University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Environmental Studies Undergraduate Student Theses

Environmental Studies Program

2021

How is Remote Sensing Being Used to Prevent Wildfires Today?

Luke Lauby
University of Nebraska-Lincoln

Follow this and additional works at: https://digitalcommons.unl.edu/envstudtheses

 Part of the Environmental Education Commons, Natural Resources and Conservation Commons, and the Sustainability Commons

Disclaimer: The following thesis was produced in the Environmental Studies Program as a student senior capstone project.

Lauby, Luke, "How is Remote Sensing Being Used to Prevent Wildfires Today?" (2021). *Environmental Studies Undergraduate Student Theses*. 288.
https://digitalcommons.unl.edu/envstudtheses/288

This Article is brought to you for free and open access by the Environmental Studies Program at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Environmental Studies Undergraduate Student Theses by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

How is Remote Sensing being used to prevent wildfires today?

An Undergraduate Thesis Proposal

By

Luke Lauby

Presented to
The Environmental Studies Program at the University of Nebraska-Lincoln

In Partial Fulfillment of Requirements

For the Degree of Bachelor of Science/Arts

Major: Environmental Studies

Emphasis Area: Natural Resources

Thesis Advisor: Name: Denise Wally

Thesis Reader: Name: Seth Peterson

Lincoln, Nebraska

Date: 4/22/21

Abstract

Wildfires frequencies and severities are on the rise. To properly combat and contain them, artificial intelligence should be utilized. An in-depth literature review was conducted in order to evaluate the current state of artificial intelligence specifically relating to wildfire prevention and suppression efforts. The findings in this research sheds further light on the helpful implications that these technologies (both satellites and UAVs) do, and can have on wildfire suppression. If further adopted in wildfire suppression efforts, artificial intelligence can play a more effective role. Through this, fires can become better prevented, more controllable, and better understood using modern technology.

Acknowledgments

Thank you to Denise Wally and Seth Peterson of the Nebraska Forest Service for providing me assistance throughout the research and writing process. Thank you to Dave Gosselin for assisting me throughout the research and constructing of this research paper. Their contributions helped make this research possible and thorough.

Introduction

Wildfires are often thought of as disastrous and destructive to forests, wildlife, and humans. Though this may be true, there are also benefits in terms of forest ecology. Through my research I've explored both good and bad effects of wildfires and the technology we are currently using to protect ourselves and the environment. Artificial Intelligence (AI) is extremely important because of the consequences that wildfires have and the millions of dollars we spend annually in combatant efforts. The perception of wildfires has definitely shifted over time. Now, they are seen as devastating and demoralizing without any consideration for the positive effects

they may possess. Through this research, I have been able to study exactly how a fire turns in our minds from a “healthy occurrence” to a “devastating disaster.” This is an especially important concept to understand. It can lead us closer to a consensus surrounding polarizing topics such as climate change. With this research, future studies will hopefully be done and more research can be conducted in this area of environmental science, specifically when artificial intelligence can have extremely productive and effective impacts on wildfire suppression.

Today, there are many different types of AI that are being used to fight fires. The purpose of my research is to synthesize exactly what these technologies are, how they work, and how they are being used. In an internet and information driven world, it’s necessary to follow a specific set of protocol in order to effectively evaluate articles and their relevancy. This is important for the advancement and, hopefully, greater adoption of such technologies as the effects of climate change enhance the rate and intensity of wildfires annually. Regardless of how a wildfire is started, they are becoming a more formidable opponent for firefighters. Fortunately, new technologies for prediction, detection, and suppression are beginning to be created, developed, and tested. These technologies can hopefully do two things; first, make wildfire suppression more effective, and second, make it safer and minimize the risks for firefighters.

The purpose of my research is to synthesize the findings and knowledge of those more familiar with wildfire suppression technologies and strategies. It is much more effective to incorporate the knowledge and experience of those individuals than to individually make generalized claims that may or may not be based in fact. To study this concept more fully, I’ve conducted a large-scale literature review and interviewed current professionals who have knowledge and experience with the developing technologies being used for fire prevention and

suppression. If artificial intelligence is incorporated more into the scope of wildfire prevention, then the severity of wildfires will decrease, and they will also become more predictable.

Methods

This paper seeks to evaluate many scholarly articles and their relevancy towards artificial intelligence and wildfire suppression. It synthesizes information that other studies have previously researched and concluded. Combining the research of others and making it readily available in one place is an important part of research. Conducting a literature review is an extensive process. Navigating many journal articles and being able to decipher which are quality and/or relevant takes patience, focus, and determination to gain the knowledge and information that is useful to you. First, this research started with a question. *How is artificial intelligence being used to prevent wildfires today?* After a question is posed, then research can begin. Research can often be overly vague or indefinite. This can have negative impact on the reader or anyone who may want to use your findings (Creswell, 2018). It is extremely important to keep your investigation precise. Having an end goal in mind or making sure the information you are absorbing and ultimately using is pertinent to that goal is crucial. To properly deduce whether or not a block of research is relevant, I needed to have a system or protocol in place.

