Estimating anthropogenic carbon release in north-western Europe during the Holocene – integrating pollen-based land use reconstructions with a dynamic vegetation model

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Jörgen Olofsson[1], Anna Broström[2], Anneli Poska[1], Anna-Kari Trondman[3], Florence Mazier[4], Guy Schurgers[1], Marie-José Gaillard[3], Thomas Hickler[5], Martin T Sykes[1] and LANDCLIM members*

Early agricultural activities have been suggested to explain the pre-industrial increase of atmospheric CO_2 and CH_4 concentrations since the mid-Holocene. Several studies have attempted to estimate the effect of past land use on global terrestrial carbon storage, based on spatial estimates of land use intensity primarily inferred indirectly using e.g. historical records, population density and per capita land requirement estimates, soil and climate suitability. However, the estimates on past human population size and locations incorporate high uncertainty levels, and the actual area of land used per person for agricultural activities is even less known. As a result, the existing global land use datasets show large discrepancies in spatial pattern and intensity of estimates

An alternative, and more direct, approach is to use palaeoecological proxies such as pollen records to quantitatively reconstruct past vegetation including human-induced land cover changes. In this study, a new direct method for quantifying past land use extent has been developed by combining (1) pollen-based quantitative vegetation reconstructions in north-western Europe for five time windows (6k, 3k, 600 and 200 cal. BP, and modern) by applying the REVEALS model and (2) simulated potential natural vegetation using a dynamic vegetation model, LPJ-GUESS. The developed continuous and dynamic land use scheme was applied to estimate the net effect on terrestrial carbon storage using LPJ-GUESS, and compared with results based on the indirect land use datasets HYDE v3.1 and KK10. Sensitivity analyses were performed to separate climate, atmospheric CO_2 and land use effects, and to determine the effect of alternative agricultural harvest implementations.

All three land use schemes showed a decrease in terrestrial carbon due to anthropogenic land use since at least 4k cal. BP, but the timing and spatial patterns (e.g. Baltic countries, central Europe, southern Scandinavia) of these decreases varied greatly. The impact on terrestrial carbon storage for the newly developed (direct) land use scheme for north-western Europe was found to be substantial, and of the same order as applying the KK10 land use dataset based on indirect methods. The cooling climate was found to be the main driver for carbon storage increase in potential natural vegetation during the mid- and late-Holocene, while atmospheric CO_2 became most important only in the industrial era. The carbon storage-enhancing climate and atmospheric CO_2 effects were roughly counterbalanced by land use effects since the mid-Holocene. Details in the agricultural harvest implementation were found to have a large impact on the course of terrestrial carbon storage.

Keywords Anthropogenic impact, carbon cycle, deforestation, dynamic vegetation model, Holocene, land cover reconstructions, land use, LPJ-GUESS, pollen data, REVEALS model.

[1]Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden
[2]Swedish National Heritage Board, Lund, Sweden
[3]Department of Biology and Environmental Sciences, Linnaeus University, Kalmar, Sweden
[4]GEODE UMR 5602, Toulouse University, Toulouse, France
[5]Biodiversity and Climate Research Centre (BiK-F) and Department of Physical Geography at Goethe-University Frankfurt, Frankfurt am Main, Germany
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Corresponding author: Jörgen Olofsson (jorgen.olofsson@nateko.lu.se)