Analyzing whether forest management practices influenced Oregon's Labor Day Fires

The Holiday Farm Fire burns above the McKenzie River, September 2020. Photo: USFS

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Executive Summary

In September 2020, Oregon experienced the most extreme wildfire event in the state's history. In a matter of days, the "Labor Day Fires" ripped across vast swaths of public and private forestland on the westside of Oregon's Cascade Mountains—a region that rarely sees widespread fire activity. Thousands of homes were lost, numerous people died, and over 10% of Oregon's population was placed on some level of evacuation notice. Now that the smoke has cleared, researchers from around the region have begun to study the event to draw lessons about wildfire behavior under extreme weather events.

Our team initiated this research project in November 2020 to drill into the following question: ***How do fuel conditions (and associated forest practices) influence wildfire behavior during extreme weather events?***

Our inquiry focused on two of the major westside fires, the **Holiday Farm Fire (HFF, or "Holiday")** and the **Archie Creek Fire (ACF, or "Archie")**—both of which burned over 100,000 acres through mixed-ownership landscapes (private industrial and federal). Our aim was to ascertain whether forest management practices across different ownerships influenced wildfire behavior, both in terms of rate of spread (i.e. progression) and wildfire severity (i.e. vegetation mortality). More specifically, our chief objective was to learn more about the relative importance of weather conditions and fuel conditions in determining wildfire behavior.

Below are the key findings of our analysis:

Rate of Spread

- The extreme rate of spread of both fires was primarily driven by a unique constellation of weather and climatic conditions (strong winds from central/eastern Oregon, low relative humidity, and underlying drought conditions).
- Holiday consumed over 100,000 acres in its first 24 hours; at its peak, it burned through roughly 19,400 acres per hour (324 acres per minute). Archie consumed ~97,300 acres in its first 28 hours; at its peak, it burned through ~5,913 acres per hour (99 acres per minute).
- The literature supports our findings that extreme weather events (such as the east wind event of September 2020) are the primary drivers of large wildfires covering vast areas.
- Recent research suggests that plantations may contribute to faster rates of wildfire spread when compared to more heterogeneous, complex forests; however, more research is needed.

Burn Severity

- Private industrial timberlands that burned during the Holiday Farm and Archie Creek Fires burned at higher severities during and after the wind event than federal forestland did, with the disparity between the two being more pronounced post-wind event. The data suggest that weather conditions were the primary driver of high severity fire for both fires, with vegetative conditions playing a secondary (but important) role.
- A thorough review of the scientific literature corroborates our findings about burn severity. The preponderance of the scientific literature suggests that tree plantations on private industrial timberland—which are characterized by their homogenous, dense fuel structure—burn at higher severities than older, more diverse forests on federal public land.

Implications for Forest Policy and Management

- In the forest policy arena, fuel conditions are commonly assumed to be the most important variable determining wildfire behavior. This assumption is often wielded rhetorically to advance a deregulatory agenda that expands logging on federal public lands; however, as demonstrated by the Labor Day Fires and other major fire events, weather conditions are the primary driver of wildfire behavior for the largest (and most dangerous) fires—not fuels.
- Our research found that fuel conditions exert a greater influence on wildfire behavior in the absence of extreme fire weather, but when strong winds conspire with underlying drought conditions, the importance of fuels diminishes. Since climate change will only continue to increase extreme fire weather, we must prioritize community adaptation efforts that make our homes and communities more resilient to the inevitable fires to come.
- Our results (and the literature reviewed here) suggest that tree plantations on private land burn more severely than federal forestlands, and therefore, efforts to reduce "hazardous fuels" should prioritize thinning plantations close to where people live—not federal forests in remote backcountry areas. Promoting alternatives to industrial forest practices may also moderate future fire behavior, although further research is needed on this topic.

Opportunities for Further Research

- Additional research is needed to determine whether clearcuts and plantations in the Pacific Northwest contribute to faster rates of wildfire spread during wind events.
- More research is also needed to ascertain whether high severity fires contribute to faster rates of spread through the production of fire brands (e.g. spotting).

The Labor Day Fires

In early September 2020, the Pacific Northwest (PNW) experienced an "east wind event" that drove dry winds from east to west over the Cascades and through westside river valleys, which is the opposite direction of most PNW winds. Sparks from downed power lines and other sources quickly turned into raging infernos that consumed over a million acres of forest and grassland across the PNW within a matter of days. The scale of this east wind fire event was unprecedented in the past 100 years, both in terms of its spatial distribution and its impacts to homes and communities. While Washington State experienced numerous large fires during this event, Oregon was hit the hardest. Oregon's Labor Days Fires consumed hundreds of thousands of acres during the week of Labor Day, destroying over 4,000 homes and killing 10 people.

A confluence of weather and climatic variables were the primary driver of this regional weather event. Beginning on Labor Day, strong east winds sent a half dozen fires tearing across Oregon's westside Cascade foothills and towards the Willamette Valley, where approximately 70% of Oregonians live. In the days that followed, over 500,000 people were placed on some level of evacuation notice, which represents over 10% of the state's population. During and after the east wind event, communities throughout the region experienced extremely hazardous smoke conditions, measured at 300-500 on the air quality index throughout the Willamette Valley. By mid-week, the east winds subsided and the fires' rate of spread decreased dramatically.

While this event was unprecedented in recent history, scientists believe events of this scale are well within the historical norms. For over 10,000 years, large fires have played an integral role in westside forest ecosystems; however, westside events of this spatial scale are very rare. One scientist theorized that the last similar event occurred roughly 300-400 years ago (Krawchuk interview, 2020). Similar weather events caused major PNW fires in the past, including the Yacolt Burn (1902) and the Tillamook Burns (mid-1930s – early 1950s). Indeed, the USFS produced a report in 1957 about the relationship between east wind events and large westside fires (USFS 1957).

The Labor Day Fires of September 2020 corresponded with the strongest summertime east wind event of the past century. Originating in the Canadian interior, fast-moving, dry winds with very low relative humidity blew across Oregon's dry eastside, over the Cascade crest, and into western Oregon's wet conifer-dominated forestlands. According to Oregon's State Climatologist, Larry O'Neil, a weather station near Salem recorded the strongest combination of low relative humidity and high wind speed ever recorded at that location during the event (O'Neil interview, 2020).

The wind event was so powerful because it combined with pre-existing drought conditions, which had been developing throughout the year. Indeed, drought conditions have been developing across the American West in recent decades, primarily due to anthropogenic climate change ([Abatzoglou et al. 2016](#)). The US Drought Monitor, administered by various federal agencies, categorized most of the state as experiencing moderate, severe, or extreme drought by September 1, 2020 (see Figure 1). Most of the forestlands that experienced extreme wildfire activity during the east wind event were designated as severe drought or extreme drought, likely contributing to abnormally dry fuels, increased heat, and water stress on trees and shrubs.

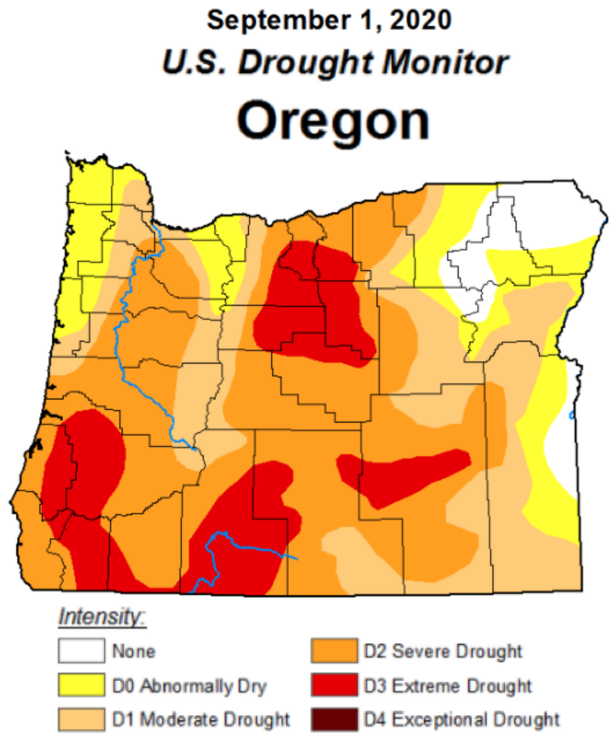


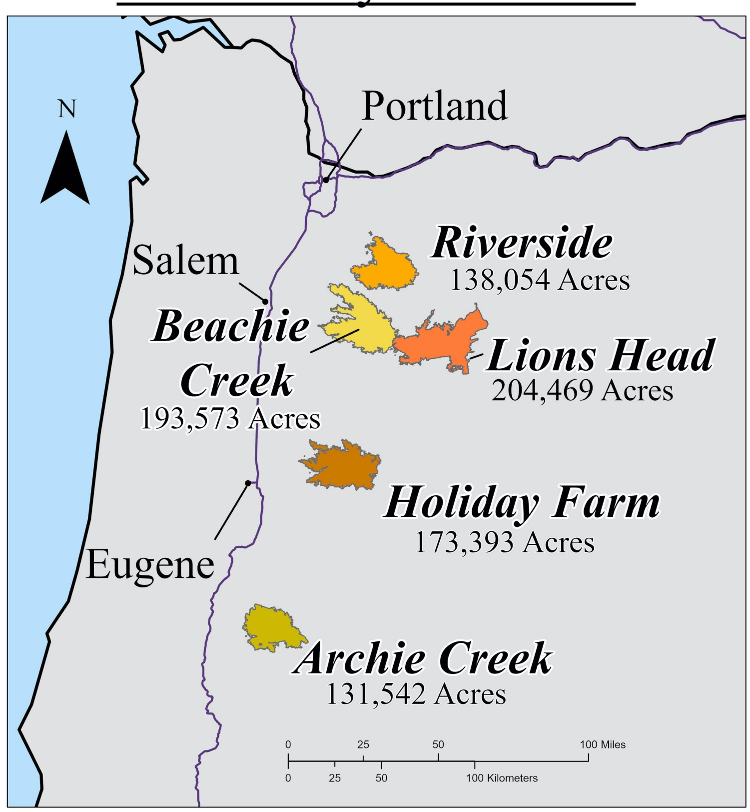
Figure 1. Map: National Drought Mitigation Center.

This perfect storm resulted in five fires burning over 100,000 acres:

