Fire in the Ashland Watershed Compared to Regional Fire History: A Systematic Literature Review

Image source: City of Ashland, 2013

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Abstract

During the last century fire suppression efforts in the Ashland watershed have led to a dense forest and have increased wildfire fuel. Prior to fire suppression, low intensity fires returned to the area frequently. The temperate forests of the Pacific Northwest include frequent fire-adapted forests now at high risk of uncharacteristically large, severe fires due to fire suppression efforts. The Ashland Forest Resiliency Stewardship Project conducts ecological forest restoration in the Ashland watershed to reduce wildfire fuel, improve species habitat, and provide a resilient watershed. Our work consisted of a comparative systematic literature review and geospatial data analysis between fire history in the Ashland watershed and other temperate forests of the Southwest Oregon and Northern California region. Current fuel reduction efforts conducted by the Ashland Forest Resiliency Stewardship Project operate under the assumption that fire plays a similar role in the Ashland Watershed as it does regionally. We challenged that assumption, looking for evidence that fire histories differ. We found that median fire frequency is best explained by mean precipitation in the region including the Ashland watershed. This model allows us to conclude that the fire history of the Ashland watershed does resemble its regional setting.

Introduction

For approximately the last century fire in the Ashland watershed in Ashland, Oregon has been heavily suppressed, allowing for a dense forest and a build-up of fuel for fire. Fire suppression came about at the turn of the century, when massive fires in the West destroyed many acres of forested land. This prompted policy makers into suppression efforts to protect private and public property. Species of trees have certain characteristics that make them more or less susceptible to damage from fires and allow fire occurrence and severity to be studied through fire scars present in the history of older tree growth. Prior to this suppression, low intensity fires returned to the area quite frequently. The temperate forests of the Pacific Northwest include frequent-fire-adapted forests which are at high risk of uncharacteristically large, severe fires that can be destructive to habitats, species, and people (Hessburg and Agee, 2003; Spies et al., 2006).

Currently, the Ashland Forest Resiliency Stewardship Project (AFRSP) is implementing forest ecological restoration to reduce forest fire fuel, improve species habitat, and provide a healthier forest that will benefit us and sustain not only our lives, but the lives of other species that occupy the same region (some of which are endangered). Efforts are being made through federal, private, and state funding to monitor these restoration activities. This study conducts a systematic literature review and geospatial data analysis comparing the fire history of the Ashland watershed to other temperate forests of the Southwest Oregon and Northern California region.

Project Context and Background

The role of fire in forest ecosystems has become a frequently debated topic among scientists and the public generally. Knowledge of fire history within forest ecosystems is pivotal for forest management practices. The exclusion of fire, and the use of prescription fire, can have dramatic impacts on forest ecosystems. A number of studies have been done to assess the historic role of fire in western forest ecosystems (Agee, 1991; Taylor and Skinner, 1998) , and the understanding of fire's role in forests has grown over the last few decades (Mohr et al., 2000; Odion et al., 2004; Taylor and Skinner, 2003). Broad generalizations have been made concerning what role fire plays in these ecosystems, but from a management perspective understanding historical fire behavior in a specific watershed like the Ashland watershed is perhaps more important.

The Nature Conservancy (TNC), as a member of the AFRSP, is gathering fire data within the Ashland watershed. TNC has gathered 226 fire scar samples within the Ashland watershed, and plans to obtain another 100 by spring of 2014. These samples have been cross-dated with data collected by Dr. Carl Skinner of the US Forest Service and analyzed at the US Forest Service Pacific Southwest Research Station to construct accurate fire history timelines within the basin. Historically, fires were frequent within the watershed, and somewhat widely distributed (44% of fires were recorded in at least 3 sites). Evidence of the severity of these fires exists in the number of fire scars found in a single tree. Some trees sampled survived tens of fires over their lifetime, indicating a pattern of frequent, low intensity fire that was strong enough to scar the tree but not replace the stand. Fire suppression efforts have successfully excluded fire from the Ashland watershed since the early 1900's (Metlen et al., N.d.).