Research began with identifying the problem or question that would be addressed. Then I sifted through academic articles for precise and relevant information. In this systematic literature review, the best practices in evaluation, inclusion, and exclusion of research were followed. First, a keyword-based search was performed in credible scientific databases along with Google Scholar to find any outliers. I started by using a database through the University of Nebraska-Lincoln known as Academic Search Premier to find some relevant data. After this, Bielefeld Academic Search Engine (BASE) and “Greenfile” were used for the bulk of the research.

Greenfile specializes in environmental articles, some of which fit directly into wildfire research. When the reviewing first began, it was difficult to find information that was directly related to artificial intelligence and wildfires. It was not until more specific searches were used that more useful information was found. For instance, instead of searching "artificial intelligence," a more specific "satellite imagery" was searched. This made the information provided to be much more relevant towards my topic and allowed me to gain overall more accurate information. Instead of searching "drones" which turns out is a very broad term, "UAVs," (Unmanned Aerial Vehicles) was searched.

Systematic literature reviews have undoubtedly been done before for other research projects both at the undergraduate and graduate research levels. Conducting this literature review was very enlightening. Whether it was actual publications that I was able to gain access to, or conducting interviews with real world professionals, the information I have gained has been substantial and very insightful. I excluded some articles from my research strictly because they failed to pertain directly to my topic. This was necessary to keep my research focused and direct. Embarking on this research was much more exhilarating because of simply how new some of the information was. Published research pertaining to UAVs and wildfire suppression was especially limited. The majority of the information I was able to find came directly from word-of-mouth interviews with real world professionals. Published research on the overall topic was, at times, few and far between, yet I was able to contact, interview, and have conversations with some current professionals who are doing this with the intent of wildfire applications.

Results

Historically in the US, Native Americans used fire to clear brush, open land for their crops, and restore the soil (W. Ladrach, 2009). Fire ecologists will tell you that there are numerous

benefits for an ecosystem, especially plants, when a fire occurs. Fires have been used by farmers for clearing land, reducing the risk for pests, and utilizing the associated low maintenance land costs (Alves and White, 2019). Wildfires, though necessary to a forest ecosystem, seem to have been brought to the forefront of a lot of minds in recent years as they continue to burn millions of acres of forested land. People have begun to perceive wildfires as a natural disaster and a demoralizing occurrence. In a study done in St. Louis, it was found that 40% of people associated poor air quality with smoke, but only 16% associated it with vehicle emissions (W. Ladrach, 2009). This signifies that wildfires, though a naturally healthy occurrence, are blamed for some things that maybe they are not guilty of. Although controlled burns and small reasonably contained wildfires have certain benefits and advantages, when they become wild and uncontrolled, they can have harmful effects to several key stakeholders. From the government to civilians, wildfires can and do make an economic impact.

The National Institute of Standards and Technology (NIST) estimates that the annual cost of wildfire management ranges from $7.6 billion to $62.8 billion, while the annual losses caused by wildfires ranges from $63.5 billion to $285.0 billion (D. S. Thomas, D. T. Butry, S. 2017). Whether they are occurring naturally or are human induced, wildfires can be extremely dangerous and lead to some threatening implications. Although historically occurring naturally, wildfires have become increasingly frequent and severe in recent years. Annually, wildfires increasingly cause more devastating effects to ecosystems, people, and the global environment. They burn millions of acres every year and are seemingly becoming more difficult to contain. According to the National Interagency Fire Center (NIFC), since 1980, there has been a general uptrend in the number of acres burned annually in the United States.

Record breaking wildfires have motivated policymakers, government agencies, communities, and researchers like myself to take a closer look at this issue. In fact, this has caused a movement towards better systems and technology to play a bigger role in the mitigation of wildfires in the US (McWethy, D.B., Schoennagel, T. 2019). However, since wildfires do serve an essential purpose for the forest's ecosystem, we must make the distinction between a healthy wildfire and a disaster. It is only when a fire becomes enormous and out of control that negative consequences take place. When they become very widespread and exacerbated, they can be detrimental to certain stakeholders. Uncontained wildfires rage through forests and mountain towns, wreak havoc on private and public lands, and sometimes extend to civilized locations. In fact, they burned or damaged over 10,000 structures in 2020 alone. In addition to the economic impacts of wildfires, they can also have extreme consequences to human health and well-being. Air quality is something that can cause severe health issues including asthma and bronchitis to those who are exposed to the toxic fumes. Research shows that during a wildfire other forms of health issues arise as well. Different from physical health problems, mental health issues have been linked to the effects of wildfires (Brown, M.R.G., Agyapong, V., Greenshaw, A.J. *et al.*, 2019). According to this study, kids in grades 7-12 showed an increase in mental health symptoms after the McMurray wildfire (occurring in Alberta Canada, 2016) versus control group.