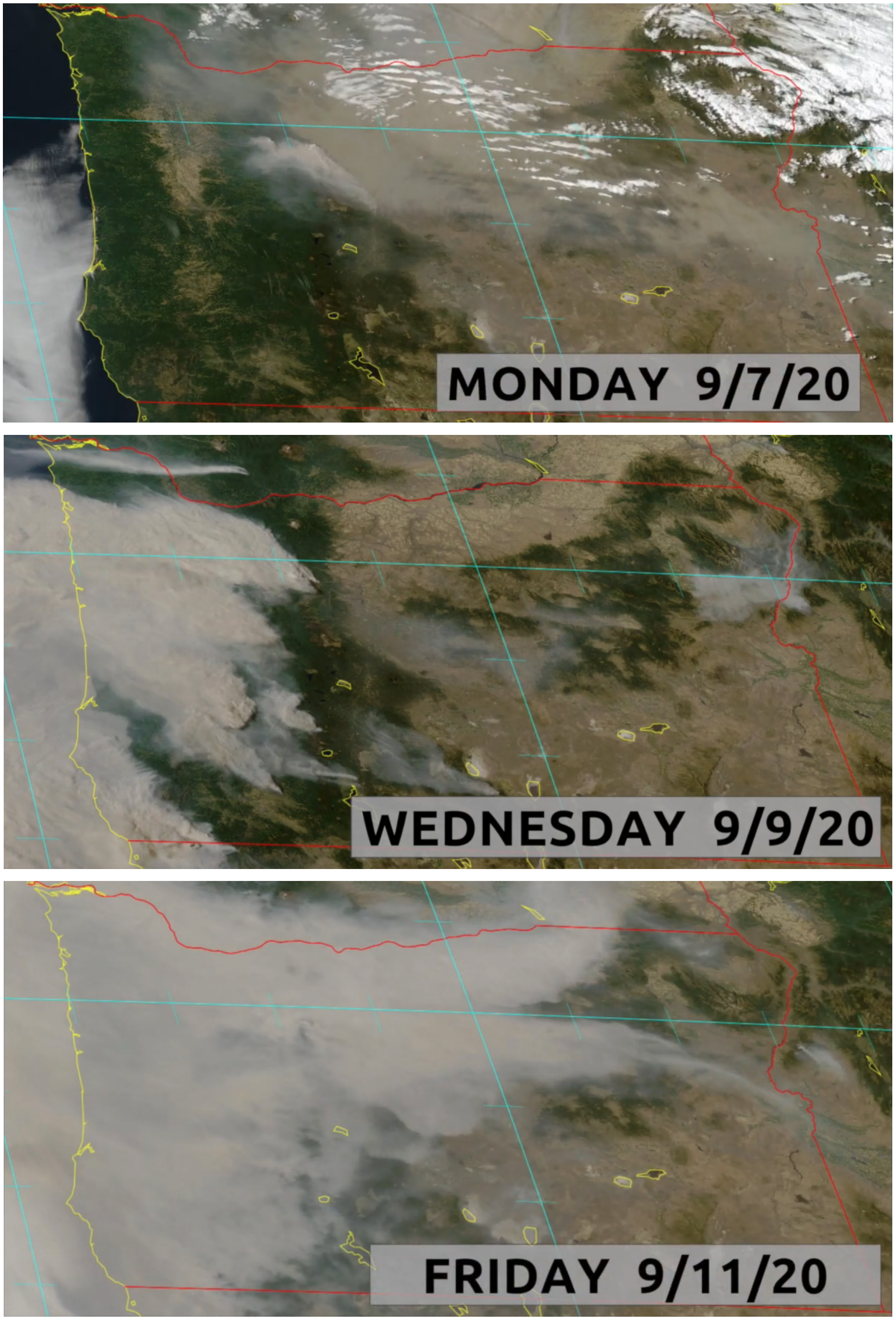
- **Holiday Farm Fire:** ~173,400 acres
- **Archie Creek Fire**: ~131,500 acres
- **Beachie Creek Fire:** ~193,500 acres
- **Lionshead Fire:** ~204,500 acres
- **Riverside Fire:** ~138,000 acres

Figure 2 (right). Map of the five major Labor Day Fires that burned in Oregon during September 2020 (J. Koffel). The vast majority of this acreage burned during the week of September 7 (Labor Day).

The 2020 Oregon Labor Day Wildfires



Figures 3, 4, and 5. To truly understand the scale of this wind event, watch [this short timelapse](). The video allows the viewer to observe the rapid growth of these westside fires, and the subsequent smoke that blanketed the region for over a week. Video by A. Harris, using NASA images.



Holiday Farm Fire

The Holiday Farm Fire (HFF, or "Holiday") began around 8:20PM on Monday, September 7, 2020 (Labor Day). The cause of ignition remains uncertain; however, some speculate this fire was ignited by a downed power line, as was the case with numerous Oregon Labor Day Fires (Register Guard, October 12, 2020). Fueled by strong winds from the east, the fire exploded westward through the McKenzie River Drainage, destroying over 400 homes and killing one person.

Holiday advanced across a mixed-ownership landscape at breathtaking speed, consuming roughly 100,000 acres in its first 24 hours. The fire's extreme rate of spread and wide distribution of high severity drew us to a very specific research question: ***How do fuel conditions (and associated forest practices) contribute to wildfire behavior during extreme weather events?***

The fire primarily burned through private industrial timberlands managed by large logging corporations and timber investment firms, and federal public lands managed by the US Forest Service (USFS) and the Bureau of Land Management (BLM).

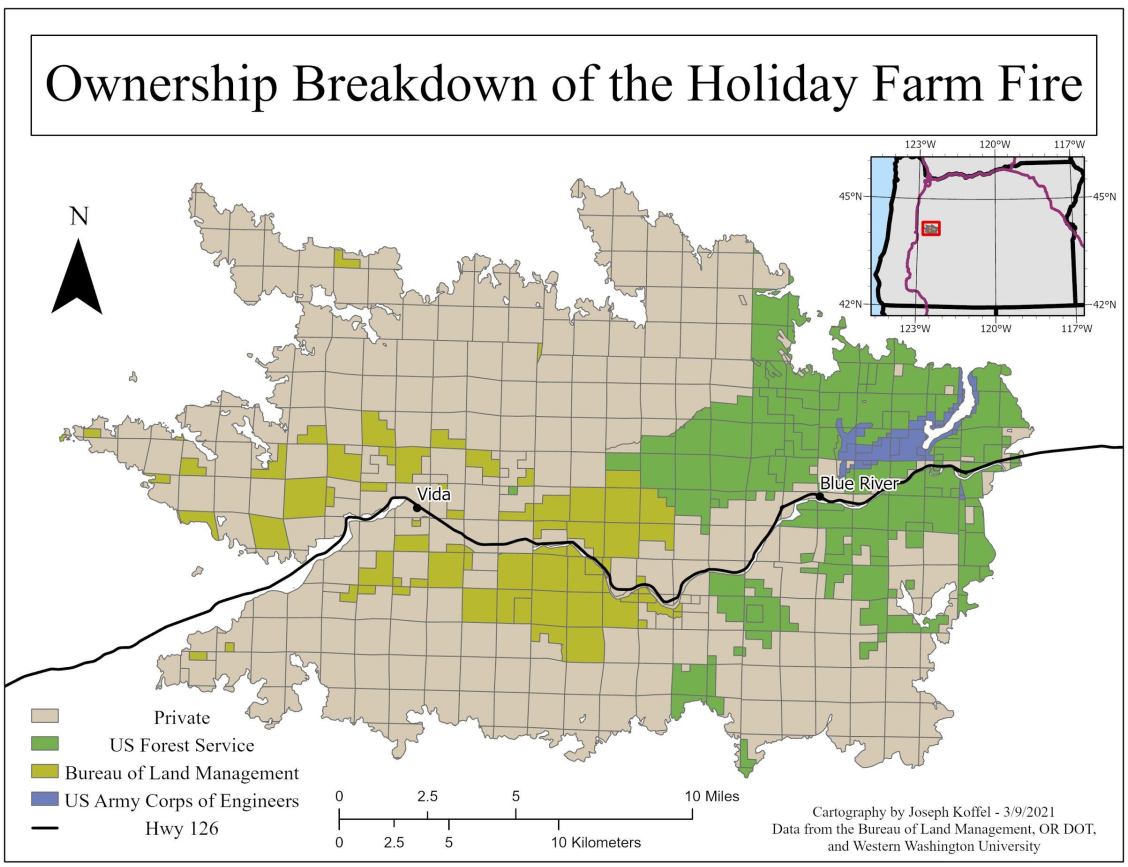


Figure 6. Map showing private and federal ownerships within the HFF burn perimeter (J. Koffel).

The forest management practices on these public and private ownerships differ starkly. Private industrial forests are managed intensively for timber production, whereas federal lands are managed with a wide variety of goals, not limited to watershed health, endangered species habitat, recreation, and timber production. Federal lands in western Oregon generally contain more mature forests with greater diversity in tree ages, forest structure, and species composition than private forestlands (Donato et al. 2011; Franklin et al. 2002). The spatial distribution of ownerships in the McKenzie Drainage makes our study area uniquely suited to this inquiry.

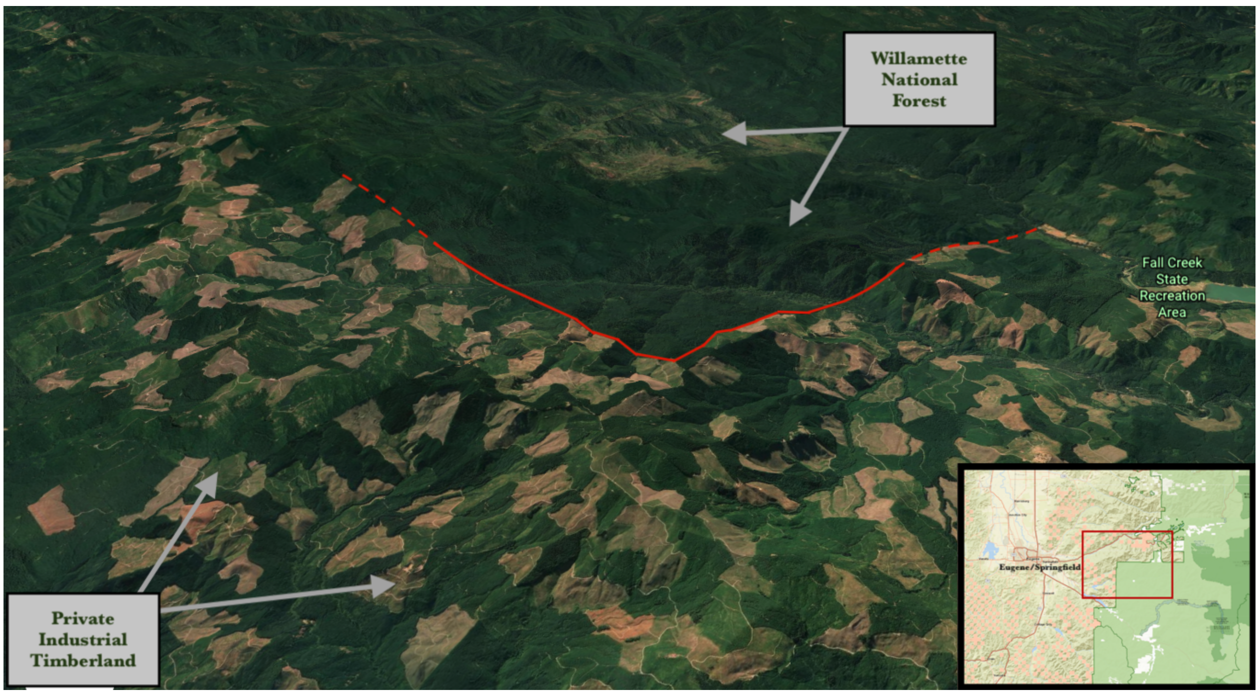


Figure 7. Approx. boundary of the Willamette National Forest (in red), McKenzie River Drainage (A. Harris). The differences in forest management practices on private industrial timberlands and federal forestlands can be clearly observed from space.

Holiday Farm Fire: Weather

Not surprisingly, our analysis found that weather conditions were the primary driver of Holiday's wildfire behavior. As shown in Figures 8 and 9 (next page), the time period when winds were highest and relative humidity was lowest directly corresponded to the fastest rates of spread. The most extreme rate of spread was roughly 19,449 ac/hr during the late afternoon of September 8, which was also one of the hottest times during the wind event.

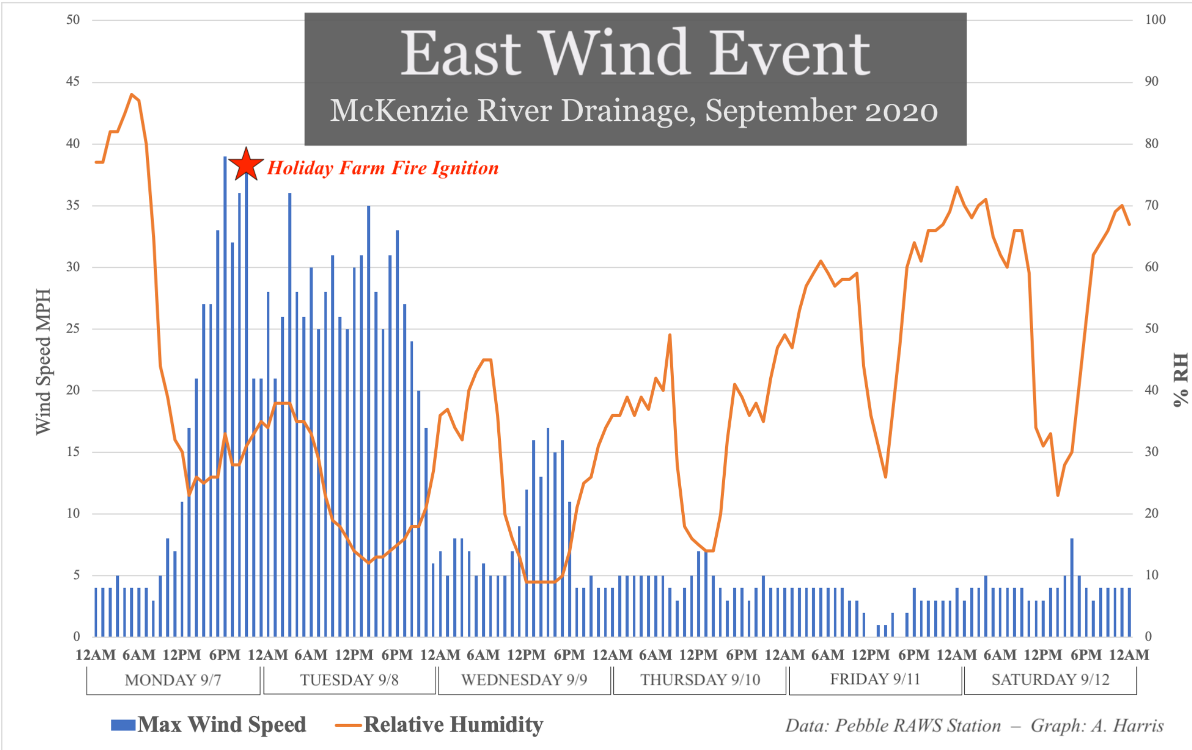


Figure 8. Weather data from the Pebble RAWS Station, McKenzie River Drainage (A. Harris). Notice as max wind speeds peak, RH levels plummet. Diurnal fluctuations in RH every 24 hours are normal.

