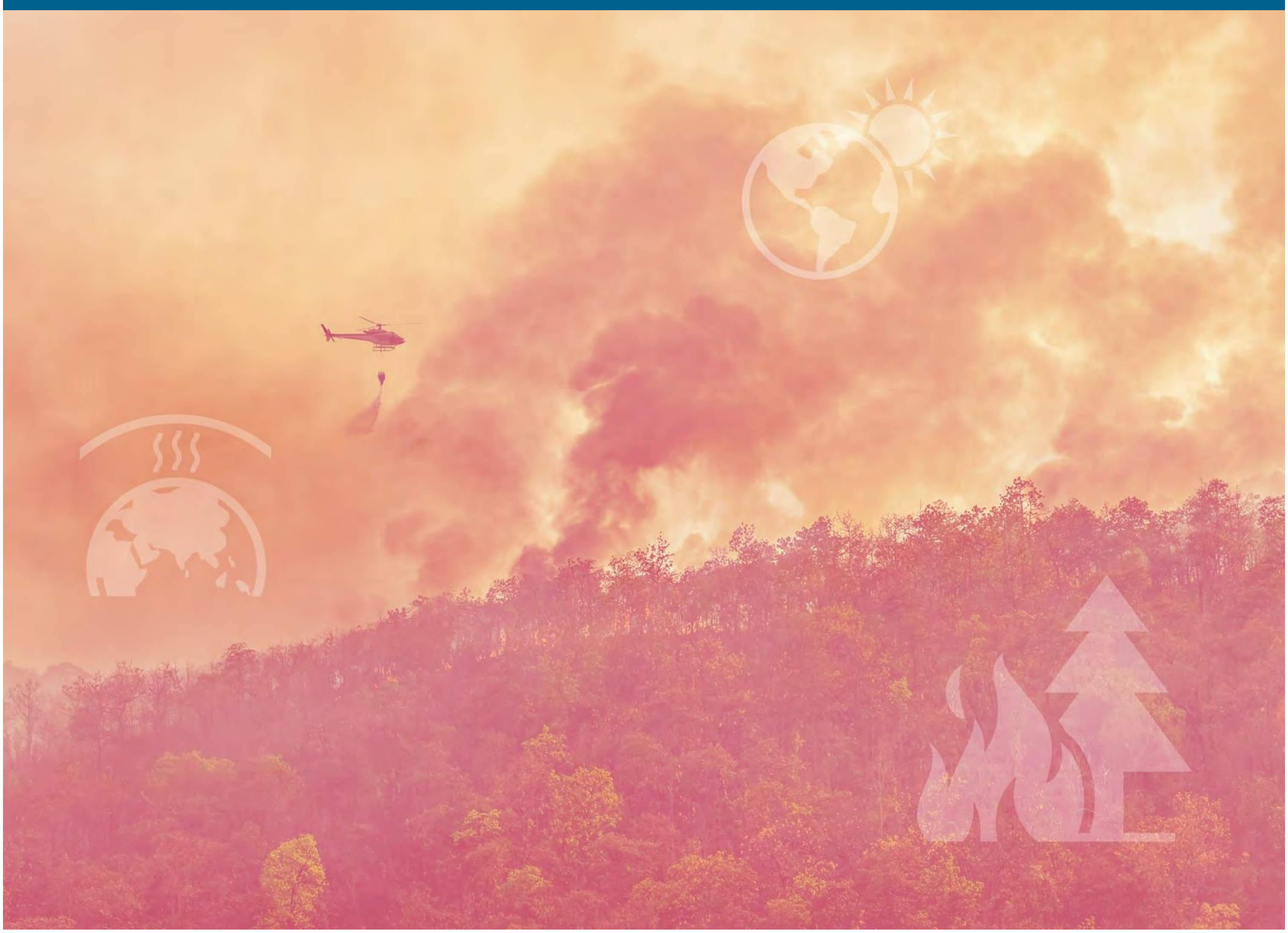
Catastrophe and Climate

New Fire Hazard Risk from Policy Responses to Climate Change



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New Fire Hazard Risk from Policy Responses to Climate Change

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Executive Summary

The unprecedented losses associated with recent wildfires are yet another call to insurers to understand how climate change is impacting the landscape of fire hazards. In this context, it is important to understand that individual and policy responses to wildfires and climate change, in particular carbon sequestration, are introducing desired benefits but also unintended new fire hazard risks. A case in point comes from highly publicized tree planting initiatives that aim to sequester carbon from the atmosphere or restore regions previously affected by wildfires or agricultural degradation. Unfortunately, without careful planning and maintenance, afforestation and reforestation initiatives such as these can lead to dramatically increased fire hazard. When fire hazard mitigation efforts have been made, the residual fire risk is subject to contributing factors such as the impact of tree types, their spatial arrangements, and relationships between trees and surrounding ecosystems. As an example, the efficiently planted fast growing species in the “pines in lines” arrangement can be surprisingly highly prone to fire hazard. These determinants should be of interest to insurers in order to model accurately the new fire risks emerging from these policies. It is only by accurately understanding emerging wildfire risks that the insurance industry has the opportunity to encourage conscientious policy action and land management through green policies while operating in a sustainable manner.

