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Regional summer cooling from agricultural management practices that conserve soil carbon in the northern North American Great Plains

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Conserving soil carbon resources while transitioning to a C negative economy is imperative for meeting global climate targets, and can also have critical but under-investigated regional effects. Parts of the North American northern Great Plains have experienced a remarkable 6 W m^{-2} decrease in summertime radiative forcing since the 1970s. Extreme temperature events now occur less frequently, maximum temperatures have decreased by some 2 ˚C, and precipitation has increased by 10 mm per decade in some areas. This regional trend toward a cooler and wetter summer climate has coincided with changes in agricultural management. Namely, the practice of keeping fields fallow during summer (hereafter 'summerfallow') has declined by some 23 Mha from the 1970s until the present in the Canadian Prairie Provinces and across the U.S., an area of similar size to the United Kingdom. In addition to potential climate impacts, replacing summerfallow with no-till cropping systems results in lesser soil carbon losses – or even gains - and usually confers economic benefits. In other words, replacing summerfallow with no-till cropping may have resulted in a 'win-win-win' scenario for regional climate, soil carbon conservation, and farm-scale economics. The interaction between carbon, climate, and the economy in this region – and the precise domain that has experienced cooling - are still unknown, which limits our ability to forecast coupled carbon, climate, and human dynamics. Here, we use eddy covariance measurements to demonstrate that summerfallow results in carbon losses during the growing season of the same magnitude as carbon uptake by winter and spring wheat, on the order of 100 – 200 g C m^{-2} per growing season. We use eddy covariance energy flux measurements to model atmospheric boundary layer and lifted condensation level heights to demonstrate that observed regional changes in near-surface humidity (of up to 7%) are necessary to simulate observed increases in convective precipitation, and use a slab atmospheric model to quantify the role of land cover in convective initiation. We analyze climate data to demonstrate that areas with extensive summerfallow decline are not necessarily those that have experienced summer cooling, and provide a framework for quantifying connections between climate, carbon, and human behavior across the northern North American Great Plains using a coupled modeling framework. Ongoing research will quantify how biofuels and other approaches to manage lands for energy create opportunities and conflicts within the food-energy-water nexus in the Upper Missouri River Basin, and investigate sustainable pathways during the transition toward a BECCS (Bio-energy with carbon capture and storage) economy.