Potsdam Institute for Climate Impact Research

Extreme fires and drought in the Amazon rainforest

The Amazon rainforest is important for maintaining global and continental climate. Under low governance, deforestation rates and fire increase again, while ongoing climate change increases droughts.

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ABSTRACT

Fires are again increasingly used to clear land in the Amazon rainforest which fragment tropical rainforests. High-resolution, remotely sensed data are required to link fire activity to land-cover and deforestation. We apply a complex networks approach to identify high-intensity, i.e. extreme, fires occurring in evergreen tropical forest between 2002 and 2019. We analyse the spatiotemporal distribution of extreme fires in under different observed climate conditions and human pressure. Where deforestation is most prevalent, extreme fires occur along major roads. All extreme forest fires occur within a 0.5-km distance from forest edges and up to 56% of them are found within a 1-km distance from roads.

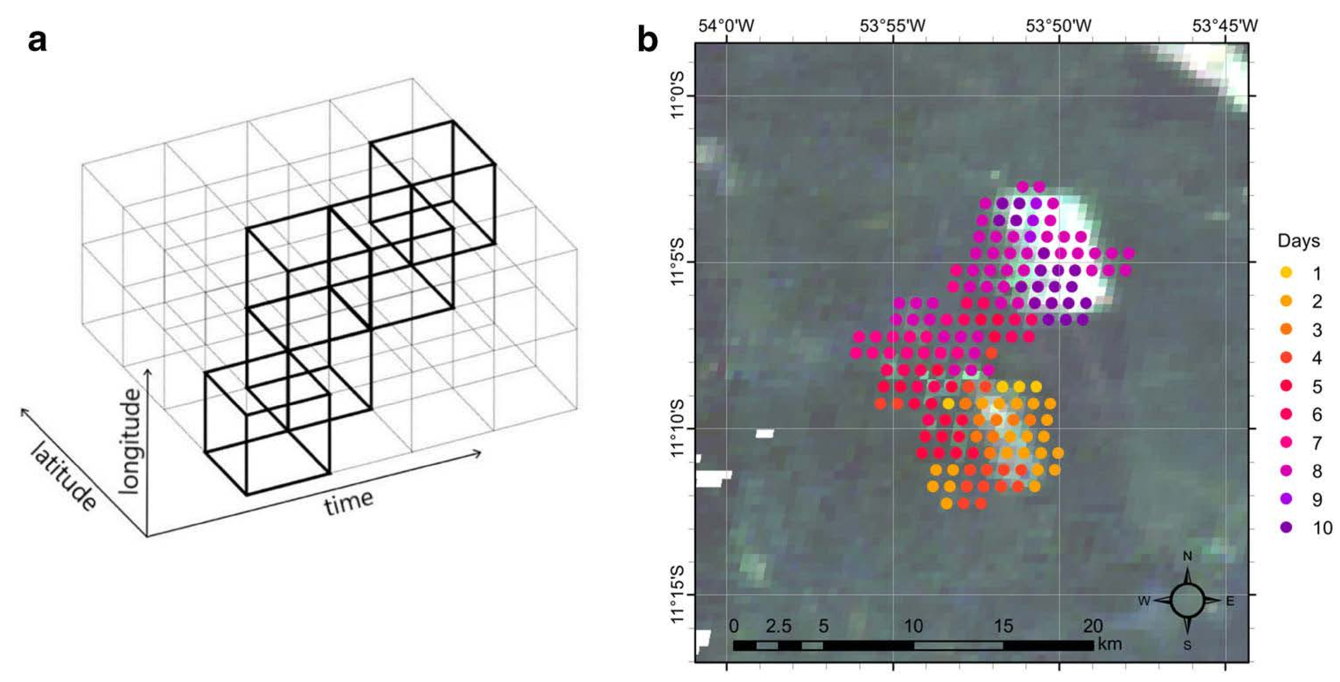

***Fig. 1** Sketch of a spatiotemporal fire cluster (black lines in a) propagating over space and time (grey lines). Example of an extreme fire which occurred in NE Mato Grosso in 2004, coloured dots show its propagation over space and time.*

DATA AND METHODS

We analyse remotely sensed fire (MOD14A1 and MYD14A1 C6 datasets from MODIS), land cover (IGBP classification of MODIS MCD12Q1 Land Cover Type C6) and deforestation areas (PRODES project from INPE) for the Brazilian Legal Amazon (BLA) which entails Brazilian Federal States in the Amazon region. We use daily hot pixels in a 1-km sinusoidal grid for the period from 2002 to 2019 to compute spatiotemporal fire clusters in evergreen tropical forests. We additionally obtained information on the road network by the Brazilian Institute of Geography and Statistics (IBGE).

