5-11-2023

Fight to Ignite: The Impacts of Climate Change on Prescribed Burning in Pine Forests

Chloe Anderson
College of Saint Benedict/Saint John's University, canderson005@csbsju.edu

Fight to Ignite:

The Impacts of Climate Change on Prescribed Burning in Pine Forests

Chloe Anderson

ENVR 320

April 4, 2023

Fight to Ignite: The Impacts of Climate Change on Prescribed Burning in Pine Forests

Abstract

Prescribed Burning is a strategy that has been used to manage the health of forest ecosystems for thousands of years. Fire acts as a catalyst by returning nutrients to soil and promoting healthy regrowth. While these practices have certainly evolved over time, recent impacts of climate change are threatening the future of implementing fire in forest management altogether. This paper will use a combination of background information taken from scholarly and scientific texts, as well as current climate data to analyze the progression of climate effects on forest conditions, while examining solutions to mitigate these issues going forward.

Introduction

Prescribed burning is a restorative ecological process that has been used in many geographical regions, especially forests, to promote regrowth by returning nutrients to the soil and providing many species with the conditions needed to reproduce. When prescribed burning is implemented in pine forests, there is an increase in radial growth, which means plants are able to grow with a more substantial and bulkier circumference. This is because there is less competition for resources such as water, nutrients, and light.[1] Fire can also affect naturally occurring processes such as runoff and sediment collection, aiding in transporting nutrients in these terrestrial ecosystems.[2] Prescribed Burning is a valuable tool used to manage the health of western pine forests. Without using prescribed burning to manage pine forests, the vegetation in

[1] Douglas J. Westlind and Becky K. Kerns, "Repeated Fall Prescribed Fire in Previously Thinned Pinus Ponderosa Increases Growth and Resistance to Other Disturbances," *Forest Ecology & Management* 480 (2021), https://doi.org/10.1016/j.foreco.2020.118645.

[2] "Prescribed Fire and Its Effects on Forested Ecosystems," U.S. Forest Service, 2023, https://www.srs.fs.usda.gov/coweeta/research/prescribed-fire/.

those ecosystems is more susceptible to droughts and wildfires.[3] However, increasing impacts of climate change in recent years are creating unsuitable conditions to execute controlled burns in areas that need it most. A combination of meteorological variables must be met in order for a prescribed burn to take place. Changing patterns in temperature, humidity, and windspeed are shortening this already small burn window.[4] Now we must ask the question: can we continue using prescribed burn techniques under the worsening conditions of climate change, and if so, how? **Prescribed burning is an effective management technique which requires new adaptations to ensure the health of forests can be maintained under the increasing effects of climate change.**

Methods

The main method used in this paper will be literature review. I will use a combination of primary and secondary sources such as science focused websites, educational textbooks, and reputable information-based articles. These will be used to create a general background section to provide a comprehensive description of what prescribed burning is, the different methods used, and the conditions required to facilitate the management strategy. I will also draw on secondary sources such as journal articles, books, and scholarly papers. These will be used to provide a historical and cultural component which will help me gain a more thorough understanding of how fire was viewed and utilized in the past, and how this influences the way we manage it currently. The bulk of my paper will be using primary and secondary sources to

[3] Lena Vilà-Vilardell et al., "Prescribed Fire after Thinning Increased Resistance of Sub-Mediterranean Pine Forests to Drought Events and Wildfires," *Forest Ecology & Management* 527 (2023), https://doi.org/10.1016/j.foreco.2022.120602.

[4] John A. Kupfer et al., "Climate Change Projected to Reduce Prescribed Burning Opportunities in the South-Eastern United States," *International Journal of Wildland Fire* 29, no. 9 (2020), https://doi.org/10.1071/WF19198.

draw on climate change data and other fire and pine tree-based field studies. These will be interpreted to further prove challenges with prescribed burning and to anticipate possible solutions.

