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Correlation Between Fire and Preservation in the Pacific Northwest & Most Cost-Efficient Mitigation Tactics

An Undergraduate Thesis Proposal

By
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Abstract:

This study was conducted entirely online with occasional help from advisors and editors on zoom meetings. I completed the research in Lincoln, Nebraska. A meta analysis of online data has been conducted to form the answers to my hypotheses and research questions. I used specific keywords and phrases in research databases, and search engines such as google scholar to point me towards the answers I was looking for. The keywords and phrases were split up into four different categories which are mitigation techniques, ecosystems, fire severity: PNW, and fire season: PNW.

The reason the topics land preservation and fire science merged for this specific project was because of the natural worlds' growing need for support and understanding. Not only does work need to be done to preserve the natural world, but we must also minimize other work that has been previously given a good reputation. When fighting fires, the main goal is to contain, control, and suppress them. What a lot of people lack in understanding is that ecosystems, specifically in the Pacific Northwest, need wildfire to be healthy. If we do not let wildfire run its course then environmental quality will diminish. Nutrient cycles are rejuvenated by the wildfires in the spring. The more land we preserve today, the more natural beauty future generations will be able to enjoy in the future. Finally, the effects that nature can have on the human condition are . Images and sounds of nature demonstrate beneficial physiological/stress and psychological (Bratman et al. 2019).

The purpose of this project is to create awareness of the good that fires can provide. Creating separation between massive wildfires and their reputations from smaller fires that are necessary for the health of an ecosystem.

Among the highlights of the research are two main important findings. The first is that there is no accuracy behind the idea of the best mitigation technique. The best strategy to contain or control a wildfire is using a range of different techniques in conjunction. The other main finding that was accrued from the research is that wildfires are imperative to the long term health of a natural ecosystem in the Pacific Northwest.

Introduction:

Wildfires have become a major concern around the world due to their destructive nature, leading to significant impacts on natural resources, human lives, and the environment. The need for effective wildfire management has led to extensive research into the causes, prevention, and mitigation of these events. One area of interest is the relationship between wildfires and land preservation. This relationship is complex and multifaceted, as both natural and anthropogenic factors can influence the occurrence and behavior of wildfires in protected and conserved areas.

Wildfires can occur naturally, or they can be human-caused. Natural causes include lightning strikes, while human-caused fires are often due to unintentional or intentional ignition, such as campfires, cigarettes, or arson. Regardless of the cause, wildfires have significant impacts on the environment, often leading to the loss of biodiversity, soil erosion, and the release of greenhouse gasses. In addition, wildfires can be particularly destructive in protected and conserved areas, where the risk of damage to natural and cultural resources is high.

The primary objective of this thesis is to investigate the specific relationship between wildfires and land preservation. This research will explore the various factors that contribute to the occurrence and behavior of wildfires in protected areas, including climate, fuel loads, and land management practices. The study will also examine the impacts of wildfires on conserved ecosystems, biodiversity loss and its' causes, and the economic costs of fire suppression.

In line with the research questions, I have a two part hypothesis. The first part is that small scale, and less frequent fires are essential to the long term health of most natural environments in the Pacific Northwest. The second; there are fire mitigation techniques that are more cost efficient than others. To prove my two part hypothesis there are questions that need to be answered. First, what is the specific relationship between wildfires and land preservation? Second, What are the cost-efficient mitigation techniques that we are using or that can be implemented further across all fire suppression agencies?

The media coverage on fires has created a stigma that all wildfires are bad, leading to misconceptions about the role of fire in natural systems. While large, destructive fires can have devastating impacts, small-scale, and less frequent fires are an essential part of many ecosystems' natural cycles. The exclusion of fire from many ecosystems has led to a buildup of fuels, making them more susceptible to severe and destructive wildfires (Weir et al. 2017). Therefore, it is crucial to recognize the benefits of fire in ecosystems and promote the use of controlled fires for management purposes.

Finally, there are several fire mitigation techniques that should be utilized more often. This research will evaluate the effectiveness as well as cost analysis of different mitigation techniques, including drone surveillance, prescribed burning, fuel reduction, and overall fire suppression, and explore their potential for future implementation in conserved areas. In addition, the study will consider the economic and social costs of implementing these techniques and their impacts on natural resources and ecosystems. Understanding the most effective and sustainable wildfire mitigation techniques is crucial for protecting natural resources, human lives, and the environment from the negative impacts of wildfires.

Methods:

The main objective of the research is to describe the correlation between wildfires and land preservation. Trees, of all kinds, provide their local ecosystems and humans with oxygen, as well as decreasing carbon dioxide levels in the atmosphere. Nature and more specifically the ecosystems affected by fire have the ability to provide much needed support for mental health as well. Time spent in nature has been proven to have stress reducing properties as well as influence mental health restoration (Ulrich et al. 1991). To determine whether or not humans are at risk of losing nature access research will be conducted.

There are two main search engines that will be used in order to conduct the correct research needed to complete the project. The first search engine to be used is Google Scholar. Google Scholar offers a range of different databases. The databases include all scholarly articles from universities, as well as scholarly articles, and journals released from the US and State governments which are important when dealing with land. A large amount of the wildland fire fighting, research, and surveillance is done by the US Forest Service. The total spending on fire suppression from the Us government is about $2.5 billion per year (Congressional Budget Office, 2022). The other search engine that will be used is the UNL online library. This grants access to all journals, articles, and reports associated with University of Nebraska.

Being such a broad topic, there are a few ways to conceptualize the correlation. The first way to conceptualize the relationship between preservation and wildfires is to understand the differences in ecosystems. In other words; how fires, on different scales, affect the local flora and fauna. A deciding factor for which direction my research will continue towards, will be the general location to study. The focus of my research will be fires in the Pacific Northwest including Idaho, Oregon, and Washington state.