Project Goal

Does fire history in the Ashland watershed resemble fire histories of the greater Southwest Oregon and Northern California region? Our goal is to compare fire history data gathered within the Ashland watershed to regional studies that direct current forest management practices. First, we conducted a systematic literature review to obtain fire histories of the Ashland watershed and those of other sites within Southwest Oregon and Northern California. Then, we utilized geospatial technology to prepare a dataset of key variables extracted from the systematic literature review to compare the fire history of the Ashland watershed to the broader Southwest Oregon and Northern California region.

We hypothesized that fire history of the Ashland watershed does not resemble fire histories of Southwest Oregon and Northern California. We evaluated our data with statistical tools to determine if significant differences existed between fire histories of the Ashland watershed and the greater Southwest Oregon and Northern California region. This evaluation determined whether or not we rejected our hypothesis.

Applicable Studies

Systematic literature reviews have proven useful to the field of medicine. The nature of medical studies and access to medical information make systematic literature reviews relatively straightforward. The field of ecology has less of a history of using systematic literature reviews as a data synthesis tool, though existing literature using these methods grows every year. The field of ecology must balance literature reviews between including many confounding variables with eliminating variables that may prove useful to the study question. Additionally, the lack of a centralized database of organized literature for ecology, such as exists within the medical community makes systematic literature reviews more difficult (Pullin and Stewart, 2006). These limiting factors aside, much can be learned from a systematic review of ecological literature that may not be found with single pieces of literature alone. For example, a literature review of studies on the effects of wind farms on local and migrating bird populations found that impact increased over time, a result not found within the individual studies reviewed (Stewart et al., 2005). Similar results could be found regarding fire history through a systematic literature review.

Extensive documentation of fire history within the Klamath-Siskiyou region exists (Kaufmann, 1990; Agee, 1991; Agee, 1993; Mohr et al., 2000; Taylor and Skinner, 1998; Taylor and Skinner, 2003). The AFRSP is developing similar data for the Ashland watershed. However, no systematic literature review comparing fire histories exists at this time. Further, no comparison of fire history within a single watershed to the regional historical fire setting exists. Moritz (2003) questioned the assumption of similarities of fire history between chaparral forests of Southern/Central California and coniferous forests of Western U.S. He also questioned the assumption that chaparral forests will respond to fuel reduction treatments in a similar manner to coniferous forests. Odion, et al., (2004) also questioned the assumption that fuels reduction in closed canopy forests of the Klamath-Siskiyou region would lead to reduced fire severity. It is assumed that fire history within the Ashland watershed is similar to the more regional fire history of the Klamath-Siskiyou region, but preliminary research shows that the Ashland watershed experienced frequent, low intensity fires (Metlen et al., N.d), whereas the more regional Klamath-Siskiyou region is characterized by mixed severity fires (Taylor and Skinner, 2003). Similar data from other basins within the Rogue Valley show that fire resulted not only from lightning strikes, the predominant cause of wildfire in the region, but also from practices of indigenous peoples (Metlen et al., N.d).

The AFRSP has spent millions of dollars laying the groundwork for an intensive fuels reduction plan in conjunction with numerous local, regional, and national stakeholders to reduce the likelihood of severe wildfire within the Ashland watershed. This framework has based fuel reduction efforts on the regional literature of the Klamath-Siskiyou region. To inform policy decisions, it is therefore evident that a systematic literature review of the relationship between the fire histories of the Ashland watershed and the Southwest Oregon and Northern California region would be useful.

Project Methods and Design

Does fire history in the Ashland watershed resemble fire histories of the greater Southwest Oregon and Northern California region? We hypothesized that fire history in the Ashland watershed does not resemble fire histories in Southwest Oregon and Northern California. We analyzed data on fire return intervals (FRI) and climate for significant departures from regional FRI to test our hypothesis.

