



New research is measuring the role of climate change and its effects on fire regimes in the inland Northwest. Photo of Wenatchee National Forest-Pacific Northwest Research Station collaborative study area by D. Keenum.

Fire and Climate in the Inland Pacific Northwest: Integrating Science and Management

Summary

Climate is a vital force shaping much of life on Earth. People have long suspected a link between climate and susceptibility of forests to fire. But measuring such a relationship has been challenging without tools capable of taking into account climate, forest structure through space and time, and other variables. Managers and planners who make decisions to maintain forest health need an accurate understanding of how climate is linked to fire regimes, as well as tools to help them do it. Such tools would take complex information and allow it to be accessed in a straightforward and effective way.

Don McKenzie is a research ecologist with the USDA Forest Service at the Pacific Northwest Research Station. He and a team of scientists linked two types of data from sites across eastern Washington: fire scar records (the Eastern Washington Fire History dataset) and tree ring chronology data that show the effect of climate on tree growth. By uniting these two datasets, the scientists looked at how climate has affected fire history. They found an undeniable relationship between fire and climate, including a link to short and longer term periodicity of fire regime with the El Niño Southern Oscillation and the Pacific Decadal Oscillation. They also found that the 20th century era of fire exclusion “decoupled” the strong link between fire and climate. They expect global climate change to be a major player in the future with surprises in store.

Key Findings

- A broad-scale relationship exists between fire occurrence and drought in eastern Washington.
- A quasi-periodic relationship exists between fire occurrence and the El Niño Southern Oscillation and the Pacific Decadal Oscillation.
- The strong link between fire regime and climate was seriously weakened during the 20th century because of fire exclusion and land-use changes.
- With strong evidence for the link between climate and fire regime, researchers expect more fires and surprises in the future with global warming.
- The spatial and temporal complexity of fire occurrence and climate can be shared with a new, user-friendly Web-based approach to GIS-based data delivery and visualization.

Climate is a vital force shaping much of life on Earth. It has also played a role in forest fires. For as many years as people have tried to understand fire, they have suspected that climate has affected the potential for fire. Today, tools are emerging that are allowing scientists to understand more about weather and how climate actually affects fire regimes in an area, and furthermore, how to use this information in management and planning. With climate change now affecting forests and management decisions, it is even more imperative to have a clear grasp of the link between climate and fire.

Don McKenzie is a research ecologist with the USDA Forest Service at the Pacific Northwest Research Station. With funding from the Joint Fire Science Program (JFSP), he headed up a team of scientists whose goals were both to understand more about how climate affects fire regimes and to integrate this scientific understanding with management needs. McKenzie and his team have done just that, and now offer managers and planners accessible, relevant, and useful information on fire and climate in the Inland Pacific Northwest.

Says McKenzie, “From a scientific standpoint, it is the first study I know of to use spatially explicit fire-scar records that are also extensive (across watersheds). This opens



Ponderosa pines dominate the area used in this study. This photo shows part of one of the seven study sites. Photo by D. Spurbeck.

up new frontiers for data analysis and inference. From the management perspective, the study area exemplifies ecosystems and landscapes of concern to management and policymakers.”

The team of scientists used study sites east of the Cascade Mountains in Washington State. Ponderosa pines dominate these sites, making this study area useful for managers working elsewhere on this widespread forest type. Further, the scientists had a valuable dataset (the Eastern Washington Fire History dataset) on fire history from these sites that, up until then, was the only one of its kind in existence.

McKenzie explains, “The spatial information lets us analyze many more things than would be possible with other databases. There are many studies that compare fire scar records to climate records derived from tree rings or other ‘proxies,’ but without the spatial information at fine scales.”

Casting a Net of Rings and Scars

Perhaps the most remarkable thing about this research is the way researchers captured their understanding of fire and



The map shows the locations of the seven study sites in eastern Washington used in the fire history analysis. The seventh site, “Twenty Mile,” was added in 2005 and helps to fill in the geographic NE-SW gradient in the study area.

climate. They acquired and linked two information sources that are outstanding in their own right. The researchers compared fire scar data with tree ring chronologies to literally peer into the past and watch how forests responded to shifts in climate in terms of their susceptibility to fire. By dating fire scars in recorder trees and comparing those data with tree ring chronologies that show how climate affected growth, the scientists could see how climate affected historical fire regimes.