Uncontained wildfires can have devastating effects on terrain, climate, and local economies. They are also a serious threat to the preservation of biodiversity today. Most wildfires are caused by human activity, both directly and indirectly. Whether it be campfires that have been left, discarded cigarettes, power lines, or industrial consequences related to climate change, fires are burning each season at a generally more intensive and widespread manner.

However, they are ignited by natural occurrences as well, such as lightning. Wildfires are becoming more frequent and more severe because of human activity. Recently, studies have pointed to climate change as the culprit to worsened fire occurrences over the years (Thomas Ambadan J, Oja M, Gedalof Z, Berg AA, 2020). Climate change has increased the frequency of droughts that have become more intense and caused rainfalls to become more sporadic and unreliable. This leads to the drying of previously lush or healthy forested areas and are now becoming more flammable. Especially during and prior to fire seasons, trees are becoming more likely to be ignited. Dry conditions can catalyze a forest fire and make it increasingly uncontrollable once it ignites. The effects of an uncontained wildfire can be disastrous. A loss in biodiversity and a large population threat to native forested trees are just two of the immediate impacts (Mirza Dautbasic, Genci Hoxhaj, Florin Ioras, 2011). Wildfires also cause an increase in nitrogen deposition from ash falling and blanketing the ground, which leads to a spike in invasive weeds or other plant species on the forest floor. Although somewhat contested today, the effects of climate change have been linked to be of anthropogenic causes. This theory is of scientific consensus currently. Population growth is something that has been and will continue to stress our civilizations and climate. Population growth will lead to land use change, which will be threatening to forests and, in turn, cause an increase in wildfire susceptibility and frequency.

Remote Sensing through Satellites

Satellites and remote sensing are and have been used very frequently in the detection and prevention of wildfires in the United States and the rest of the world. Remote sensing can be defined as the acquisition of information about some feature of interest without coming into direct contact with it (Lechner, Foody and Boyd, 2020). According to this research, remote sensing is being used for more than just wildfire prevention. It helps track and manage forest

vegetation health, vegetation chemistry and moisture, biodiversity, and soil characteristics. Popular forms of remote sensing used to study the environment can be categorized as either airborne, planes or Unmanned aerial aircrafts (UAVs), or spaceborne (Satellites). The types of systems vary greatly as does the kind of image or analysis they display. Some may be visible characteristics like color or elevation that can be seen by the human eye, while others are complex enough to examine heat signatures and the chemical makeup of Earth's surface. Spaceborne satellite sensors are just one of the ways these characteristics are being recorded and used in wildfire prevention. Satellites have been utilized to provide valuable information to foresters for ecological, biological, and now, wildfire purposes. A common challenge we currently see with a satellite's capture of information is the obstruction of clouds. For most sensors, clouds can eliminate their ability to gather information on the ground. For this reason, there are certain sensors that can penetrate through clouds from great heights. Referred to as active sensors, they use light detection and ranging (LiDAR), and synthetic aperture radar (SAR) (Lechner, Foody, Boyd, 2020). These active sensors can reach the ground and use a pulse that is sent through the obstruction of the clouds, reaches the ground and reflects back to the sensor. This is particularly beneficial to wildfire prevention because of their ability to overcome the challenges of smoke as well. Wildfires that burn through healthy green vegetation often result in an enormous amount of smoke and smog. If it were not for active sensors like these, detection and analysis would not be possible.

Spaceborne sensors take measurements of the Earth's surface in different intervals. Unsurprisingly, there are lots of different ways that satellites are being utilized. From pre-ignition, during the fire, and post burn, these systems are collecting and distributing information that then is the basis for calculated decisions for crews on the ground.

