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# Complex systems approach to fire dynamics and climate change impacts

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I present some recent advances in complex systems theory as a contribution to understanding fire regimes and forecasting their response to a changing climate, qualitatively and quantitatively.

In many regions of the world, fire sizes have been found to follow, approximately, a power-law frequency distribution. As noted by several authors, this distribution also arises in the "forest fire" model used by physicists to study mechanisms that give rise to scale invariance (the power law is a scale-invariant distribution). However, this model does not give and does not pretend to give a realistic description of fire dynamics. For example, it gives no role to weather and climate.

Pueyo (2007) developed a variant of the "forest fire" model that is also simple but attempts to be more realistic. It also results into a power law, but the parameters of this distribution change through time as a function of weather and climate. Pueyo (2007) observed similar patterns of response to weather in data from boreal forest fires, and used the fitted response functions to forecast fire size distributions in a possible climate change scenario, including the upper extreme of the distribution.

For some parameter values, the model in Pueyo (2007) displays a qualitatively different behavior, consisting of simple percolation. In this case, fire is virtually absent, but megafires sweep through the ecosystem a soon as environmental forcings exceed a critical threshold. Evidence gathered by Pueyo et al. (2010) suggests that this is realistic for tropical rainforests (specifically, well-conserved upland rainforests). Some climate models suggest that major tropical rainforest regions are going to become hotter and drier if climate change goes ahead unchecked, which could cause such abrupt shifts.

Not all fire regimes are well described by this model. Using data from a tropical savanna region, Pueyo et al. (2010) found that the dynamics in this area do not match its assumptions, even though fire sizes are also well fitted by a power law. A possible interpretation is that the spatial structure of fire in savannas is strongly constrained by the spatial structure of their environment. Instead of resulting from ecosystem self-organization as in the model, in this case the scale invariance in fire events would be just a reflection of scale invariance in the environment in which the ecosystem lives.

These results suggest at least three major types of fire dynamics: endogenous scaling, percolating, and exogenous scaling, in addition to intermediate options. The world's biomes can be classified based on the type of dynamics that is most likely to apply in each of them, and forecasts can be carried out with the tools developed for each of these types.

References

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