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Causes of Indonesia's forest fires

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ABSTRACT

The economic costs of Indonesia's 2015 forest fires are estimated to exceed US $16 billion, with more than 100,000 premature deaths. On several days the fires emitted more carbon dioxide than the entire United States economy. Here, we combine detailed geospatial data on fire and local climatic conditions with rich administrative data to assess the underlying causes of Indonesia's forest fires at district and village scales. We find that El Niño events explain most of the year-on-year variation in fire. The creation of new districts increases fire and exacerbates the El Niño impacts on fire. We also find that regional economic growth has gone hand-in-hand with the use of fire in rural districts. We proceed with a 30,000-village case study of the 2015 fire season on Sumatra and Kalimantan and ask which villages, for a given level of spatial fire risk, are more likely to have fire. Villages more likely to burn tend to be more remote, to be considerably less developed, and to have a history of using fire for agriculture. Although central and district level policies and regional economic development have generally contributed to voracious environmental degradation, the close link between poverty and fire at the village level suggests that the current policy push for village development might offer opportunities to reverse this trend.

1. Introduction

Deforestation accounts for over ten percent of global carbon emissions: more than the entire European Union. Reducing tropical deforestation is one of the most cost effective ways to address climate change. Halting deforestation while allowing damaged forests to recover could reduce global net emissions by as much as 30 percent (Busch & Seymour, 2016). An increasingly prominent yet understudied mechanism to clear tropical forests is fire (Abood, Lee, Burivalova, Garcia-Ulloa, & Koh, 2014). Whether spontaneous or deliberately lit, wildfires are becoming increasingly common, intense, and costly in the face of drying landscapes and rising temperatures in many countries (Tasker & Arima, 2016). One of the world's largest contributors to deforestation and land related emissions in recent years is Indonesia, where fire is commonly used to clear forest, manage semi-forested landscapes, and prepare land for agriculture.[1] The third most populous and third largest developing economy in the world and the largest in the equatorial tropics, Indonesia provides the ideal setting to study the anthropogenic drivers of tropical forest fires. Indonesia's experience also offers important insights for other countries at risk of deforestation (Ordway, Asner, & Lambin, 2017), where fires are increasing in prevalence and intensity.

Indonesia's 2015 fire season burned more than 2.6 million hectares, an area larger than the entire U.S. state of Vermont. Much of this land was rich in biodiversity and endangered species like the orangutan, tiger, rhino, and elephant (World Bank, 2016). Though the 2015 fire season was extreme, it was not unique. 163,000 hectares burned in 2013 (Gaveau, Salim, & Hergoualch, 2014) and between 2 and 5 million hectares (forest and non-forest) are estimated to have burned in 1997–98 (Dennis, 1999). Impacts span environmental, economic, and social dimensions. Fires release extreme amounts of carbon into the atmosphere and are a major contributor to air pollution and climate change (Bowman et al., 2009; Page, Siegert, & Rieley, 2002; Pribadi & Kurata, 2017; Reddington, 2014). The 1997 fire season released the carbon equivalent to 15% of global fossil fuel emissions that year. On more than one occasion, a single day of burning in the 2015 fire season emitted more carbon than the entire United States economy (Harris, Minnemeyer, Stolle, & Payne, 2015; World Bank, 2016).

Fire can destroy homes, crops, and forest resources, cause work and school closures, damage human health, reduce hours worked,

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[1] The U.S., Canada, and Russia also have large area of forest loss and forest fires, and Brazil surpasses Indonesia in cumulative forest loss over the past decades. See Alisjahbana and Busch (2017) for a helpful review on recent developments in Indonesia.

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increase the caregiving burden, and create significant firefighting and rebuilding expenses (Kim, Manley, & Radoias, 2017). The economic costs of Indonesia's fires are estimated to exceed, in current prices, US $4.5 billion in 1997–98 and $16 billion in 2015 (Dennis, 1999; World Bank, 2016). Pollution from the 1997 fires is estimated to have caused 15,600 child, fetal, and infant deaths, with early mortality costs of over $15 billion (Frankenberg, McKee, & Thomas, 2005; Jayachandran, 2009). The 2015 fire season caused more than half a million respiratory infectionsin Indonesia and Singapore, and is estimated to have caused more than 100,000 premature deaths (Koplitz et al., 2016; Sheldon & Sankaran, 2017). A Pollution Standard Index reading of 350 is considered hazardous, yet regularly exceeds 2,000 during fires. Although greater in number and ferocity during El Niño-induced dry seasons, Indonesia's fires are also a human phenomenon. Spontaneous ignitions are rare. Despite their political, economic, social, and environmental importance, and their growing prominence as a low-cost yet traditional way to clear land, relatively little is known about what causes the deliberate ignition of fires, how much of their variation and intensity is explained by human versus natural activity, or what constitutes effective fire prevention and management policy (Carmenta, Zabala, Daeli, & Phelps, 2017; Costafreda-Aumedes, Comas, & Vegas-Garcia, 2017).