Background

A History of Prescribed Burning in the United States

Planned or prescribed burning is a practice that was initially developed by Native American groups in North America. While fire had many uses for early Native groups, its primary uses were for clearing and replenishing nutrients in agricultural fields and managing the growth of different species throughout rangelands.[5] Through their knowledge of tobacco plants, Native American groups knew that some plant species are dependent on fire and require smoke to germinate.[6] "Substantial amounts of land belonging to indigenous and traditional peoples are located in proximity to lands controlled by the US federal government."[7] This only emphasizes the importance of acknowledging and incorporating Native practices into current land management strategies.

When Europeans first settled in North America, the climate was experiencing a particularly wet and cold period. Native populations were also declining due to Eurasian transmitted diseases. A combination of these factors reduced the number of fires which caused the landscapes to adjust to less frequent burning when the 17th century European immigration

[5] Carol Raish, Armando González-Cabán, and Carol J. Condie, "The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest," *Global Environmental Change Part B: Environmental Hazards* 6, no. 2 (2005), https://doi.org/10.1016/j.hazards.2005.10.004.
[6] Sharon Levy, "Rekindling Native Fires," *BioScience* 55, no. 4 (2005), https://doi.org/10.1641/0006-3568(2005)055[0303:rnf]2.0.co;2.
[7] Raish, González-Cabán, and Condie, "The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest."

boom took place.[8] It wasn't until the 1980s that the scientific community became aware of how important the implementation of smoke and fire is from an ecological standpoint.[9] Even though intentional fires were widely used by Native Americans to manage land in the western US for many centuries, the practice fell out of use after colonization.[10] It wasn't until the early 19th century that the combination of fire suppression, livestock grazing, and selective logging practices led to the accumulation of fuels that caused severe wildfires.[11]

What is a Prescribed Burn?

Prescribed Burning is a strategy that has been used to manage the health of forest ecosystems for thousands of years. Fire acts as a catalyst by returning nutrients to soil and promoting healthy regrowth. It is especially useful to maintain biodiversity in an ecosystem because a lot of native pine species require fire to reproduce. "For example, seeds from many pine tree species are enclosed in pinecones that are covered in pitch, which must be melted by fire for the seeds to be released."[12] Frequent burning also lets in more sunlight to the ground level of the forest, which speeds up the decomposition process allowing for quicker plant growth.

Forest ecosystems change drastically after they are burned. There are many important distinctions between a forest managed with fire and ones filled with excessive overgrowth. Fire suppression was once thought to be the best management method for forests, but ecologists have

[8] Kevin C. Ryan, Eric E. Knapp, and J. Morgan Varner, "Prescribed Fire in North American Forests and Woodlands: History, Current Practice, and Challenges," *Frontiers in Ecology & the Environment* 11 (2013), https://doi.org/10.1890/120329.
[9] Levy, "Rekindling Native Fires."
[10] Raish, González-Cabán, and Condie, "The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest."
[11] Westlind and Kerns, "Repeated Fall Prescribed Fire in Previously Thinned Pinus Ponderosa Increases Growth and Resistance to Other Disturbances."
[12] "The Ecological Benefits of Fire," (July 15th, 2022 2022). https://education.nationalgeographic.org/resource/ecological-benefits-fire/.

become increasingly more aware of the dangers that can result from suppressing fires.[13] A recent study analyzing different management strategies and their effects on forest environments showed that prescribed burning unexpectedly increases a forest's resistance to wildfires.[14]

Benefits of Prescribed Burning for Forests

It is vital to implement fire into the management strategies for pine forests. It not only lessens the risk of wildfires by reducing the fuel loads, but also promotes regeneration of both valuable plant and animal species.[15] Accumulated build-up of dry vegetation on forest floors leads to increased wildfires because this vegetation acts as unregulated fuel.[16] The excess of fire-prone vegetation also takes up a lot of extra space which inhibits important native species from growing.[17] Fire can alter vegetation structure as well as affect growth of fire-prone species in pine ecosystems.[18] With all the information scientists have today, it is difficult to believe that fire suppression was once seen as the best management practice for pine forests. When managing any type of natural resource, it is also crucial to acknowledge the role humans play in interacting with the environment. The science of fire ecology is a valuable resource to understanding natural and human fire history and fire effects on the environment, species, ecosystems, and