The greater portion of data that exists on fire regimes comes from careful examination of fire scars. Cores from live trees and cross-sections from stumps are collected and fire scars are identified and recorded for each tree or stump sampled within a given plot. The frequency and relative date of each fire is recorded using dendrochronology methods such as counting rings (Arno and Sneck, 1977). In most cases, the relative dates of each fire are then cross-dated with the U.S. Forest Service Pacific Southwest Research Station fire scar database that keeps a record of certain trees with known dates for each ring of growth. This determines the year a fire scarred a particular tree with a high degree of accuracy, usually within 1 year (Metlen, et al., N.D.). Some studies use other cross-dating methods while others use no cross-dating at all (Sensenig, et al., 2013).

We began with a systematic literature review of fire histories in the Southwest Oregon and Northern California region, and recorded our findings into an Excel spreadsheet. The spreadsheet contained fields for the source examined, which search terms located the source, and a field for each variable extracted from the source. Our list of variables included fire return intervals (mean, median, standard deviation, range, and Weibull distribution), latitude and longitude, and whether or not fire scar data has been cross-dated (Table: 1, truncated).

Table 1: Studies used for systematic literature review and selected variables for each study. Note that some studies are listed more than once due to that study having more than one plot.

Author & Date	Area (km2)	Region	Forest Type	Time Period	Mean FRI	Median FRI
Agee 1991	12.7	Siskiyou Mtns, OR	Mixed Evergreen	1746-1915	21.0	17.0
Beaty & Taylor 2001	17.4	Southern Cascade Mtns, CA	Mixed Conifer	1700-1904	7.2	7.0
Bekker & Taylor 2010	2.4	Southern Cascade Mtns, CA	Mixed Conifer	1783-1913	46.3	22.8
Bekker & Taylor 2010	4.9	Southern Cascade Mtns, CA	Mixed Conifer	1783-1913	46.3	22.8
Bekker & Taylor 2010	3.0	Southern Cascade Mtns, CA	Mixed Conifer	1783-1913	46.3	22.8
Bekker & Taylor 2010	4.4	Southern Cascade Mtns, CA	Mixed Conifer	1783-1913	46.3	22.8
Bekker & Taylor 2010	1.2	Southern Cascade Mtns, CA	Mixed Conifer	1783-1913	46.3	22.8
Foster 1998	82.7	Southern Cascade Mtns, OR	Mixed Conifer	1623-1910	30.0	23.0
Fry & Stevens 2006	2.4	Klamath Mtns, CA	Mixed Conifer	1750-1924	1.7	1.0
Gill & Taylor 2009	132.6	Sierra Nevada Mtns, CA	Mixed Conifer	1600-1904	1.3	1.0
McNeil & Zobel 1980	8.4	Southern Cascade Mtns, OR	Mixed Conifer	1748-1902	18.0	13.0
Metlen et al unpub. data	38.6	Siskiyou Mtns, OR	Mixed Conifer	1619-1911	11.9	11.0
Moody et al 2006	7.9	Sierra Nevada Mtns, CA	Mixed Conifer	1775-1849	6.4	6.0
Moody et al 2006	6.9	Sierra Nevada Mtns, CA	Mixed Conifer	1775-1849	6.2	6.0
Moody et al 2006	5.7	Sierra Nevada Mtns, CA	Mixed Conifer	1775-1849	8.2	8.0
Moody et al 2006	5.2	Sierra Nevada Mtns, CA	Mixed Conifer	1775-1849	9.8	8.5
Nagel & Taylor 2005	2.2	Sierra Nevada Mtns, CA	Mixed Conifer / Chaparral	1714-1882	31.0	N/A
Nagel & Taylor 2005	4.1	Sierra Nevada Mtns, CA	Mixed Conifer / Chaparral	1714-1882	30.0	N/A
Nagel & Taylor 2005	8.2	Sierra Nevada Mtns, CA	Mixed Conifer / Chaparral	1714-1882	21.5	N/A
Olson & Agee 2005	18.6	Central Cascade Mtns, OR	Douglas Fir / Western Hemlock	1650-1900	34.0	29.0
Sensenig et al 2013	298.8	So. Cascade, Siskiyou, Coast Mtns, OR	Mixed Conifer	1700-1900	17.0	N/A
Sensenig et al 2013	829.9	So. Cascade, Siskiyou, Coast Mtns, OR	Mixed Conifer	1700-1900	17.0	N/A
Sensenig et al 2013	178.1	So. Cascade, Siskiyou, Coast Mtns, OR	Mixed Conifer	1700-1900	17.0	N/A
Skinner 2003a	39.6	Klamath Mtns, CA	Mixed Conifer	1525-1933	N/A	14.5
Skinner 2003b	5.9	Klamath Mtns, CA	Mixed Conifer	1376-1941	10.6	6.8
Skinner et al 2009	10.9	Coastal Mtns, CA	Mixed Conifer	1700-1900	8.1	4.0
Skinner et al 2009	7.2	Coastal Mtns, CA	Mixed Conifer	1700-1900	8.9	4.0
Skinner et al 2009	8.8	Coastal Mtns, CA	Mixed Conifer	1700-1900	11.9	5.5
Skinner et al 2009	6.4	Coastal Mtns, CA	Mixed Conifer	1700-1900	11.0	8.0
Stuart & Salazar 2000	36.8	Coastal Mtns, CA	White Fir	1614-1944	35.0	27.0
Stuart & Salazar 2000	39.8	Coastal Mtns, CA	White Fir	1614-1944	35.0	27.0
Taylor & Skinner 1998, 1995	19.0	Klamath Mtns, CA	Mixed Conifer	1626-1904	20.5	13.5
Taylor & Skinner 2003	13.1	Klamath Mtns, CA	Mixed Conifer	1628-1904	1.6	3.0
Taylor 1993	10.8	Southern Cascade Mtns, CA	Red / White Fir	1740-1945	12.9	7.5
Taylor 2000	28.8	Southern Cascade Mtns, CA	Mixed Conifer	1750-1904	7.3	31.8
Taylor 2010	12.5	Southern Cascade Mtns, CA	Ponderosa Pine	1750-1904	16.0	12.0

