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Holocene Land Cover Change in North America: Trends, Drivers, and Feedbacks

Andria Dawson[1], John W. Williams[2], Marie-José Gaillard[3], Simon Goring[2], Behnaz Pirzamanbein[4], Johan Lindstrom[5], R. Scott Anderson[6], Andrea Brunelle[7], David Foster[8], Konrad Gajewski[9], Daniel G. Gavin[10], Terri Lacourse[11], Thomas A. Minckley[12], Wyatt Oswald[13], Bryan Shuman[12], and Cathy Whitlock[14]

[1]Department of Mathematics and Computing and Department of Biology, Mount Royal University, Calgary, Canada
[2]Department of Geography and Center for Climatic Research, University of Wisconsin-Madison, Madison, USA
[3]Department of Biology and Environmental Science, Linnaeus University, Kalmar, Sweden
[4]Department of Statistics, School of Economics and Management, Lund University, Lund, Sweden
[5]Division of Mathematical Statistics, Centre for Mathematical Sciences, Lund University, Lund, Sweden
[6]School of Earth and Sustainability, Northern Arizona University, Flagstaff, USA
[7]Geography Department, University of Utah, Salt Lake City,
[8]Harvard Forest, Harvard University, Petersham, USA
[9]Département de géographie, environnement et géomatique, Université d'Ottawa, Ottawa, Canada
[10]Department of Geography, University of Oregon, Eugene, USA
[11]Department of Biology and Centre for Forest Biology, University of Victoria, Victoria, Canada
[12]Department of Geology and Geophysics, University of Wyoming, Laramie, USA
[13]Marlboro Institute for Liberal Arts and Interdisciplinary Studies, Emerson College, Boston, USA
[14]Department of Earth Sciences, Montana State University, Bozeman, USA

Land cover governs biogeophysical and biogeochemical feedbacks between the land surface and atmosphere. Holocene vegetation-atmosphere interactions are of particular interest, both to understand the climate effects of intensifying human land use and as a possible explanation for the Holocene Conundrum, a widely studied mismatch between simulated and reconstructed temperatures. Progress addressing the Conundrum has been limited by a lack of data-constrained, quantified, and consistent reconstructions of Holocene land cover change. Following protocols from PAGES LandCover6k, a network of 1445 sedimentary pollen records from the Neotoma Paleoecology Database, and the REVEALS pollen-vegetation model coupled with a Bayesian spatial model, we developed land cover reconstructions with uncertainty for North America for 25 time intervals spanning the Holocene. We use these spatially comprehensive land cover maps to determine the pattern and magnitude of land cover changes at continental to regional scales and discuss underlying ecological, climatic, and anthropogenic drivers. Finally, we infer Holocene radiative forcing from these land cover shifts.

Major land cover changes in North America include: 1) Early Holocene afforestation is attributed to rising temperatures and deglaciation, which likely amplified early Holocene warming via the

albedo effect; 2) A continental-scale mid-Holocene peak in summergreen trees and shrubs (8.5 to 4 ka) may have been caused by a positive and understudied feedback loop among insolation, temperature, and phenological seasonality. 3) A last-millennium decrease in summergreen trees and shrubs with corresponding increases in open land, likely driven by intensifying land use and neoglacial cooling.

Land cover trends vary within and across regions due to individualistic taxon-level responses to environmental change. Major species-level events, such as the mid-Holocene decline of eastern hemlock, may have altered regional climates. The substantial land-cover changes reconstructed here underscore the importance of biogeophysical vegetation feedbacks to Holocene climate dynamics. Continental-scale radiative forcing inferred from land cover change indicates early and late pre-industrial Holocene warming interrupted by a mid-Holocene period of cooling and followed by cooling in the recent millenia. These forcings from natural vegetation change are of the same order of magnitude as global forcings resulting from changes in atmospheric greenhouse gas concentrations from 1750 to 2019.

These Holocene reconstructions for North America serve the Earth system modeling community by providing better-constrained land cover scenarios and benchmarks for model evaluation, that improve the understanding of regional- to global-scale processes driving Holocene land cover dynamics.