[13] Levy, "Rekindling Native Fires."
[14] Vilà-Vilardell et al., "Prescribed Fire after Thinning Increased Resistance of Sub-Mediterranean Pine Forests to Drought Events and Wildfires."
[15] "Prescribed Fire and Its Effects on Forested Ecosystems."
[16] Andrew S. Mathews, "Interlude Ii
Pine Cultivation and Pine as an Agent of Landscape Transformation," in *Trees Are Shape Shifters*, How Cultivation, Climate Change, and Disaster Create Landscapes (Yale University Press, 2022).
[17] Glenn R. Matlack, "Reassessment of the Use of Fire as a Management Tool in Deciduous Forests of Eastern North America," *Conservation Biology* 27, no. 5 (2013), https://doi.org/10.1111/cobi.12121.
[18] "Prescribed Fire and Its Effects on Forested Ecosystems."

landscapes.[19] Fire ecology is a significant contributor aiding in the development of fire and ecosystem management plans and activities.

Cultural Influences

The U.S. Forest Service played a critical part in developing our perceptions of fire, especially from a cultural standpoint. Although the US Forest Service wasn't officially established until 1905, federal forest management has been happening since 1876.[20] In the initial stages of forest management, agencies like the US Department of Agriculture began by simply examining the quality of forests. During this time, management agencies viewed controlled burning as a useless management strategy and a waste of valuable resources. This is because from the late 1800s to the mid 1900s, the success of the timber industry was the primary focus of the U.S. government. The economy was heavily depending on the revenue from timber and needed to continue producing timber crops indefinitely. Prescribed burning challenged the success of this industry because it involved 'wasting' the valuable timber material the industry was relying on. To ensure that controlled burning would not garner public support, the government also began funding state and local agencies to implement fire suppression policies.[21] These fire suppression techniques only grew in scale throughout the 20th century. The timber industry is only one example of how these influential systems of power can control our understanding of natural resources in a way that aids in promoting their agenda. This can in turn lead to negative environmental repercussions because of how it affects the management strategies that are implemented.

[19] "The Ecological Benefits of Fire."
[20] Matlack, "Reassessment of the Use of Fire as a Management Tool in Deciduous Forests of Eastern North America."
[21] Ryan, Knapp, and Varner, "Prescribed Fire in North American Forests and Woodlands: History, Current Practice, and Challenges."

Regardless of educational background, many Americans share the same understanding that fire is destructive and harmful to the environment. While the fostering of this perception comes from the USFS, much of this belief can be more specifically attributed to the cultural influence of Smokey Bear. This media icon was created in 1944 by the Cooperative Forest Fire Prevention program (CFFP), which was established by the US Forest Service. During World War II, the U.S. government needed as much labor as possible to aid in wartime production. Many government employed individuals, including firefighters, were temporarily removed from their positions during the war period. With limited firefighters suppressing/preventing fires, wildfires were getting out of control. Smokey's initial purpose was to inform the public about the dangers of forest fires by promoting the continuation of fire suppression as a management solution.[22] This way, the public could help take on the responsibility of preventing wildfires in forests throughout the U.S. Smokey Bear quickly grew in popularity, becoming both the longest standing and most successful government branding campaign in U.S. history. It was also one of the first instances where a media campaign was used to influence natural resource management.[23] Symbolizing a shift in fire suppression and prevention policies, the prevalence of Smokey Bear in mass media perpetuated a common American belief that fire is destructive and harmful to the environment. Smokey's influence made it extremely difficult for American culture to unlearn the long-ingrained teachings that fire is inherently 'bad.' However, the USFS has since been making efforts to change Smokey the Bear's message from its prior focus on fire suppression. Now, the official Smokey the Bear website has a multitude of resources to educate

