LandCover6k: Global anthropogenic land-cover change and its role in past climate

Marie-José Gaillard¹ and LandCover6k Interim Steering Group members²

There is today a general understanding of the need for powerful climate models to inform societies on the climate’s possible development in the future. Climate models help us to understand the climate system as a whole and envisage our future. They have existed for many decades and have developed progressively into very complex Earth system models (ESMs) in which the atmosphere, the ocean and land-surface processes are coupled. Although already powerful, many of these ESMs are still under development. By using a model-data comparison approach, i.e. comparing model outputs with actual climate data over decades, centuries, and millennia back in time (paleoclimate data), both model outputs and paleodata can be better understood and evaluated, which also contributes to model improvements.

Land cover (here referring essentially to vegetation cover, but also bare soils and rocks) is an inherent part of the climate system. Natural, primarily climate-driven vegetation and ecosystem processes interact with human land use to determine vegetation cover on earth and its development through time. The resulting land-surface properties feed back to climate by modulating exchanges of energy, water, and greenhouse gases with the atmosphere through biogeochemical feedbacks (affecting sources and sinks of greenhouse gases, aerosols, pollutants, and other gases) and biogeophysical feedbacks (affecting heat and water fluxes, and wind direction and magnitude). The sum of these feedbacks may be either positive, i.e. amplifying changes in climate (e.g. amplifying a warming or a cooling trend), or negative, i.e. slowing trends in climate (e.g. slowing a warming or a cooling trend). Biogeochemical feedbacks, especially involving the carbon cycle, have received particular attention. However, biogeophysical feedbacks can have an effect of comparable magnitude; but because biogeophysical feedbacks generally operate at the regional scale they may be missed or underestimated at the relatively coarse resolution of Global ESMs. These feedbacks still represent a major source of uncertainty in climate projections under rising greenhouse gas concentrations. Therefore, the incorporation of dynamic vegetation into ESMs currently is one of the high priorities among climate modelers.

The effects of anthropogenic burning and deforestation on past global climate are not fully understood yet, and the question of whether humans had more impact than previously assumed on climate in prehistory (the Ruddiman hypothesis; Ruddiman 2003) is still a matter of debate. As long as the effects of land-use changes are not properly understood, mitigation strategies such as afforestation to sequester CO₂ and cool the climate might be erroneous. Moreover, the scenarios of past ALCCs often used in climate modeling, such as HYDE (Klein Goldewijk et al. 2011), the KK scenarios (Kaplan et al. 2009), and others (e.g. Pongratz et al. 2008), show large differences between each other (Gaillard et al. 2010). Therefore, climate modeling in paleo-mode taking into account anthropogenic land-cover change (ALCC) is seriously hampered. Thus, there is an imminent need for independent descriptions of past vegetation cover based on empirical data and an improved ALCC history at regional scales and globally. Such independent descriptions can be provided by pollen-based quantitative reconstructions of past vegetation cover such as those recently achieved for a large part of Europe (Trondman et al., in press; Fig. 1).

The methodological starting point for LandCover6k

Objective, quantitative long-term records of past vegetation cover changes are, however, still limited globally. Although biomization of pollen data (Prentice et al. 1996) has become a robust tool to reconstruct the distribution of biomes and their boundaries over the

Figure 1: Grid-based REVEALS estimates for the plant functional type (PFT) grassland (GL) for three Holocene time-windows. The scale is percentage cover, with the different colors indicating different percentage intervals: >0-10% in 2% intervals, 10-20% in a 10% interval, and 20-100% in 20% intervals. The category 0 (grey) corresponds to the grid cells with pollen records but no pollen data for the actual PFT and, therefore, no REVEALS estimates. The category >0-2 corresponds to REVEALS estimates different from zero (can be less than 1%) up to 2%. The uncertainties of PFT REVEALS estimates are shown by circles of various sizes in each grid cell with an estimate. The circles represent the coefficient of variation (CV; the standard error divided by the REVEALS estimate). When SE ≤ REVEALS estimate, the circle fills the entire grid cell and the REVEALS estimate is considered unreliable. This occurs mainly where REVEALS estimates are low. GL (all most common herbs): Artemisia species, Cyperaceae, Filipendula species, Poaceae (Gramineae), Plantago lanceolata, Plantago media, Plantago montana, Rumex acetosa-type (several species). Modified from Trondman et al. (in press).
The ultimate goal of LandCover6k is to improve the ALCC models and produce pollen-based land-cover reconstructions of past land cover and unforested for the 0.05 ka time window (modified from Pirzamanbein et al. 2014). From top to bottom, the pollen-based REVEALS estimates, the reconstruction from the intrinsic-Gaussian Markov Random Field model (IGMRF), and the present day land-cover data extracted from the forest map of Europe compiled by the European Forest Institute (EFI-FM). For details, see text and Pirzamanbein et al. (2014).