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Climate- and disturbance-driven changes in vegetation composition and structure limit future potential carbon storage in the Greater Yellowstone Ecosystem, USA

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The Greater Yellowstone Ecosystem (GYE) provides unique opportunities to understand how changing climate, land use, and disturbance affect ecosystem carbon balance. The GYE is one of the largest, most intact ecosystems in the United States. However, distinct management histories on National Park, National Forest, and private lands, elevational climate gradients, and variable fire activity, have created a mosaic of stand ages and forest types. It is uncertain how greenhouse forcing may alter the carbon balance of the GYE. Whereas increasing temperatures may enhance productivity and perpetuate the GYE as a carbon sink, climate-driven increases in fire frequency may offset productivity gains by limiting biomass accumulation. We investigated how changes in fire frequency and size may affect vegetation dynamics and carbon sequestration potential in the GYE using the LANDIS-II dynamic landscape vegetation model. LANDIS-II provides sufficient spatial resolution to capture landscape-level variation in forest biomass and forest types (i.e. 90×90 m grid cells), but can integrate disturbance regimes and vegetation dynamics across the entire GYE (92,000 km^2). We initiated our simulations with biomass and stand conditions that preceded the exceptional 1988 fire, when 16% of the GYE burned. We inferred the biomass, species abundances, and stand demographics of each model cell by combining satellite imagery with forest inventory data, and developed two fire regime scenarios from historical fire records. We developed a historic wildfire scenario with infrequent fires by excluding 1988 from our calibration of fire sizes and frequencies, and a future scenario with more frequent and larger fires by including 1988 in our calibrations. Fire frequency increased in all forest types in our future scenario, with a 152% increase in the annual forest area burned relative to observed area burned during recent decades. However, the changes in fire frequency varied among forest types, with the largest increases in lodgepole pine (*Pinus contorta*; 332% increase) and spruce/fir (*Picea engelmannii*, *Abies lasiocarpa*; 243% increase) stands. In model runs with the historic fire regime, average stand age and live biomass remained consistent with pre-1988 values during the 200-year simulation period; biomass increased significantly only in recently-logged areas. In contrast, a marked shift to younger stands with lower biomass occurred in the future fire scenario. Average stand age declined from 112 years to 31 years in lodgepole pine stands, and from 191 years to 65 years in spruce/fir stands, with consequent reductions in living biomass. A smaller shift in stand age was simulated for douglas-fir (*Pseudotsuga menziesii*) stands (i.e. 121 to 92 years). These fire-driven changes in stand age and biomass coincided with important shifts in species abundances. Specifically, lodgepole pine stands replaced large areas previously dominated by spruce and fir. Our results suggest that the potential for increasing the amount of fossil fuel emissions offset by carbon sequestration on public lands in the American West is limited by ongoing changes in disturbance regimes. Instead, land managers may need to consider strategies to adapt to climate change impacts.