Declining Snow Cover Reduces Radiative Cooling from Historic Land Use Change in the Western Great Lakes Region

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The Midwest in the Anthropocene

- Land use and snow cover have changed in the Great Lakes Region since European settlement
- These changes alter the brightness and temperature of the land surface with implications for climate

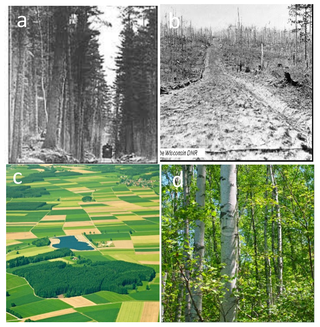

Figure 1: Typical land use history in the Great Lakes Region. Landscapes (a) before deforestation, (b) immediately after deforestation, and (c, d) today.

Questions

- How have historic changes in land use altered the **albedo and surface temperature** of the Great Lakes Region?
- What are the **radiative forcings** of these changes and how do they **offset each other?**
- How has the climatically driven **decrease in snow cover** impacted these effects?

Reconstructing Historic Vegetation

- Forest cover has decreased since European settlement
- Deciduous and mixed forests have mostly replaced evergreen forests where forest regrowth is occurring

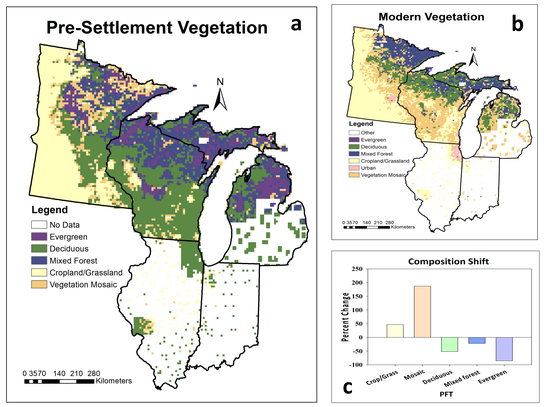

Figure 2: Vegetation cover on the (a) historic landscape (b) modern landscape. Percent change in vegetation cover is shown in (c). We used gridded Public Land Survey (PLS) data to assign land cover classifications using International Geosphere Biosphere Programme (IGBP) designations as follows: evergreen forest (> 60% evergreen sp. cover), deciduous forest (> 60% deciduous sp. cover), mixed forest (> 60% forest cover, mixed composition), vegetation mosaic (20% - 60% forest cover), and cropland/ grassland(< 20% forest cover).

Reconstructing Land Surface Traits

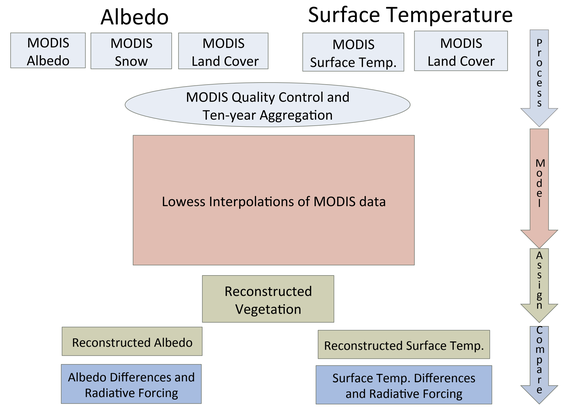

Figure 3: Methodology for reconstructing historic albedo and surface temperature, calculating changes since European settlement and calculating radiative forcing of those changes. Interpolations of modern MODIS data were used to assign biophysical properties to the map of historically reconstructed vegetation.

Land Surface Changes

Albedo

- Albedo forcing is always negative with the greatest cooling in winter
- Overall radiative forcing from albedo change is large and negative (μ = -1.64 W/m^2)

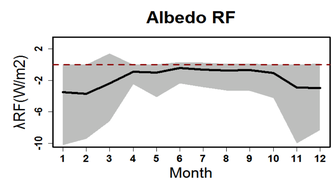

Figure 4: Seasonal profile of radiative forcing for albedo change. Gray shading designates 10% and 90% quantiles.

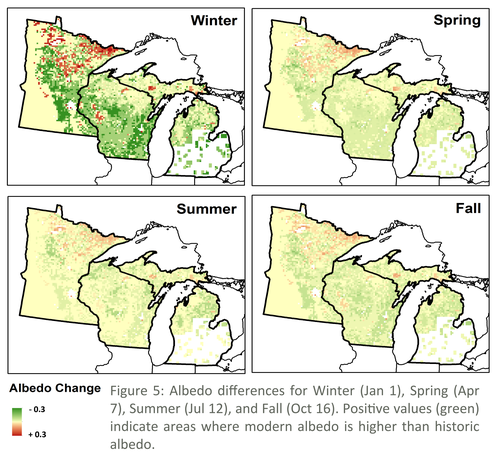

Figure 5: Albedo differences for Winter (Jan 1), Spring (Apr 7), Summer (Jul 12), and Fall (Oct 16). Positive values (green) indicate areas where modern albedo is higher than historic albedo.