Table 1: Keywords and Phrases Matrix for Research

Mitigation Techniques	Ecosystems	Fire Severity: Pacific Northwest	Fire Season: Pacific Northwest
Forest Floor Fuel Removal: "How to remove forest debris"	Step 1: "Flora Native to Pacific Northwest", "Native tree species; PNW", "Native fruit bearing plants; PNW", "maps of types of ecosystems PNW"	"average size of fire in Pacific Northwest", "	"when in is the average fire season in PNW", "how does fire season in PNW differ from the rest of the US"
Clear Cutting:"clear cutting techniques", "clear cutting costs"	Step 2:"Fauna native to Pacific Northwest", "nutrient cycles", "positive feedback loop of fire in forests"	"where are fires most common PNW", "Oregon fires", "Washington fires", "Idaho fires"	"is fire season increasing in PNW" "adverse effects of prolonged fire season in PNW"
Prescribed Burns: "prescribed burn techniques", "prescribed burn costs", "prescribed burn risk assessment"	Step 3: "Effects of fire on ecosystems", "Effects of fire on PNW ecosystems" "biodiversity effects"	"Old growth fires", "old growth adverse effects of fire"	"Adverse effects of prolonged fire season on natural ecosystems" (avoiding effects on human development)
Drone Surveillance: "what types of radar is used for drone surveillance?", "Lidar drone surveillance fires", "Thermal surveillance fires", "drone surveillance cost"	Step 4: "nitrogen cycle and biodiversity" "nitrogen cycle and ecosystem health"	"is fire severity increase actually a problem in the natural world"	"why is fire always considered bad" "what are negative connotations of wildfire based on"

Table 1 *shows the different strings of keywords and phrases used as an input for different search engines. There are four main categories of research that labeled in the top row.*

Methods continued:

Following the decision for what geographical location the research will be based is quantifying the pros and cons of fire in specific ecosystems. With that, research on how fire affects seed germination, soil temperature and growing conditions, light penetration through forest canopies, and so on. Given that the research is based on a specific area of the country, we have to identify the types of ecosystems in the area. With the identification of the ecosystems, we will be able to determine the types of native trees, shrubs, grasses, and so on. After identification of flora, we can analyze how fire affects each individual species. There are 40 different species of trees native to the Pacific Northwest (Minore, 1979). Throughout the 40 species, there are broadleaf, as well as pine trees, all with very different attributes. Instead of analyzing all 40 species of trees, a selection of broadleaf and pine trees will be used as a sample and will represent the other trees. The trees selected will be from all across the region, and have completely different characteristics, including cone size, tree height, bark strength, and so on. This will eliminate the need for research on every species, and the species selected will do a good job representing the left out species.

After researching tree species, research will be conducted on the flora and fauna beneath the canopy. The research conducted will be focused on the relationship of animals and the shrubs, and grasses they consume and that act as dens, and safe bedding areas. In order to start this research, we will have to first start with what species of grass and shrub thrives in fire rich ecosystems. When fire takes down trees in an area, the canopy will open up and let sunlight reach the forest floor. Some species will prosper with more direct sunlight. For example, highbush blueberries grow the best when in direct sunlight. After researching different fruiting bushes, shrubs, and grasses that would theoretically do well in sunlight, with warmer soil, or any other qualities of the forest that arise when fire strikes, research must be done on the animals that would do well with a lot of available provisions, and denning areas, and which, if any, would suffer.

A good way to continue research is understanding the best ways to mitigate fires. Fire mitigation is the bridge between protecting nature, and wildfire. With climate change increasing, the severity and frequency of fires, and wildfire season will all continue to intensify as the years go on (Flannigan, 2000). Mitigation techniques that will be researched are clear cutting, drone surveillance, hotshot crews, and prescribed burns. Research will determine whether or not fire conditions increasing, will force wildfires to cross over the boundary of necessary for ecosystems, to dangerous for specific ecosystems. As we continue to get closer to this line, fire mitigation is becoming increasingly more important. Mitigation is particularly important in old growth forests where ecosystems can be delicate. Old growth forests are particularly prevalent and important in the Pacific Northwest, in traditionally wet areas. Research will be conducted as climate change increases in old growth forests to determine the possible increase in fire frequency and severity. Another mitigation technique to be researched is forest floor fuel removal. This is a broad topic that can be classified into physical

removal of debris, as well as prescribed burns, and canopy clearing. As prescribed burns and clear cutting have already been discussed, physical clearing of debris is left. Research will be conducted on the instruments and tools used to clear forests of debris. The

Results:

To answer the research questions, 1) *what is the specific relationship between wildfires and land preservation in the Pacific Northwest?*, and 2) *what are the most cost effective mitigation techniques that we are using or that can be implemented in the future?* We have formulated two hypotheses. The first is that small scale and less frequent fires are essential to the long-term health of most natural environments. The second is that there are fire mitigation techniques that should be utilized more often.

Research Question 1: Benefits of Wildfire:

Wildfires are a natural phenomenon that play an important role in the Pacific Northwest's ecology. While wildfires can be destructive, they also have important ecological functions that are critical for the region's long-term health. This region is known for its vast stretches of old growth forests, high sage desert, and open grasslands, which have been shaped by a history of recurring fires. These fires have been vital for sustaining the region's ecological health and maintaining its diverse plant and animal communities.

Wildfires are essential in the Pacific Northwest as they provide habitat for different native fauna (Moritz et al., 2014). This is especially important for native species that are having offspring because the fire season generally starts in May and ends in October which aligns with the birthing and raising of offspring. With the start of fire season being in the spring, it creates a higher availability of denning, and bedding areas (Moritz etl., 2014).

Wildfires complete essential tasks for an ecosystem that cannot be replicated by anything artificial. Wildfire contributes to the nutrient cycles in that they cause a release of Nitrogen from the soil and forest debris through volatilization (Johnson et al., 2009). Without the release of Nitrogen in mesic old growth forests of the Pacific Northwest, water quality starts to diminish. When forest debris builds up in an ecosystem it will eventually start to decay which will cause leaching of nutrients like Nitrogen and Carbon into the soil, and eventually will reach the ground and surface water. When the Nitrogen levels build up in fresh water the process of eutrophication increases and causes algal blooms leading to a lack of oxygen in the water, killing all aquatic life in the area (Conley et al., 2009). Without a healthy aquatic system in a natural ecosystem, the health of the

area will decrease rapidly. Fish, insects, and aquatic plants are essential parts of food chains. With the lack of hundreds of aquatic species in a food chain, the whole ecosystem falls apart. This is a constant process and will increase exponentially with the lack of fire.