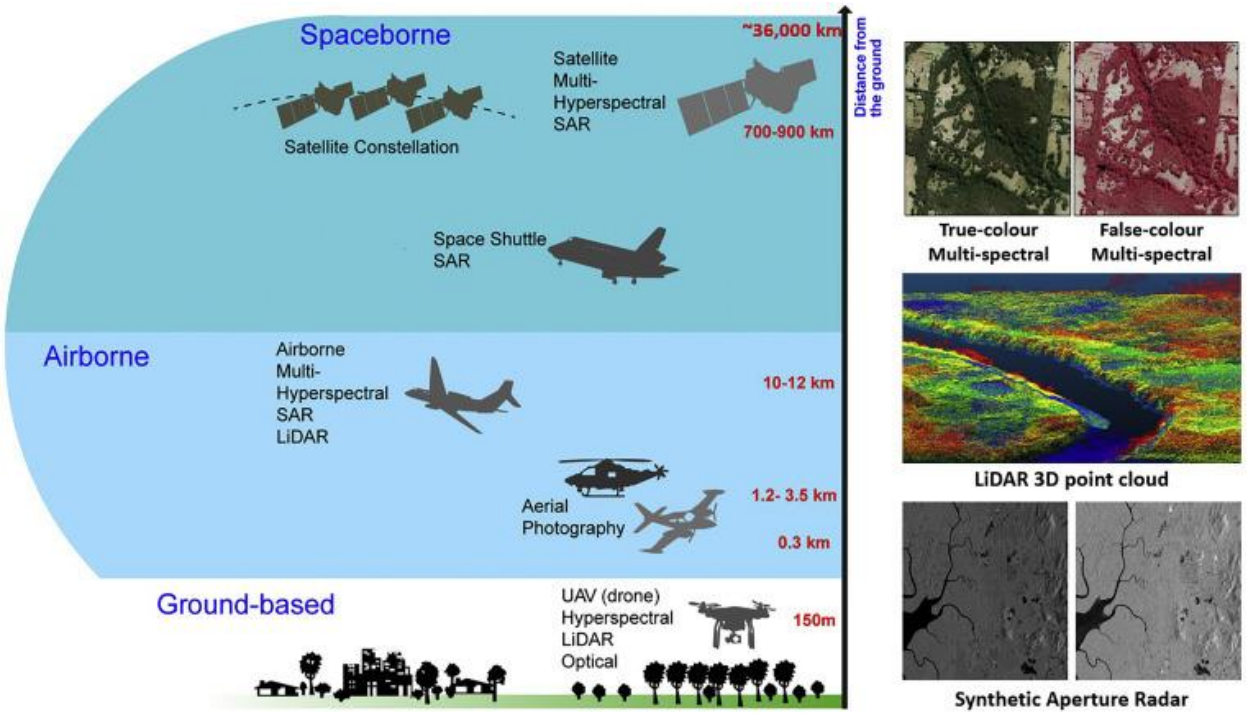

Figure 1: Details the different types of Remote sensing systems and elevations at which they operate (Alex M. Lechner, Giles M. Foody, Doreen S. Boyd, 2020)

Remote sensing was first brought into the scope of wildfire suppression in recent decades and continues to become a bigger part of it. They can analyze and tell us things that we otherwise would not know. In fact, according to a study done in 2012 and 2014, wildfires typically have what are called “islands” or unburned areas inside the perimeter of the fire. They act as refuges for wildlife and aid enormously in preserving the biodiversity of that specific ecosystem, however they have historically been ignored by remote sensing research (Arjan J.H. Meddens, Crystal A. Kolden, James A. Lutz, 2016). In this study, it was found that in non-forested areas,

like grasslands or rangelands, unburned areas were much larger than that of forested areas. Using Landsat, a spaceborne satellite that captures images once every 16 days, to calculate this difference, the researchers were able to conclude that these islands need to be taken more seriously and preserved either before or after a burn. These islands will be increasingly important, especially given the rate at which anthropogenic climate change is impacting the frequency of wildfires and the rate at which it is expected to continue.

Satellite imagery is another tool that is being used to determine different elements of the landscape that might make a particular area at risk for ignition. In certain cases, they are evaluating the hydrological scale of a particular area to assess its fire risk. According to the National Fire Danger Rating System in the United States, some are programmed to incorporate elements of wind, precipitation, air temperature, and humidity. Additionally, many satellites are used for imagery. There are two types of risk assessments that can be evaluated by orbiting satellites, structural and dynamic. Structural fire risk indexes, as they are called, evaluates the landscape based on a long set of parameters that can be considered somewhat permanent. The vegetation, or "fuel type," the topography, elevation, population, and even fire history can be taken into account (Carrao, H., Freire, S., and Caetano, 2003). This technology, since it uses parameters that only need to be updated annually, do not need to be done very often and often and only at the beginning of each fire season. Dynamic fire risk indexes are used for short term parameters and are often more complex. Slight differences in the vegetation type within a landscape, variations in flammability of the forest cover, live or dead ratio of the vegetation are considered. Traditionally, satellites like the Landsat Thematic Mapper™ and Système Pour l'Observation de la Terre (SPOT) have been used for large scale more simplistic overlays and evaluations. However, the National Oceaninc and Atmospheric Administration's (NOAA)

satellite, Advanced Very High-Resolution Radiometer (AVHRR) has been used for mapping and finding out intricate details about a stretch of land that has a certain level of significance to firefighters (Carrao, H., Freire, S., and Caetano, 2003).

