The Merits of Prescribed Fire Outweigh Potential Carbon Emission Effects

Photo Credit Jane Park

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Executive Summary

While North American ecosystems vary widely in their ecology and natural historical fire regimes, they are unified in benefitting from prescribed fire when judiciously applied with the goal of maintaining and restoring native ecosystem composition, structure, and function. On a modern landscape in which historical fire regimes cannot naturally occur due to fuel load build-up and resulting public safety concerns, the cornerstone ecological role of fire cannot be left to chance. Unintentional wildfires, which inevitably result due to fuel accumulation, are often ecologically disruptive and socially costly; yielding post-fire ecosystems with reduced ecological value (e.g., carbon sequestration, habitat for wildlife, etc.) and high vulnerability to insects and pathogens. While cessation of prescribed burning may seem appealing in the short term as a means of curbing carbon emissions and improving air quality, this perspective lacks long-term vision and ecological understanding. The overarching imperative for prescribed fire is that it can be used safely and responsibly to reduce hazardous wildfires, while perpetuating stable and resilient ecosystem with regard to ecosystem health, services, and lasting carbon sequestration.

It is estimated that wildfires in the United States and Canada produce an average of 452 Tg/year in carbon emissions (Amiro et al. 2001; Weidinmyer and Neff 2007), compared to average annual fossil fuel emissions of 1,585 Tg/year (Carbon Dioxide Information Analysis Center http://cdiac.ornl.gov). The trend in wildfire activity, according to climate and fire scientists, is expected to increase as the planet warms (Flannigan et al. 2005; Intergovernmental Panel on Climate Change 2007). An unfortunate feedback loop exists where more fires lead to greater emissions of greenhouse gases leading to conditions increasingly conducive to wildfire (North et al. 2009; Stephens et al. 2009; Weidinmyer and Hurteau 2010). An additional, albeit much smaller source of carbon emissions, results from the application of prescribed fire. Across North America prescribed fire is used in a wide range of ecosystems to meet many different goals. Rarely is prescribed fire applied with only one objective in mind; instead it is used holistically to achieve a range of social, cultural, ecological, and economic objectives – often all at once and on the same piece of ground. For example, a prescribed fire management regime may serve to maintain desired ecosystem composition and structure, reduce damaging pathogens and insect pests, increase plant biodiversity, provide and restore required habitat for endangered species, and reduce subsequent wildfire risk through fuel reduction. Carbon emissions associated with both wildfire and prescribed fire include the direct emissions of carbon compounds (carbon dioxide, carbon monoxide, methane, particulate matter, etc.) during the flaming and smoldering phases of combustion, plus some longer-term emissions associated with the decomposition of vegetative material killed in the burn. Carbon emissions from prescribed fire vary by region and ecosystem, as well as year to year depending on weather conditions, political support, and availability of human and financial resources.

Recently, questions have arisen over the potential for prescribed fire to reduce or offset undesired wildfire effects and carbon emissions. Some authors and researchers contend that if managers applied more prescribed fire and other similar interventions (such as mechanical and manual thinning) we would see a reduction overall in fire-related carbon emissions (Weidinmyer and Hurteau 2010). Still others suggest that these interventions, which in some regions of the US can be costly and risky to apply, are of little value in limiting the scope and consequences of wildfire (Williams and Baker 2012) including carbon emissions (Meigs and Campbell 2010; Morton et al. 2012; Campbell et al. 2012). To sort out the facts from the fiction with regards to prescribed fire's overall benefits and carbon implications, it is helpful to review the contexts in which prescribed fire is used in a variety of different ecosystems characterized by specific fire regimes.

A fire regime is a set of attributes that describe how fire has affected a given ecosystem over an extended period of time. The "historical fire regime" is often used as a benchmark for guiding the timing, execution, and expectations for prescribed fire implementation. Historical fire regimes are the set of fire characteristics that, since the last large-scale glacial retreat over 10,000 years ago, influenced the resulting ecosystems European settlers encountered when they reached North America. The plants, wildlife, structure and processes of all North American ecosystems evolved in the context of some type of fire regime, even if the regime included highly infrequent fire. Fire regimes are comprised of fire frequency, timing (seasonality), extent, severity, type (e.g. crown, ground), intensity, and synergy with other disturbance regimes (e.g. drought, disease, insects). Prescribed fire is most often applied with the goal of restoring or mimicking the historical fire regime known to have resulted in the ecosystems present at the time of Settlement. In many cases, ecosystems exhibiting significant departure from historically frequent fire regimes are most susceptible to whole-scale transformation into alternative ecosystems with new fire regimes: This transformation is what prescribed burners are attempting to avoid, for the perpetuity of our native ecosystems.