Fire Season and Severity, and Their Relation to Land Preservation

The fire season and the severity of fires have been expanding and increasing over the last decades as climate change continues to act as a catalyst for wildfire (Jones et al. 2020). Between 2017 and 2021, the average number of acres burned on an annual basis was approximately 8 million acres. This is more than double the average number of acres burned from the years 1987 to 1991. In addition, the number of wildfires in total has decreased slightly since 1991 (Campbell et al. 2022) This is proof that the severity of fires has increased dramatically over the past few decades. The fire season has been increasing as well. The warmer springs, and dryer falls have contributed to a 64% longer season when comparing the time frames of 1970-1986 and 1987-2003 (Westerling, A. et al. 2006). A 64% longer season on average equates to an extra 76 days added to the season.

Figure 1: Number of Wildfires, and Number of Acres Burned

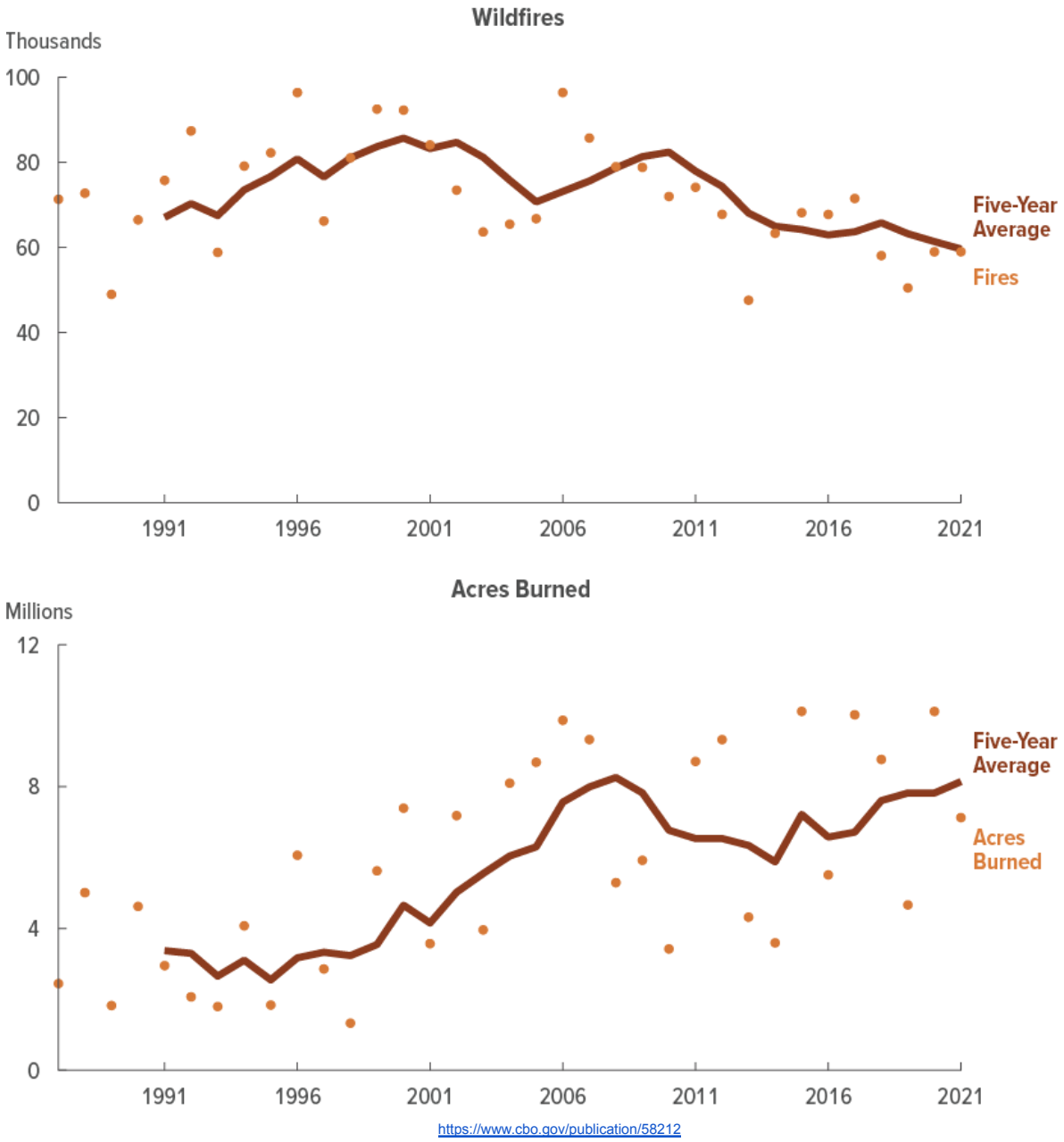

Figure 1 *shows the representative line of the average number of acres burned (in millions) in a five year period taken over a total period of 35 years.*

Pacific Northwest Forests and Native Species

To best describe the found relationship between wildfire and land preservation, a breakdown of different ecosystems is necessary. According to Senate hearing 110-430 that took place on March 13th, 2008, there is an estimated 2 million hectares of old growth forests which is approximately 36% of all forests in the Pacific Northwest (PNW). Not only are they a large portion of the forest cover in the Pacific Northwest, these old growth forests are fire resistant. The main reason that they are resistant is because of the way that "clumps" of trees and shrubs were formed in fires of the past.

> "*Young trees often establish in clumps, as a legacy of patchy fuels and fire behavior; and this structural legacy may last for centuries. Gaps between clumps may result from a combination of competition with grasses and shrubs, from uneven distribution of seeds, and also the pattern of fire that interacts with the pattern of soils, vegetation, and fine fuels*" (Binkley, 2007).