We omitted variables that could not be located within the source or extrapolated their values based on the data given. In the final compilation of data, we only used studies from our list that reported mean or median FRI from a period of time before fire exclusion. This time period differed among sites, and we interpreted this date based on the description of the site found in the published study.

We then used the GIS software package ArcMap 10 to create a geospatial map of each study area using the NAD 1983 projection and the GCS North American 1983 coordinate system. We created each study area based on coordinates when provided or made rough estimates of size and shape of the study area based on details found within the published study, such as locater maps or names of landmarks and locations (Figure: 1). Finally, we gathered climate data from the Oregon State University PRISM (Parameter elevated Regression on Independent Slope Model) 800m normalized 30 year (1981 to 2010) datasets that fall within the geospatial locations covered in our literature review and from the Ashland watershed. We compiled data from the systematic literature review and PRISM data into one geospatial dataset.

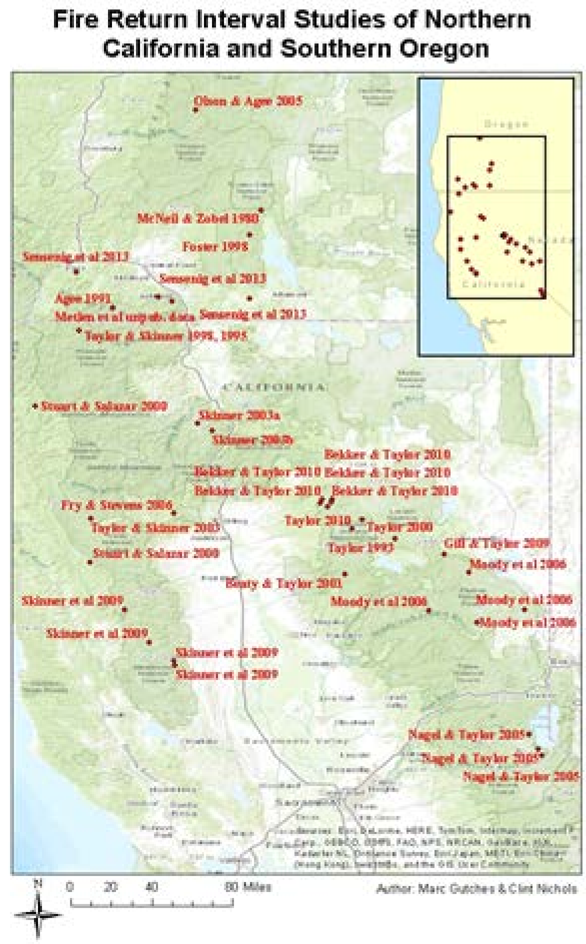


Figure 1: Map of all studies used for systematic literature review.

To test our hypothesis, we used the software package SPSS to create single variable regression models on two FRI variables as a function of four climate variables. Our models examined the relationship between mean FRI and mean precipitation, mean temperature, mean minimum annual temperature, and mean maximum annual temperature. We also created models comparing median FRI to the same climate variables. For significance to falsify our hypothesis, we used a confidence interval of 95%.

We also examined the relationship between mesic (wet) and xeric (dry) forest types and FRI. We used the software package Minitab to construct box plot models comparing mean and median FRI to both mesic and xeric forests. We used 95% as our confidence interval, and looked for evidence that the median of one relationship fell within or outside the confidence interval of the other. For the purpose of our study, we categorized mesic as forests dominated by fir or hemlock species, while xeric forests included mixed conifer, mixed evergreen, chaparral, and ponderosa pine.