It is important to note that there is large uncertainty associated with estimating carbon emissions from both prescribed fires and wildfires. Estimates depend on a wide range of fire regime factors, including the severity and type of fire, as well as the spatial heterogeneity of the vegetation and postfire recovery patterns (Weidinmyer and Neff 2007). In contrast, there is little uncertainty surrounding our knowledge of the ecological benefits of prescribed fire, substantiating the imperative of using prescribed burns to restore historical fire regimes and maintain our natural ecosystems.

Frequent, low-severity fire regimes

Historically frequent, low-severity fire regimes (mean fire-return interval <30 years) characterize the lower-elevation, dry coniferous forests of western North America, as well as the pinelands of the southeastern US. These forests have undergone significant transformations in structure and species composition over the last century due to fire exclusion, livestock grazing, timber harvest, and the introduction of non-native, invasive species. Landscape-scale, high-severity fire has become the norm for some of these ecosystems, which evolved under the influence of smaller-scale, low-severity surface fires. This dramatic shift to higher severity wildfires can spur negative social, cultural, ecological and economic consequences. The use of prescribed fire in these systems is driven by the need to circumvent high-severity wildfire effects by restoring resilience before a wildfire occurs. A host of other objectives compliment this over-arching goal, including hazard reduction for Wildland-Urban Interface (WUI) dwellers, the maintenance or habitat enhancement of dependent wildlife, or the perpetuation of the ecosystem itself. What research has shown is that strategically planned and executed prescribed fire can result in forests resistant to high-intensity wildfire. The cumulative effects of prescribed fire management on ecosystem composition and structure can help to improve the survival of mature trees during wildfire events and reduce the likelihood of ecosystem-altering processes caused by high intensity fire such as extreme organic soil consumption, soil sterilization, hydrophobic layer development, widespread erosion, and stream siltation and nutrient pollution. These ecological benefits translate into a wide range of potential human social benefits, including a safer and ultimately more successful and less costly fire suppression environment, economic productivity of forests, intact hydrologic systems and clean water supplies, reduced emissions of particulate matter and other potentially harmful compounds, and, improved protection of communities, businesses and other important resources valued by society.

Much theoretical research has gone into assessing the carbon emission benefits of western North American dry forest restoration using thinning and prescribed fire (Stephenson et al. 2009; Hurteau and Brooks 2011; North and Hurteau 2011). The central premise is that high severity wildfires result in large direct carbon emissions and reductions in ecosystem carbon pools as well as prolonged carbon emissions and subsequent pool reductions due to the decomposition of surface and subsurface carbon stocks. Following fire, carbon pools gradually recover as net ecosystem productivity increases. How long this ecosystem and carbon pool recovery takes is highly dependent on the initial site productivity, previous fire and disturbance history, burn severity and the post-fire environment. Prescribed fire, often preceded by thinning to reduce forest density, also results in the reduction of ecosystem carbon pools through direct and indirect emissions. However, these reductions and emissions may be offset by the retention and increase in gross primary productivity (GPP) of mature trees due to reduced competition, and the re-sequester of most emissions by plant growth, often in as little as 2-7 years depending on the region (Hurteau and North 2010). Most importantly, such structural restoration followed by the implementation of a frequent prescribed fire regime will result in a forest that is in carbon equilibrium (or positive soil carbon sequestration) from one fire interval to the next, avoiding unnaturally severe wildfires that are highly destabilizing to both the ecology and carbon balance (Hurteau and North 2012).

One factor that has driven this new look at prescribed fire as a carbon benefit is the emergence of carbon registry programs, such as British Columbia's Forest Carbon Protocol, which support a non-intervention policy because dry forests in their current, baseline, untreated state are considered to be functioning as carbon stores and the storage capacity can be traded on the carbon market. Wildfire, if it occurs, is considered natural, therefore the baseline carbon stock is simply reduced as if no emissions had occurred as a result of the fire. Thinning and prescribed fire, which are intended to mitigate the impacts of wildfire, including high carbon emissions, are penalized under these programs because their carbon consequences are subtracted from the baseline carbon stocks. The arbitrary nature of carbon accounting under this and other carbon registry systems does little to help inform the public and policy makers. Such accounting does not consider the consequences of maintaining the status quo in forest structure for the sake of short-term financial benefit on the carbon market. Worse yet, present accounting practices suggest that wildfire should be chosen over prescribed fire, regardless of the consequences. The short-term financial gain from the sale of carbon credits from non-treated land pales in comparison to the potential long-term economic and environmental consequences of wildfire.