[22] James G. Lewis, ""Smokey Bear: From Idea to Icon"," *Forest History Today* 2018, https://foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/smokey-bear/.
[23] Jesse Minor and Geoffrey A. Boyce, "Smokey Bear and the Pyropolitics of United States Forest Governance," *Political Geography* 62 (2018), https://doi.org/10.1016/j.polgeo.2017.10.005.

both kids and adults on the importance of fire and prescribed burning as a tool to prevent wildfires.[24]

Figure 3: Vintage advertisement from 1953 of Smokey the Bear and Bambi.[25]

Challenges with Prescribed Burning

Within the last 20 years, wildfires have become bigger and more destructive. Climate change is a key factor in why this is happening, and it is also affecting our ability to manage forests.[26] Due to greenhouse gas emissions, the number of days per year when the conditions are right for a prescribed burn to take place is rapidly decreasing. This is because temperatures are rising which makes intentionally set fire riskier and more difficult to control.[27] Controlled burns are scheduled

[24] "Smokey the Bear," 2023, https://smokeybear.com/.
[25] U.S. Forest Service, "Our Most Shameful Waste
" (1953), advertisement poster.
[26] "Confronting the Wildfire Crisis," U.S. Forest Service, 2022, https://www.fs.usda.gov/managing-land/wildfire-crisis.
[27] Kupfer et al., "Climate Change Projected to Reduce Prescribed Burning Opportunities in the South-Eastern United States."

based on certain weather and environmental conditions, as well as the needs of that specific ecosystem.[28] The period of time when these conditions are met is referred to as a 'burn window' is the only time when a controlled burn can be performed safely. The graph below depicts the burn window by comparing the number of days within the ideal burn window for each season. EOSDA forest monitoring systems help to predict weather, precipitation, and temperature trends. This is more important now than ever because changing conditions create risks to both people and nature if a controlled burn is set under the wrong conditions.[29]

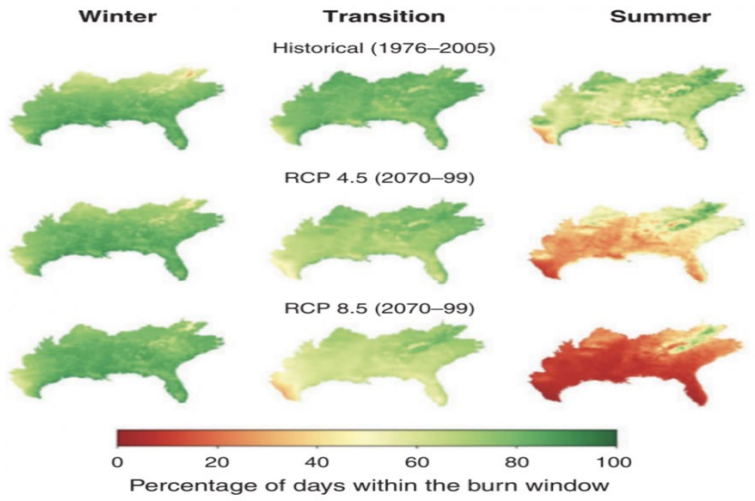

Figure 1: Graphic illustrating the percentage of days within the burn window depending on the season.[30]

[28] National Geographic Society, "Controlled Burning," ed. National Geographic Society (Washington DC: National Geographic, 2022).

[29] Vasyl Cherlinka, "Perscribed Burn: How to Do Controlled Fires Safely," *EOS Data Analytics*, *EOS Data Analytics*, July 15th, 2022, 2022.