Further, there are a handful of trees native to old growth forests in the Pacific Northwest. The most commonly found tree in the old growth forests are Western Hemlocks. Although they do not have fire resistant qualities, they are protected by the attributes of the old growth forests mentioned earlier (*Pacific Northwest Research Station,* 2022).

The main characteristics of native tree species of the PNW that classify them as fire resistant are listed in the matrix below. See Table 2.

Table 2: Species of Native Trees Found in Pacific Northwest and Their Fire Resistant traits

	Thick Bark	Fire Induced Sprouts/Grow from Root Crown	Serotinous Cones	Fire-Activated Seeds	Other Resistant Qualities
Lodgepole Pine (scattered) Least concern	✓		✓		
Western Hemlock (mountain					

ecosystems) Endangered					
Whitebark Pine (scattered) Endangered					
Ponderosa Pine (scattered) Least Concern	✓				
Western Red Cedar					Large size sometimes helps in low intensity fires
Grand Fir (East of Cascades, Valleys) Least Concern	✓				
Paper Birch					Constant moist canopy
Red Alder (Scattered) Least Concern					Thin litter, very little debris, seeds are often carried by wind and grow quickly
Quaking Aspen (Scattered in Mountains) Least Concern		✓			Moist leaves, and forest floor litter
Bigleaf Maple (Scattered through valleys up to 200 miles from coast)		✓			Moist leaves, and forest floor litter

Least Concern					
Pacific Dogwood (Scattered through Valleys) Endangered only in Idaho	✓	✓			epicormic branching
Vine Maple (scattered West of the Cascades) Least Concern		✓			

Table 2: *Information provided by Gymnosperm database and USFS Database: https://www.conifers.org/ , https://www.fs.usda.gov/database/feis/plants*

Pacific Northwest Forests and Native Species

There is a clear correlation between fire-resistant characteristics and level of species endangeredness. According to the U.S. Forest Service, the only two tree species that are universally endangered do not have any recognizable fire-resistance traits; Western Hemlock, and the Whitebark Pine. The other listed native tree species of the Pacific Northwest all have one or more fire-resistant qualities and are all considered "Least Concern" by the U.S. Forest Service.

Loss of Biodiversity

Even with the increase in forest fire, a majority of trees native to the Pacific Northwest are continuing to protect themselves. Such trees will be labeled as "Least Concern" in Table 2. Trees that have evolved to have fire resistant, and even pyrophilic traits continue to thrive in fires with a range of different severities. On the other hand, there are trees that are adversely affected by fire such as the Pacific Dogwood, Whitebark Pine, and the Western Hemlock. The Whitebark Pine and the Western Hemlock have no fire resistant qualities, so after a burn, it may take five to ten years to reproduce in which other species with fire resistant qualities will have taken over the area that the Western Hemlock or Whitebark Pine previously inhabited (Macbean, A. P, 1941). These processes are common in the Pacific Northwest and are one of the key factors to loss of biodiversity in ecosystems. The loss of biodiversity can pose a number of problems for an ecosystem. The first major problem with the loss of biodiversity in an ecosystem is that there is less carbon uptake through the trees (Naeem, S., et al, 1994). More specifically, "plant productivity, related in part to

community respiration, was higher in the high-diversity ecosystems" (Naeem, S., et al, 1994). The decline of forest respiration through native tree species contributes to a positive feedback cycle in that when there is less Carbon uptake completed by the trees, there is more carbon in the air which contributes to further warming of the local atmosphere which can contribute to more frequent and severe fires.

Another downfall of loss of biodiversity in an ecosystem is the diminished efficiency of nutrient cycling. Nutrient cycling is important to the health of any ecosystem. The ability for an ecosystem to harbor and cycle nutrients through it will determine the ecosystems ability to be resilient against drought, and other natural disasters (Koller-France, E, et al., 2021). Nutrient cycling not only helps an ecosystem be resilient but it also maintains groundwater and surface water cleanliness. Biodiversity plays it's part in the nutrient cycle as well. A good method for proving this is analyzing the Nitrogen cycle in an ecosystem. In a study done on grasslands it was found that the more different species of plants in an area there are, the less nitrogen is "left over" in the soil. When there is less nitrogen in the soil, less nitrogen leaches into the groundwater which in turn will protect water quality and ecosystems associated with freshwater (Koller-France, E, et al., 2021). With the loss of biodiversity in regard to tree species in an ecosystem, the nutrient cycle runs with less efficiency and can cause health problems for the ecosystem.

Research Question 2: Mitigation Techniques

Although there are ways to prevent wildfire passively through maintaining forest health, setting fire bans in dry areas, and so on, there are four main forms of active fire mitigation. This will be an analysis of the two mitigation techniques, in which the outcome will be determining how cost efficient they both are. The fire mitigation techniques that will be discussed are drone surveillance, pruning, and mastication, and prescribed burns.

Drone Surveillance and Weather Balloons

There are two main types of aerial observation Firstly, there are high altitude weather balloons that are used to calculate specific fire conditions. Conditions that a weather balloon can detect include relative humidity, wind velocity, and temperature, which are all necessary when forecasting for fire(NOAA, 2023). Aside from weather conditions, another determining factor for fire warnings in areas is the topography. Drones are launched specifically to monitor topography, fuels classifications, while weather balloons report information on relative humidity, wind velocity, temperature, and different specific heat patterns in specific areas.

One of the more important and widely used instruments used on a drone is Laser imaging, detecting, and ranging (LiDaR). LiDaR captures uniquely high quality, three dimensional models of areas (Wells, G. et al, 2013). The images captured from the LiDaR equipped drones makes “it possible to map LIDAR’s distinctive spectral signatures of grasses, shrubs, and bare ground to already-developed classification systems that define these types in terms of their characteristics as fuel” (Wells, G. et al, 2013). In this case, drones map out what types of fuels are present which gives fire captains insight into which hand-crew strategies should be administered. LiDaR has become a household name in wildfire response tactics and is widely used by state and federal wildfire teams (Wells, G. et al, 2013).