Results

When analyzing FRI against PRISIM climate data we found and show in Table 2 that the mean temperature relationships as well as minimum and maximum temperature relationships all have a negative correlation that does not explain much variance and p-values that are not a significant determinant of FRI. The mean temperature relationship (Figure: 6) shows a mean r^2 value = 0.082, SE = 14.011, and a p-value = 0.095, and the median r^2 value = 0.080, SE = 9.014, and a p-value = 0.131. The minimum mean temperature (Figure: 7) shows a lower amount of significance with mean having a p-value = 0.186 and median FRI having a p-value = 0.252. The mean FRI as a function of mean minimum temperature has an r^2 value = 0.052 with a SE = 14.236, while the median shows an r^2 value = 0.047 with a SE = 9.175. In contrast, when we look at the mean and median r^2 values for mean maximum temperatures (Figure: 8) we find they are more significant. Mean FRI as a function of mean maximum temperature shows an r^2 = 0.087, SE = 13.978, and p-value = 0.086. The median FRI as a function of mean maximum temperature shows an r^2 = 0.085, SE = 8.986, and p-value = 0.117. The precipitation relationship (Figure: 5) shows a positive correlation. The median model explains more variance and is statistically significant. Mean FRI as a function of mean precipitation shows r^2 = 0.079, SE = 14.036, and p-value = 0.102. Median FRI as a function of mean precipitation shows r^2 = 0.125, SE = 8.639, and p-value = 0.031. The best fit regression model is the median FRI as a function of mean precipitation. Using the unstandardized coefficient from our regression analysis, we show that 143 mm change in precipitation equals 1 years change in FRI.

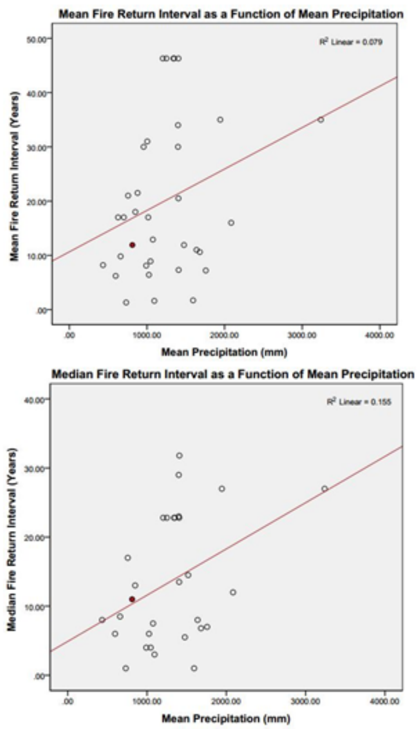


Figure 5: Mean and Median FRI as a function of precipitation (mean p value = 0.012, median p value = 0.031).

