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A regional scale assessment of land use/land cover and climatic changes on water and energy cycle in the upper Midwest United States

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ABSTRACT: This study examines the relative impact of regional land-cover/land-use patterns and projected future climate change on hydrologic processes. Historic, present and projected future land cover data were used to drive the variable infiltration capacity (VIC) model using observed meteorological forcing data for 1983–2007 over Wisconsin (USA). The current and projected future (year 2030) land cover data were developed using the land transformation model (LTM). The VIC model simulations were driven using downscaled and bias-corrected projected future climate forcing from three different Intergovernmental Panel for Climate Change (IPCC) AR4 general circulation models (GCMs): HadCM3, PCM and GFDL. Sensitivity results conducted on a single grid cell show that annual average surface runoff and baseflow were increased by 8 and 6 mm, respectively, while evapotranspiration was reduced by 15 mm when a fully forested grid was converted to cropland. Results also indicate that annual average net radiation and sensible heat flux were reduced considerably due to forest-to-cropland conversion, and the reduction was more prominent in winter and spring seasons due to effect of snow albedo. Forest-to-cropland conversion also resulted in increased latent heat flux in summer (JJA) while this land transformation increased the snow water equivalent in winter (DJF) and spring (MAM). Complete conversion of forest to cropland resulted in a decrease of the radiative surface temperature on an annual basis with more cooling occurring in winter and summer. Impacts of historic deforestation were similar to what was expected based on a single grid sensitivity analysis.

KEY WORDS Land cover change; land-use change; climate change; land surface response; sensitivity analysis; water and energy cycle; deforestation/reforestation; urbanization; VIC; IPCC

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1. Introduction

Land-use and climate changes are major drivers of the Earth's water and energy cycle (Mahmood *et al*., 2010). Land-cover/land-use change (LCLUC) has extensively altered the Earth's surface with forest to cropland and ongoing conversions of cropland to urban (Foley *et al*., 2005). Historically, LCLUC in the upper Midwestern United States has been largely deforestation, as forests were cleared to obtain wood products and to expand agriculture (Whitney, 1987; Radeloff *et al*., 2005; Ray and Pijanowski, 2009). Today, only half of the original forested land remains (Cole *et al*., 1998). More recently, urban expansion is becoming a dominant LCLUC process in the region doubling its footprint every 20–30 years.

Deforestation has been shown to impact water and energy fluxes as well as alter near-surface climate dynamics (Pielke *et al*., 2002). Bonan (1997, 1999, 2001) studied the role of temperate forest conversion to cropland on near-surface climate and found that it led to spring cooling in the Eastern United States but summer warming in the Western United States. Temperate forests experience high seasonal variability in their impacts on water and energy fluxes due to the presence of snow in winter and spring seasons (Snyder *et al*., 2004). During winter and spring, the removal of temperate forests results in higher snow accumulation, higher surface albedo and less absorption of net radiation at the land surface. In summer, removal of temperate forests results in lower latent heat fluxes and latent cooling, an increased surface albedo and decreased net radiation (Snyder *et al*., 2004). There is, however, great uncertainty in assessing the impacts of removing temperate forests on land surface interactions (Betts, 2001; Bala *et al*., 2007; Betts *et al*., 2007; Jackson *et al*., 2008; Bonan, 2008).

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