Our objective in this study is to analyze the anthropogenic causes of forest fires systematically in Indonesian jurisdictions at district and village scales and over different time horizons. We first assess the short-run impacts of El Niño events, government decentralization, and regional economic growth. Combining a new geospatial panel dataset on district forest fires and climatic conditions with administrative data on government decentralization and district economic growth, we use panel data techniques to disentangle time-varying common factors (e.g., national policies, commodity prices, and seasonality) and fixed spatial determinants (e.g., regional climate, culture, and geography) from key political and economic changes of interest. To identify causal effects, we exploit exogenous variation in sea surface temperature anomalies (SSTAs) associated with El Niño-Southern Oscillation (ENSO) events,[2] the timing of administrative reforms, and the longitudinal features of the data (i.e., fixed effects and unit-specific trends).

Our first key finding is that El Niño events explain most of the annual variation in fires within districts. Although the influence of El Niño on rice production in Indonesia has been well documented (Naylor et al., 2001; Naylor, Falcon, Wada, & Rochberg, 2002; Naylor, Battisti, Vimont, Falcon, & Burke, 2007), its impacts on fire for agricultural expansion of palm oil and other crops has received less attention. Here, we find that a one-degree Celcius increase in SSTA in the central Pacific, relative to the long run trend, corresponds to over a 50 percent increase in average annual hotspot detections per rural district. The mean number of hotspots from 2001—2015 is 286 and the SSTA was over 2 degrees in the 2015 and 1998 fires seasons. Negative district rainfall shocks (i.e., dry years) are important in explaining year-on-year variation, while local temperature shocks appear less important.

Our second key finding is that political decentralization has caused more fire.[3] The proliferation of local district governments—which enjoy considerably more funding, autonomy, and power in relative terms—is associated with increased fires in split jurisdictions, with an almost 60 percent increase relative to pre-split years. Local government proliferation also exacerbated the impacts of positive SSTAs on fires, a critical climate-politics interaction receiving little attention to date. More recent decentralization, which similarly has increased autonomy, resources, and administrative institutions at the village level, could potentially present a similar fire threat.

The third key finding is that regional economic development has gone hand-in–hand with the use of fire in rural districts over the 2000s. There tends to be more fires in periods of stronger than average economic growth. Specifically, a year with a district economic growth rate one percent higher than its sample (2001–13) average has around 50 percent more fire. Economic-environmental trade-offs have long characterized large-scale agricultural expansion in the Indonesian countryside, and rural economic development and environmental degradation does not yet appear to have decoupled, at least not at the regional scale. Districts appear to use fires to create economic opportunity, which in turn may increase the capacity of residents and firms to move, acquire land, and burn more.

Districts mask considerable variation within them. We next shift our focus to longer-term determinants and the village level, with a case study of the 2015 fire season—the largest fire catastrophe since collection of satellite-based fire records began at the start of this century. We create a new cross-sectional dataset linking geospatial and administrative information for over 30,000 villages on the large, fire-prone islands of Sumatra and Kalimantan and ask the following simple question: what types of villages were more likely to set fire? To this end, we use a spatial fixed effects approach to compare villages against their neighbors facing similar climate variability, geography, history, institutions, and any other spatially-correlated unobservable characteristics. Our focus on the village is also important. Like district-level decentralization before it, the Village Law of 2014 (and earlier decrees) devolved significant fiscal, administrative, and policy responsibilities to rural villages and placed them at the heart of Indonesia's development policy agenda (Antlov, Wetterberg, & Dharmawan, 2016; Naylor et al., 2019). Emergent fire prevention and response efforts are often centered around the village as an autonomous administrative unit.

We find that villages more likely to burn tend to be more remote, be involved in secondary crops (e.g., corn, beans, roots) or plantation crops, have a history of burning for agriculture, and be less developed according to a wide variety of multi-dimensional poverty indicators. A one-percentage point increase in the village poverty rate corresponds to a staggering 20 percent increase in the probability of having a fire detected, after accounting for district-level spatial fire risk. Based on our estimated impacts of district-level decentralization funding windfalls, further village-level fiscal decentralization may present an imminent fire threat. On the other hand, the village proliferation rate is far lower than districts' and the close links between poverty, underdevelopment, and fire at the village level suggest that rural development could potentially offer counter-veiling positive effects. While central and district level policies in the post-decentralization era have contributed to voracious resource extraction and environmental degradation, the strengthening of the village as an administrative and developmental unit might offer opportunities to reverse this trend (Naylor et al., 2019).

[2] In our analysis, we use the Nino 3.4 SSTA, recorded in the central Pacific Ocean (5 N–5S, 120–170 W), to measure El Nino-Southern Oscillation (ENSO) effects on fire risk in Indonesia. We average monthly SSTA data from May to December on a calendar-year basis, corresponding to the natural development of the ENSO cycle. An SSTA measure exceeding +0.7 degrees Celcius relative to the long-run average represent El Nino (warm-mode) events. (The "long-run average" represents a 30-year based period updated by NOAA every five years.) El Nino events correspond with a delayed monsoon onset (Naylor, Falcon, Rochberg, & Wada, 2001, 2007) and drier conditions during Indonesia's typical fire season (July–December). La Nina (cold-mode) events, reflected in negative SSTAs, have little effect on fire risk relative to neutral conditions. SSTA data are fromhttps://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v4.shtml.

[3] For more details on the decentralization process in Indonesia and its relationship to forest fires, see Naylor, Higgins, Edwards, and Falcon (2019).