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Economic Drivers of Global Fire Activity: A Critical Review

Yeon-Su Kim[1], Marcos Rodrigues Mimbrero[2], François-Nicolas Robinne[3]

[1]School of Forestry, Northern Arizona University, Flagstaff, AZ 86011, USA -ysk@nau.edu
[2]Department of Geography and Land Management, University of Zaragoza, GEOFOREST Group, 50009, Spain
[3]Canadian Partnership for Wildland Fire Science, University of Alberta. Edmonton, Alberta, Canada

Abstract

The special issue on Fire$: Economics and policy of global fire activities in the journal Forest Policy and Economics, was organized as part of the Task Force initiative of the International Union of Forest Research Organization (IUFRO). The special issue endeavored to provide specific and practical economic guidelines that help deal with the wicked problem of managing wildland fire risks with much needed insights from the global South. We present the critical review of economic drivers of global fire activities with the key insights from other papers in the special issue. Overall decline of global burned area paradoxically hides a number of economic realities that have increased the likelihood and costs of wildfire-caused disasters. We identified global patterns of worsening wildfire risks with the double-exposure to globalization and climate change. Current developments call for a paradigm shift in how we understand and manage wildfires to promote an adaptation-mitigation-resilience strategy. We propose expanding the science-policy interface to global scale with new indicators for assessing and communicating the impacts of global economic drivers on wildfire activities. We also identified the areas where research is lacking, highlighting future research areas in wildfire economics to advance effective, efficient, and equitable global governance of wildfires.

Keywords: Wildfire economics; Disaster risk reduction; Altered fire regimes; Teleconnections; Global economy

Introduction, scope and main objectives

After a number of recent catastrophic fire years, there are now growing calls for modern society to co-exist with wildfires, especially in fire-adapted ecosystems—as many traditional communities still do—rather than fight them (e.g. Doerr and Santin, 2016). Effective wildfire governance requires comprehensive land use planning coordinated with risk and ecosystem management (Doerr and Santin, 2016). However, characterization of wildfire risk is still heavily driven by ecological studies and human causes of fires are still poorly understood (Chuvieco et al. 2021), while costs and loss statistics dominate the global wildfire narrative (IUFRO 2018). In this critical review, we argue that devising a governance scheme addressing the worldwide wildfire "problem" should start with understanding macroeconomic forces underpinning wildfire hazard geography and its system-wide impacts. Notwithstanding the importance and variability of local factors influencing wildfire risk, we posit that common patterns exist worldwide. Our goal is twofold: 1) synthesizing our current understanding of wildfire economics and identifying where research is lacking, and 2) generating insights into economic dimensions of wildfires to inform sound policies and sustainable fire management. The focus is not on reviewing related economic theories and formalizations, which have received limited academic attention thus far (Rideout et al., 2008; Fitch and Kim, 2018). We employed the Drivers-Pressures-States-Impacts- Responses (DPSIR) framework to highlight economic drivers behind wildfire patterns and the economic consequences triggered by detrimental fires and advocate building inclusive cross-scaled science-

policy interfaces to manage wildfires. We conclude with possible pathways forward for managing wildfires at a global scale.

Methodology/approach

The Drivers-Pressures-States-Impacts-Responses (DPSIR) framework is a problem-structuring method that helps establish a coherent foundation and causal pathways between five categories of influential factors: Drivers (D), Pressures (P), States (S), Impacts (I) and Responses (R) (Smeets and Weterings, 1999). We modified the formalization by Balzan et al. (2019) as the adaptive wildfire DPSIR framework (Fig.1), that addresses some of the main criticisms of the DPSIR framework for building linear relationships among compartmentalized components. The five categories are:

