman WF, Kutzbach JE and Vavrus SJ (2011) *The Holocene* 21(5): 865-879

For full references please consult:
http://www.pages-igbp.org/products/newsletters/ref2012_1.pdf