We apply network theory to analyse spatiotemporal dynamics of fire. In network theory, a complex system is represented as a graph. Pixels affected by fire are the nodes, while their pairwise relations depending on their spatio-temporal proximity are the edges (Fig. 1a). A pair of fire events are neighbours, if they are in the same 3-D Moore neighbourhood (lon, lat, time) without spatial or temporal gaps. The resulting structure is then used to identify spatiotemporal fire clusters (Fig. 1b). We compute fire intensity (Fire radiative power, FRP) for each fire cluster and define extreme fires when FRP ≥ 95th percentile of the variables' distribution. We compare the spatio-temporal pattern of extreme fires for different drought and deforestation years in the BLA.

RESULTS AND DISCUSSION

Nearly 352.000 fire clusters in evergreen forests of the BLA from 2002 to 2019 were identified, which is 43% of the total fire clusters detected in all land-cover classes. 17.606 fire clusters were identified as extreme fires. Numbers of (extreme) fires and deforestation are at their maximum during the early 2000s, later on maxima occurred during drought years caused by ocean warming (Fig. 2a,b). The BLA experienced extreme droughts in 2005, 2010 and 2015, caused by anomalous warming of the northern Atlantic (AMO) and tropical eastern Pacific (ENSO), or the combination of both (Fig. 2a). The recent increase in deforestation in 2019 - a non-drought year - also increased the number of extreme fires (Fig. 2b).

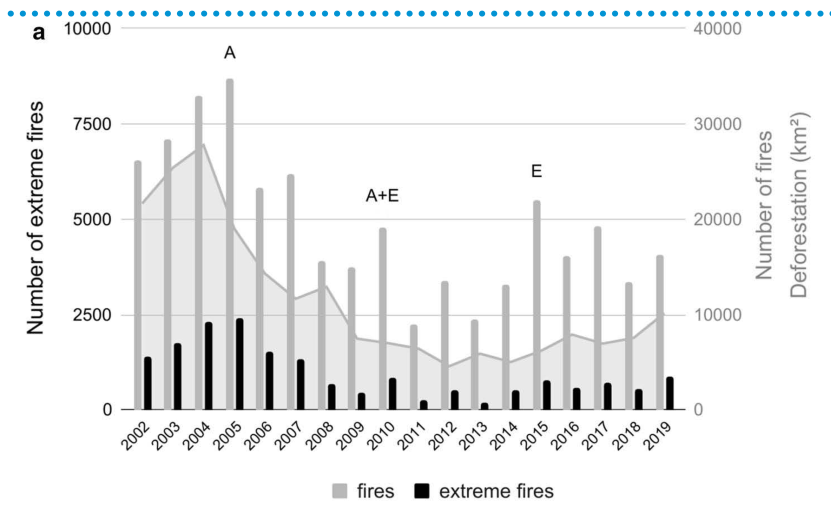

***Fig. 2a** Interannual variability of numbers of fires (grey bars, right y-axis), extreme fires (black bars, left y-axis) and annual deforested area (km², grey line on left y-axis) in the BLA from 2002-2019. Anomalous warming of the northern tropical Atlantic (A) and tropical eastern Pacific (E), or combination (A+E) caused drought years.*

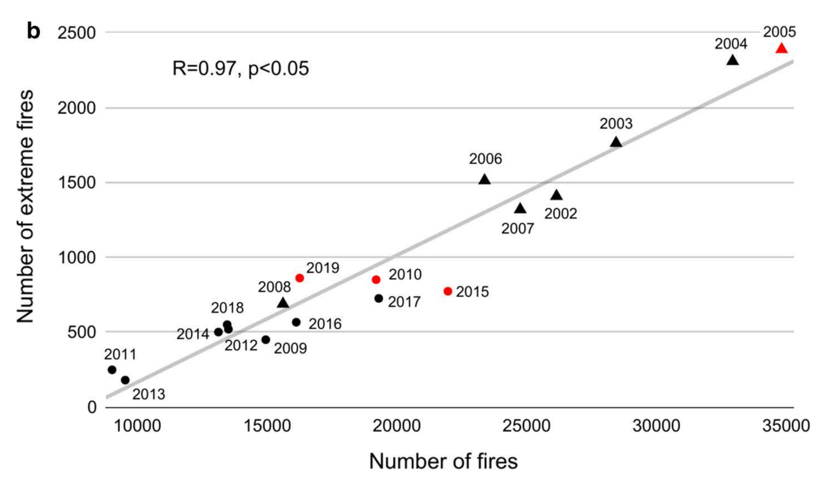

***Fig. 2b** Relationship between annual extreme fires and annual numbers of fires. Above-average deforestation years are marked by triangles, others years by circles. Spatial analysis is done for years marked in red.*