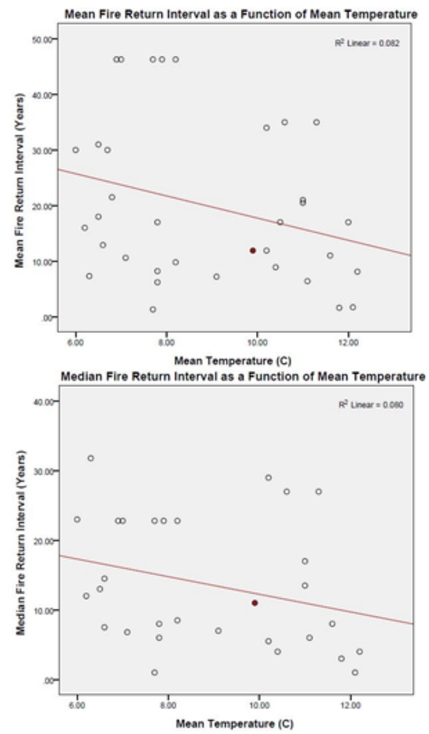


Figure 6: Mean and Median FRI as a function of mean temperature (mean p value = 0.095, median p value = 0.131).

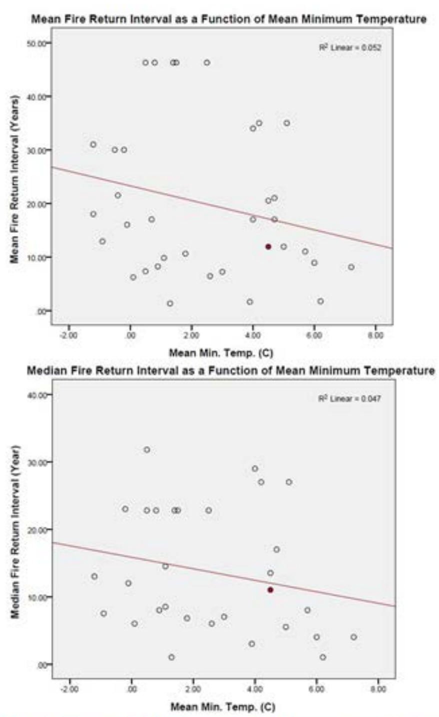


Figure 7: Mean and Median FRI as a function of mean min. temperature (mean p value = 0.186, median p value = 0.252).

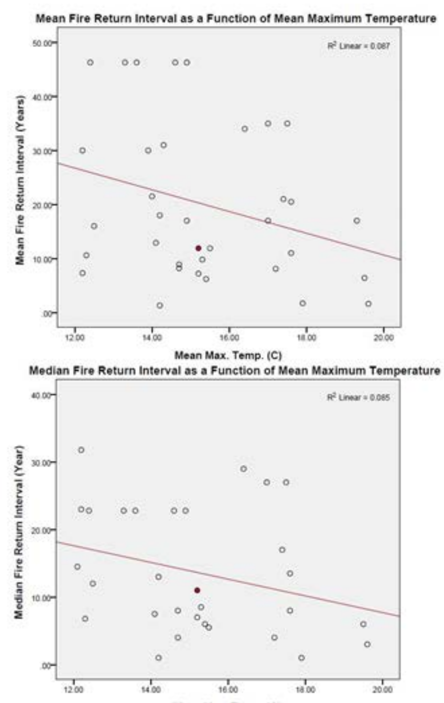


Figure 8: Mean and Median FRI as a function of mean max. temperature (mean p value = 0.086, median p value = 0.117).

