Environmental Science and Policy 81 (2018) 104–107

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Discussion

Portugal and Chile: Longing for sustainable forestry while rising from the ashes

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ARTICLE INFO

Keywords:
Biodiversity
Ecosystem services
Fire ecology
Forest plantation
Fuel management
Sustainability

ABSTRACT

The recent catastrophic wildfires in Portugal and Chile shared similar features, not just because they developed under extreme weather conditions but also because extensive forest plantations were involved. Dense forest plantations of flammable pine and eucalypt species favor the development of high-intensity large fires, threatening people and the forest industry sustainability under increasingly frequent and severe drought events. Preventive land-use planning and cost-effective fuel management are key elements of sustainable forestry. Understanding the fire ecology context prior to plantation establishment is also crucial for the success of fire management planning. Although the forest industry has contributed to the economy of these countries, improved regulation and science-based management policies are strongly needed. Fuel treatment strategies can be optimized by risk-based modeling approaches, and should be mandatory in wildland-urban interfaces. The tragedy caused by these wildfires is an opportunity to change towards more sustainable landscape arrangements that reconcile ecosystem services, biodiversity conservation, and protection from life-threatening wildfires.

Last 17–21 June 2017, a large wildfire caused by faults in the electricity distribution grid raged in central Portugal, killing and injuring respectively 64 and 254 people (BBC, 2017). Worldwide it was the most tragic wildfire event since the 2009 Black Saturday fires in Australia, burning ca. 30 kha in a rugged landscape extensively afforested with eucalypt and pine plantations. Also in central Portugal, 45 human lives were further claimed by the unprecedented hurricane-driven fires that burned ca. 200 kha on 15–16 October 2017. These events resemble the mega-fires that occurred in Chile during the last austral summer (December 2016–February 2017), causing at least 11 fatalities, affecting thousands of people, and destroying some towns (CONAF, 2017a). More than half of the 600 kha burnt in Chile were forest plantations akin to those in Portugal (CONAF, 2017a). Fast-growing, high-density forest stands planted for commercial purposes are highly flammable and favor the development of large and severe wildfires when established over large continuous tracts of the landscape (Fernandes et al., 2016, Fig. 1). Because of this, the sustainability of the forest industry and the effectiveness of environmental policies are currently under debate in the media (BBC, 2017).

Climate change is increasing the frequency and severity of large fires worldwide (Jolly et al., 2015). When extreme fire weather conditions combine with abundant fuel, fire spread and intensity surpass the capacity of any fire suppression organization. Effects of climate change on the fire regime are out of human control but we can work to re-shape the composition and quantity of fuels in our landscapes making them less prone to large fires in anticipation of a warmer future. In this sense, preventive land-use planning and cost-effective fuel management are key elements of sustainable forestry. Reducing fuel continuity and load by pruning and thinning reduces fire intensity and the likelihood of crown fire occurrence in *Pinus radiata* (Cruz et al., 2017) and *Pinus pinaster* plantations (Fernandes and Rigolot, 2007), at least under non-extreme weather conditions. Prescribed underburning is the most effective way of tackling surface fuel accumulation, but its feasibility is determined by bark thickness (hence by tree size and species; Bellows et al., 2016) and can favor fire-adapted weeds (Úbeda and Sarricolea, 2016). In the case of eucalypt plantations, recent research indicates that fuel removal is needed at shorter intervals (*e.g.* disk harrowing every 2–6 years) than commonly recommended, particularly when the terrain is steep and productivity is high (Mirra et al., 2017). Fuel-treated areas need to be strategically placed in the landscape considering not only the fire risk to human population and relevant ecosystem services, but also the effectiveness (*i.e.* likelihood of

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https://doi.org/10.1016/j.envsci.2017.11.006
Received 24 July 2017; Received in revised form 7 November 2017; Accepted 10 November 2017
Available online 20 November 2017
1462-9011/

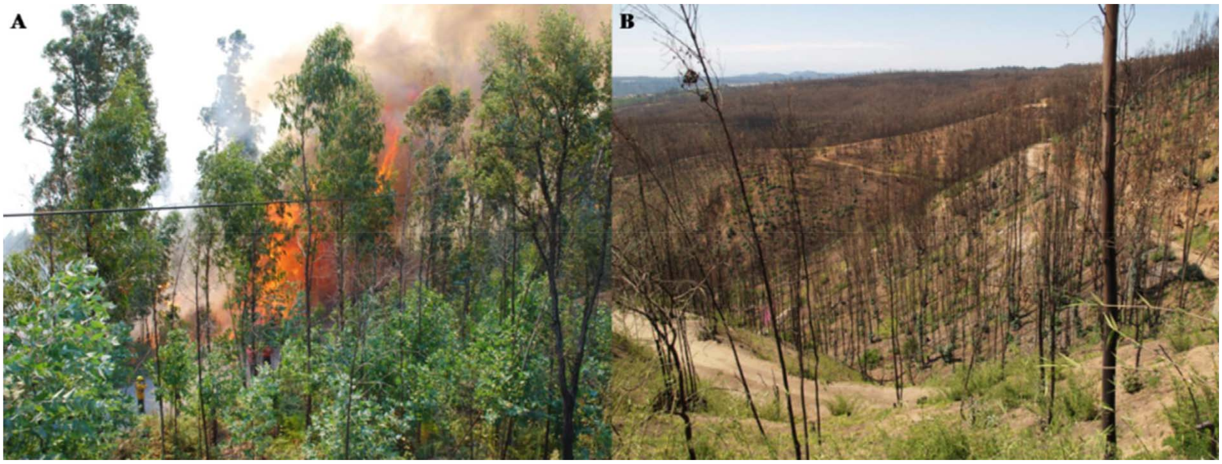

Fig. 1. Examples of wildfires in forest plantations from Portugal and Chile. A) Fire burning an unmanaged *Eucalyptus globulus* plantation in Terras de Bouro (NW Portugal), in September 2009. B) Burned landscape after a wildfire in an extensive forest plantation (dominated by *Eucalyptus* spp. and *Pinus radiata*) that occurred during the austral summer of 2014 in Valparaíso (Central Chile).