Researchers have determined that while suppression costs for large wildfires are increasing, the true cost of wildfires, which can accrue over a decade or longer as environmental impacts become more apparent, is 20 to 50 times the suppression cost (Western Forestry Leadership Institute 2010). Importantly, the overstocked forests resulting from non-intervention carbon maximization and fire suppression/exclusion policies can result in high severity wildfires that lead to prolonged ecosystem type conversions from forestlands to grass and shrublands. As reducing deforestation has been identified as a key strategy for combating continued global climate change, restoring and maintaining frequent fire regimes has been identified as a way of perpetuating fire resilient forests. Forests provide valuable plant and wildlife habitat, persistent above and below-ground carbon pools, timber products, and increasingly important social, ecological, recreational, and hydrologic ecosystem services (Hurteau and Brooks 2011; McKinley et al. 2011).

In the southeastern US, a wide variety of ecosystems require frequent, low-intensity fire in order to maintain a healthy diversity of plants and animals (e.g., in Florida, over 26 ecosystems are considered fire-dependent, associated with over 750 plant and 300 animal species), as well as keeping fuel loads at a safe level. Ecosystems such as sandhills and pine flatwoods can experience fire frequencies as high as yearly and even bi-annually. The amount of carbon stored within underground plant components, as well as above ground in the form of charcoal, is currently being tracked by collaborative public agency-university efforts. Preliminary results point to these ecosystems becoming a carbon sink within one month following a fire. In order to reduce fuel hazard and improve habitat conditions within many pyrogenic ecosystems, prescribed burning can be implemented at a fraction of the cost of wildfire suppression. For example, prescribed fires conducted during the past five years within the Merritt Island National Wildlife Refuge has reduced hazardous fuels, thereby protecting NASA and Refuge infrastructure, employees, and lucrative tourism by minimizing the intensity and duration of wildfires. Two such prescribed burns cost $56,000 ($9.08/acre) to implement. During this same time, three wildfires that occurred within this landscape cost $106,000 ($191.68/acre) to extinguish. The projected cost savings to wildfire suppression due to the prescribed burning fuels reduction treatments was an impressive $3.6 million (Hamilton 2012).

Frequent, high-severity fire regimes

It seems counter-intuitive but rangeland, marsh, and shrubland fire regimes are characterized as high frequency (mean fire interval <30 years) and also high-severity. The "high-severity" designation is associated with the top-killing of the majority of the above ground vegetation. This does not suggest that fire has permanently killed the vegetation, it simply means that the above-ground plant parts have been girdled and/or consumed, while the root stocks remain intact. Historically, millions of hectares of these types of systems in North America, including the extensive pine and oak savannas throughout the east, burned every year through both indigenous and lightning ignitions, to the benefit of the ecosystem and it's wildlife and human inhabitants. Grassland and former grassland ecosystems are burned today to meet a wide range of objectives, from the restoration and maintenance of native grasslands, to control or reduce invasive species, to the burning of agricultural stubble for cropland management purposes.

Prescribed burning of grasslands and croplands (i.e., agricultural burning) has been targeted by climate scientists as an unnecessary carbon emission source (Morton et al. 2012). While burning croplands certainly has some negative environmental consequences (volatilized nutrients, emissions of particulate), alternatives to burning croplands also carry some undesirable consequences: tilling and turning the stubble exposes the surface to wind erosion and immobilises soil nitrogen; added cost of applying chemical nitrogen fertilizers; or, having to introduce grazing animals leading to soil compaction without providing much nutrient value to the animals. All three of these alternatives produce large quantities of carbon emissions from either fossil fuels or livestock.

In reality, wildfire and prescribed burning in grasslands and croplands, while constituting a large annual area burned/year in North America (Morton et al. 2012), does not contribute significantly to the overall annual US CO2 fire emissions inventory. Carbon dioxide emissions from grasslands account for 5% of the 2006 estimated fire emissions inventory, and emissions from cropland burning contribute <3% (Weidinmyer and Neff 2007). Most importantly, these systems sustainably sequester carbon within the time scale of their fire frequency (burning typically every 1 – 3 years), which makes them carbon neutral in terms of vegetation pools and possibly carbon sinks due to soil carbon sequestration through reduced tillage.