Cost Analysis of LiDaR Equipped Drones

As far as cost goes, LiDaR equipment and other drones can be expensive in comparison to other forms of mitigation. The Damon Project in Malheur National Forest in Oregon serves as a precedent for drone usage. The cost breakdown was $1.34 per acre over a total area of 31,164 acres. The total cost of service is $41,759.76 (Hummel et al. 2011). In 2021, there were a total of 4,075 wildfire incidents with a total burn size of 1.5 million acres. Based on the number of wildfires and the number of acres burned, the mean size of wildfire in the Pacific Northwest is 368 acres. This would mean that the average cost of a LiDaR equipped drone would be $469.25 (Northwest Interagency Coordination Center, 2022).

Weather Balloons

On the other hand, there are weather balloons that detect relative humidity, wind velocity, and temperature changes that give insight into the possibility of wildfire. There are 92 weather balloons that are circulating throughout all of the United States and its territories, 6 of which rotate throughout Idaho, Oregon, and Washington on any given day (NOAA, 2023). Tracking humidity, wind velocity, and temperature changes is essential to the early detection of fire.

Figure 1: Radiosonde Parts

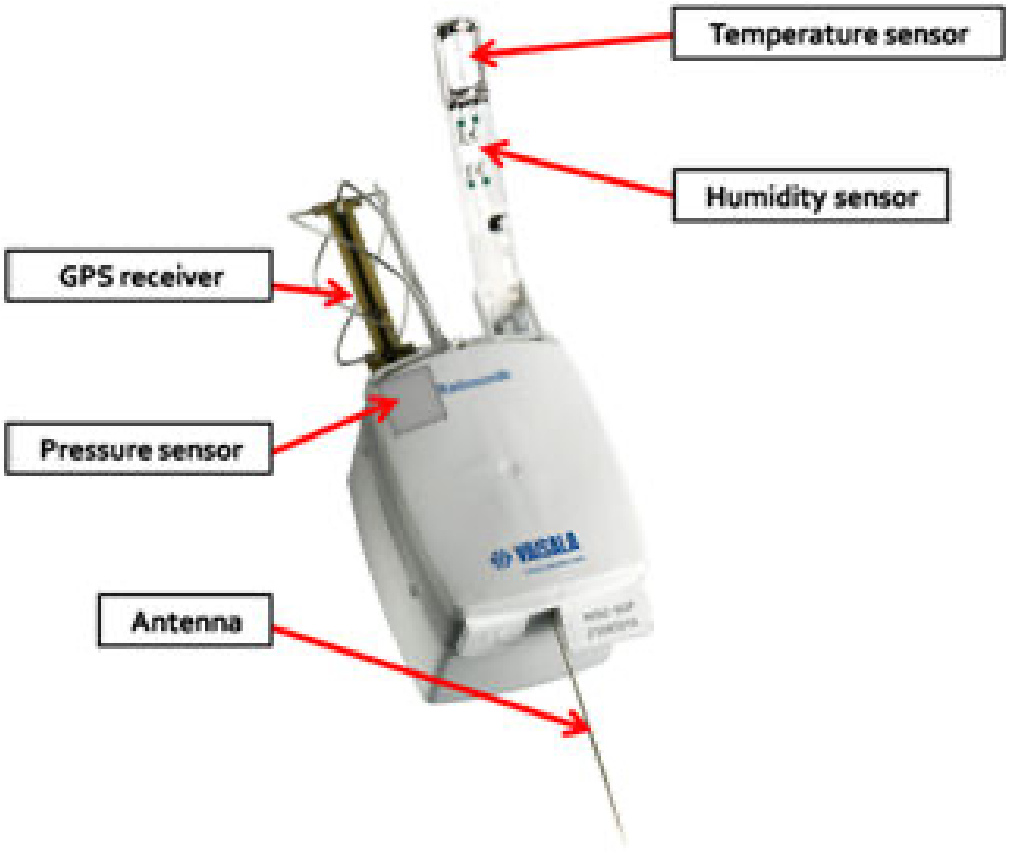

Figure 1 *depicts all parts of a radiosonde the is attached to a weather balloon. All parts are necessary for data retrieval of fire conditions.*

Cost Analysis of Weather Balloons

The weather balloons released by the National Oceanic and Atmospheric Administration (NOAA) are significantly less expensive than other forms of fire mitigation. According to the NOAA, each launch of a weather balloon only costs about $200. This includes the cost of production of each piece of equipment that is attached to the balloon. Each weather balloon consists of only a few parts. There is a latex, biodegradable balloon that elevates the parachute, de-reeler, and the radiosonde. The radiosonde is where all of the technological equipment is held. The radiosonde holds

the temperature sensor, humidity sensor, GPS receiver, pressure sensor, and finally the antenna which propels information gathered from the other parts of the radiosonde back to a place where the information will be analyzed.

Weather Balloon Flights

The typical weather balloon as described has a flight duration of about 2 hours before the balloon bursts in very high altitudes. As previously stated, there are 92 balloons circulating around all of the United States territories at any given time, and about six balloons in the northwestern states. This means that each day, the NOAA spends about $1200 per day launching weather balloons to cover the entire area of Idaho, Oregon, and Washington. The map below highlights general locations of weather balloons in the United States at any given time.