[30] International Journal of Wildland Fire, "Historical/Current Availability of Burn Windows and Projected Availability under the Two Climate Scenarios.," (2020). https://cals.ncsu.edu/applied-ecology/news/climate-change-will-decrease-prescribed-fire-opportunities-in-southeastern-us/.

In order to continue using prescribed burning, we must also take into account additional barriers that are creating logistical challenges, such as the budget and resources that can be allocated to implement this management strategy. Congress passed the Infrastructure Investment and Jobs Act in 2021 that invests about $5.5 billion in lands and resources managed by the Forest Service.[31] The federal government is unable to independently create fire policy across the entire country. The support of the states is essential to managing forest fires.[32] With climate change narrowing the burn window of ideal weather conditions, it is difficult to plan and schedule a prescribed burn because there is no way to guarantee it will take place. In most regions of the United States, the burn window is a lot longer during the winter months. However, the USFS most other management agencies in charge of executing prescribed burns rely on labor from seasonal employees. In the winter, there is limited access to the amount of labor that is needed, which also makes it difficult to allocate funding for the high-costs and resources required to execute a burn.[33]

Additionally, each year, more and more people are choosing to settle farther away from the city, expanding human impact on different ecosystems like forests. The two relational graphs below show the perceptions of fire managers, and how they predict prescribed burning as a management strategy will be affected by both land use and climate change respectively. The people settling in these areas are often not equipped with much knowledge of fire and forest management. This, coupled with the fact that it is often easier to regulate land managers fire use over other emissions when it comes to pollution control/ air quality issues makes it difficult to

[31] "Managing Forests in a Changing Climate," US Forest Service, updated July 28th, 2022, https://www.fs.usda.gov/features/managing-forests-changing-climate.

[32] Stephen J. Pyne, "Burning Out," in *Between Two Fires*, A Fire History of Contemporary America (University of Arizona Press, 2015).

[33] Raymond Zhong, "How to Save a Forest by Burning It," (New York City) 2022.

consistently implement burns.[34] "Recent transmigrations have fragmented the land with subdivisions."[35] Environmental laws tend to either help fire managers or make it more difficult for them to use fire under different circumstances.

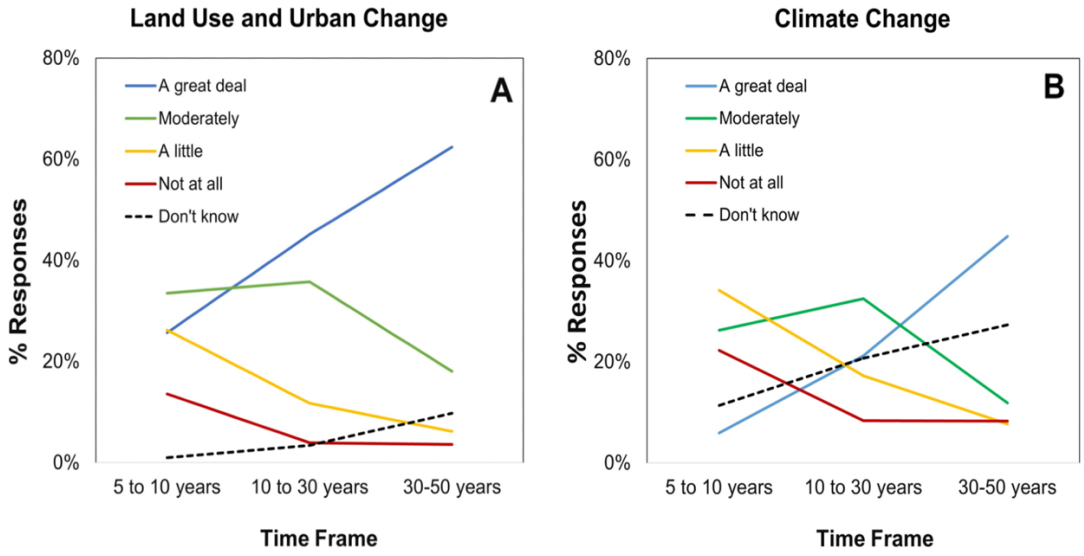

Figure 2: Relational graphs showing fire manager perceptions of how prescribed burning decisions will be affected by changes in land use (A) and climate change (B).[36]