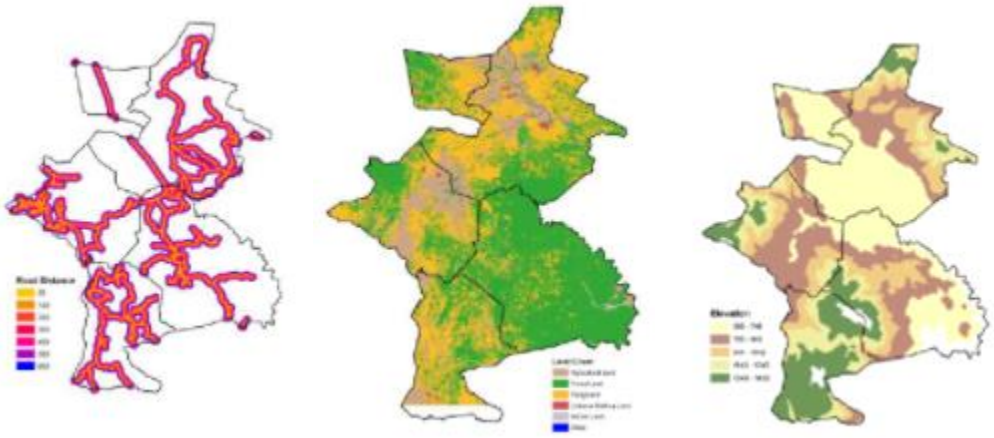

Figure 2: Reading left to right, different layers captured from a satellite that shows distance to roads, land cover, and elevation respectively (Carrao, H., Freire, S., & Caetano).

It is evident that satellites have a wide range of functions and are impacting the detection, tracking, and suppression of wildfires in a major way. In fact, the Soil Moisture and Ocean Salinity (SMOS) satellite has helped measure the soil moisture levels in many areas to better conclude where high ignition areas would be. According to a study done in Canada, this SMOS satellite technology was tested on 14 different ecozones where wildfires had occurred were studied over the time span of 2010-2017. It was found that this technology was a promising and effective way to detect "hot spots" or potential areas where a wildfire would occur (Thomas Ambadan J, Oja M, Gedalof Z, Berg AA, 2020). According to a study done in South America, satellites are also being utilized to diagnose an areas risk for ignition. This technology allows

firefighters to realize what areas specifically they should be prepared to deal with, and which ones may be considered “low risk.”

In California in 2020, the state suffered one of the worst wildfire seasons on record. At one point, there was 367 active wildfires across the state that seemed to be spreading at a record pace and were being prolonged by a west coast heat wave and high winds. While this was happening two satellites became especially useful for scientists and wildland firefighters alike. The Geostationary Operational Environmental Satellite (GOES), first launched in February 2019 to scan the west coast, Hawaii, and Alaska, had provided geostationary coverage of the western hemisphere and thus the California fires (National Satellite Environmental Data and Information Service). Additionally, the NOAA 20 satellite is equipped with something called a Visible Infrared Imaging Radiometer Suite (VIRRS) instrument. This tool works at an incredible level and is able to scan the entire earth twice per day at 750-meter resolution. This detects dust, smoke, smog, and haze, all of which could lead to detection of an active or young wildfire.

On November 8th, 2018, California experienced its worst wildfire on record sparked in Butte County. It was named the Camp Fire and claimed 88 lives, destroyed over 18,000 structures, and burned a total of 62,052 acres (Syifa M, Panahi M, Lee C-W, 2020). While this fire raged and ground forces were dispatched and hard at work fighting, remote sensing was being used to detect, track, and target certain areas that were deemed safe and effective locations for ground crews.

Regardless of whether a fire is started in a forested area or the Great Plains, satellite and remote imagery have become crucial tools to evaluate its severity, estimate habitat loss, and even

observe habitat recovery. 2016 and 2017 were damaging years for wildfires in Texas, Oklahoma, and Kansas. They resulted in significant social, environmental, huge agricultural damages, and economic losses (Steiner JL, Wetter J, Robertson S, et al., 2020). The indices used in this study showed rapid vegetation regeneration after the fires had gone through. The Leaf Water Stress Index (LSWI) and Gross Primary Productivity (GPP) were used to show a distinct response by the vegetation following the wildfires and differentiated between burned and unburned areas throughout the post-wildfire growing seasons (Steiner JL, Wetter J, Robertson S, et al., 2020). I found the information presented in this article, specifically about vegetation recovery to hold true according to similar studies done on grassland wildfires.