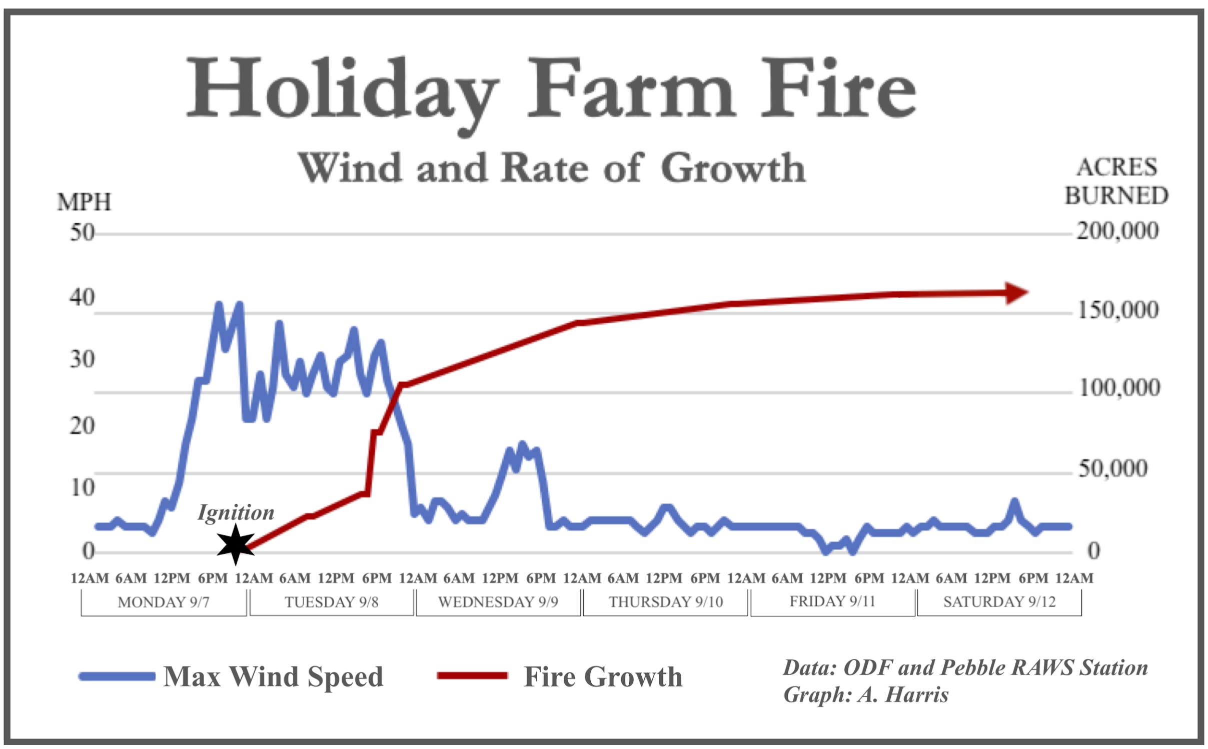


Figure 9. Max wind speeds and growth of the HFF over time (A. Harris). The fire grew to over 100,000 acres in its first 24 hours. Growth plateaued when wind speeds normalized.

Holiday Farm Fire: Progression

To map the progression of the fire, we utilized vector data generated by the Oregon Department of Forestry (ODF). ODF used infrared data from MODIS, a NASA satellite, to map the progression of the HFF over space and time. As can be seen in Figure 10, the vast majority of the acres burned in the HFF burned in the first 24 hours, which corresponded with the timing of the most extreme weather conditions. Due to a lack of data, we were unable to determine if Holiday's rate of spread was influenced in any meaningful way by vegetation condition and ownership status.

Our analysis found that at its peak, the Holiday Farm Fire burned over 19,400 acres per hour—an average of 324 acres per minute. In other words, during the afternoon of its first day, the Holiday Farm Fire was consuming more than 290 football fields (without end zones) every 60 seconds!

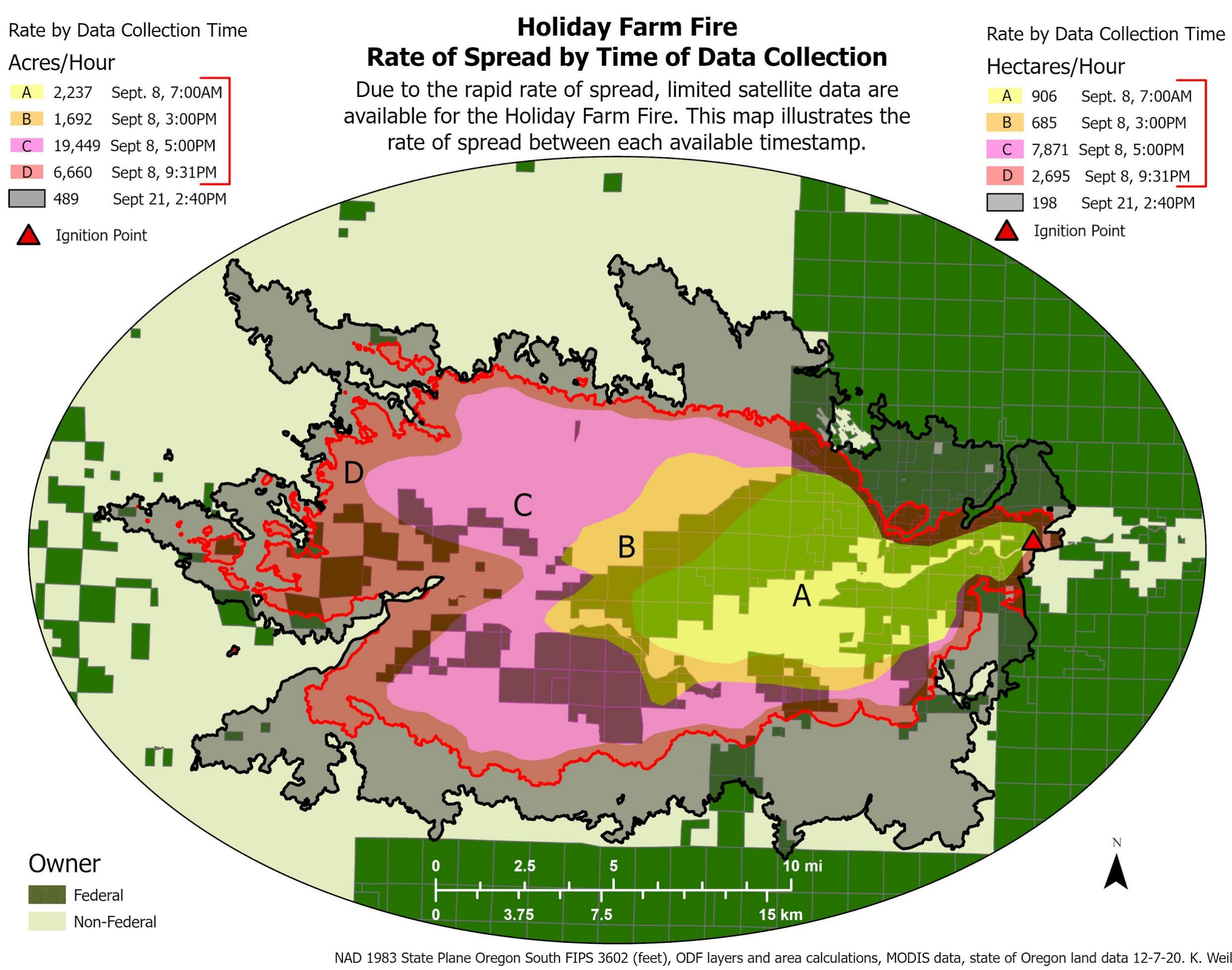


Figure 10. Map showing progression of the HFF (K. Weil). Polygons A, B, C, and D all burned in the first 25 hours of the HFF. Polygone C (pink) represents fire growth between 3-5pm, September 8.

Holiday Farm Fire: Burn Severity

Holiday included large swaths of stand-replacing fire (high severity), but still had significant amounts of mixed-severity mosaics throughout its outer perimeter. By overlaying severity data with ODF's progression polygons, we were able to determine which areas burned during the wind event and which burned afterwards. We then overlaid federal and private ownership layers to understand how burn severity was distributed across these different ownerships.

We found that during the wind event, high severity fire was widely distributed on both ownerships, with private lands burning more severely than federal lands (see Figures 14 and 15). When the wind event ended, however, high severity rates dropped dramatically across both ownerships and mixed-severity mosaics (patches of high, moderate, and low severity) became more widespread. Post-wind event, private lands burned significantly more severely than federal lands, with the disparity between the two ownerships becoming more pronounced post-wind event. **This suggests that burn severity was predominantly driven by weather conditions during the wind event and predominantly driven by vegetative conditions after the event.**

The scientific literature supports our empirical results, as is described in greater detail in the Literature Review section below. The literature suggests that timber plantations on private lands burn at higher severities than forests on public lands due to their dense and homogenous forest structure, and due to the fact that older, diverse forests are better equipped to withstand fire.

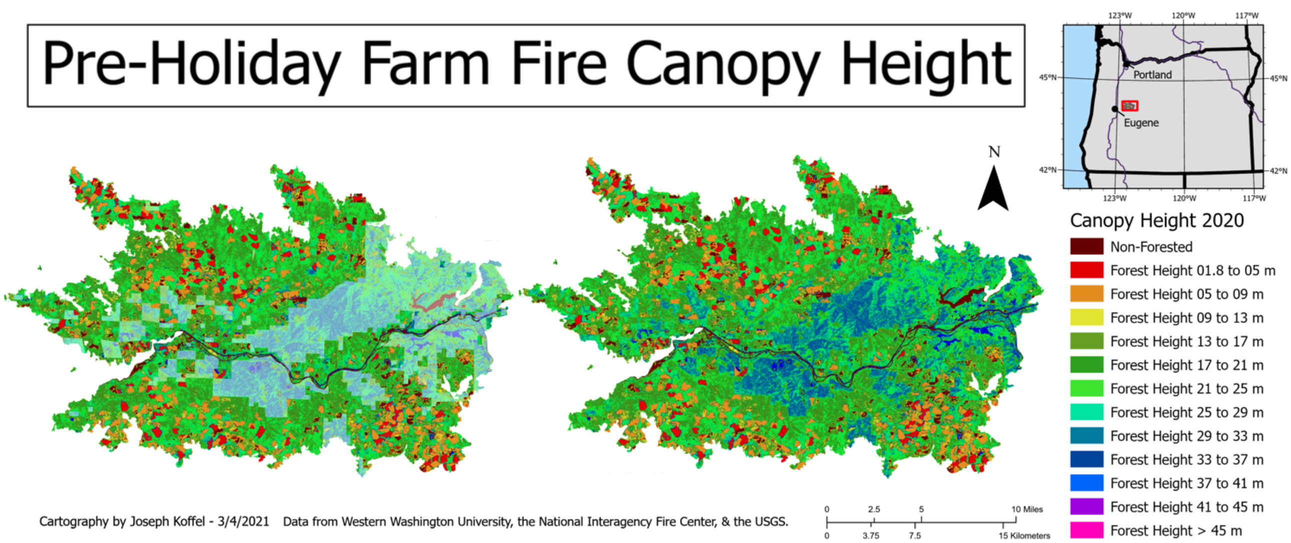


Figure 11. Canopy heights of the HFF, pre-fire (J. Koffel). Note: The tallest (and oldest) trees are overwhelmingly concentrated on public lands (shaded in grey in left map).