- Drivers (D), as underlying changes in the biophysical, social, economic and political systems, as well as their relationships, creating Pressures on social-ecological systems;
- Pressures (P), as consequences of underlying changes, which have the potential to cause both positive and negative Impacts. The analytical focus here is on the negative impacts;
- States (S) of wildfire systems, as represented by the fire triangle of fuel, heat and conducive conditions. Ecological conditions, such as structures and functions of forests, woodlands, grassland, and peat ecosystems, make the system vulnerable to wildfires and other disturbances, while social conditions can increase ignition sources and frequencies.
- Impacts (I), conceptualized in stages: changes in fire regimes affect ecosystem service supply and drive up costs and losses related to wildfires, which in turn drive changes in human perception, attitudes and values about wildfires leading to biased economic incentives aggravating wildfire disaster risks.
- Responses (R), as policy and management actions initiated by institutions or groups (e.g., politicians, managers, stakeholder groups) to prevent, eliminate, compensate, reduce or adapt to Impacts. Assessments of Drivers, Pressures and States and Impacts and their interactions are essential to inform and enable adequate Responses.

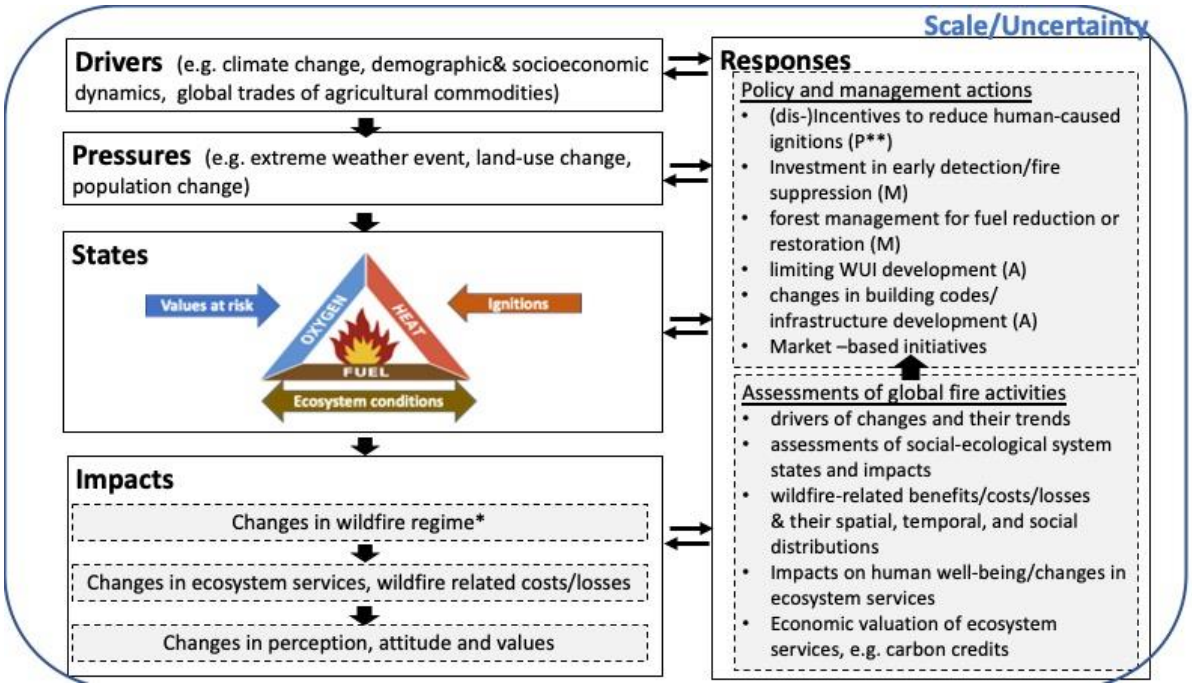

Fig. 1: DPSIR framework for economic drivers of global fire activities. Arrows indicate causal relationships between driver, pressure, state, impact and response (adapted and modified from Balzan et al. 2019; Butry 2009).

Results & Discussion

Drivers (D) and Pressures (P) on wildfires

Climate patterns govern types and distributions of vegetation (i.e., biomes) as well as their flammability (i.e., species, fuel moisture, and fuel structure) and burning potential (i.e., ignition and spread) in general. There is a global consensus among a wide array of studies on climate-fire relationships that we are experiencing more hazardous fire-weather conditions over the recent decades, which is expected to get worse in the future under changing climate (e.g. Dupuy et al 2020; Hessburg et al., 2019). However, research is still lacking in many active fire regions of the world, especially in tropical regions where altered fire regimes has become a global concern for greenhouse gas emission and biodiversity losses (Bowman et al., 2020).