According to a different study done in 2015, satellite technology can use infrared sensors from space to detect when a fire has been ignited in just minutes. More times than not a fire is not detected until it has already spread and grown substantially. As a firefighter, it is crucial that a forest fire is detected soon after it is lit, as this is the most important time to fight it. Often times when a fire has been given time to grow, it is almost too late to make significant progress in the fight. This technology is called "Firesat" and can detect a fire when it has reached 35-50 meters wide. If implemented and used more, fires can be fought faster and more effectively, and many acres of forest can be saved in the process.

These technologies are ever changing and being innovated. New technology can bring some challenges as well. Adoption can be slower and less frequent when dealing with more traditional firefighters. To better implement some of the technologies listed below, training must take place which can be difficult and time consuming, especially with crews that are not necessarily eager or open for change. Along with satellites, comes a newer and potentially more powerful technology in unmanned aircrafts.

Remote Sensing through Drones and UAVs

Drones and Unmanned Aerial Vehicles (UAVs) are becoming more of a useful tool for wildland firefighters in the mitigation of dangerous wildfires. According to industry professionals, they are receiving an enormous amount of attention because of their ability to navigate high risk and sometimes dangerous missions while limiting the risk for human injury (C. Phan and H. H. T. Liu, 2008). UAVs have been used in wildfire suppression for only roughly the last 10-15 years. Researchers are currently working on drones to be able to cooperate with both the pilot, remotely, and collaborate with other drones during a mission. Not only does it limit the amount of risk a wildland firefighter takes on, they also are more effective in detecting, mapping, and monitoring wildfires.

According to Weston Irr, Director of Unmanned Aircraft Systems at Bridger Aerospace, drones and UAVs aren't necessarily the same thing. A UAV, commonly known as a drone, is what it sounds like, an aerial vehicle that is controlled remotely by a pilot. They are being used for many different tasks related to wildfire suppression today. Prescribed burns, information relay, and remote sensing all can be performed by one model or another, depending on the supplier. Bridger Aerospace is currently under contract to supply UAVs to both the United States Forest Service (USFS) and the Department of the Interior (DOI) which nine total agencies fall under. These relationships are mainly driven by demand. When an agency wants more systems, they will supply them. Bridger Aerospace currently supplies drones for imagery and mapping purposes. These systems normally have a 15-foot wingspan and are used for tactical assignments. This includes gathering data in real time as a fire burns, displays aerial images that have been corrected for distortion, collecting information on a landscape that has already been

burned, and aid GIS experts and firefighters with information that allows them to make justified and accurate decisions. Not only are they used during wildfires, but these systems are used extensively for forest replanting and habitat loss after a landscape has already burned.

Figure 3: Using mapping software and an advanced imagery system, the UAVs supplied by Bridger Aerospace is able to map areas with multiple layers day or night and gather fast outlines of fires (Weston Irr).

Though incredibly useful, drones and UAVs specifically, do not come without their share of challenges. According to Weston, with Bridger Aerospace, it is often difficult to get traditional firefighters to transition from their sometimes-outdated approaches and embrace the new technology. A lot of these firefighters have been doing their job a certain way for many years, and those habits can be hard to break. Additionally, these systems are not easy to operate. Sometimes extensive training is needed before you can pilot one of these aircrafts. UAVs supplied by Bridger Aerospace do not fly autonomously. They can hover and capture data, make adjustments during wind shifts or gusts, but they need a skilled operator.

According to Nick Zaczek, who works UAVs in the Wyoming Forestry Division (WFD), there are some technical issues and software problems that some operators experience. Using UAVs, Nick does fuel reduction evaluations when not in fire season. The technology helps him evaluated where large fuel areas are, and how he, and his crew, might target them. Problems range from aerial images being distorted, to the system simply encountering trees or other aircrafts, or even capability issues, there are definitely some challenges that need to be accounted for upon implementation. Almost all the flights that he and his team do are at night. This is to eliminate the risk of interfering for larger wildfire suppression aircraft during a fire. The systems that are used by Nick and the WFD can fly autonomously. If the pilot desires, a flight plan can be created beforehand, and the UAV will carry out that flight and collect data without the pilot's action. Along the flight path, it maps vegetation density which can then be used by Nick and his crew to determine where highest risk areas are and where the best places to do prescribed burns are, as well. One of the most fascinating new developments in this field is the prescribed burns, using UAVs, to either prevent or suppress wildfires.

According to Carrick Detweiler, who is an engineer with the Lincoln based company-Drone Amplified, drones are being integrated into the mitigation of wildfires much more in recent years. When a wildfire isn't burning, out of season, or not a threat UAVs can be used to create prescribed burns. These can be enormously helpful for fuel reduction or enhancing the overall health of the forest. Prescribed burns were something that I was not familiar with before my research but is a huge part of what wildland firefighters do and now what some UAVs are being used for. On the other hand, once a fire is ignited, it spreads in any direction and forms a perimeter. This perimeter is then used for creating back burns that can redirect or put out an incoming wildfire altogether.