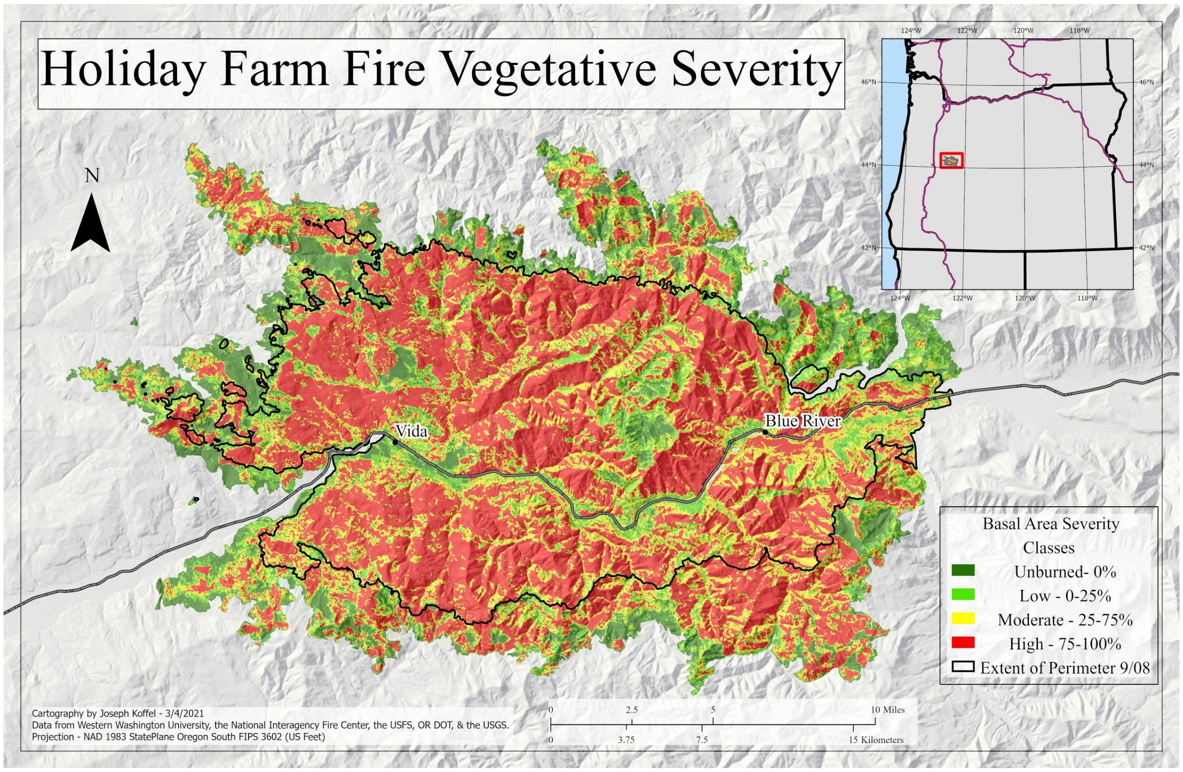


Figure 12. Vegetative Burn Severity, Holiday Farm Fire (J. Koffel). Note: the black line delineates the extent of the fire as of the evening of Tuesday, September 8 (first full day of HFF).

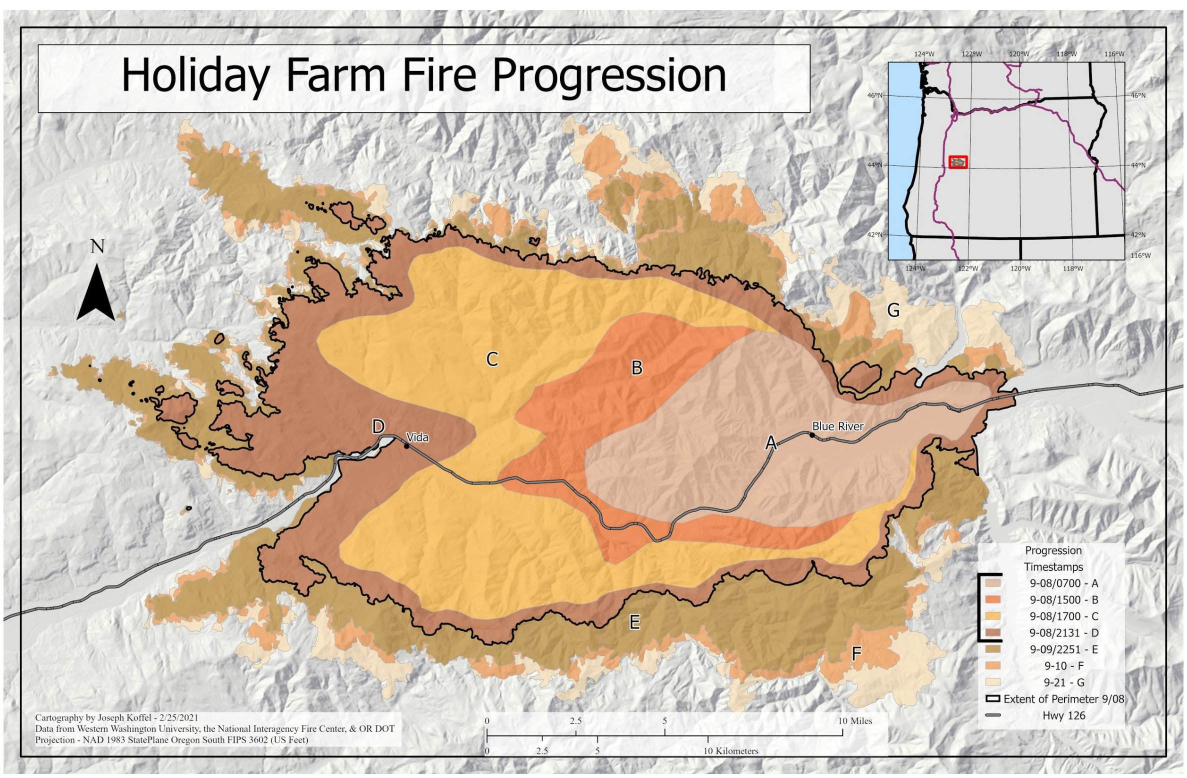


Figure 13. HFF Progression Map (J. Koffel). Polygons A-D burned during the wind event. Check this map against the severity map above to observe the influence the wind event had on severity.

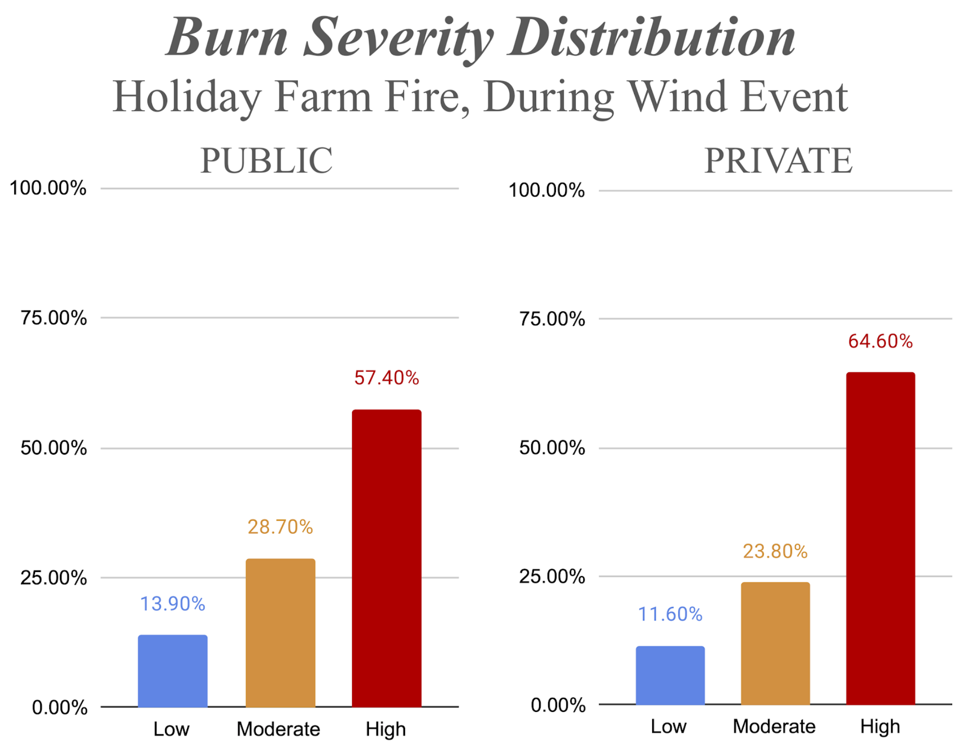


Figure 14. Distribution of burn severity DURING wind event, HFF (A. Harris, J. Koffel).

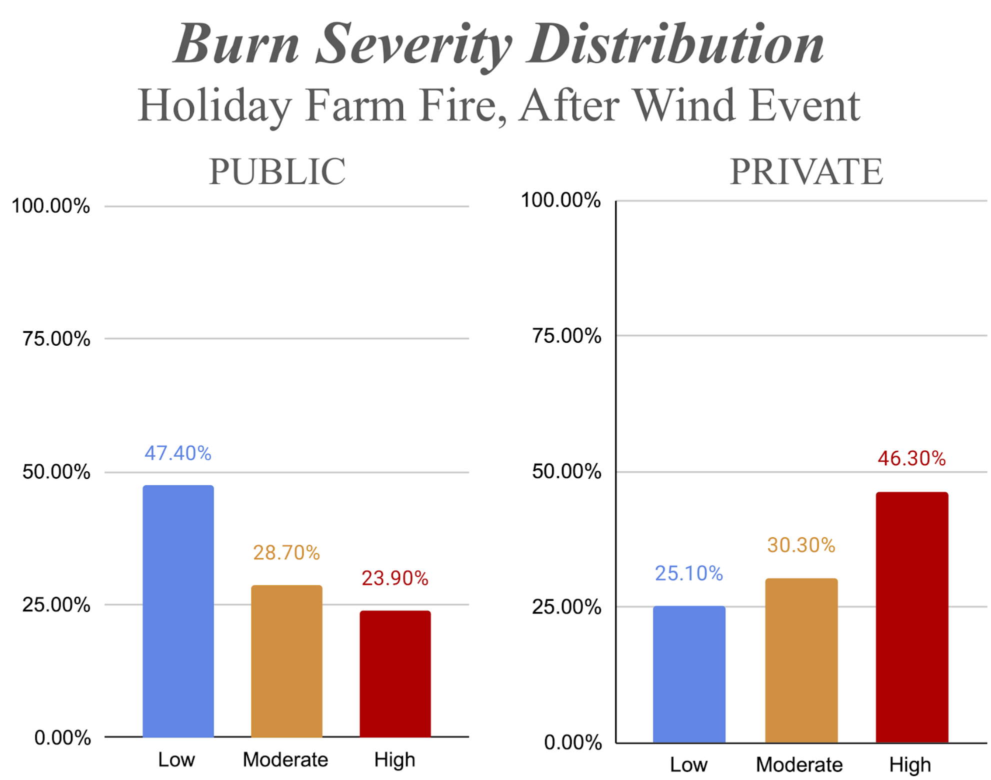


Figure 15. Distribution of burn severity AFTER wind event, HFF (A. Harris, J. Koffel).