Section 1: Introduction

The actuarial community is at the forefront of understanding the impacts of climate change on human conditions. Increased frequency and severity of extreme weather events - such as intense droughts, wildfires, and hurricanes - are some of the most obvious manifestations of climate change (NASA, 2020), and numerous studies over the last two decades have explored the impacts of climate change on losses due to extreme events such as hail, floods, and winter storms (Botzen & Bergh, 2008; Changnon, 2009; Born, et al., 2013). Responding to recent dramatic losses, the Actuaries Climate Index has tracked climate change in a similar manner as the consumer price index since 2016 (American Acadmey of Actuaries, Canadian Institute of Actuaries, Casualty Actuarial Society, Society of Actuaries, 2020), and climate change was identified as the number one current emerging risk by the 12th Emerging Risk Survey sponsored by the Joint Risk Management Section of SOA, CAS, and Canadian Institute of Actuaries (CIA) (Rudolph, 2019).

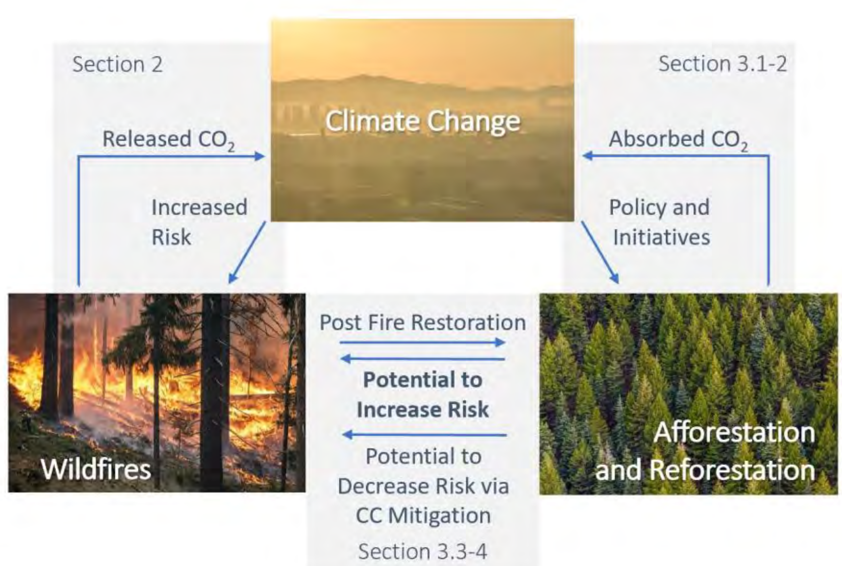
Less investigated, however, are the impacts of new policy actions and human behavior in response to the effects of climate change, a pressing example of which is removing carbon from the atmosphere (carbon sequestration) by planting trees. Additionally, reforestation (i.e., planting trees) is a common approach to restoring regions already damaged by forest fires more rapidly than through natural reseeding. Planting trees without informed consideration to what, where, and how the planting is done, may overlook important secondary effects on future hazards. The number of trees planted cannot safely be the sole focus of these policies.

That is why, in this report, to further advance understanding of relationship between fire hazard and climate change, for both academic and practitioner communities, we review emerging evidence showing that policies surrounding tree planting are increasingly important for fire hazard insurance. We outline the dynamic relationships between climate change, tree planting policies and initiatives, and wildfire risk as illustrated in Figure 1, and illustrate their importance for insurers. Furthermore, we discuss relevant risk factors and potential mechanisms when accounting for these policies.

Figure 1

CLIMATE CHANGE, POLICY, AND WILDFIRE

Arrows denote relevant relationships addressed in the report. Afforestation is defined as planting trees in a previously unforested area. CC stands for Climate Change. (Images from Pixabay- no attribution required.)



