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An eco-evolutionary approach to modelling wildfire regimes

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Wildfires are ubiquitous and an integral part of the Earth System, vital for maintaining the biodiversity and functioning of many ecosystems. Wildfire-induced changes in vegetation and landscape properties also have important feedbacks to climate through modulating water- and energy-exchanges and the carbon cycle. The current state-of-the-art global models used to predict how wildfires might behave in a changing climate capture some aspects of wildfire behaviour, but are poor at simulating fire seasonality, interannual variability and extreme fires, in large part because they do not adequately capture the vegetation-wildfire interactions regulating fire occurrence. Eco-evolutionary optimality approaches are increasingly being used to provide simple but robust models of vegetation functioning, and here we extend this approach to modelling wildfires.

Fuel availability and fuel dryness are consistently shown to be the primary drivers of wildfire occurrence, intensity and burnt area. Differences in the timing of fuel build up and drying determine the optimal time for wildfire occurrence and give rise to pyroclimates with distinct wildfire regimes. The phase difference in the seasonal time course and magnitude of gross primary production (GPP) and vapour pressure deficit (VPD) is used to provide a measure of the "propensity to burn", which in turn can be translated into a probability for fire occurrence. An EEO-based model of the seasonal cycle of GPP is then used to derive litter fall and hence the inputs to dead fuel loads along with an empirically based formulation of decomposition to determine changes in the actual dead fuel load through time. We use an EEO-based model of biomass production efficiency to derive tree and grass cover, where the grass cover and dead fuel load together will determine the incidence of ground fires and tree cover the incidence of crown fires. We show that this simple model produces realistic simulations of spatial and temporal patterns in wildfire occurrence, and thus provides a basis for simulating the impact of wildfires on vegetation loss, post-fire recovery and ultimately feedbacks to climate.