At the time of this study, the Eastern Washington Fire History dataset was the only one of its kind in existence. It was unique not only because every selected “recorder tree” (trees deemed as reliable sources of fire scar information) held the record for one or more fires, but also because every tree in the dataset was mapped with X and Y coordinates using topographic maps and global positioning systems (GPS). Scientists used both living and dead recorder trees. Fire scars dated back as far as 1257, with the latest fire scar appearing in 1994. The most reliable “pre-settlement” data occurred between 1700 and 1900. So scientists used this period to compare “pre and post” settlement periods since they suspected settlement affected the relationship between fire and climate.

During 1700–1900 fire intervals at individual trees (fine scale) were quite variable and relatively frequent, whereas after settlement (1900), fire intervals increased markedly (2–6 times) and the total number of trees recording fire dropped sharply. Knowing this, the scientists were even more curious to see how climate affected fire susceptibility both pre and post European settlement.

So they took existing tree ring chronologies known to portray both fine scale (year to year) and broad scale (decadal) climate variation, and in a sense, lined them up together to see how climate related to fire occurrence. Like putting two siblings back to back to see who is taller, the researchers used their statistical tools to quantify the relationship between fire scars and tree rings. Only these data sets are quite different from each other—unlike two sisters standing head to head—so their tools of choice were rather more sophisticated than a measuring tape!

Climate indexes used in this study were the Palmer Drought Severity Index (PDSI), the El Niño/Southern Oscillation (ENSO), and the Pacific Decadal Oscillation (PDO). The researchers were eager to understand variation in climate and fire occurrence at short and longer time scales, because as they write in their report to the JFSP, “From a management perspective, the connections between fire and interannual climatic variability allow managers to predict wildfire severity at a broad range of temporal scales, from daily and seasonal predictions of fire hazard to annual and multi-annual predictions of fire occurrence and extent.” They know that with a more precise and real understanding of fire and climate, managers will be far better equipped to do their jobs effectively.

Adds McKenzie, “We’re already seeing other researchers adopt these methods to increase the level of

spatial detail in their studies. In a broader sense, we are learning what historical fire records can and can’t tell us about fire regimes.”

Seeing the Role of Climate on the Trees

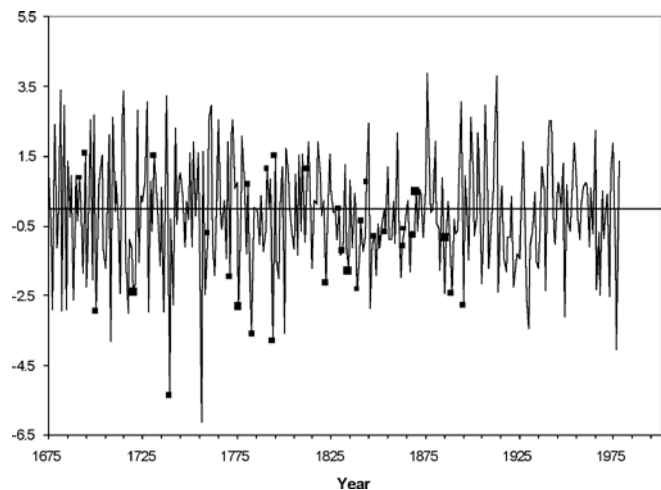
As it is for so many other ecological systems and responses, climate plays a vital role in forest fire dynamics. McKenzie says, “No matter what else goes on—suppression, fuel build up, grazing, or the like—climate is really important. This massive historical dataset confirmed what we already knew: that no matter what scale we look at, spatially or temporally, we see that climate is linked to fire regime.”

Specifically, the researchers quantified a broad-scale link between fire extent and drought in eastern Washington. McKenzie says, “It confirms that fires increase, both in extent and frequency, in a hot dry climate.”