1.1 MOTIVATING EXAMPLES

To this day, the 2016 fire in Fort McMurray, Alberta, Canada remains a stark illustration of the unintended consequences of planting new forests. The fire resulted in the costliest disaster in Canadian history, totaling CAD $3.7 billion in insurance losses (Statistics Canada, 2015). In its wake, 5,890 square kilometers (3,660 square miles) of land were burned. While there were no deaths, 8% of the town's private dwellings were destroyed (Statistics Canada, 2015). After the event, Wilkinson, et al. (2018) pinpointed the source of the fire on groups of trees planted by the Canadian government back in the 1980s. Regretfully in hindsight, the trees were planted in peatland, a type of wetland area that typically has very low fire risk. However, the trees dried up the peat, sending the water-table deeper underground. Thus, humans grew a dry, highly flammable forest in place of the once fire-resistant, natural peat moss. Once sparked, the resulting wildfire was catastrophic, burning both the newly planted trees and the original peat, releasing carbon that had been stored for thousands of years and taking almost five hundred days to fully extinguish (Elbein 2019).

In Europe, the Iberian Peninsula has also witnessed undesirable effects of tree planting on wildfire disasters. Over the last century, large scale reforestation and afforestation policies arose to combat the erosion and flooding that had occurred with historical deforestation (Jones, et al., 2011; Vadell, et al., 2016). While these policies provided highly desired economic opportunities through the timber industry and aimed to improve the landscape, many stands were nonnative monocultures, such as Eucalyptus. These species were highly fire prone (Gómez-González et al, 2018). The resulting land conversion resulted in a staggering increase of area burned by wildfire in subsequent years (Carreiras, et al., 2014; Viedma, et al., 2015). Even today across Spain and Portugal, many of these stands remain and continue to increase fire risk (Jones, et al., 2011; Vadell, et al., 2016). The June 2017 wildfire in Portugal is a case in point: 47 people died in their cars along a Eucalyptus lined highway while trying to flee the flames that had erupted (BBC, 2017). In all, 66 were killed in June wildfires, with 53 more fatalities in October fires, resulting in over $1.45 billion in losses (Aon, 2017; Molina-Terren, et al., 2019).

Sadly, the future may yield many more such examples. Around the world, reforestation and afforestation are highly sought tools for carbon sequestration. Effective mitigation of climate change through carbon sequestration can help on a global level to reduce the risk of the higher temperatures and drier conditions that can drive fire risk. On a local scale, however, the wrong trees planted the wrong way in the wrong places can increase local fire danger. This includes attempting to grow forests in already water-limited environments. The Australian Emissions Reduction Fund, for example, has supported carbon sequestration projects in the semi-arid drylands of New South Wales. There, fire weather and probability of ignition are consistently high, and wildfires are already devastating (Nolan, et al., 2018). Since the fire risk in the region is highly dependent on fuel levels, dedicated fuel management is necessary to prevent burning of areas where forest-based carbon sequestration is occurring (Nolan, et al., 2018). In 2019, over 12 million acres were burned in Australian bushfires, with New South Wales particularly affected, putting sequestered areas at risk. At least 24 people and millions of animals were killed across the country (Gunia and Law, 2020). Some plantations in Victoria were affected, although the exact impact is unknown, as the Clean Energy Regulator has not released estimates of affected assets (Clean Energy Regulator, 2019; Ludlow, 2020).

1.2 CHALLENGES AND OPPORTUNITIES FOR THE INSURANCE INDUSTRY

Changes in the fire risk profile of recent years, particularly in California, not only poses a significant threat to human life and health, but has also left the insurance industry facing unexpectedly high claims. In 2018 alone, $12 billion in losses were attributed to wildfires in California, an increase of $2 billion dollars from the previous year (Evarts, 2018, 2019). Other costly wildfires of 2018 included Oregon's Klondike fire, totaling over $104.5 million in losses, Cougar Creek Fire in Washington State costing $42.2 million, and the "416 Fire" in Colorado, costing over $39.5 million. While the western United States has been most significantly affected, other large, costly fires occurred in Oklahoma ($6.9 million), Florida ($21.2 million), and Arkansas ($2.5 million) (National Interagency Coordination Center, 2019). These losses have not gone unnoticed by leading catastrophe risk experts such as Senior Director Chris Folkman with Risk

Management Solutions (RMS). He cites climate change in conjunction with the increase of homes in wildland-urban interfacing areas and decades of fire suppression methods as contributing factors increasing risk for these catastrophic events (CAS, 2019). Unfortunately, given the recent trends in climate (Wuebbles, et al., 2017), it is to be expected that these losses will continue to mount.