Another aspect of fire management that cannot be ignored is the impact of public opinion. People can have a lot of influence over how land is managed, especially communities local to where fires are taking place. In 2022, the US forest service was pressured by the public to pause their use of prescribed fires. This was in response to two federally authorized fires in

[34] Ryan, Knapp, and Varner, "Prescribed Fire in North American Forests and Woodlands: History, Current Practice, and Challenges."
[35] Ryan, Knapp, and Varner, "Prescribed Fire in North American Forests and Woodlands: History, Current Practice, and Challenges."
[36] John A. Kupfer, "Prescribed Fire in Longleaf Pine Ecosystems: Fire Managers' Perspectives on Priorities, Constraints, and Future Projects," (2022).

New Mexico becoming out of control, leading to 200,000 acres of damage.[37] Many indigenous groups also have management concerns that need to be addressed. Tribal resource professionals often express their desire to implement their own burning programs because they are able to economically benefit more and control important areas more easily. They also don't need to deal with any communication issues from federal agencies.[38]

Analysis

Adaptations/Solutions

Before addressing solutions, it is important to establish why we still need the benefits of prescribed burns. According to a recent study, planting endangered Whitebark Pine Seedlings in prescribed burn areas created the highest survival rate of all the tested site conditions. This shows the importance of fire for management as well as restoration purposes.[39] "Increased use of prescribed fire and ecologically beneficial management of wildfires will be necessary to treat fuels and restore fire-adapted landscapes."[40]

We need to develop new ways to technically manage prescribed burns more effectively by factoring in climate change. Seeing as this is still an emerging issue, research is an essential first step to creating new methods. The US Geological Survey's Wildland Fire Science Program has provided valuable information into why fire science is needed, and the ways we can use fire

[37] Fohringer Emma Merchant, "The Us Forest Service Planned to Increase Burning to Prevent Wildfires. Will a Pause on Prescribed Fire Instead Bring More Delays?," *Inside Climate News* (Brooklyn, NY) 2022, Politics and Policy.
[38] Raish, González-Cabán, and Condie, "The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest."
[39] E. R. Lonergan, C. L. Cripps, and C. M. Smith, "Influence of Site Conditions, Shelter Objects, and Ectomycorrhizal Inoculation on the Early Survival of Whitebark Pine Seedlings Planted in Waterton Lakes National Park," *Forest Science* 60, no. 3 (Jun 2014), https://doi.org/10.5849/forsci.13-511.
[40] Ryan, Knapp, and Varner, "Prescribed Fire in North American Forests and Woodlands: History, Current Practice, and Challenges."

science to manage wildfires and prescribed burns.[41] The US forest service has also released a comprehensive climate adaption plan, outlining the issues, corresponding solutions, and the steps needed to achieve them.[42]

It is vital to have the support of the public to be able to implement any solutions pertaining to climate change and prescribed burns. The public holds the power and influence required to bring change. In order to gain more public support for prescribed burning, we need to be intentional about including indigenous peoples in management practices. “Fire ecology will benefit from culturally distinct forms of expertise on preventing and combating wildfires.”[43]

To be able to continue prescribed burning, fire managers need to work with government officials to introduce better policy flexibility.[44] A possible option could be to implement a policy that limits settlement from expanding deep into forest areas. By establishing set regulations for where people can live, it ensures that there will be forest land that is protected from human development. Additionally, there are less barriers in the way of land managers when they are using management techniques like prescribed burning. Effective natural resource management policies not only protect the land but also protect the rights and responsibilities of those who manage it.