Figure 2: Radiosonde Map

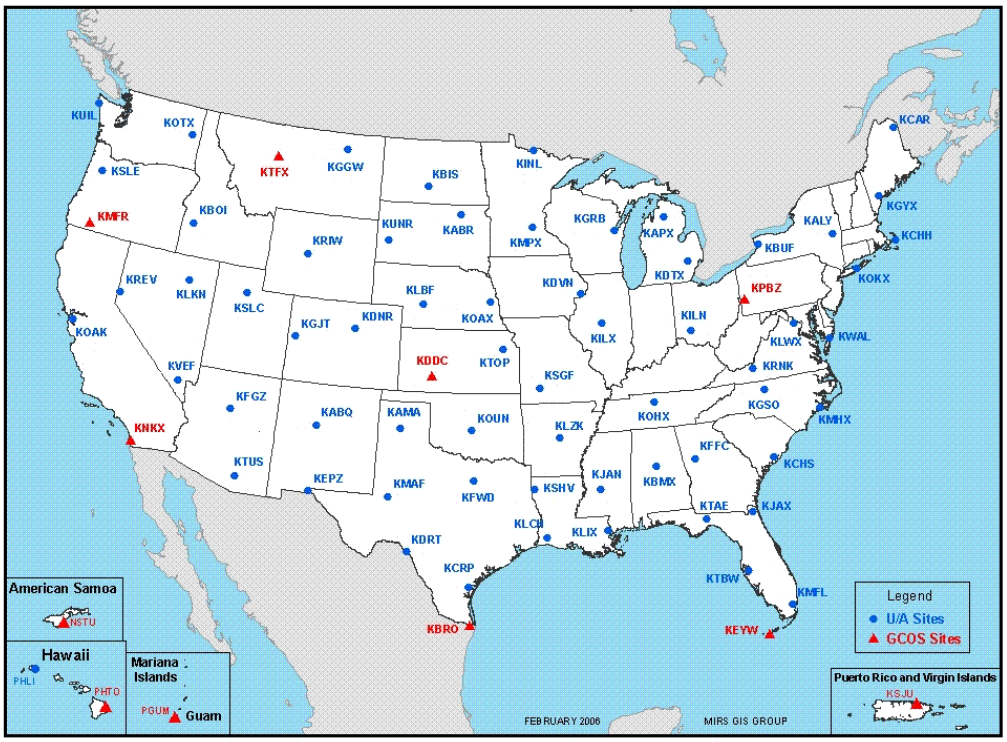

Figure 2 shows UA sites and GCOS sites. The UA sites mark individual weather balloons. The GCOS (The Global Climate Observing System) regularly assesses the data coming from the radiosondes. In

figure 2 balloons marked KSLE, KOTX, KUIL, KBOI, KLKN, and KREV will generally rotate and move through Idaho, Oregon, and Washington depending on wind velocity.

Forest Fuel Removal

Another form of fire mitigation and suppression is Forest Fuel Removal. Within the general term of Forest Fuel Removal there are several different techniques that are utilized. the first and most commonly used is prescribed burning. There are two types of prescribed burns; silvicultural burns and preparation burns. The third is pruning and mastication of trees and shrubs.

Prescribed Burns

There are three types of prescribed burns that are utilized in fire mitigation strategies. The first strategy that is used by State Forest Departments as well as private organizations is preparation burning. Preparation burns are typically low intensity fires that are used to destroy forest debris. Forest debris is dry shrubs, dry and dead grass, any downed vegetation, and dead leaves. With the absence of forest debris, a theoretical wildfire is limited in its ability to spread or increase in intensity. The other type of prescribed burning is called Silvicultural burns. These burns are typically used in an attempt to preserve and protect natural ecosystems and their native and possibly endangered species. These burns will rid the ecosystem of a lot of invasive species as well as burning some forest debris. The last form of prescribed burning is creating a fireline. The firelines will create a barrier made up of a lack of vegetation, dead or alive, through the use of burning physical lines into the forest. This creates a set line where the theoretical advancing fire can no longer advance in the same direction.

Cost Analysis of Forest Fuel Removal Techniques

The prescribed burns are generally relatively cost efficient. A study done in an experimental forest in Montana cultivated a variety of different sets of data pertaining to firelines, silvicultural burns, and preparation burns. The data shows an accurate cost analysis of the different types of burns done in three different ranges of ecosystems. The range of ecosystems includes the mountain region, piedmont region, and coastal plain region. Cost per acre as well as duration of man hours of each type of prescribed burn was done in the three regions.

In regard to the Preparation burns, the mountain region cost about $61.90 per acre, the piedmont region cost about $31.57 for the piedmont region, and $16.07 for the coastal plain region. The average cost per acre for preparation burns is $36.51 (Myers, 2007). The same study highlights that there were 90 total preparation burns covering a total area of 2559 acres. The average preparation burn size is 28.43 acres.

On the other hand, the Silvicultural Burns are less expensive. Silvicultural burns in mountain regions averaged about $35.98 per acre. Piedmont regions were calculated out as $16.01 per acre. And the coastal plains region came out to be $9.88 per acre. The average of the three regions is $20.62 per acre (Myers, 2007). In the same study, there were 76 total silvicultural burns that burned a total area of 3932 acres. This puts the average silvicultural burn size at 51.7 acres. Firelines are an inexpensive and safe way to mitigate fires and gain control of their direction and strength. The total cost per mile to create a fireline is $513.26 (Myers, 2007).