Already, failure to correctly assess the risk of wildfires has left some insurance companies in a financially unenviable position. For example, Merced Property and Casualty Co was liquidated after failing to meet obligations of the 2018 Camp Fire (Insurance Commissioner of the State of California, 2018). The companies that did survive this incident were forced to recuperate by increasing premiums to accurately cover the expected losses (Cignarale, et al., 2018). Further complicating the matter for insurers, the California regulations require insurers to base catastrophe loading on 20 years of historical data rather than predicted catastrophe losses (Cignarale, et al., 2018).

As the effects of climate change are expected to induce increased losses, the problem for insurers becomes apparent. Since one way to control portfolio risk is to avoid issuing policies in high-risk areas, enough companies took this route that it became difficult for many homeowners in fire-prone areas of California to find coverage (Lara, 2019). In response, California Insurance Commissioner Ricardo Lara temporarily banned insurers in December 2019 from issuing non-renewals due to increased risk. In his own words, the Commissioner made the case for the decision by stating "… this wildfire insurance crisis has been years in the making, but it is an emergency we must deal with now if we are going to keep the California dream of home ownership from becoming the California nightmare, as an increasing number of homeowners struggle to find coverage. I am calling on insurance companies to push the pause button on issuing non-renewals for one year to give breathing room to communities and homeowners while they adapt and mitigate risks, give the Legislature time to work on additional lasting solutions, and allow California's insurance market to stabilize" (Lara, 2019).

It should be noted that the main driver of fire danger in the case of the California wildfires was not carbon sequestration projects. However, afforestation and reforestation projects on a large enough scale could alter fire risks in certain locations, including those seeking to restore habitats after devastation from fires. Given all of these issues, it seems apparent that better-informed pricing and pricing policies are needed. We suggest that this can be achieved mainly through a deeper understanding of fire risk on a fine scale to better predict future fire losses and apply this knowledge to market segmentation. This process is already underway as new modeling methods are emerging in attempts to properly assess the risk of wildfire (CAS, 2019).

Section 2: Direct and Reciprocal Effects of Climate Change on Wildfire Risk

Before unpacking the impact that afforestation and reforestation have on climate change and fire hazard, we first summarize the general relationship between climate and wildfire as outlined in Figure 1. Historically, large wildfires have fallen under the category of catastrophic events, evaluated based on low frequencies and portfolio level severities (Banks, 2005; Barrieu, 2009; Dietz & Walker, 2017). Yet, the examples above and recent scientific studies demonstrate that climate change is drastically changing the risk profile of these natural disasters.

Wildfires are a natural and even necessary part of many ecosystems. For example, many species of pine rely on fire to release their seeds for new growth. Wildfires are driven by many interacting factors such as fuel levels, forest composition, and elevation (Mallek, Safford, Viers, & Miller, 2013). To more clearly understand the impact of climate change on this naturally occurring process, new modeling techniques have emerged. These "attribution" models robustly determine if an extreme event can be attributed to changes in climate as opposed to other causes such as fuel buildup (Scott, 2016). Using these modeling tools, numerous studies have turned their attention to the recent increase in frequency and severity of wildfires in the western United States. These studies estimate theoretical area burned without climatic changes and compare them to actual burned area. Such models have demonstrated that much of the increase in area burned in recent years can indeed be attributed to climate change (Barbero, et al., 2015; Yoon, et al., 2015; Abatzoglou, et al., 2014).

In a vicious cycle, wildfires caused by climate change exacerbate its effects, as burned forests release carbon into the atmosphere. In 2018, while 37 billion metric tons of CO_2 were released due to burning of fossil fuels, an estimated 14% of total carbon emissions were due to changes in land use, such as deforestation or burned wildland (Global Carbon Project, 2019). One estimate, from 1997 to 2016, states that an average of 2.2 billion metric tons of CO_2 released each year came from forest fires (Werf, et al., 2017). The U.S. Department of the Interior estimated that the 2018 California wildfires released approximately 68 million U.S. tons (61.7 million metric tons) of carbon. To put this into perspective, this amount is close to the state's carbon emission due to annual power usage (US Department of the Interior, 2018). Thus, recent instances of wildfires further fuel climate change which in turn may increase their frequency.

Section 3: New Fire Hazard Emerging from Tree Planting

Understanding fine-scale fire risk involves knowledge not only of climate change but also human responses to it, such as planting trees to sequester carbon or restore burned forests. We establish two mutually non-exclusive motivations for such planting, both of which can result in new fire hazards. The first motivation, carbon sequestration, is grounded in the fact that trees grow by removing carbon dioxide from the air and use the carbon to make new cells and tissue (Bastin, Finegold, Garcia, & Mollicone, 2019). When managed in a sustainable way, increased tree biomass therefore "sequesters" the carbon from the atmosphere. Reforestation is a second and complementary motivation which represents societal efforts to replace forests destroyed by wildfires or anthropogenic land clearing.