Urban sprawl and nearby resource exploitation often are characterized by extensive land use and transformation, with disseminated housing patterns and large-footprint infrastructures mixing with natural and agricultural areas, referred to as interfaces (e.g. Meyfroidt et al., 2013). The growth of these interfaces rapidly became associated with the occurrence of wildfire-caused disasters. Diverse types of dispersed rural, intermix and interface communities have emerged and colonized fire-prone environments, setting up the conditions towards increased ignition risks, increased complexity and higher costs of management and suppression, and increased damages and losses (Fischer et al., 2016; Thomas et al., 2017). The WUI issue is also growing in emerging and developing countries, thus underlining the worldwide problem it has become (Chuvieco et al. 2014; Godoy et al. 2019; Pliscoff et al. 2020).

The relationship between land use/land cover change and landscape fires has been described across a range of spatial and temporal scales (Curtis et al., 2018). However, wildfire economic studies over large extents remain rare, while studies on local economic drivers of wildfires have received more attention, especially in the USA, and in Europe to a lesser extent. In many areas around the world, research has shown that local to regional-scale land-use changes have been driven by macroscale (i.e., national to international) economic forces (e.g. Lambin et al., 2011). Distant effect of global trade driven by the most affluent countries has had detrimental effects on wildfire activity, effects observed in South America, Africa, and southeast Asia (e.g. Nathaniel et al. 2021; Leal and Marques, 2021; Curtis et al. 2018). Although wildfire is often mentioned in the studies related to global commodity trade-driven deforestation, research on specific effects of global trade on wildfire activities is generally lacking. Negative impacts of macroeconomic forces on land use changes may be most pronounced in non-fire-adapted ecosystems in the wet tropics, where extensive human-caused fires result in dramatic ecological degradation associated with losses of hydrological function, biodiversity, and organic soils such as peat, as well as increases in greenhouse gas emissions (e.g. Martin, 2019).

States (S) and impacts (I)

Out of the over 450 million hectares burned on average every year in the world, most come from human-caused fires ignited for a variety of reasons such as forest clearing, soil preparation for crops or fodder, outdoor activities, socio-economic conflicts, arson, and accidents (Andela et al., 2019; Ganteaume et al., 2013). The role of environmental and climate drivers of wildfires has been extensively addressed in the scientific literature, but the role played by humans is far less understood (Chuvieco et al., 2021; Costafreda-Aumedes et al., 2017).

The interplay of humankind and climate has caused many changes to regional fire regimes worldwide (Rogers et al, 2020). Changes in fire regimes in North America have been well-documented through a number of empirical and modeling studies, in terms of increased frequencies and extents of large fires with high severity, lengthening durations of wildfires and fire-season, and their worsening trends with warmer and drier climate affecting regional water-balance (e.g. Mueller et al., 2020; Singleton et al., 2019; Westerling et al., 2006). The trend of changing fire regime is similar in southern Europe (e.g. Rodrigues et al., 2020). Wildfires became one of the most important agents of land-use/land-cover change in the tropics (Lavorel et al., 2007). However, the

scientific capacity for detailed study of wildfires is lacking in many tropical developing and emerging countries (Barber et al., 2014). Figure 2 highlights that burned areas are increasing in many regions with high global economic pressures and weak governance.