Archie Creek Fire

The Archie Creek Fire (ACF, or "Archie") was a major westside fire that burned through the North Umpqua River Drainage during the Labor Day Wildfire Event of September 2020. The fire started around 7:30AM on Tuesday, September 8; however, the cause of ignition is still undetermined. In the following 12 hours the fire burned through ~68,000 acres (over 5,500 acres per hour), and by morning of Wednesday, September 9, the fire had consumed almost 100,000 acres. As wind speeds normalized around Thursday, September 10, the fire slowed dramatically and was effectively stopped in its tracks by a rain event on September 18. By the time the ACF ended, roughly 131,542 acres had burned, two thousand people had been forced to evacuate, and 109 homes had been destroyed (Burned Area Emergency Response Team, BLM, October 2020).

Archie burned through a mixed-ownership landscape consisting of private industrial forest land as well as federal public land managed by the USFS and BLM (see Figure 16). The vast majority of the area burned was private industrial land (~64,000 acres), followed by BLM land (~40,000 acres), then USFS (~25,000 acres).

Photo of the North Umpqua River, post fire (USFS). Currently, the BLM is advancing a proposal to clearcut over 6,200 acres that burned in the ACF.

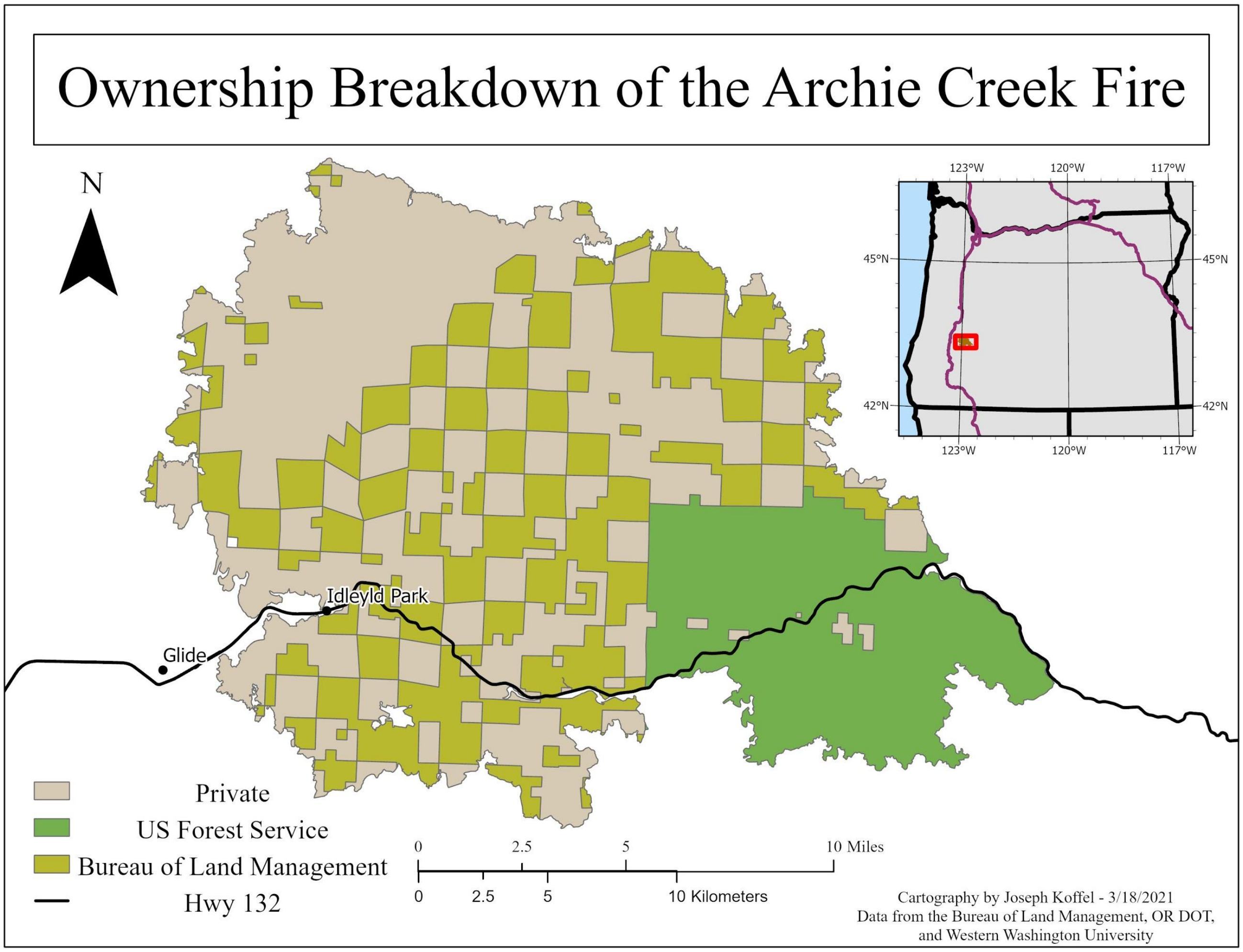


Figure 16. Map showing private and federal ownerships that burned in the ACF (J. Koffel). Notice the checkerboard pattern of the BLM's "O&C Lands," which are interwoven with private industrial land every other square mile. This unique spatial arrangement of intermixed ownerships make this study area valuable to our inquiry, which is focused on how fire behaves in different vegetative conditions.

Archie Creek Fire: Weather

Our analysis studied the wildfire behavior demonstrated by the Archie Creek Fire, and we found that Archie followed the same trend as Holiday, with the vast majority of its total acreage burning in the first 24 hours (during the wind event). As shown in Figures 17 and 18, the time period when winds were highest and relative humidity was lowest directly corresponded with the fastest rates of spread.

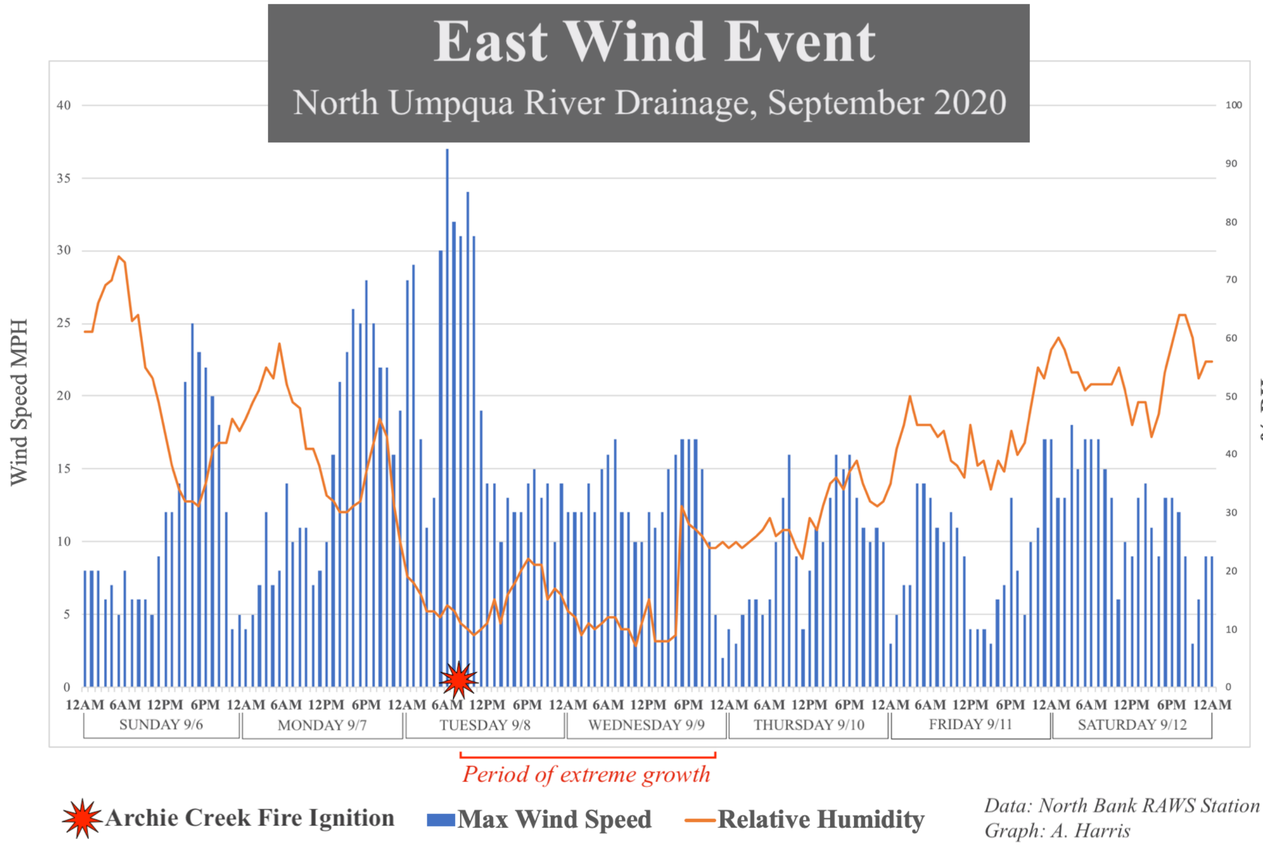


Figure 17. Temperature and RH in the North Umpqua River Drainage (A. Harris). Notice as max wind speeds peak, RH levels plummet; RH begins to normalize as winds subside.

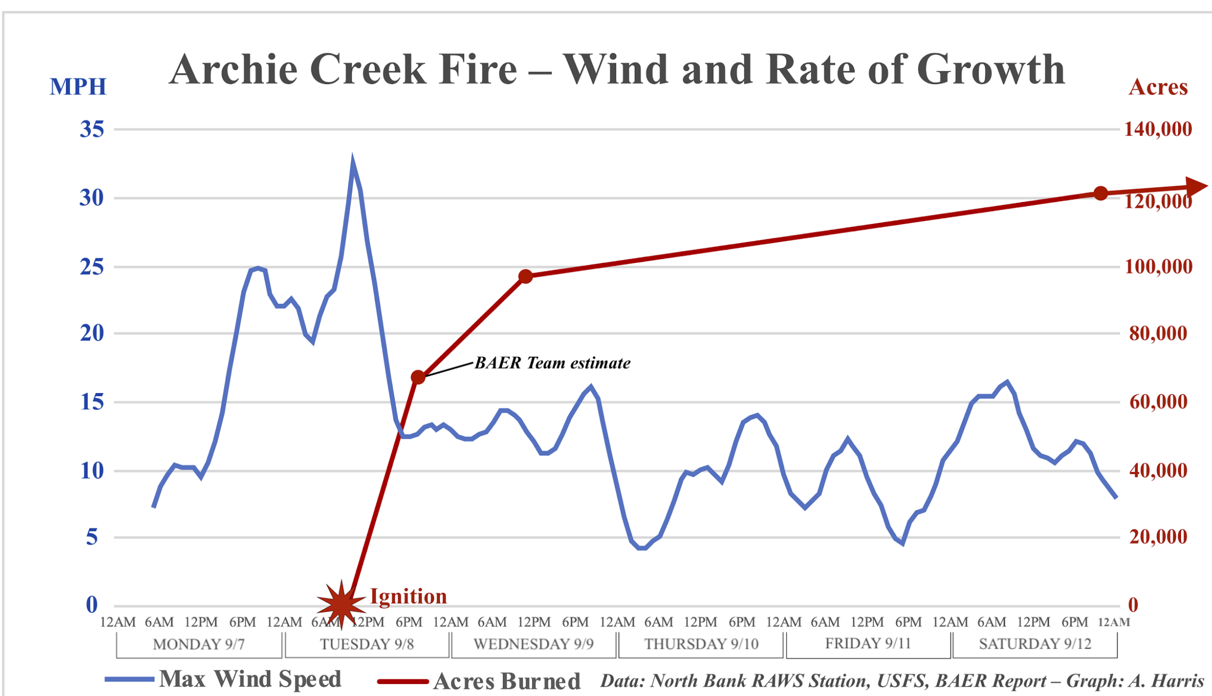


Figure 18. Max wind speeds and growth of the ACF over time (A. Harris). The fire grew to over 100,000 acres in its first 24 hours, and growth plateaued when wind speeds normalized.