3.1 CARBON SEQUESTRATION BY AFFORESTATION

Since climate change is mainly driven by the release of greenhouse gases into the atmosphere (Global Carbon Project, 2019), mitigation strategies include lowering atmospheric CO_2 levels by capturing and sequestering carbon. Trees take in CO_2, convert it to photosynthate, and store it in their biomass as well as in the soil (Bastin, Finegold, Garcia, & Mollicone, 2019). In 2019, a controversial paper published in the journal *Science* (Bastin, Finegold, Garcia, & Mollicone, 2019) asserted that forestation is one of the "most effective strategies" to fight climate change, and identified 900 million hectares that could potentially be planted. Policies and programs embracing this strategy have gained immense traction in recent years, and practitioners should be aware of such programs operating within their market.

For example, in early 2020 the World Economic Forum announced their 1t.org initiative, which aims to catalyze planting of one trillion trees worldwide (Cann, 2020). The planting efforts range from government funded projects such as the United Kingdom's Urban Tree Challenge Fund, to children's organizations such as Plant for the Planet and Plant-Ed. A world record was set in July 2016 when over 50 million trees were planted in one day in India (Howard, 2016). Similarly, tree planting policies in China such as "Grain for Green" and the "Great Green Wall" aim to recover ecosystem benefits and prevent desertification. By 2050, the Chinese State Forestry Administration aims to increase forest coverage from 5% to 15%. Cost for the project is expected to exceed $14 billion, with over 300 million individuals involved in the effort (Minqin, 2019).

Carbon sequestration has also been a particular focus of many Payments for Ecosystem Services (PES) and government schemes. Ecosystem services are any human derived benefits arising from ecosystems. These services include food and water, building materials, areas for public enjoyment, flood regulation, air quality regulation, and pharmaceuticals, among many other services. PES schemes have emerged to ensure delivery of some non-marketed services, such as freshwater provisioning (downstream users of water paying upstream users of water for a particular quality and/or quantity of water) and carbon sequestration (Perrings, 2014). In 2008, for example, the United Nations launched the REDD program: Reducing Emissions from Deforestation and Degradation. This program incentivizes carbon sequestration by funding reforestation and preventing deforestation in developing countries.

Another popular catalyst for tree planting is the purchase of carbon offsets. Carbon offsets allow an individual to pay to plant trees that will sequester carbon equal to their carbon footprint. As airline travel results in a high quantity of emissions, many airlines have chosen to offer passengers an option to pay for a carbon offset when purchasing their ticket. In 2018, the voluntary carbon offset market was valued at USD $295.7 million, sequestering 98.4 metric tons of CO_2. While some offsets are invested in other projects such as renewable energy or clean transportation, sequestration through forestry and land use remains the most popular form of offset, valuing at $171.9 million and sequestering 50.7 metric tons of CO_2 (Donofrio, Maguire, Merry, & Zwick, 2019). Though the market is still in its infancy, there are many signs suggesting future growth. In February 2020, Delta Airlines announced that they would work toward becoming carbon neutral, in part through planting trees to sequester carbon, offsetting the amount emitted by their planes (Delta, 2020). In January 2020, Microsoft announced their ambitions to be carbon negative by 2030, and to sequester all carbon they have released since the company's inception by the year 2050 (Smith, 2020).

A particular challenge with carbon sequestration schemes is that their focus is tied to the provision of one ecosystem service without other ecosystem considerations (Kinzig et al., 2011). For example, if a client pays for a certain amount of carbon to be sequestered, they may not necessarily account for resulting increased risks that this might engender. Planting forests in inappropriate locations, or planting the wrong species, can increase fire risk. If more trees are planted haphazardly, more fire risk can be generated. As an example, fast-growing monocultures, such as eucalyptus or pine, might on the surface seem desirable for sequestration. Counterintuitively, these forests increase fire and pathogen risks, with consequent impacts on, for example, water quality within the watershed (Felton, et al., 2016). Hence, while some ecosystem services are complementary, and enhancing delivery of one will enhance delivery of another, others "trade off" against each other (Veldman, 2015). In the case of China's tree-planting initiatives, ecosystem recovery and protection against desertification are much needed, but water shortages and poor choice of tree species, both of which can contribute to increased fire hazard, have raised concern (Zastro, 2019). Recent efforts have focused on planting more water-efficient shrubs and trees that are native to the region, instead of risky nonnative monocultures (Cao, et al., 2011).