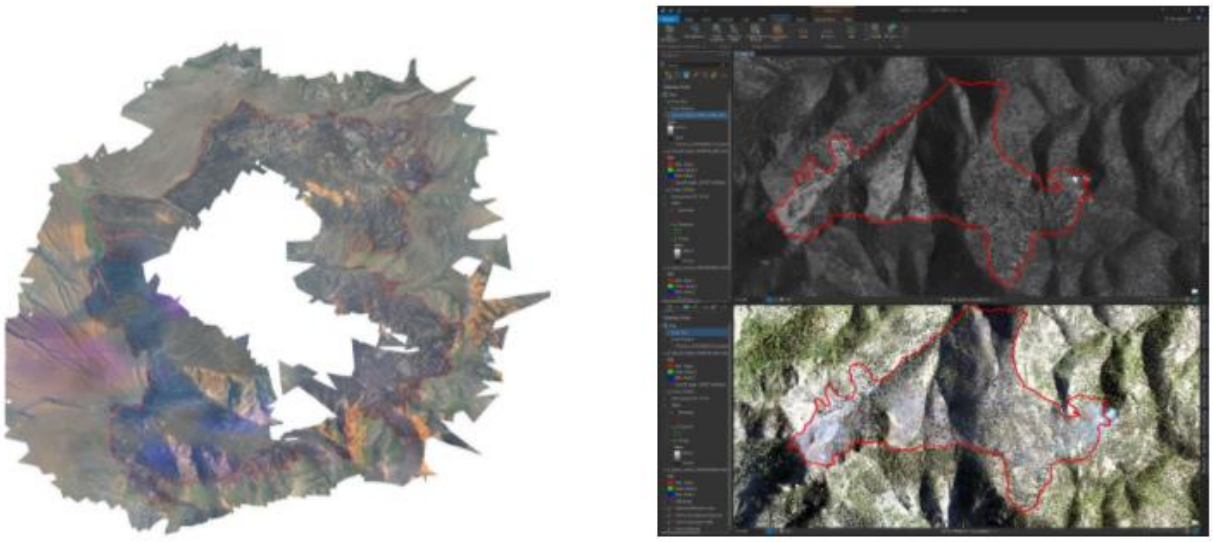

Figure 4: These images show examples of multi layered images that are captured with some UAVs made by Bridger Aerospace. The perimeter of fires can be much more visible and better utilized by GIS experts.

Firefighters will typically look for natural deterrents like lakes, rivers, and sometimes even highways that they can use as an advantage in the suppression process, these are called control lines. Just before dropping the spheres, the plastic sphere dispenser (PSD) will inject them with glycol which catalyzes the chemical reaction for ignition on the ground. Just seconds after being dropped, the reaction takes place, and a second fire is ignited. This line is used to suppress and contain the wildfire as it moves out towards the perimeter. UAVs have many different uses depending on what company is supplying them and what they are needed for. Specifically for Drone Amplified, they have developed a software termed “IGNIS” that allows the UAV to create back burns and do prescribed burns to reduce the risk for a fire on a

landscape. So, to create an effective fire line, these UAVs armed with a PSD will fly within the perimeter of the fire and drop the spheres that contain the compound potassium permanganate.

Figure 5: “IGNIS” a software created by drone amplified that is used to chemically set prescribed burns that help prevent wildfire spread (Carrick Detweiler).

This technology is incredibly important for a lot of reasons. First, using UAVs to help combat wildfires drastically reduced the risk for human life on the front lines. Second, the fact that these machines are capable of detecting and relaying information to the ground crews for them to make more informed tactical decisions is remarkable. Third, the system can detect wind patterns and calculate distances and heights while flying. IGNIS is currently serving front line fire fighters in the peak of the fire seasons and helping them to start back burns with precise accuracy.

Although there are certain challenges and drawbacks, using a cost-benefit analysis one can see that if UAVs become fully functional and used properly, they have many greater advantages than disadvantages. With the technology available and being implemented correctly, there is an increasing potential for using this cutting-edge technology in wildfire suppression.

Discussion

Artificial intelligence is aiding in wildfire prevention suppression much more successfully than previously imaginable. To embrace innovation and make suppression efforts much safer and more effective, firefighters must adopt this new technology into their job. This is the way the world is moving; greater technology is giving us the capabilities to do things we never thought possible. The objective of this research was to explore the positive effects the AI has on wildfire suppression and prevention and make a case for its further implementation. Through this research, other researchers can find a greater synthesis or summary of the technologies that exist and how they are being utilized today.

Furthermore, the findings in this research should improve the overall sentiment towards the forms of AI addressed above (satellites and UAVs). Though challenges are present, advantages outweigh the drawbacks associated with implementation. This synthesis should add to, and help researchers better understand how AI is helping and can help in wildfire prevention applications. Its informative data should be used to support the findings of other research and persuade those that doubt the efficacy of artificial intelligence today.