Infrequent, high-severity fire regimes

Prescribed fire is increasingly being applied in high-severity fire regimes in western North America. With long fire-return intervals, high-severity, or stand-replacement, fire regimes have been considered to be little influenced by a century of fire exclusion, and therefore, under the pretext of ecosystem restoration, not in need of active intervention (Keeley et al. 2009). However, with the mountain pine beetle epidemic in western North America -now approaching 20 million hectares in Canada and 4 million hectares in the US, wildfire, which eventually follows these epidemics, is not considered to be the preferred management alternative. Research suggests that this current epidemic is unprecedented. In the past the landscape contained a heterogeneous patchwork of stand ages and structures, making epidemics much less likely to become extensive before running into stand types that would not support overwintering beetles (Taylor and Carroll 2004). A century of fire exclusion coupled with a warming climate has resulted in a homogeneous landscape with few biological barriers to prevent the spread of extensive and lethal insect infestations. Leaving the landscape to be "re-set" by high severity wildfire is not the preferred option, due to the negative consequences for public safety, and cultural, environmental and economic impacts. Hence, prescribed fire is being used more often in an attempt to protect important values, and to reduce the potential size, cost, intensity and severity of future wildfires. Prescribed fire is the stepping stone towards re-establishing the historically resilient ecosystem structure and process across these landscapes.

In the absence of wildfire, these 24 million hectares of dead pine are a long-term source of carbon emissions via heterotrophic respiration sources (i.e., decomposition), even though regeneration is occurring in many of these stands. Should wildfire occur, burn severity, through its impact on vegetation recovery, becomes the critical element. If the postfire stand has poor or no regeneration (owing to high burn severity and extent of wildfire, coupled with the limited availability of seed sources), forest growth will not replace the carbon lost to combustion and decomposition, and the net carbon storage over a fire cycle will decrease. Recovery of carbon lost through combustion appears to be far slower in sparsely regenerated stands; in fact, carbon lost in the fire may not be recovered even after 250 years if postfire tree density is very low (Kashian et al. 2006). Prescribed fire in these situations is typically carried out during periods of higher soil and fuel moisture in order to limit burn severity and improve future ecosystem resilience, thus tipping the carbon balance towards sequestration over the long term.

Recommendations:

- **Carbon registry systems need to re-evaluate accounting of wildfire and prescribed fire emissions.** Carbon registry systems should apply full carbon accounting principles evenly to sites whether they have experienced a wildfire or the site has been proactively treated to reduce potentially negative impacts of wildfire. The effects of wildfire are considered natural, with baseline carbon stocks simply reduced with no concomitant emissions considered. Prescribed fire, and antecedent forest thinning to reduce fire hazard and promote other ecosystem services, has to account for all emissions produced throughout the process. This disparity in accounting suggests that non-intervention (i.e., wildfire), or intervention in the form of full wildfire suppression, are more favorable management options than pro-active management of fuels. All management options need to be assessed over a level playing field and inclusive of all potential social, cultural, ecological, and economic benefits and consequences.
- **Need increased research into carbon dynamics for a range of fire regimes and management options (i.e., wildfire, prescribed fire, thinning, etc.).** In this relatively new field of research some fire regimes, ecological conditions, and management strategies have received a great deal of research attention while others have received very little. Considering the potential consequences for carbon accounting, both environmentally (contributions to global warming and attendant subsequent impacts) and economically (emerging carbon offset marketing), as accurate a picture of the carbon implications of ranges of management actions on all fire regimes would be prudent. Furthermore, the spatial and temporal dimensions of carbon dynamics need to be considered.
- **Need further research into quantifying and mapping current terrestrial carbon reserves (aboveground live, litter, duff, downed woody debris, and soil carbon), as well as estimating subsequent emissions from prescribed fire or wildfire.** A national/international effort is needed to gain a better understanding of baseline terrestrial carbon reserves as well as emissions of carbon compounds from fuel management treatments, prescribed fire and wildfire. Over the long-term this information should be housed in a national/international database to be used by policy makers and resource managers to make more informed decisions on the range of potential carbon emissions management activities.

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