---

[41] Miller Mark P. Steblein Paul F., Soileau Suzanna C., *Wildland Fire Science — Supporting Wildland Fire and Land Management,* Forest and Rangeland Ecosystem Science Center and Office of the AD Ecosystems (USGS Publications Warehouse, 2019), https://www.usgs.gov/publications/wildland-fire-science-supporting-wildland-fire-and-land-management.

[42] "Managing Forests in a Changing Climate."

[43] James R. Welch and Carlos E. A. Coimbra Jr, "Indigenous Fire Ecologies, Restoration, and Territorial Sovereignty in the Brazilian Cerrado: The Case of Two Xavante Reserves," *Land Use Policy* 104 (2021), https://doi.org/10.1016/j.landusepol.2019.104055.

[44] John A. Kupfer et al., "Prescribed Fire in Longleaf Pine Ecosystems: Fire Managers’ Perspectives on Priorities, Constraints, and Future Prospects," *Fire Ecology* 18, no. 1 (2022/11/26 2022), https://doi.org/10.1186/s42408-022-00151-6, https://doi.org/10.1186/s42408-022-00151-6.

Conclusion

After a long history of fire suppression, land managers now understand the importance of using prescribed fire to manage the health of forest ecosystems, as well as to prevent wildfires. Climate change is having a major effect on prescribed burning because the 'burn window' is getting smaller and smaller causing the conditions for burning become riskier and more dangerous. It is imperative that we implement thoughtful and effective solutions to this issue so that we can continue using prescribed burning to manage the health of forest ecosystems.

Bibliography

"Confronting the Wildfire Crisis." U.S. Forest Service, 2022, https://www.fs.usda.gov/managing-land/wildfire-crisis.

"Managing Forests in a Changing Climate." US Forest Service, Updated July 28th, 2022, https://www.fs.usda.gov/features/managing-forests-changing-climate.

Cherlinka, Vasyl, "Perscribed Burn: How to Do Controlled Fires Safely," *EOS Data Analytics*. *EOS Data Analytics*, July 15th, 2022, 2022.

Fire, International Journal of Wildland. "Historical/Current Availability of Burn Windows and Projected Availability under the Two Climate Scenarios.", 2020. https://cals.ncsu.edu/applied-ecology/news/climate-change-will-decrease-prescribed-fire-opportunities-in-southeastern-us/.

Kupfer, John A. "Prescribed Fire in Longleaf Pine Ecosystems: Fire Managers' Perspectives on Priorities, Constraints, and Future Projects." 2022.

Kupfer, John A., Kirsten Lackstrom, John M. Grego, Kirstin Dow, Adam J. Terando, and J. Kevin Hiers. "Prescribed Fire in Longleaf Pine Ecosystems: Fire Managers' Perspectives on Priorities, Constraints, and Future Prospects." *Fire Ecology* 18, no. 1 (2022/11/26 2022): 27. https://doi.org/10.1186/s42408-022-00151-6. https://doi.org/10.1186/s42408-022-00151-6.

Kupfer, John A., Adam J. Terando, Peng Gao, Casey Teske, and J. Kevin Hiers. "Climate Change Projected to Reduce Prescribed Burning Opportunities in the South-Eastern United States." *International Journal of Wildland Fire* 29, no. 9 (2020): 764-78. https://doi.org/10.1071/WF19198.

Levy, Sharon. "Rekindling Native Fires." *BioScience* 55, no. 4 (2005): 303-08. https://doi.org/10.1641/0006-3568(2005)055[0303:rnf]2.0.co;2.

Lewis, James G. ""Smokey Bear: From Idea to Icon"." *Forest History Today*, 2018. https://foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/smokey-bear/.

Lonergan, E. R., C. L. Cripps, and C. M. Smith. "Influence of Site Conditions, Shelter Objects, and Ectomycorrhizal Inoculation on the Early Survival of Whitebark Pine Seedlings Planted in Waterton Lakes National Park." *Forest Science* 60, no. 3 (Jun 2014): 603-12. https://doi.org/10.5849/forsci.13-511.