Figure 9 shows box plots of FRI based on moisture regimes. Both mean and median FRIs are displayed. Table 3 gives the descriptive statistics for the moisture regimes for Figure 9.

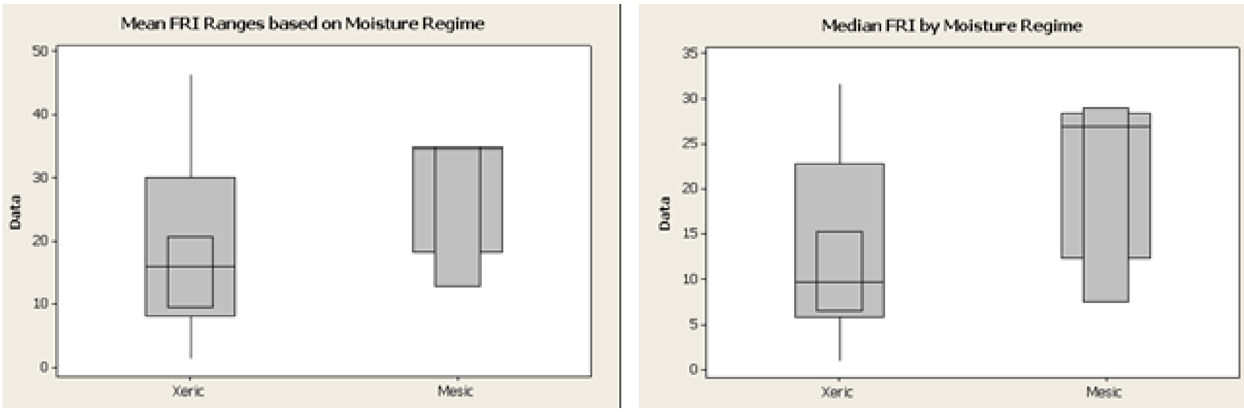


Figure 9: FRI ranges based on moisture regime. Smaller boxes represent the median confidence interval.

Table 3 describes mean FRI as a function of xeric forests having a mean = 18.79, SD = 14.51, median = 16, range = 45 with the minimum being 1.3 and the maximum of 46.3 (n = 31). Mean FRI as a function of mesic forests shows a mean = 29.22, SD = 10.89, median = 34.5, range = 22.1 with the minimum being 12.9 and the maximum of 35 (n = 4). Median FRI as a function of xeric forests has a mean = 12.25, SD = 8.46, median = 9.75, range = 30.75 with a minimum of 1 and a maximum of 31.75 (n = 26). Median FRI as a function of mesic forests shows a mean = 22.63, SD = 10.13, median = 27, range = 21.5 with a minimum of 7.5 and a maximum of 29 (n = 4).

Table 3: Descriptive statistics for moisture regime ranges.

Variable	N	N*	Mean	SE Mean	St Dev	Min	Q1	Median	Q3	Max	p-value	df
Mean FRI ƒ Xeric Forests	31	4	18.79	2.61	14.51	1.30	8.10	16.00	30.00	46.30		
Mean FRI ƒ Mesic Forests	4	31	29.22	5.45	10.89	12.90	18.18	34.50	35.00	35.00	0.177	33
Median FRI ƒ Xeric Forests	26	4	12.25	1.66	8.46	1.00	5.88	9.75	22.80	31.75		
Median FRI ƒ Mesic Forests	4	26	22.63	5.06	10.13	7.50	12.38	27.00	28.50	29.00	0.147	3

Discussion and Conclusions

Of the 8 regression models we ran, only median FRI as a function of precipitation showed any statistical significance. Other independent/dependent variable relationships fit the general understanding of the controls of fire frequency. Higher mean temperatures and lower mean precipitation resulted in lower FRI (more frequent fires). Alternatively, lower mean temperatures and higher precipitation resulted in higher FRI (less frequent fires). We found it interesting that of the given independent climate variables, only precipitation explained the variance in data with statistical significance. Visually, temperature data points have greater scatter than our precipitation data (Figures 5-8), but precipitation showed a wide range of values. From our data, we concluded that while precipitation does appear to drive fire frequency more so than the other climate variables we modeled, many confounding variables make identifying a single variable as the principal factor in fire frequency difficult.