He continues, “The climate in the Pacific Northwest is unusual in that despite being on the cool and wet side of things (relative to the rest of the US), we have a summer drought that produces fire regimes similar to those in the Southwest and other hotter drier ecosystems.”

As the scientists write in their JFSP report, “Not every dry year produced a fire, but most fire years were associated with dry years.” The fire scar records also confirmed that from 1700–1900 fires were generally frequent and of low intensity.

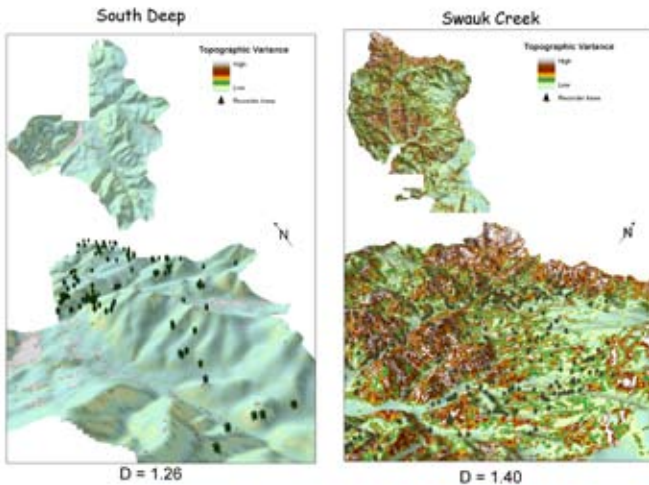
What’s more, they discovered some periodicity between fire occurrence and the El Niño Southern Oscillation (a 3–7 year periodicity) and the Pacific Decadal Oscillation (a 20–30 year periodicity). This compelling result shows the exquisite and powerful dance between climate and fire.



Palmer Drought Severity Index (PDSI) reconstructed from tree-rings plotted with large squares for large regional fire years and with small squares for smaller regional fires. Notice the large number of fires that occurred between ~1820 and 1895 when PDSI was consistently low, whereas the drought period between 1915 and 1935 did not produce regional fires, presumably because of effective fire suppression.

Again, even with many other factors at work in the forests, climate profoundly influenced forest dynamics.

Still, the scientists also saw a lot of variation in fire frequency and timing depending on the spatial scale they examined. Clearly, climate is important, but the scale they looked at determined how the relationship looked. They also found that topography—the lay of the land—is generally more important in determining fire regime than other biophysical or environmental factors.



Topographic variance and complexity in two of the study sites. South Deep has the least complex topography, whereas Swauk Creek has the most complex. Topographic variance is calculated from a combination of changes in slope, aspect, incident solar radiation, and a topographic relative moisture index. “D” = fractal dimension of a surface transect and ranges between 1 (for flat topography) and 2 (“infinitely” rugged). Values above 1.5 are rare in nature. 3D graphic by Lara–Karena Kellogg, University of Washington.

But perhaps most fascinating was the clear demonstration of the “decoupling” of climate from fire regime during the 20th century—the post settlement era of fire exclusion and land use changes. Indeed, so strong was the influence of the post-settlement era of fire regime that the fire regime itself during this time was, according to the JFSP report, “difficult to describe statistically due to the scarcity of fire events.”

People, Climate, and Fire

Like many other areas of the West, forested lands in the Pacific Northwest saw a fairly abrupt shift in fire regime after European settlement. Both fire exclusion and human-effected changes in land use shifted the system away from frequent low intensity fires to uncommon but often large stand-replacing fires.

Relative to some other places, the Pacific Northwest wasn’t fully settled until late in the 19th century, after the Northern Pacific railroad was finished in 1877. The railroad itself instituted an active no burn policy in 1878, and the Forest Service began a major program of fire suppression in 1908. Furthermore, logging and grazing in the late

1800s and into the 1900s changed the nature of fuels, fuel accumulation, and forest function.