3.2 REFORESTATION

Planting trees after a fire is a direct means of speeding up forest regrowth (White & Long, 2019). After loss to a wildfire, desire to replant arises for many reasons. For profitability reasons industrial foresters are incentivized to replant their crop, while private landowners may wish to restore the forest for aesthetic or environmental reasons. Others hope to re-sequester lost carbon stores (Waks, Kocher, & Huntsinger, 2019). While burned forest area has the ability to regrow on its own, in some cases invasive species, such as particular grasses, can quickly take hold. This makes natural regrowth of the forest slow and difficult. Some of these invasive grasses are highly flammable themselves, potentially altering the fire regime and preventing reestablishment of the original forest. They may not support biodiversity or provide ecosystem services (Fusco, Finn, Balch, Nagy, & Bradley, 2019).

Through years of planting clear cut or burned areas on national, industrial, and privately owned forests, the commercial forestry industry and U.S. forestry service have developed a system for reforesting that allows tall trees to grow quickly, filling an entire area with as much crop as possible. The method, often referred to as "pines in lines" creates perfectly homogenous forests that are especially susceptible to fire as we discuss in the next section (North, et al., 2018).

Aside from forestry-service-led reforestation, recently burned areas in Australia and California have gained attention from tree planting initiatives such as One Tree Planted and California Releaf. Similarly, Tree Canada has been carrying out their "Operation Releaf" since 2016 to replant trees lost to the Fort McMurray wildfire. These tree planting initiatives have a focus on both forest restoration and carbon capture. They attempt to increase sustainability by relying on local foresters to advise on appropriate management practices and choice of tree species. However even the leading forestry experts are advocating for more research to be conducted on fire-resistant reforestation, as this avenue of study has been neglected historically (North, et al., 2018).

3.3 DRIVERS OF RISK

A forest is not simply the sum of the individual trees it contains. Rather, the ways trees interact with each other, water resources, other vegetation, and human behavior impact the overall ecosystem. If not carefully planned, tree planting methods have the potential to increase wildfire risk. Homogeneous stands of similarly aged trees, for instance, are more fire prone (once they have aged and fuel loads have increased) than heterogeneously aged stands (Stephens, et al., 2012). This is particularly problematic in areas where human activities routinely provide a risk for ignition, such as from campfires or power lines (Press, 2020). New trees act as a carbon sink to alleviate the effects of climate change, but they can also act as fuel for dangerous wildfires. Thus, tree planting efforts can generate, and already have generated, new sources of risk, with the potential to exacerbate the already increasing costs of catastrophic fires. All of this should be of concern to insurers.

In areas of naturally occurring wildfires, such as the drier climates of the western U.S., planting trees without taking into account water resources, tree density, spatial distribution, shrub growth, and preexisting fuel levels can lead to an increase of fire risk. For example, forest growth has known impacts on water resources that can increase flammability. Trees use water, which can reduce water availability, but they also cast shade on soils, which can decrease evaporation and increase water availability. Careful planning and modelling would be required in reforested areas to determine changes in water availability and possible water stress in plants. Low plant moisture is a major contributor to plant flammability (Etlinger & Beall, 2004). In addition, fuel aridity is highly correlated with both increased frequency and severity of wildfires, suggesting a mechanistic relationship (Abatzogloua & Williams, 2016).

Densely packed trees not only use up more water resources, but can increase wildfire severity through their spatial relationships. A large number of same-height trees close together allow the fire to spread from tree to tree in crown or canopy fires, increasing fire severity (Song & Lee, 2017). This is one reason that the “pines in lines” method of planning can create larger-scale fires, as it allows easy spread of canopy fires. However, if trees are not planted densely enough, breaks in the canopy can allow for the growth of grasses, shrubs, and new trees that can increase fuel load and fire risk. Early on in forestation, these grasses and shrubs compete with tree seedlings for resources and can choke out the new forest. In older stands, these small plants — called ladder fuels — allow for the spread of fire from the forest floor to the crown, thereby increasing fire severity (Stephens, et al., 2012).