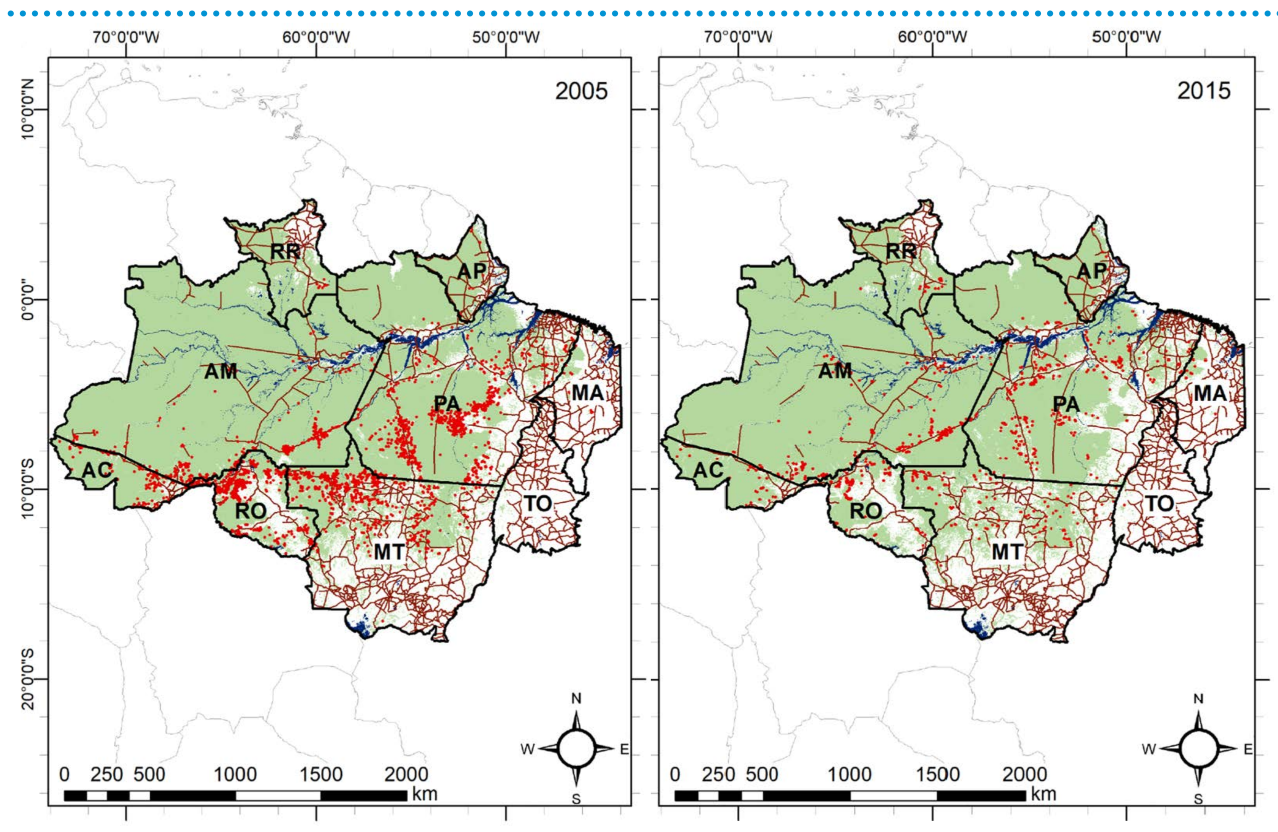

***Fig. 3** Spatial distribution of extreme fire years in the BLA in 2005 (left) & 2015 (right). Extreme fires shown as red points, road network as dark-red lines, extension of tropical evergreen forest in green, and federal states of the BLA as black polygons.*

Extreme fires are concentrated along major roads in extreme drought years (Fig. 3). Wider areas were affected when annual deforestation rates were higher (Fig. 3, left). Improved law enforcement lowered deforestation rates and reduced extreme fires, while still concentrated along roads (Fig. 3, right). All extreme fires are within 0.5-km distance from forest edges, 56% within a 1-km distance from roads. These pattern define the spatial distribution of fire and show the strong human influence on the Amazon rainforest. These findings underline the importance of environmental protection by strong institutions and policy implementation.

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