Figure 3: Fire Mitigation Strategies Cost Per Service

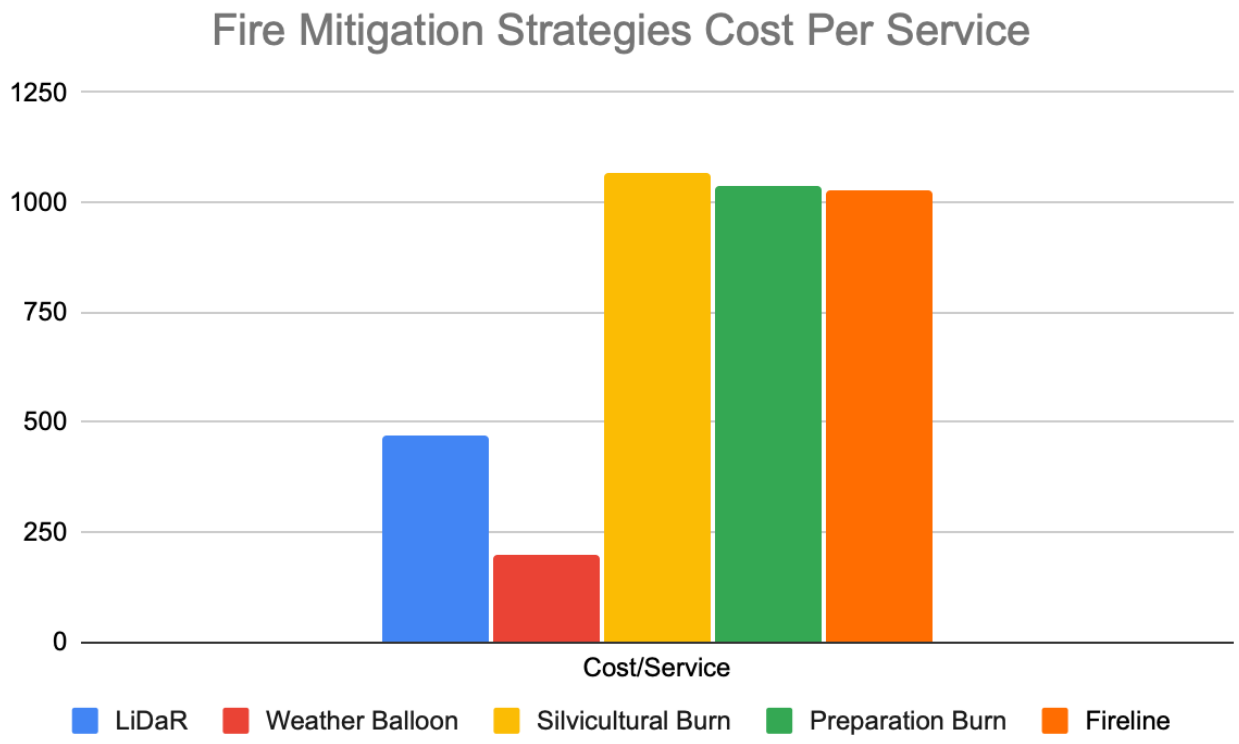

Figure 3 *displays the total cost per total service of the previously discussed fire mitigation strategies. These services and numbers used as an input for the purpose of the graph are based on the average size of a wildfire in the Pacific Northwest*

Figure 4: Fire Mitigation Strategies Cost Per Acre or Mile

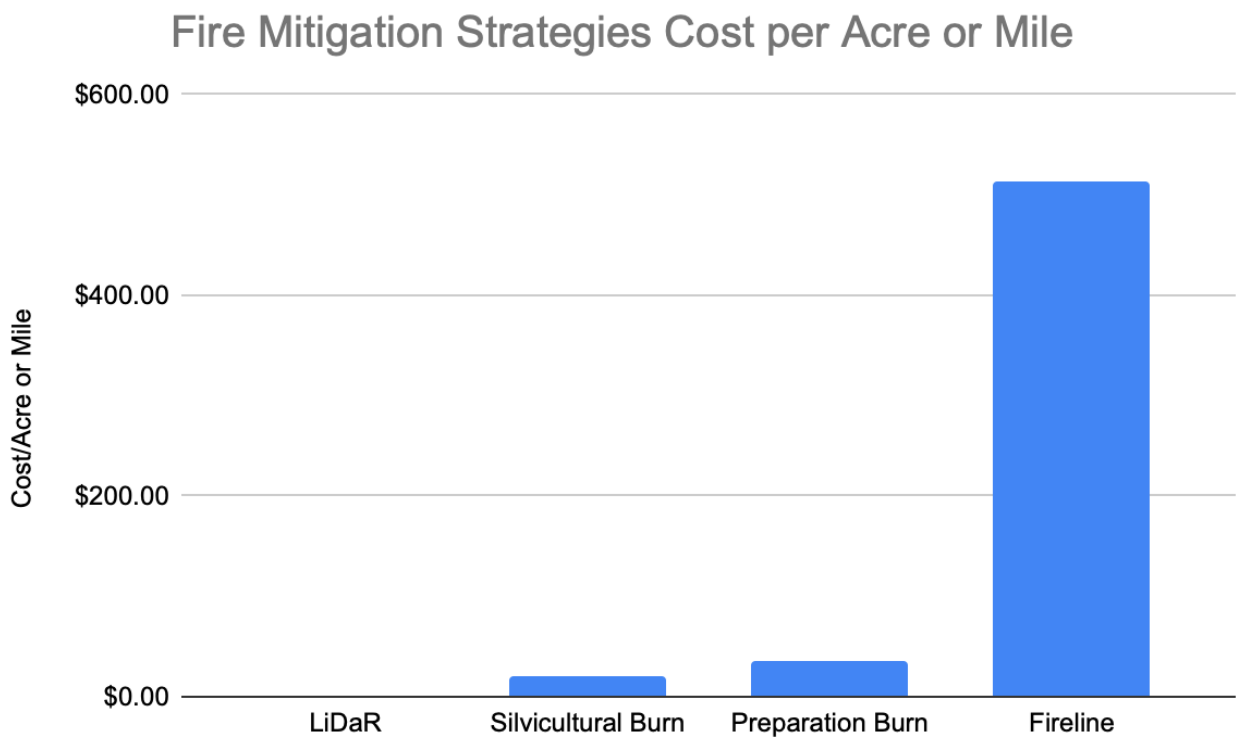

Figure 4 *displays the cost per acre or mile of each mitigation strategy discussed in the previous sections. The cost per acre or mile depends on how they strategy is conducted. Firelines are measured in road miles or chains. In the graph pictured, the fireline cost is based on a calculation that a fireline costs $513.26 per mile of construction.*

Dangers of Prescribed Fire

The other important detail to note is that prescribed burns can turn into wildfire as well. A study was done in Oklahoma to see just how often fire escapes from its predetermined boundaries as a prescribed burn. There were 661 prescribed fires reported from 2015 to 2016. 107 of the prescribed fires turned into spotfires. This is a percentage of 16.2 percent. A spotfire is a fire that has temporarily crossed over the intended boundaries of the prescribed burn but is quickly extinguished before burning much land. Most of these spotfires only burn about an acre of land. On the other hand,

out of the 661 prescribed burns, and 107 spotfires, 24 of them turned into escaped fires. Escaped fires are called this because they have surpassed all attempts of being extinguished by a hand crew. They are essentially human-caused wildfires. Although escaped fires did not happen as often, there is still a 3.6 percent chance that a prescribed burn can turn into an escaped fire (Weir, et al, 2017). These escaped fires have the ability to cause damage, which is the exact opposite of what is intended.