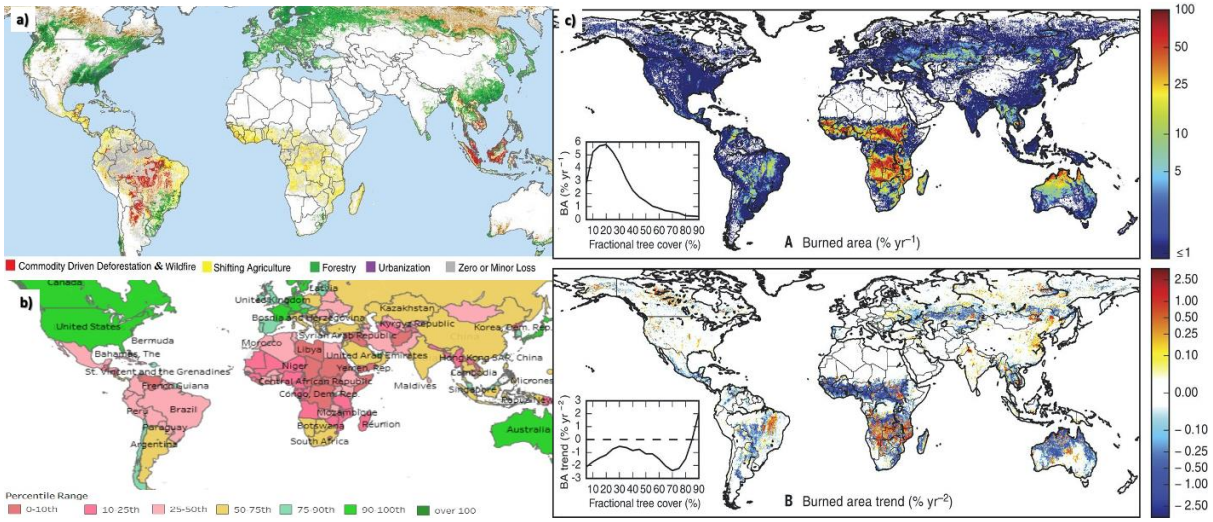

Fig. 2: Global map of: a) Primary drivers of forest cover loss 2001-2015 (Curtis et al. 2018); b) World Bank Indicator of Governance Effectiveness for 2018 (World Bank, 2019); c) A. Burned area %/yr); B. Burned area trend (%/yr) (Andela et al. 2017).

Despite efforts from scientists and practitioners to emphasize the positive role of natural and cultural fire regimes and active forest management using prescribed burns (Alcasena et al., 2019), the Western bias that frame wildfires as a 'public enemy' to be fought at all costs still dominates how policy-makers perceive and respond to wildfires globally (Matlock et al., 2017). More research is needed to understand changing wildfire regimes and their regional variations to elaborate more effective, efficient and equitable wildfire risk management at a global scale.

Changes in wildfire regimes, both through decreases and increases in wildfires, affect the capacity of ecosystems to deliver goods and services for human well-being, such as carbon storage (Harris et al., 2019; Huteau et al. 2008; 2014), watershed services (Robinne et al., 2016; 2018; 2020;), and biodiversity (e.g. Miller et al., 2018). Leveraging the economic importance of these key ecosystem services can be effective for promoting fuel management and forest restoration more generally. Direct costs of fire prevention and suppression are minor components in the full spectrum of economic costs and losses related to altered wildfire regimes (Fig. 3).