Surface Temperature

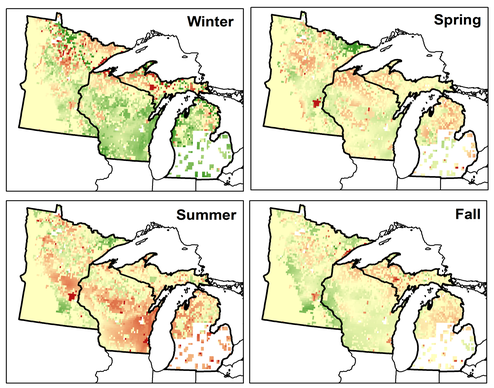

Figure 6: Surface temperature differences for Winter (Jan 1), Spring (Apr 7), Summer (Jul 12), and Fall (Oct 16). Negative values (green) indicate areas where modern surface temperature is lower than historic surface temperature.

- Surface temperature forcing is strongly positive in summer and weakly negative in winter.
- Net forcing from surface temperature change weighted by day length is small and positive (μ = +0.37W/m^2)

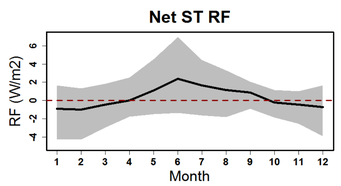

Figure 7: Seasonal profile of radiative forcing for surface temperature change. Gray shading designates 10% and 90% quantiles.

Snow Cover Changes

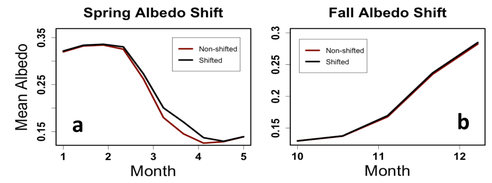

Figure 8: Spring (a) and Fall (b) shifts in Albedo due to changes in snow cover. Black lines represent historically reconstructed Albedo shifted to reflect historic snow cover. Red lines show non-shifted historically reconstructed Albedo.

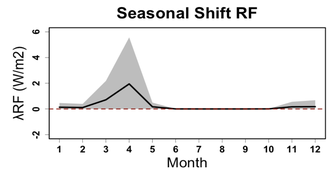

Figure 9: Seasonal profile of radiative forcing for surface temperature change. Gray shading designates 10% and 90% quantiles.

- Spring snow melt is delayed, increasing albedo in Feb - May
- Spring forcings are typically an order of magnitude larger than fall
- Net forcing from the shift in snow seasonality is positive but small (+0.45 W/m^2)

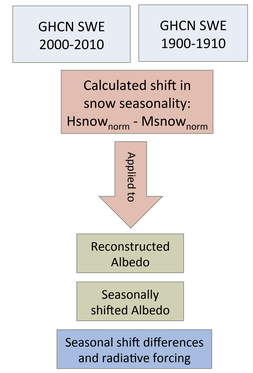

Figure 10: Methodology for seasonal shift in albedo based on changes in snow cover. Global Historic Climate Network (GHCN) snow water equivalents were used to calculate seasonal shift

Combined Forcing

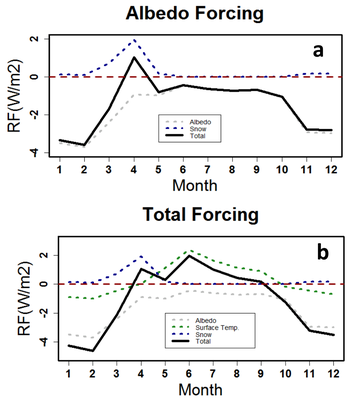

Figure 11: Albedo (a) and total (b) radiative forcings of land use change in the Great Lakes Region. Dashed lines indicate component forcings.

Conclusions

- Surface temperature changes offset 23% of year-round albedo forcing
- Climatic shifts in snow seasonality offset 18% of year-round albedo forcing
- Combined forcing is **41% lower** than vegetation-mediated albedo forcing alone

The negative forcings of historic land use change currently provide a "discount" on regional warming but these benefits are likely to disappear with time as snow cover decreases and forest regrowth continues

Acknowledgements

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