Conclusion

In response to this research, further implementation of artificial intelligence in wildfire suppression and prevention is warranted. As stated above, the various benefits of utilizing this technology can aid wildfire prevention in numerous ways. Satellites are currently able to do incredible things and provide invaluable information about wildfires. Given that fires are normally not detected sometimes until after they have grown and spread substantially, satellites can and should be utilized to alleviate this problem. For example, the Infrared Imaging

Radiometer Suite (VIRRS) instrument that is equipped on several orbiting satellites, detects smoke, smog, and even dust that can make wildfire detection much faster. Infrared sensors can sometimes pick up a spark in the forest in just minutes, making them extremely useful assets in the field of wildfire prevention. Additionally, UAVs can have similar tremendously beneficial effects on wildfire prevention, though there is not extensive research that has been done on their impact on it to date. According to leading professionals and experts, UAVs are helping in both imagery processing, doing prescribed burns, and even actual containment or setting backburns during a fire. Although faced with some implementation challenges, satellites and UAVs have the capability to detect, measure, and relay data at a rate that would not be possible without them.

As climate change is forcing our global community into a world that may be plagued by more intense and frequent wildfire events, it will be crucial to further embrace this technology as it develops. The damage that has been seen in recent years is tremendous and only projected to get worse. The capabilities of artificial intelligence will make us more effective, precise, and efficient in our strategies to mitigate the impact of intense forest fires.

References

Alex M. Lechner, Giles M. Foody, Doreen S. Boyd, “Applications in Remote Sensing to Forest Ecology and Management,” *One Earth*, Volume 2, Issue 5, Pages 405-412. 2020.

Alves, Benjamin L., White, Benjamin L. “Detection of fires and forest fires via satellite in South America.” *Forest.* , Vol. 49 Issue 4, p851-858. 8p. 2019.

Arjan J.H. Meddens, Crystal A. Kolden, James A. Lutz, “Detecting unburned areas within wildfire perimeters using Landsat and ancillary data across the northwestern United States.” *Remote Sensing of Environment.* 2016.

Brown, M.R.G., Agyapong, V., Greenshaw, A.J. *et al.* “After the Fort McMurray wildfire there are significant increases in mental health symptoms in grade 7–12 students compared to controls.” *BMC Psychiatry* 19, 18. 2019.

Carrao, H., Freire, S., & Caetano, M. R. “Fire risk mapping using satellite imagery and ancillary data: towards operationality.” *Remote Sensing for Agriculture, Ecosystems, and Hydrology IV.* 2003.

Carrick Detweiler, Drone Amplified. Personal communication, November 2020.

C. Phan and H. H. T. Liu, "A cooperative UAV/UGV platform for wildfire detection and Fighting." *2008 Asia Simulation Conference - 7th International Conference on System Simulation and Scientific Computing*. 2008.

Creswell, John W., Creswell, David J. “Research Design: Qualitative, Quanitative, and Mixed Method Approaches.” *Sage Publishing.* 2018.

D. S. Thomas, D. T. Butry, S. W. Gilbert, D. H. Webb, and J. F. Fung, “The Costs and Losses of Wildfires,” National Institute of Standard and Technology (NIST), Tech. Rep., 11. 2017.

McWethy, D.B., Schoennagel, T., Higuera, P.E. *et al.* Rethinking resilience to wildfire. *Nat Sustain* 2, 797–804. 2019.

Mirza Dautbasic, Genci Hoxhaj, Florin Ioras, et al. “Climate Change: Wildfire Impact, *Biodiversity Loss in a Changing Planet*. 2011.

Nick Zaczek, Wyoming Forestry Division. Personal Communication, March 2021.

Steiner JL, Wetter J, Robertson S, Teet S, Wang J, Wu X, Zhou Y, Brown D, Xiao X. “Grassland Wildfires in the Southern Great Plains: Monitoring Ecological Impacts and Recovery.” *Remote Sensing*. 2020.

Syifa M, Panahi M, Lee C-W. “Mapping of Post-Wildfire Burned Area Using a Hybrid Algorithm and Satellite Data: The Case of the Camp Fire Wildfire in California, USA.” *Remote Sensing*. 2020.

Thomas Ambadan J, Oja M, Gedalof Z, Berg AA. “Satellite-Observed Soil Moisture as an Indicator of Wildfire Risk.” *Remote Sensing*. 2020.

Weston Irr, Director of Unmanned Aircraft Systems, Bridger Aerospace. Personal Communication. January 2021.

W. Ladrach, “The effects of fire in agriculture and forest ecosystems,” ISTF NEWS, June 2009.