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Quantifying land fragmentation impacts on fire at global, biome and population scale

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Abstract

Human land use change (LUC) affects a third of the terrestrial surface, whose fragmentation results in large-scale biodiversity loss, habitat degradation, changes to the surface energy balance and biogeochemical cycling, resulting in around one-third of global carbon (C) emissions. LUC is forecast to increase substantially by 2100, while C emissions and attendant increases in global temperatures will perturb atmospheric and hydrologic circulations, combining to increase the future frequency and severity of fire event, the global area prone to frequent fire (+ ~30%), and population-exposure to their immense socioeconomic cost. LUC and fire may thus be united by a third theme: how differential pathways toward socioeconomic development feed back onto socioeconomic risk. To date however, no process-based representation of the link between the two has been developed, severely restricting the capacity of a sustainable land and transport infrastructure policy to plausibly reflect their cost-benefit implications with respect to fire probability. It also fundamentally hampers mechanistic understanding and forecasting of fire behaviour, and efforts to understand humans' role in altering prehistoric fire regimes. Here we target these shortfalls by using a global land surface model to quantify the impact of land fragmentation on fire, and the spatial and biome - scale sensitivity of fire to population density and fragmentation extent. We find that overall, fragmentation leads to decreases and increases in annual burned area (BA) of -21.5 and +17 mHa yr-1, equivalent to around 4% and 3% of global BA, (net ~1%), although this masks localised BA changes of <-90% and >+100%. Generally, highly fragmented regions experience less fire, while low-moderately fragmented regions saw a positive effect on BA. The BA response to increasing fragmentation was highly biome-specific however, with a generally decreasing BA trend over temperate grasslands, and a positive sinusoidal BA trend over tropical forest areas. While the effect of fragmentation on BA and fire intensity was generally coupled in sign, we found that in large swathes of

boreal and tropical forest, fragmentation could lead to less BA but greater fire intensity. Tropical forests are shown to be especially fire-sensitive to fragmentation, as has been suggested empirically, with modelled increases in fragmentation-related fire activity greatest over existing areas of deforestation and plantation clearing, particularly in Indonesia and Amazonia. Overall, the geographic and biome-specific fire effects of fragmentation found herein provide a starting point for risk-based impact assessments of sustainable economic, land and transport development policies in an increasingly anthropocentric future.

Keywords: Fragmentation, global burned area, land use policy, tropical degradation

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