Section 4: Emerging Policies and Practices to Reduce Wildfire Risk

Active management policies are essential to maintaining value derived from forest ecosystems while mitigating risks. One example of a past policy that had unintended detrimental effects was fire suppression. Wildfire risk frequency and severity is increased by surface fuel levels. Fuel for forest fires can consist of any combustible matter, however dry, dead biomass on the forest floor poses the largest risk for high intensity fire (Stephens, et al., 2012). While fire is relatively rare in peatlands, for example, it is an expected and necessary part of forest ecosystems in drier areas such as California. Trees in these areas are specifically adapted to be resilient to frequent fires. In these areas, frequent low-severity fires maintain forest health by removing dead organic matter and killing smaller trees that compete for water resources. When allowed to take their course, these low severity fires prevent susceptibility to the larger catastrophic and destructive fires that California has seen in recent years. Unfortunately, decades of fire suppression policies have led to a buildup of fuel, which has had a large part to play in the catastrophic events seen in recent years (Agee & Skinner, 2005). The insurers should take notice of the impacts of this policy.

While the previous management policy has increased fire risk, some forestry scientists are testing a new method for tree planting that, if successful, could reduce forest susceptibility to wildfire loss. The method is called ICO, which stands for Individual, Clump, and Open. In this method, some trees are planted in clumps together, with individual trees planted farther apart from each other, and some areas left open. The clumps of trees provide a denser forest cover and are able to grow more quickly, as they do not have to compete with shrubs. Quickly growing trees will be able to quickly recapture lost carbon after a burn. Individual trees provide additional forest cover, while reducing fire spread due to spacing. Open areas provide additional buffer against spreading wildfire and account for areas that are infeasible to replant. Additionally, when allowed regular prescribed burns, vegetation on the forest floor such as shrubs will not grow tall enough to create ladder fuels. Previous research suggests that such a model should greatly reduce wildfire severity, however the study is still ongoing (North, et al., 2018).

Another ongoing and complex area of research is determining flammability of trees and vegetation to aid in homeowners' landscaping choices. One well known mitigation strategy is to create a "fire defensible zone" that prevents fire from spreading across landscaped trees and plants to the home (Calfire, 2019). While many local organizations provide lists of suggested fire-resistant plants, these lists can be contradictory and poorly researched (Kiers & Colvin, 2019). In fact, flammability itself is not a clearly defined concept, but rather consists of interacting component measurements. Aspects of flammability include time to ignition, flame temperature and height, time sustained burning, and mass of plant burned. Because these components can be competing, it is difficult to rank plants along a single flammability scale. Intricacies of the multidimensional risks of flammability can be found in the excellent review given by Prior, Murphy, & Bowman, 2018. Furthermore, these flammability components have dynamic relationships with fuel loads and planting patterns.

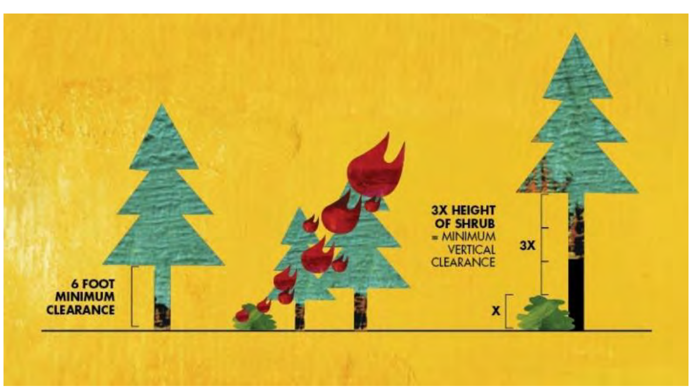
Currently there are many unknowns, but forestry science has found certain measures can be taken to reduce wildfire risk. In an area previously burned by wildfire, salvaging and clearing out remaining fuel and large snags will reduce severity of reburn (Stephens, et al., 2018). Treating for competing vegetation such as invasive plants will allow planted trees to establish and grow faster while reducing fire risk (Lanini & Radosevich, 1986). Careful choice of tree species and placement to account for available water will reduce risk of water stress in drought. Planting multiple species and leaving areas unplanted creates firebreaks (Long, et al., 2016). No matter how dense the trees are originally planted, continued management of fuel reduction through prescribed burns or manual thinning of small ladder fuels will reduce risk of ground fires spreading to crown fires (Stephens, et al., 2012).

Figure 2

PLANTING STRATEGIES

Left: Suggested planting guidelines from CALFIRE for property owners include trimming branches to be at least 6 feet from the ground and at least three times higher than any nearby shrubs (Calfire, 2019).

Right: An aerial view of an ICO forested area (North, Stine, O'Hara, Zielinski, & Stevens, 2009).



Section 5: Assessing New Fire Risk for Actuaries

In order to accurately quantify wildfire risk, insurers need to know which factors are drivers of losses after tree planting. The rich history of academic studies concerning wildfire modeling developed over the last century are a valuable resource for further understanding how to model losses. The tools developed vary from theoretical models built on mathematical probabilities of spread to semi-empirical and empirical models based on historical fire regimes, climate, and fuel levels (Pastor, Za´rate, Planas, & Arnaldos, 2003).