Archie Creek Fire: Progression

We followed the same methodology we used for Holiday to track the spatio-temporal progression of Archie. As can be seen in Figure 19, the vast majority of the acres burned in the HFF burned in the first ~27 hours, which corresponds directly with the timing of the most extreme weather conditions. According to an estimate by the ACF BAER Team, the fire grew to ~68,000 in its first 11.5 hours, making for a stunning rate of growth: ~5,913 per hour (almost 100 acres per minute).

While this rate of growth was truly extreme, it pales in comparison to Holiday Farm Fire's peak rate of growth of ~324 acres per minute. We surmise that this discrepancy can be primarily explained by the fact that the HFF peak rate of spread occurred on Tuesday afternoon when winds and temperatures were highest in the McKenzie River Drainage; however, winds in the North Umpqua Drainage began to subside in the early afternoon on that same day, and therefore, Archie never experienced a growth rate quite as extreme as Holiday.

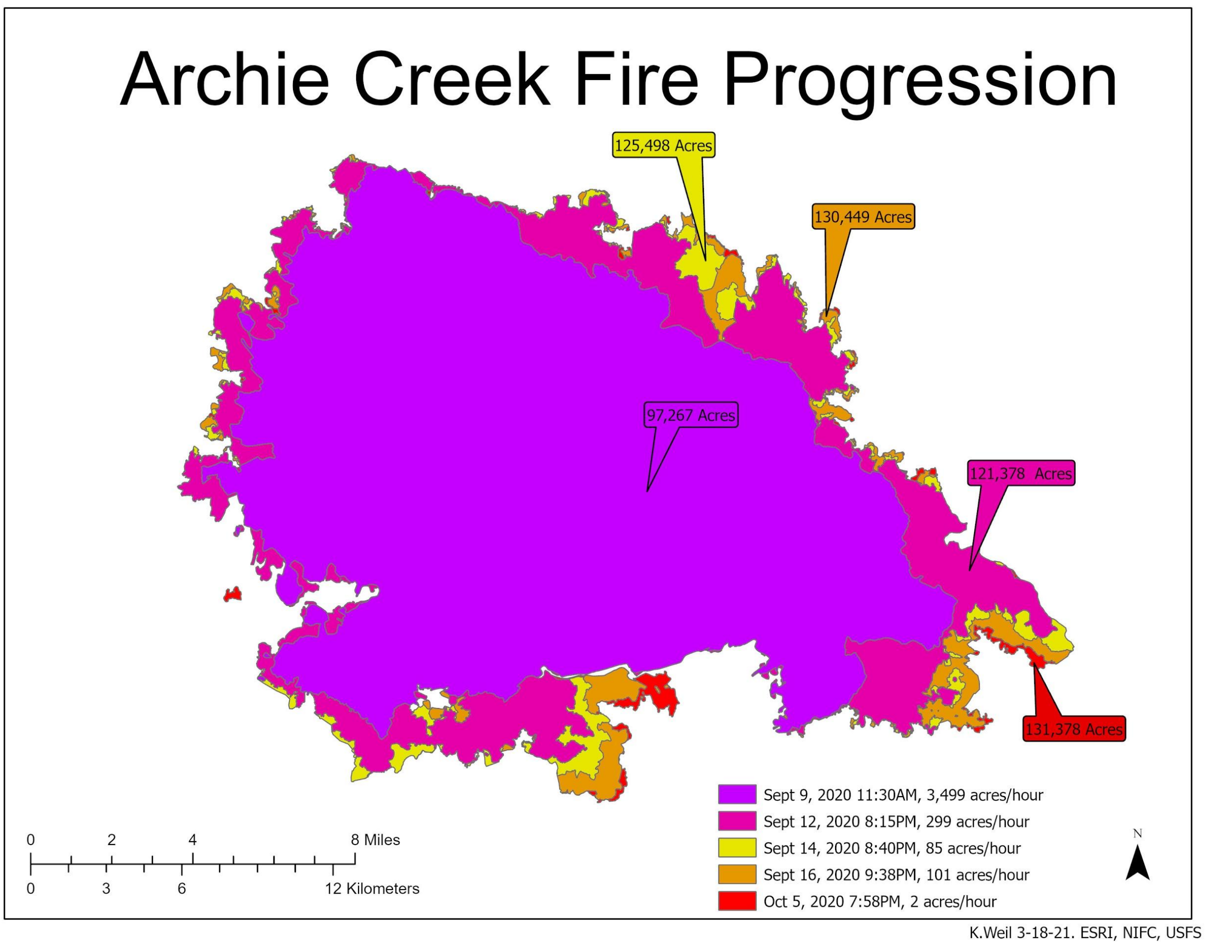


Figure 19. Progression of the ACF (K. Weil). Note: The first polygon (purple) delineates the extent of the ACF roughly 28 hours after ignition.

Archie Creek Fire: Burn Severity

By mapping data available from USFS showing the distribution of vegetative severity (tree and shrub mortality), we were able to overlay numerous layers to analyze the severity and its correlation with weather conditions and ownerships. Like with Holiday, Arhcie's acreage that burned during the wind event was predominantly high severity across both ownerships; however, private lands still burned at higher severities during the wind event (see Figures 21 and 22).

After the wind event, there was a sharp decline in high severity fire and we observed an increase in mixed-severity mosaics. Post-wind event, private lands burned at significantly higher severities than federal lands, with the disparity between the two ownerships becoming accentuated after the wind event. **These results suggest that during the wind event, severity was predominantly driven by top-down, weather conditions; whereas, after the wind event, bottom-up, vegetative conditions likely played the greatest role in determining severity distribution.** This is corroborated by the scientific literature, which is explored in greater detail below.

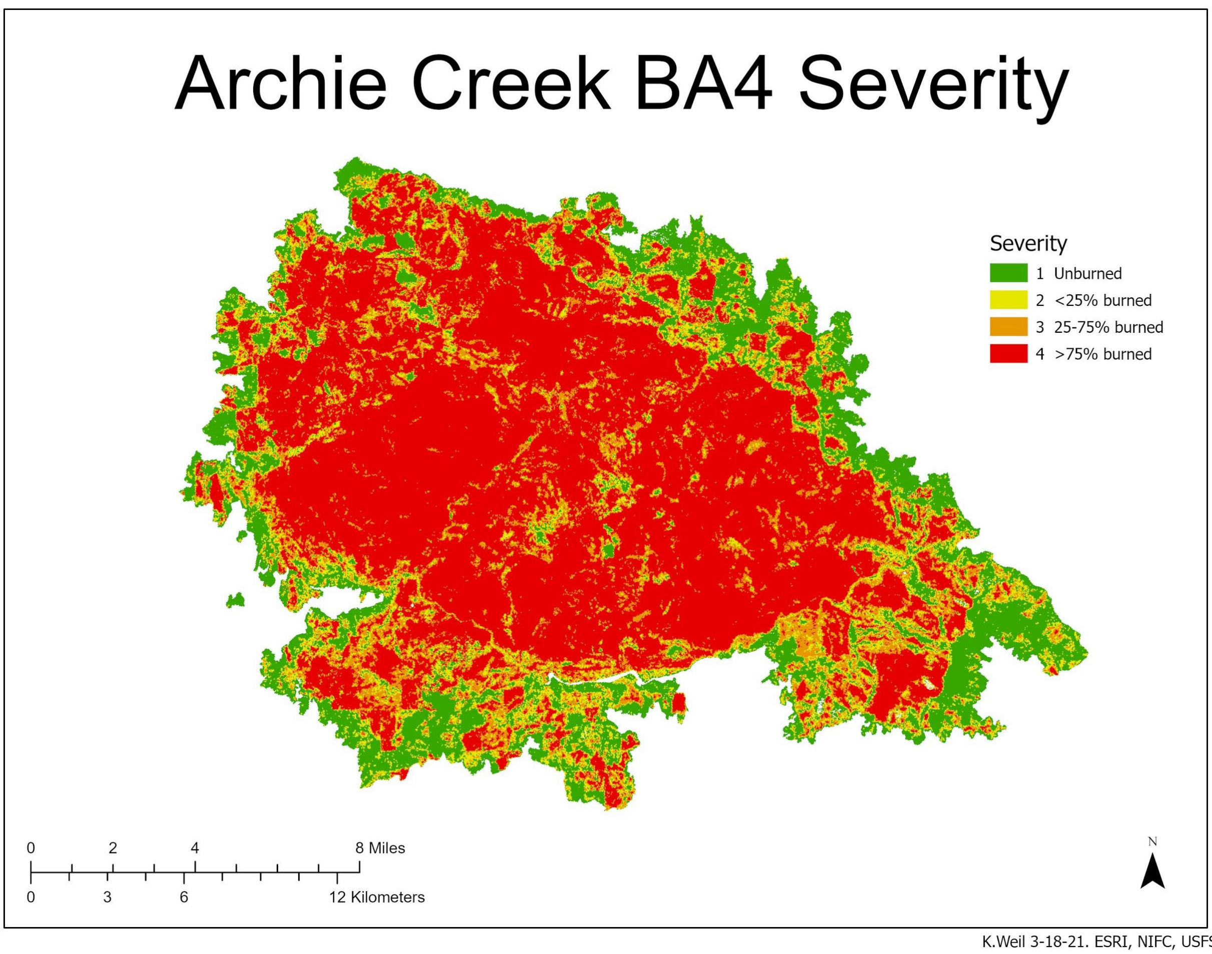


Figure 20. Distribution of high, moderate, and low severity in the ACF (K. Weil).

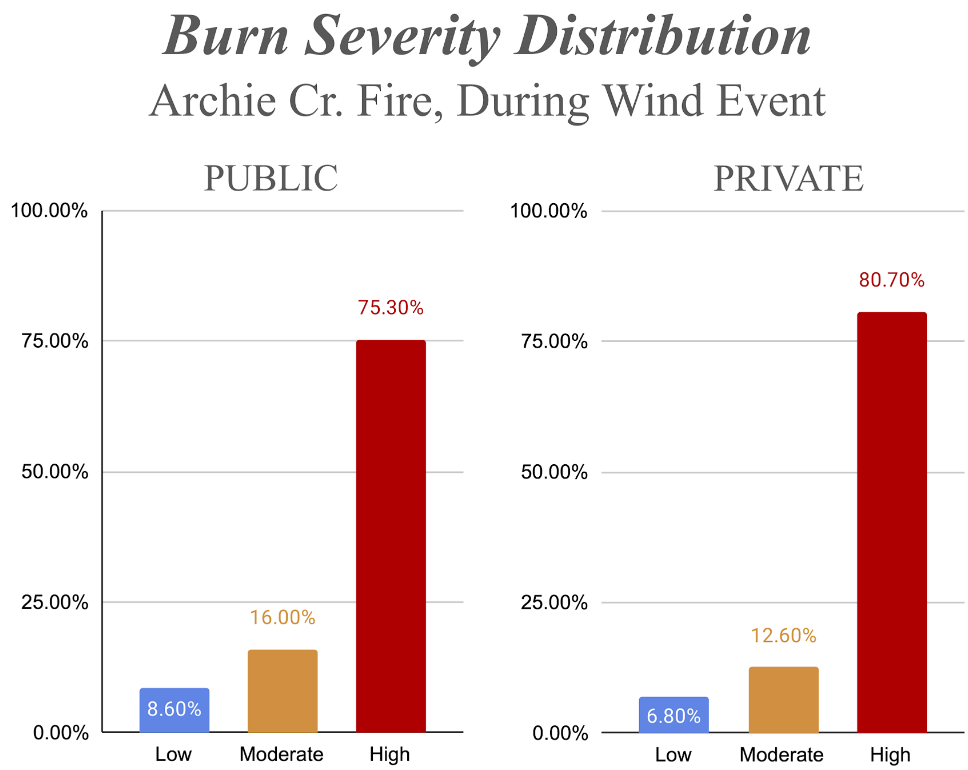


Figure 21. Distribution of burn severity DURING wind event, ACF (A. Harris, K. Weil).