As a result of these major changes to the forests themselves, climate—at least on the surface—became far less important to fire regime in the 20th century. The scientists write in their report, “Major land use changes in the 20th century altered not only the fire regime, but also the relationship between climate and fire on annual time scales. Fire frequency and the number of trees recording fire decreased dramatically in the 20th century in all study sites, reflecting a period of regional land use and land covers change that coincides with reduction of Native American ignition sources, major European American settlement (1890–1910), introduction of domestic livestock, logging, and active fire suppression (>1908).” As a result, they write, “During the 20th century, summer drought was relatively less important in affecting fire extent than it was previously.”

To some, the decoupling of climate from fire regime could be breathtaking. Yet McKenzie is swift to point out that climate is always a major player, and that a short-term period in forest history where human influence has temporarily broken the strong link between climate and fire is just that: temporary. He and his colleagues write in the report, “Recent large fires in the Pacific Northwest (not included in this study) associated with drought conditions indicate that although fire extent and climate were weakly associated in the 20th century, current fuel levels may have elevated average fire risk to a point where thresholds will once again be sensitive to the influence of climatic variability in coming decades, regardless of fire suppression activities.”

McKenzie says, “Humans can break the relationship between climate and fire temporarily, but not forever.” Furthermore, the century of fire exclusion will muddy researchers’ ability to forecast fire risk due to climate.

What’s more, McKenzie stresses that climate change will play an increasingly important and somewhat unpredictable role in the link between climate and fire. “We will see a lot more fire in the West with global warming. Warmer temperatures will increase the likelihood of drought. It will be easier for forests to burn, and burns will be more severe. There are surprises in store. This and other studies suggest that warming temperatures over the next decades/centuries can be expected to produce larger more frequent fires.”

Another important piece of the climate change issue says McKenzie, is that, “We have to be careful not to try to restore the fire regimes associated with a different climate than what we are expecting for the future.”

Beautiful Truth: Sharing the Meaning of the Data

The rich information gathered from this work is complex through space and time. Yet it is crucial data for

managers and planners who need to plan and implement effective fuel treatments. McKenzie and his team knew they wanted to find a way to share and convey this richness, and with emerging techniques available with database and GIS technology, they have crafted a tool that allows users to see the data with ease.

The researchers crafted user-friendly Web-based GIS tools that allow users to compare and contrast historical patterns. The relational database at its heart links “fire history data and summary fire statistics to spatial coordinates for over 19,000 fire scars on over 2,000 trees.”

This innovative tool will support managers not only in the local Washington State area who want this information, but it will also be available to users all over the world who may want insight into the relationship between climate and fire. Furthermore, those working at the Okanogan-Wenatchee and Colville National Forests of eastern Washington will have ongoing support for using this database through the Pacific Northwest Research Station. Anyone can find the GIS web server at: <http://flames.cfr.washington.edu/>.

It is hard to overstate the value and meaning of this set of tools, as well as the way in which complex data are being interpreted and shared. The scientists say it best in their report, “We view the ongoing support we are promising as a collaboration with land managers in eastern Washington, who are faced with complex, often conflicting prescriptions for fuel treatments and other activities. By providing a comprehensive accessible picture of historical fire regimes, which are frequently equated with ‘reference conditions,’ the GIS web server and database facilitate the exploration of alternative scenarios for both fire-regime restoration and extreme fire management and control.”

McKenzie enjoys this aspect of the work, “This study has a nice combination of cutting-edge science and usefulness to management and conservation efforts.”

Further Information: Publications and Web Resources

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Fire and Climatic Variability in the Inland Northwest. Database, maps, and data to download: <http://flames.cfr.washington.edu/>.

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Management Implications

- Understanding the measurable impact of climate on fire regime, as well as spatial and temporal forest complexity, is needed for making effective and appropriate management and restoration decisions.
- Managers and planners across the United States, and in particular, in eastern Washington, now have a comprehensive and accessible set of tools and data that have immense explanatory and management power that links climate, fire regime, and spatial and temporal complexity.
- An era of fire exclusion has seriously diminished the link between climate and fire regime in the Inland Northwest, but management decisions will need to account for the re-emergence of the effect of climate on fire regime.
- Climate change will affect fire susceptibility in forests across the West. But as in eastern Washington, the fire history record provides no analogues to expected greenhouse warming, so we can expect surprises in the future.

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Scientist Profile



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