The BehavePlus system, developed and managed by the U.S. Forestry service is of particular note, available for free download online. This model incorporates fuel and moisture conditions, wind, and probability of ignition. While there is certainly a learning curve to using and interpreting these models correctly, their website offers training materials to better understand the model's assumptions and capabilities (U.S. Forest Service, 2020). In a larger modeling context, this system could be used for repeated simulations and stress testing under various planting and atmospheric conditions. These models can predict factors such as area burned, tree mortality, or flame height. Unfortunately, they do not incorporate effects of wildland urban interfaces or fire damage impact on built environments.

In attempts to make fire hazard models more publicly accessible, in some states interactive maps are available online that specify which areas are at higher risk. Particularly in California, the so called "Bates Bill" requires the state to identify high risk areas and to inform local authorities of the risk. This was implemented in 2007 through the Fire Hazard Severity Zones maps. However, even in California where these risk maps are more detailed, they are only updated every few years and can suffer from data discrepancies (ca.gov, 2020). Each state also relies on different models, their own data, and their own methodology of what factors to include. These can range from purely historical fire regime maps to incorporating fuel levels and urban interface areas. Hence, these maps provide a starting place for insurers hoping to understand geographic risk profile, but they tend to lack information about property level variations of risk. In this context, insurers have an important role to play in influencing state regulations and driving research forward when it comes to modeling fire hazard risk in the context of climate change.

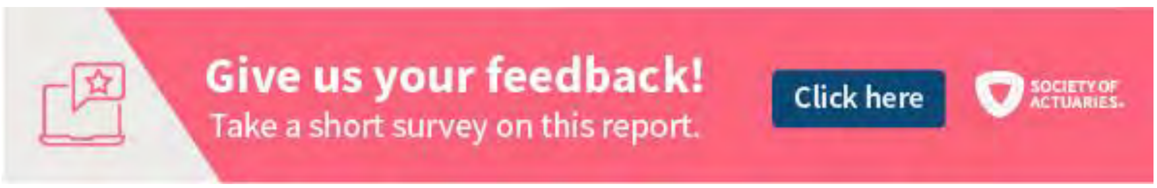
To fill the insurance industry needs not met by the government maps and fire behavior models, high-definition probabilistic commercial models, such as those from AIR (formerly Applied Insurance Research) and RMS, have emerged in the wake of the catastrophic losses seen in recent years. Their models are not based solely on historical frequency and severity; rather, like the academic models, they attempt to incorporate drivers of fire spread, such as surface fuels and weather conditions. What particularly sets them apart for insurance application purposes is their attempt to capture fire spread throughout wildland urban interface areas and their inclusion of secondary effects from embers and smoke. Finally, these models also take into account reduced risk due to some mitigation tactics such as building materials of the home.

While various commercial modeling tools are becoming more widely available, the specific needs of each insurer will differ when assessing the impact of tree planting for sequestration. Each insurer can begin by analyzing how much of their portfolio is in wildland urban interfacing areas that are at high risk, using such readily available government maps as those provided by CalFire. For properties in these areas, fire spread potential can be further understood by gathering data on the present tree and vegetation species, their diversity, and their density. Aerial imaging or LIDAR may be a useful tool to obtain this data remotely.

Section 6: Conclusion

In the U.S. it is important to note that 58% of forestland is privately owned, and 38% is private non-corporately owned (Oswalt, Smith, Miles, & Pugh, 2017). That is why private property owners have a particular role in risk evaluation and mitigation. By managing private forests in a fire-resistant manner, property risk decreases, not only for the owner, but also for surrounding properties. Thus, combining modeled risk of a property fire with on-site confirmation of modeled fuel levels and tree density can lead to more accurate assessment of risk and thus market segmentation.

Although regulations may prohibit insurers in certain states from reducing risk through premium increases or non-renewal, market segmentation through premium discounts may be a viable strategy to offer competitive rates while lowering risk profile. In particular, we propose “flammability” discounts for private property owners with sustainably managed forestland. While living near forestland is inherently higher wildfire risk than an urban home, fires started or spread through poorly maintained private property have potential to spread to urban areas. Heterogeneous type and dispersal of trees, along with low fuel levels on the forest floor reduces the potential for catastrophic fire spread while still sequestering carbon. Thus, such a discount would not only incentivize the individual property owner, but also reduce hazard to the entire portfolio.



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