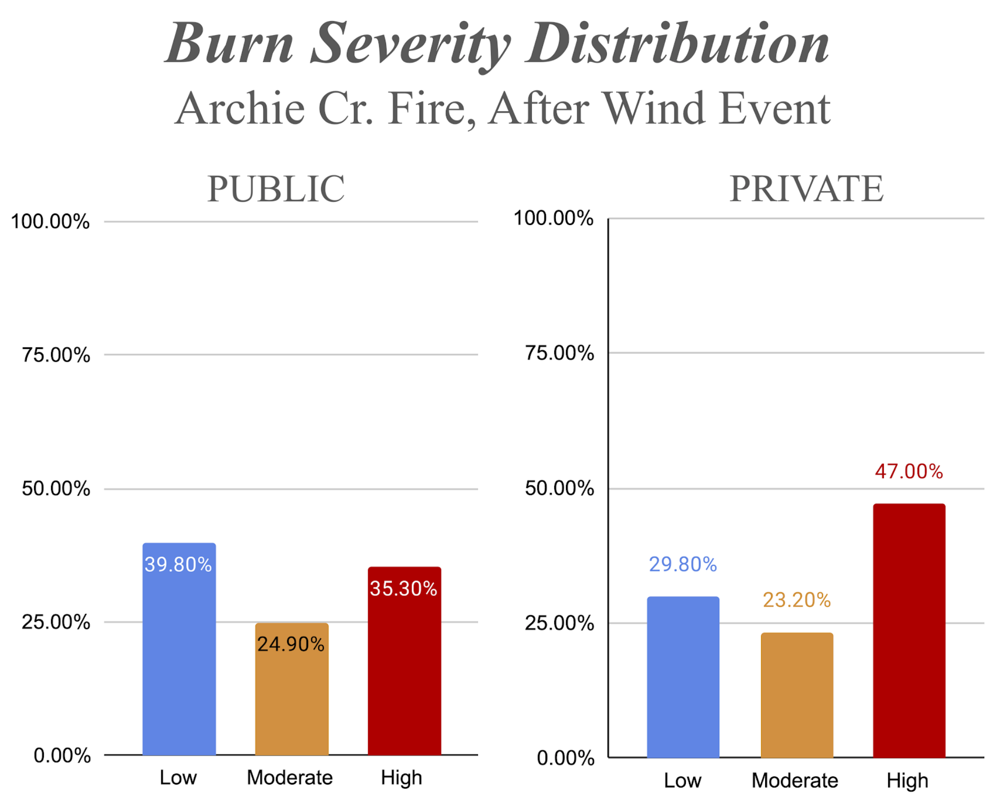


Figure 22. Distribution of burn severity AFTER wind event, ACF (A. Harris, K. Weil).

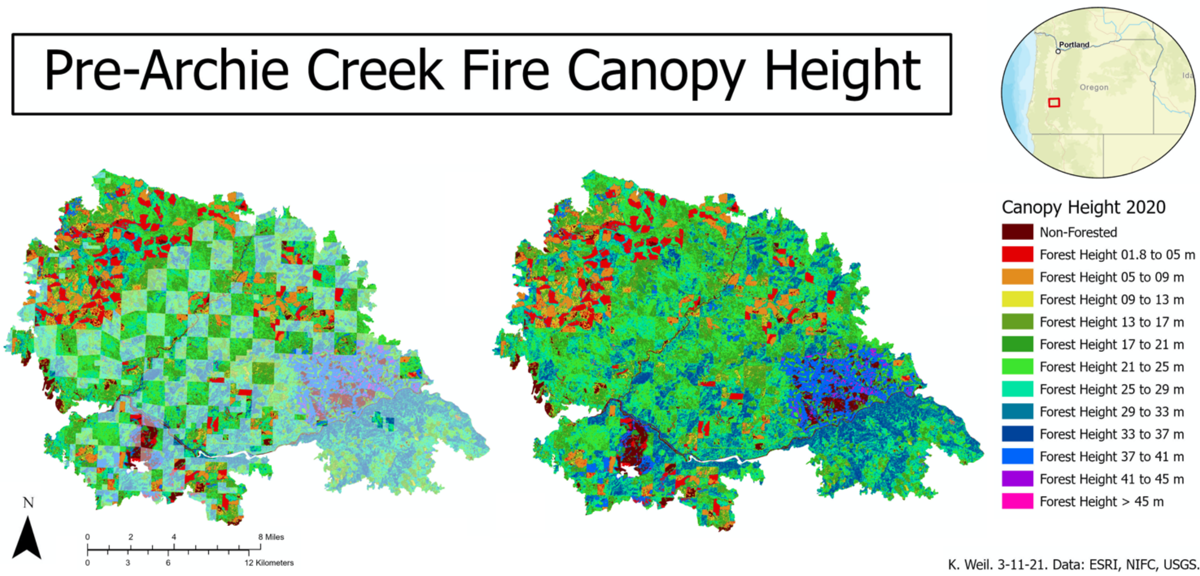


Figure 23. Canopy heights of the ACF, pre-fire (K. Weil). Note: The tallest (and oldest) trees are overwhelmingly concentrated on public lands (shaded in grey in left map).

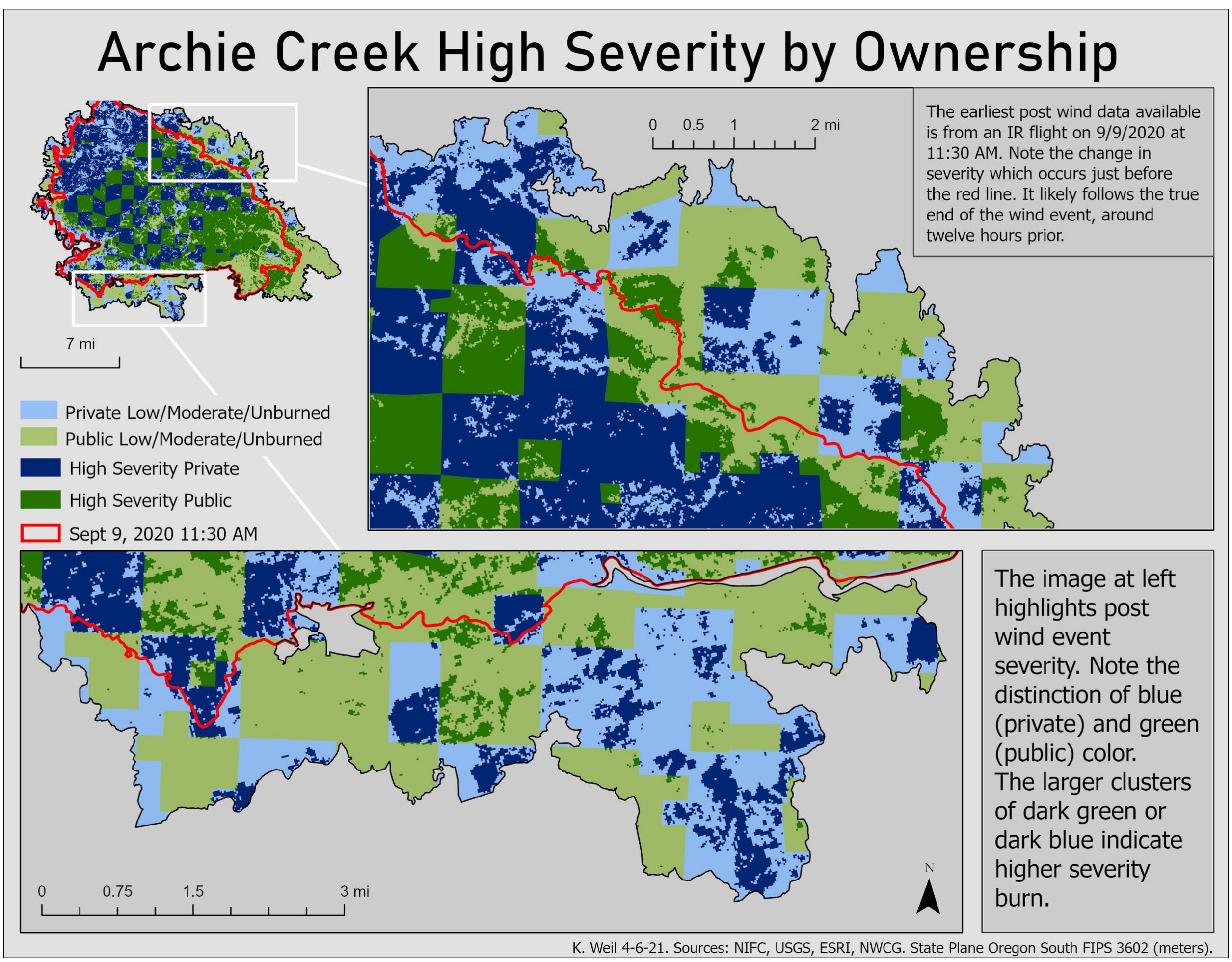


Figure 24. Distribution of severity across private and federal ownerships (K. Weil).

Literature Review

Our analysis into the wildfire behavior expressed by the HFF and ACF was influenced by the existing scientific literature on the subject; however, our inventory of the relevant literature is far from exhaustive. The literature considered below strongly correlates extreme fire weather with faster rates of spread and higher burn severities. This literature also projects extreme weather conditions that drive wildfire behavior will only increase with the continued onset of global climate change. Lastly, we review the numerous scientific studies that consider the relationship between wildfire severity and vegetation conditions that are typical of industrial tree plantations.

1. Extreme weather conditions are a primary driver of wildfire behavior in PNW ecosystems, and therefore, climate change will likely expand wildfire activity throughout the region.

Fire weather is increasingly understood as the most significant variable that drives large wildfires, which tend to be the fires that pose the greatest risks to communities. These large fires are primarily driven by weather conditions such as prolonged droughts, abnormally high temperatures, low humidity, and high-wind events (Flannigan et al. 2009).

The total acreage burned each year in the American West has dramatically increased since the mid-1980's; however, these acreages are still far lower than pre-suppression era levels at the beginning of the 20th century (National Interagency Fire Center, historic wildfire statistics). Westerling et al. 2006 studied wildfire trends over numerous decades to find an increase in the annual wildfire acres burned and the frequency of large fires. This increase in wildfire activity is correlated to a simultaneous increase in the length of the fire season and an increase in drought conditions throughout the American West (Westerling et al. 2006).

Many researchers have documented an increase in the annual wildfire area burned throughout western ecosystems, and many have concluded this is at least partially attributable to rising temperatures, increased drought, and longer fire seasons induced by global climate change (Schoennagel et al. 2017; Westerling 2016). Global climate change is contributing to diminished summer precipitation and snowpack, which exacerbates drought conditions throughout the Pacific Northwest. Researchers predict these trends will continue; therefore, **we can expect wildfire activity to significantly expand in Oregon's forests ecosystems in the years to come** (Abatzoglou et al. 2016; Dennison et al. 2014; Barbero et al. 2015; Schoennagel et al. 2017).

It is important to note, however, that climate change is not solely responsible for these fire events. Wildfire has played a fundamental role in most western forest ecosystems for millennia, and will continue to do so despite human influence. In addition, past forest management policies that relied on aggressive wildfire suppression have contributed to wildfire impacts, therefore, it is impossible to fully disentangle the legacy of fire suppression with climate impacts (Hessburg et al. 2016).

2. Tree plantations on private lands are more prone to uncharacteristically severe wildfire than structurally diverse forests on public lands.

The literature reveals a persistent finding that the vegetative conditions typical of industrial timberlands are especially conducive to uncharacteristically severe wildfires. Homogenous tree plantations are a fundamental component of intensive timber production as practiced by large timber corporations and timberland investment firms. “Clearcut-plantation forestry” is an even-aged approach to forestry that generally entails logging all trees within a unit except for those required to be left by Oregon’s Forest Practices Act (OFPA).

Plantations are harvested on increasingly short rotations of about 40-50 years, which is decades before trees meet their maximum wood production capacity (board feet per acre per year). This approach to forestry is ubiquitous across Oregon’s low-elevation, westside forestlands, and it is a rapidly expanding component of forest landscapes at all scales. Industrial timberlands tend to be located in low-elevation areas near cities, towns, and rural communities, and therefore, learning more about how wildfire moves through industrial ownerships (spatially and temporally) is absolutely pertinent to future policy programs seeking to mitigate wildfire risk to homes and communities.

