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Simulating modern-day cropland and pasture burning in an Earth system model

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Throughout the Holocene, humans have extended our influence across a larger and larger fraction of ecosystems, even creating some new ones in the process. Herds of livestock grazing either native vegetation (rangeland) or specially planted species (pasture) have modified huge areas of land. We have even developed new plant species and cultivated them as crops. The extent of our ecosystem modification intensified dramatically with the advent of industrialized agriculture, to the point where cropland and pasture (which will henceforth encompass rangeland as well) now cover over a third of the Earth's land area.

One way we have altered the terrestrial biosphere is by intentionally and unintentionally altering fire's frequency, intensity, and seasonal timing. This is especially true for agricultural ecosystems. Because their maintenance and use require a level of human control, cropland and pasture often experience fire regimes substantially different from those of the ecosystems they replaced or what would occur in the absence of active fire management. For example, farmers might burn to prepare land for planting or to dispose of crop residues, and pastoralists often use fire to prevent encroachment of unpalatable woody plants. Due to the vast global extent of agriculture, and considering the myriad ways fire affects the Earth system, it is critical that we understand (a) the ways people manage fire on cropland and pasture and (b) the effects of this management on the Earth system.

Earth system models are an ideal tool for examining this kind of question. By simulating the processes within and interactions among the atmosphere, oceans, land, and terrestrial ecosystems, Earth system models allow phenomena such as fire to be examined in their global context. However, while the past fifteen years have seen great progress in the simulation of vegetation fire within Earth system models, the direct human influence via cropland and pasture management burning has been mostly ignored. Instead, indirect functions are usually used to incorporate human influence based on population density and economic factors.

This paper describes a global fire model that incorporates knowledge from new estimates of cropland and pasture burning to explicitly simulate fire on those lands across the world. After briefly describing some of the agricultural fire patterns observed in Eurasia, we detail the structure of the model and context in which it was developed. We then use the model to investigate the contribution of cropland and pasture fire to emissions of greenhouse gases and aerosols, as well as net carbon cycling across the globe.