Discussion:

The findings of this study indicate that there is a complex relationship between wildfires and land preservation in the Pacific Northwest region of the United States. The research supports the hypothesis that small-scale, frequent fires are essential to the long-term health of most natural environments.

One of the key implications of this study is the need for a nuanced understanding of the relationship between wildfires and land preservation. It is important to recognize that certain ecosystems, such as old growth forests in the Pacific Northwest, have evolved with frequent fires and are highly fire-resistant. Therefore, it may be counterproductive to suppress all fires in these areas. Instead, carefully controlled burns and other mitigation techniques may be necessary to maintain the health of these ecosystems.

RQ1: The first research question that needs to be addressed is what is the specific relationship between wildfires and land preservation in the Pacific Northwest? Wildfire is essential to the natural ecosystems of the Pacific Northwest. The wildfires play an important role in the continuation of forests and aquatic systems' health. Wildfire keeps the nutrient cycles of an ecosystem in balance as well as making available habitat for native fauna. The wildfire keeps nitrogen levels in the soil and therefore the ground and surface water at a normal level. With a lack of wildfire water and soil quality will diminish significantly in time.

The findings of this study highlight the importance of utilizing effective fire mitigation techniques. The data indicates that the average number of acres burned on an annual basis has been increasing over the last few decades due to climate change. Therefore, it is important to implement effective fire mitigation techniques, such as prescribed burns, to reduce the risk of catastrophic damage to human infrastructure and more importantly, detriment to the natural world.

RQ2: There is no best strategy or practice. The techniques work best in combination with the other techniques. Active strategies to suppress fire on the ground or aerially are formed after data is received from weather balloons and drones. Without the use of aerial footage and modeling, or temperature and humidity it would be near impossible for operations leaders to place their hand crew in the correct position to contain or control the fire. Not only would it be hard to contain or control, it would be impossible to ensure the safety of the hand crews fighting the fire on the ground.

H1: Small scale wildfires are essential to the health of Pacific Northwest ecosystems. The small fires act as the backbone for reinvigorating the nutrient cycle in the late spring. Larger fires on the other hand can pose some problems to environments. The frequent and large fires contribute largely to loss of biodiversity. The western hemlock, common in old growth forests, and whitebark pines are keystone species that are good for tracking the health of an ecosystem and occurrence of wildfires. The loss of biodiversity is dangerous for ecosystems because it will disrupt the efficiency of a system and therefore adversely affect the resiliency from weather conditions.

H2: Yes there are fire mitigation techniques that are more efficient than others. When looking at the different techniques the cost per service of fire suppression techniques, the most cost efficient technique is using a weather balloon, followed by LiDaR drones. With that being said, as I mentioned previously, they all need to be used in conjunction with the others for them to be effective.

The findings with my research are synonymous with other sources that imply that fire conditions are worsening and that with the worsening of fire severity seasons, problems with the natural world will arise. My findings conclude that wildfires that happen too frequently with high levels of severity cause problems with nutrient cycling, natural, physical habitat (like bedding and denning areas) and loss of biodiversity. And with the loss of biodiversity starts a positive feedback cycle. the feedback cycle works in that when an ecosystem is declining in biodiversity, it is less likely to defend itself from natural disasters like fires which will only further damage the biodiversity in an area, and so on.

Conclusion:

While fires can be dangerous for human communities, they are an essential component of natural ecosystems in the Pacific Northwest. When fires occur at the right size and frequency, they clear out dead vegetation, promote nutrient cycling, and create new habitats for wildlife. However, the increasing frequency and severity of massive fires in recent years has caused significant damage to these ecosystems. As climate change continues to exacerbate the arising problem, it is important to prioritize fire mitigation strategies that protect both human communities and the natural environment.

The findings of this study also have important implications for the management of endangered species. The data indicates that there is a clear correlation between fire-resistant characteristics and the level of species endangeredness. For example, the two tree species that are universally endangered, Western Hemlock and Whitebark Pine, do not have any recognizable fire-resistant traits. On the other hand, native tree species with fire-resistant qualities are all considered “Least Concern” by the U.S. Forest Service. Therefore, it is important to consider fire-resistant characteristics when making preservation decisions when endangered species are involved.

I believe that further research needs to be done on the specificity of old growth forests and their ability to be fire resistant. If we learn more then we will be able to replicate these complex systems, or at the very least do our share of the correct preservation. As humans we adapt based on challenges that need facing and the only mentor we have are natural systems that already occur. If we can understand the environment we are trying so hard to preserve, we have a better chance at fulfilling our goals.

In the end, I would not conduct my research, meet with my advisors, or write any differently than I did if I had to restart. The only thing that I would change about my work is not being a consistent writer. I should have taken quite a bit more time on a consistent basis throughout both semesters in order to give myself an advantage with time. Furthermore, there were available resources that would have proven to be worth my time if only I had put some into them. I regret not speaking to more people, and more experts, as they would have granted me knowledge that would have saved me from wasting time on topics that proved to not be useful.

Throughout my time as a college student here at University of Nebraska, there was a constant theme of sustainability that continued to show itself in every environmental class I took. The way we are taught to think about the word sustainability at UNL is reflective of the form water takes as it passes through different containers; the definition of sustainability is never constant, and really only depends on the context of the situation. The addition to my personal definition of sustainability after conducting my research is that sustainability is a human word, a human concept, and can only be implemented by humans. There are other natural phenomena that can balance out an ecosystem and improve its' health in favor of longevity but nothing that happens naturally is representative of the conservation efforts we apply to nature. To be clear, we only have to implement them because of our previous wrong doings. Sustainability is the process in which preservationists and conservationists apply to environmental related situations that need a long term solution.

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