The fundamental component of plantations, making them burn more severely than native forests, is their unique fuel composition and forest structure. Plantations are generally composed of trees of the same age and species packed tightly together in unnaturally dense stands. This results in a homogenous fuel arrangement that contributes to higher wildfire severity. Additionally, plantations tend to be composed of small-diameter trees with thin bark and low crown heights, both of which contribute to increased risk of high severity fire (Ryan & Reinhardt 1988; Dunn & Bailey 2016).

Public forestlands, on the other hand, are generally composed of older, more diverse forests when compared to tree plantations on private industrial lands (Franklin et al. 2002). Mature forests on public lands are characterized by their diversity and complexity, both in terms of species richness and structural-heterogeneity. These forests tend to contain horizontal structural diversity (e.g. tree spacing) and vertical structural diversity (e.g. canopy heights, presence of mid-story and understory vegetation, etc), which contributes to mixed-severity outcomes (Naficy et al. 2010).

Aggressive wildfire suppression on private lands has also contributed to unnaturally homogenous fuel conditions by disrupting natural fire regimes throughout the state. Historically, wildfire was the primary agent of disturbance across Oregon's forested landscapes; however, state and federal agencies have practiced an ill-advised suppression strategy for almost a century, robbing Oregon's forests of the kinds of fire they need to thrive. Many researchers believe fire itself (especially mixed-severity fire) helped increase the structural diversity of westside forests, thereby mitigating the risks of future uncharacteristic wildfires (Reilly et al. 2017; Dunn & Bailey 2016). Promoting the re-introduction of fire to the landscape would also produce a wide array of ecological benefits, especially for plant and animal species highly adapted to regular wildfire occurrence.

The scientific literature is still maturing when it comes to studying the specific influences industrial forest practices have on wildfire behavior; however, one recent study offers critical and pertinent insight into this influence. Zald & Dunn 2017 inquired into the distribution of wildfire severity in the 2013 Douglas Fire Complex across a mixed ownership landscape consisting of federal public land (BLM) and private industrial land.

After accounting for potential confounding factors (topography, weather, etc), Zald & Dunn found that private timberlands burned 30% more severely than the public forestlands did. The researchers even found that, despite the narrative that fuel buildup on federal lands is the predominant driver of uncharacteristically severe wildfire, industrial logging practices had a greater impact on fire severity than decades of fire exclusion. Notably, fire severity was consistently higher on private lands across a range of fire weather conditions for most of the fire's duration.

Another key question considered by Zald & Dunn was whether extreme fire weather played a larger role than fuel conditions in driving higher fire severity. The researchers recognized that fuel conditions and other bottom-up drivers of high severity fire are generally overwhelmed by extreme weather conditions (top-down drivers), as reflected elsewhere in the scientific literature (Bradstock et al. 2010; Thompson & Spies 2010; Dillon et al. 2011). However, the authors conclude that "while fire weather exerted top-down control on fire severity, local forest conditions that differed between ownerships remained important, even during extreme fire weather conditions."

While Zald & Dunn's analysis was conducted on forestlands roughly 100 miles south of the Holiday Farm Fire, the researchers believe their study has implications throughout the region where similar disparities between forest conditions exist. Zald & Dunn 2017 did not investigate disparities in the rate of spread across ownerships, yet, their conclusions provide crucial insights into how wildfire behavior is influenced by forest management.

These findings are corroborated by numerous other analyses from the past two decades. Below are key take-aways from a handful of these studies:

- **Bradley et al. 2016** considered data from 1,500 fires that have burned across the western US since 1984, and took measures to account for key topographic and climate variables. Counter to the belief that less-intensively managed forests burn at higher severities, the researchers found that forests with higher levels of protection burned at lower severities than other forests, despite a general trend of these protected forests having higher fuel loads.

- **Odion et al. 2004** studied historical fire activity in the Klamath-Siskiyou bioregion and found that of the burned forests they studied, plantations experienced twice as much severe wildfire as multi-aged forests. Their explanation for this disparity in burn severity was that the plantations they studied were biologically homogenous and structurally simple.

- **Thompson et al. 2007** analyzed the distribution of burn severity from the Biscuit Fire, which burned in southern Oregon in 2002. Their study took special attention to areas within the burn perimeter that had previously burned in recent fires. The researchers found that the plantations established after past salvage logging burned at higher severities than young stands that naturally regenerated; however, they noted that even the naturally regenerated stands burned at higher severity than neighboring stands. The researchers theorize that the dense and continuous fuel structure within the plantations contributed to higher burn severities in these stands.

- **Stephens & Moghaddas 2005** studied fire behavior in the Sierra Nevadas at the University of California Blodgett Forest Research Station. The researchers found that plantations consistently burned at higher severities, and that plantation fuel structures may lead to an increased rate of spread.

- In their 2004 article, *Forest Harvest Can Increase Subsequent Forest Fire Severity*, **Stone et al.** found that intensive forest management practices can increase subsequent fire severity. The researchers studied a fire in western Montana and found that privately owned lands that had been extensively and homogeneously logged burned at higher severities than adjacent watersheds on public lands that contained higher fuel loads but more heterogeneity in fuel distribution at the stand and landscape levels. The researchers conclude that forest management techniques that create more diverse and complex forest structure can help produce diverse burn mosaics.

3. Recent research suggests that plantations contribute to faster rates of wildfire spread when compared to more heterogeneous, complex forests.

A study published in the International Journal of Wildland Fire in January 2021, Atchley et al. 2021, found that more homogenous forest structure is conducive to fast rates of wildfire spread. The researchers used fire behavior modeling and other computational resources to analyze which spatial arrangements of forest fuels are most conducive to fast-moving fires.

Atchely and colleagues found that more uniform and homogeneous forests (such as plantations) contributed to enhanced wind entrainment, thereby causing wildfire to spread at faster rates. Another key variable relating to rate of spread was the spatial continuity of fuels (at the landscape-scale) and their density (at the stand-scale). The researchers also found that large gaps with little-to-no vegetation were especially conducive to rapid fire progression. It can be extrapolated from these results that clearcuts in western Oregon, which regularly measure over 100 acres in size, lead to accelerated wind currents—thereby contributing to quicker rates of spread.

Conversely, the paper found that forests with greater structural heterogeneity generally slow wildfire progression due to the increase in wind turbulence. Structural heterogeneity is created by a diversity in tree heights, ages, and species, and other characteristics such as the presence of downed wood and snags (standing dead trees)—both of which are effectively absent from private industrial timberlands altogether. While more research is needed to understand how exactly forest structure in western Oregon contributes to wind entrainment/turbulence during wind events, this research suggests that industrial plantations in Oregon's Cascade foothills likely contribute to faster rates of fire progression.

Methodology, Data Sources, and Confounding Factors

Our team began this research project in November 2020 with the hope of better understanding the fire behavior demonstrated by the Labor Day Fires of September 2020. We utilized datasets from a variety of public sources and employed a range of methods to reach conclusions about the relative importance of fuel and weather conditions in determining wildfire behavior. As is described in more detail below, we ran into numerous problems along the way and recalibrated our approach accordingly. Despite these challenges, our findings suggest that vegetative conditions (and associated forest management practices) are a major factor in determining wildfire severity in western Oregon during "normal" fire weather. Our analysis is not definitive, however, the data displayed clear and consistent trends that were corroborated by the scientific literature, and therefore, we believe our findings can indicate where future research is needed in the coming years.

Data Sources

One of our chief goals in this project was to track the progression of the HFF and ACF over space and time. Towards that end, our team collected infrared data from numerous satellites to conduct a spatio-temporal analysis of both fires. We also used data from the Forest Service's Geospatial Technology and Applications Center to analyze the distribution of severity across ownerships.

Other data sources included:

- USGS LANDFIRE Data Distribution Site – vegetative condition data;
- Data.gov – boundaries of federal public land (USFS, BLM, etc);
- National Interagency Fire Center (NIFC) – fire perimeters and severity data;
- Western Washington University – general GIS data;
- Oregon Department of Transportation – roads and infrastructure layers;
- Oregon Department of Forestry – progression data;
- Western Regional Climate Center – weather data.

Limitations were evident in our analysis due to the complex and dynamic environment in which wildfires take place. For example, the products available at LANDFIRE are generally reliable since they are updated annually for normal growth and disturbance conditions; however, each year, many thousands of acres of forestland in western Oregon are logged, and therefore, much of the LANDFIRE data was too out-of-date to be reliable. Our goal was to measure the influence of vegetative conditions on wildfire behavior, but we struggled to find an adequate proxy for fuel conditions. We attempted to use canopy height and surface fuel models as proxies for fuel conditions in private and federal forests; however, we confronted numerous problems in these data sources and ultimately were not able to conduct geospatial analysis combining fuel models with severity data.

Methodology

Our methodology for our geospatial analysis consisted of two different approaches. As we worked with the datasets and familiarized ourselves with the workflow, our approach was refined and improved for efficiency. Using two different approaches to duplicate our results also helped verify and triangulate our findings.

Our first approach was centered on comparing Basal Area severity at target timestamps between different levels of ownerships (i.e. federal and private). Using ESRI's ArcGIS Pro, we isolated our target timestamps from NIFC using definition queries, then clipped ownership and canopy heights to match our targets. We designated two major timestamps to coincide with extreme fire weather that was responsible for the explosive growth that occurred from September 7th-9th and for all other growth that occurred after the east wind event. From there we ran intersects on all listed data layers. We exported the resulting tables to excel where we grouped and graphed the resulting data.

Our second approach was used to analyze the distribution of severity for the Archie Creek Fire. This approach entailed maintaining "multipart" features and using Tabulate Intersection to calculate severity (input class) by ownership (input zone). Originally, we used a dataset known as "Basal Area 4" to ascertain the distribution of severity in each fire; however, later we used a related, but distinct, dataset known as "Composite Burn Index" (CBI) to analyze severity. CBI combines a variety of variables associated with severity, including vegetation mortality as well as soil severity. Our results for the CBI analysis confirmed the patterns of high severity detected in our BA4 analysis, which was not surprising since these datasets are closely related.

Confounding Factors and Opportunities for Future Research

Due to the limited timeline of our project, we were unable to properly investigate potential confounding factors, such as aspect, slope angle, and other topographical variables. Future researchers should take measures to account for such variables, since topography is known as the third part of the fire behavior triangle (weather and fuels are the other two). Disentangling these factors would allow for more detailed analysis, which would produce stronger results.

Another corroborating factor was resolution, both spatial and temporal. Several of our key datasets (e.g. severity datasets and the LANDFIRE fuel dataset) were 30x30 meter pixels which proved a limitation for our work. A finer scale would potentially only serve to improve the accuracy of our results. Temporal resolution was also a major limiting factor, since we only had a handful of timestamps during each 24 hour period when analyzing the progression of the HFF and ACF. Had the fires moved slower, we would have had significantly more data to work with, which would have improved our analysis.

Numerous opportunities exist for researchers hoping to dig deeper into this issue. We strongly recommend future research into the relative impact that fuel and weather conditions have on fire behavior (rate of spread and severity) during weather events. In particular, greater research is needed to understand how industrial forest practices contribute to wind entrainment/turbulence during wind events. The literature suggests that structurally-homogeneous forests may facilitate faster rates of spread; however, fire behavior modelling and empirical research is needed to ascertain if westside plantations have this effect. Determining whether clearcuts and plantations do indeed encourage faster rates of wildfire spread has important implications for forest policy and management, and can inform fire risk reduction efforts around homes and communities.

Conclusion

Our research found that fuel conditions exert a greater influence on wildfire behavior in the absence of extreme fire weather, but when strong winds conspire with underlying drought conditions, the importance of fuels diminishes significantly. Our results (and the literature reviewed here) suggest that tree plantations on private land burn more severely than federal forestlands, and recent research indicates that clearcut-plantation forestry may hasten the spatial progression of wildfires, although further research is needed on this point.

As climate change expands wildfire activity across the American West, it is essential that we refine our understanding of wildfire behavior during extreme weather events such as the Labor Day Wildfire Event of September 2020. Such inquiry is not only needed to enhance wildfire preparedness, but also to learn if improved forest management practices can mitigate future wildfire events.

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