Mathews, Andrew S. "Interlude Ii

Pine Cultivation and Pine as an Agent of Landscape Transformation." In *Trees Are Shape Shifters*. How Cultivation, Climate Change, and Disaster Create Landscapes, 101-08: Yale University Press, 2022.

Matlack, Glenn R. "Reassessment of the Use of Fire as a Management Tool in Deciduous Forests of Eastern North America." *Conservation Biology* 27, no. 5 (2013): 916-26. https://doi.org/10.1111/cobi.12121.

Merchant, Fohringer Emma. "The Us Forest Service Planned to Increase Burning to Prevent Wildfires. Will a Pause on Prescribed Fire Instead Bring More Delays?" *Inside Climate News* (Brooklyn, NY), 2022, Politics and Policy.

Minor, Jesse, and Geoffrey A. Boyce. "Smokey Bear and the Pyropolitics of United States Forest Governance." *Political Geography* 62 (2018): 79-93. https://doi.org/10.1016/j.polgeo.2017.10.005.

"Prescribed Fire and Its Effects on Forested Ecosystems." U.S. Forest Service, 2023, https://www.srs.fs.usda.gov/coweeta/research/prescribed-fire/.

Pyne, Stephen J. "Burning Out." In *Between Two Fires*. A Fire History of Contemporary America, 418-51: University of Arizona Press, 2015.

Raish, Carol, Armando González-Cabán, and Carol J. Condie. "The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest." *Global Environmental Change Part B: Environmental Hazards* 6, no. 2 (2005): 115-22. https://doi.org/10.1016/j.hazards.2005.10.004.

Ryan, Kevin C., Eric E. Knapp, and J. Morgan Varner. "Prescribed Fire in North American Forests and Woodlands: History, Current Practice, and Challenges." *Frontiers in Ecology & the Environment* 11 (2013): e15-e24. https://doi.org/10.1890/120329.

Service, U.S. Forest. "Our Most Shameful Waste
", 1953. advertisement poster.

"Smokey the Bear." 2023, https://smokeybear.com/.

Society, National Geographic. "Controlled Burning." edited by National Geographic Society. Washington DC: National Geographic, 2022.

Steblein Paul F., Miller Mark P. , Soileau Suzanna C. *Wildland Fire Science — Supporting Wildland Fire and Land Management.* Forest and Rangeland Ecosystem Science Center and Office of the AD Ecosystems, (USGS Publications Warehouse: 2019). https://www.usgs.gov/publications/wildland-fire-science-supporting-wildland-fire-and-land-management.

"The Ecological Benefits of Fire." (July 15th, 2022 2022). https://education.nationalgeographic.org/resource/ecological-benefits-fire/.

Vilà-Vilardell, Lena, Miquel De Cáceres, Míriam Piqué, and Pere Casals. "Prescribed Fire after Thinning Increased Resistance of Sub-Mediterranean Pine Forests to Drought Events and Wildfires." *Forest Ecology & Management* 527 (2023): N.PAG-N.PAG. https://doi.org/10.1016/j.foreco.2022.120602.

Welch, James R., and Carlos E. A. Coimbra Jr. "Indigenous Fire Ecologies, Restoration, and Territorial Sovereignty in the Brazilian Cerrado: The Case of Two Xavante Reserves." *Land Use Policy* 104 (2021): N.PAG-N.PAG. https://doi.org/10.1016/j.landusepol.2019.104055.

Westlind, Douglas J., and Becky K. Kerns. "Repeated Fall Prescribed Fire in Previously Thinned Pinus Ponderosa Increases Growth and Resistance to Other Disturbances." *Forest Ecology & Management* 480 (2021): N.PAG-N.PAG. https://doi.org/10.1016/j.foreco.2020.118645.

Zhong, Raymond. "How to Save a Forest by Burning It." (New York City), 2022.