impacting wildfire growth and severity) of a given fuel treatment under given environmental and topographic conditions (Cruz et al., 2017). The fuel treatment effort should of course be commensurate with the likelihood of experiencing a wildfire; on average and per year, fuels are treated on one fifth of the forest industry estate in Portugal, with wildfire affecting only 0.7% of the area (CELPA, 2015), and while this indicates a successful fire management program it also suggests that cost effectiveness is low. Integrated fire-forest management planning and risk-based decision support systems based on modeling approaches assist on identifying and reconciling optimal harvesting and fuel treatment schedules to reduce fire losses and increase timber production (Acuna et al., 2010; Calkin et al., 2011; González-Olabarria and Pukkala, 2011). Nonetheless, despite significant scientific advances on modeling approaches to support management decisions, more research is needed to reduce uncertainties related to climate change (Calkin et al., 2011).

Extensive unmanaged fast-growth forest plantations located in the rural-urban interface are threatening the resident human population and they should be prioritized in management planning (Reszca and Fuentes, 2015; Bartlett, 2012). Fuel load reduction techniques combined with a minimum buffer zone of 150 m is advised when pine plantations adjoin urban areas (Bartlett, 2012). In Chile, for example, measures of fire prevention have targeted mainly the Valparaíso region in response to several tragic fires that have impacted the wildland-urban interface in the last years (Úbeda and Sarricolea, 2016). However, the Maule and Bío-Bío regions, which concentrate the bulk of Chile's forest mass, deserve more attention because of high population density in rural areas and increasingly frequent mega-fires (CONAF, 2017b).

Commercial forestry and farming account for 24% of the net anthropogenic greenhouse gas emissions, in part due to forest fires (Core Writing Team et al., 2014). Nevertheless, the increasing global rate of afforestation is frequently misinterpreted as a positive trend justified by the possibility of this sector becoming a net CO_2 sink in the next future (Core Writing Team et al., 2014). The Food and Agriculture Organization of United Nations (FAO, 2016) reported that Chile increased its forest cover, although it corresponded in part to the replacement of native forests by commercial exotic plantations (Miranda et al., 2016). The use of the term "forests" to jointly encompass commercial tree plantations and native forests is not appropriate since their ecological processes, as well as the ecosystem services they bring, are profoundly different. Unlike native forests, pine and eucalypt plantations can actually and substantially decrease water yield, which offsets their alleged carbon sequestration benefits (Farley et al., 2005). Regional land use planning could be strategically designed to improve both fire mitigation and water provision. In this sense, it would be desirable to reduce fuel homogeneity at the landscape scale by diversifying land use and restoring native forest patches as buffer zones, particularly in steep slopes and along the watersheds (Little et al., 2015).

Plantation forestry in Portugal and Chile has contributed to their macro-economic development and is a relevant source of income for farmers that own land unsuitable for agriculture. However, the rapid establishment of extensive commercial tree plantations has often been accompanied by deficient environmental regulations, loss of biodiversity and acute conflicts with local communities (Miranda et al., 2016; Mateus and Fernandes, 2014). Despite that, this model has been regarded as successful and sustainable (FAO, 2016), and did expand to other countries in South America (*e.g.* Uruguay and Brazil). From 1974 to date, near 3 million ha of land have been planted with exotic trees in Chile with the help of public subsidies, causing the loss of hundreds of thousands of hectares of native forest (Miranda et al., 2016) plus the concomitant increase in fire danger. In Portugal, around 1.5 million ha are occupied by *Pinus pinaster* and *Eucalyptus globulus* (16% of the country) (Rego et al., 2013), but most of the stands are either undermanaged or abandoned due to decreasing rural population and dire economic prospects. In many areas of the Iberian Peninsula, these plantations have replaced native Mediterranean heathlands of high ecological value, jeopardizing their biodiversity (*e.g.* Andrés and Ojeda, 2002). Besides, the establishment of forest plantations generally needs aggressive soil preparation techniques (*e.g.* ploughing and terracing) that eliminate native vegetation and decimate soil seed-banks. As the complexity of the root system diminishes, soil erosion risk increases, particularly when tree canopy elimination by fire leaves the altered soil open to the erosive effects of wind and precipitation (Martins et al., 2013). Therefore, most of the negative effects commonly linked to wildfires (irreversible loss of biodiversity and dramatic soil erosion) are actually promoted by afforestation *per se.* Paradoxically, forestry corporations and governments justify afforestation programs and policies by the need to protect biodiversity and recover degraded soils (CONAF, 2016).

Understanding fire regimes and their ecological and evolutionary context is crucial to develop a sustainable forest policy in fire-prone ecosystems. Central Chile and Portugal are fire-prone because of their Mediterranean-type climate and its marked seasonality that makes vegetation dry and flammable during summer. Although similar in climate and vegetation physiognomy (sclerophyllous shrublands), these regions have different fire histories (on an evolutionary time-scale) that explain differences in plant functional traits in response to fire. Lightning-ignited fires have not been frequent in Central Chile during the Quaternary due to particular oceanic and topographic features, such