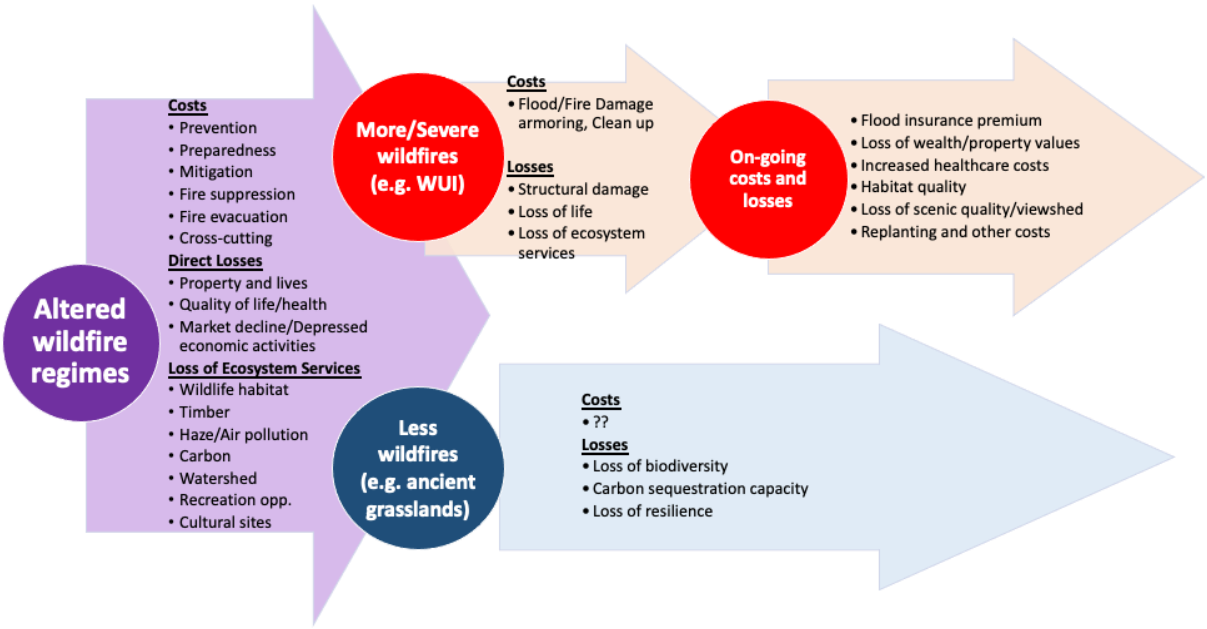

Fig. 3: Understanding costs and loss of altered wildfire regimes

The majority of wildfire related losses are intangible or indirect and also distributed spatially, temporally and socially, which make them difficult to measure (e.g. Thomas et al., 2017). Economic globalization expands the scope of cross-scale interactions externalizing ecological, social and health costs associated with wildfires in global scale, especially to tropical developing countries.

Responses (R): Pathway forward for managing wildfires in global scale

Many scholars over the years called for a paradigm shift in how we understand and manage wildfires (e.g. Moreira et al., 2020). The main focus is on shifting the emphasis on fire prevention and suppression to mitigation and adaptation for learning to co-exist with fires in fire-adapted ecosystems, while addressing underlying drivers of human-cause ignitions in non-fire adapted ecosystems. Devising appropriate responses to the worldwide wildfire "problem" should start with understanding of drivers of changes and their trends, assessments of social-ecological system states and impacts, wildfire-related benefits, costs, and losses and their spatial, temporal, and social distributions (Fig.1). Improving economic valuation of ecosystem services as well as better accounting of overall costs (Hand et al., 2014) can attract necessary investment for better wildfire management (e.g. carbon credits) (Venn and Calkin, 2011). Limiting urban sprawl within fire-prone landscapes is another important part of the equation. Where possible, imposing a shared economic responsibility for fire management and disaster losses would certainly provide an incentive to rethink urban design and more attention is needed to account for cross-scale interactions.

With recent advances in the ways we understand the complexity of ecosystem service flows across geographic boundaries (Liu et al. 2015; Schröter et al. 2018), we can conceptualize interregional flows of drivers and impacts of wildfires. Development of an indicator measuring wildfire-linked land degradation for a variety of products and activities worldwide can help communicating on the distant yet pervasive role of modern consumption patterns on global fire activity.

Conclusions/ wider implications of findings

This critical review has focused on overviewing global scale economic drivers and their impacts, and we acknowledge that the economic forces reviewed here are interdependent, as well as controlled by other aspects of fire and land management overall, politics and ecology in particular. Wildfires and their negative consequences are part of an economic continuum embodied by the Pyrocene concept suggested by Pyne (Pyne 2019; Pyne and Bowman 2020) showing the historical shift in the meaning of fire and combustion and the role of the capital economy and industrialization—maybe the most potent drivers of the current environmental state of the world—in explaining current global fire patterns.

Our review, however, did not cover the rich literatures in the US on economic optimization of fuel management strategies with fire modeling (e.g. Ager et al., 2018), advances in behavioral sciences for understanding knowledge, attitudes and practices of individuals in fire-prone landscape (e.g. Dickinson et al., 2015; Paveglio et al., 2021) and institutional arrangements promoting adaptive fire governance (e.g. Schultz and Moseley, 2019). Future research is needed to incorporate these aspects into wildfire economics as well as expand the research outside the US.

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