Despite the variance in our data, we can still be reasonably confident in having rejected our hypothesis that the fire history of the Ashland watershed does not resemble the fire history of its regional setting. Based on our median FRI as a function of mean precipitation model, we have concluded with 95% confidence that mean precipitation can be used to predict median FRI within the Ashland watershed. Further, the unstandardized coefficient (B statistic in SPSS) can allow us to make predictions into the future. For every 1mm of change in mean precipitation, we can predict a similar change in median FRI by 0.007 years. Put a more relevant way, every 143mm change in mean precipitation should produce a similar change in median FRI by 1 year. Because of how close the Ashland watershed fit the precipitation model, we found this statistic an interesting tool that could provide insight into how fire frequency could change in the Ashland watershed given the impacts of climate change over the next few decades.

Our analysis of FRI as a function of forest type did not provide significant results. Our data does support the general understanding that mesic forests would see less frequent fire than xeric forests. But our data does not support the conclusion that they will always have less frequent fire, as the p-values for both mean and median FRI did not meet our 95% confidence interval. Again, many confounding variables likely dilute the significance of any one aspect in determining the frequency of fire, even with a variable like mesic or xeric which captures several factors, such as precipitation, species present, plant associations, etc. Another factor that may have influenced our analysis of the mesic-xeric difference could lie in our low sampling of mesic sites. We could only classify 4 sites as mesic, and we classified the other 31 of our sites as xeric. It is likely that more mesic samples would increase the significance of the relationship.

Perhaps identifying a single driving factor in determining fire frequency has no place within the body of fire ecology literature. Many studies we reviewed reported FRI as a function of different variables over the same study area. One study, for example, assessed fire frequency related to vegetation composition, aspect, slope position, historical period, and stand age class group (Taylor and Skinner, 1998). Others simply reported FRI for the study area as a whole (Skinner et al, 2009; Nagel and Taylor, 2005; Skinner, 2003a; Skinner, 2003b; Moody et al, 2006; Bekker and Taylor, 2010l; McNeil and Zobel, 1980; Agee, 1991; Taylor 1993). Because of the inconsistency with which various studies reported FRI, we could not analyze data on every possible combination of independent variable and FRI. The ability to obtain climate data from an independent source and extract from that dataset specific values for our study areas allowed us to assess FRI as a function of climate over all of our studies. The same approach using a digital elevation model (DEM) to obtain topographic values for our study areas could yield interesting relationships between topography and fire frequency. Similarly, using technologies similar to Normalized Difference Vegetation Index (NDVI) to obtain vegetation values to compare to FRI could demonstrate the role of forest type in determining fire frequency. Unfortunately, most technologies do not have the capability of determining forest type to the same 800m resolution as our PRISM climate data.

Several opportunities for further study emerged from our work on this project. During our search for regional studies, we identified twelve publications that we could not gain access to within our time frame. While we cannot say that we would have used these studies in our final analysis, it would benefit the work to have at least reviewed them for possible inclusion in our dataset. Doubtless other studies exist that we did not locate that would likely help narrow the variance in our data. A multivariate approach to our data would also help discover the most likely combination of climate variables that explain the variance in FRI data. The inclusion of other variables such as topography and vegetation type would add to the effort in finding the best fit of variables that explain fire frequency of the region and the Ashland watershed. Finally, as stated above, a study that tries to extrapolate a future fire frequency of the Ashland watershed under climate change conditions based on the unstandardized coefficient could help the stakeholders of the AFRSP in planning for future forest management practices.

Project Relevance and Deliverables

This research is important for three primary reasons. First, it allows for a comparison of regional theories on the role of fire in the forest to a local watershed, and allows for further research into why there may be any differences. This sort of comparison does not exist in the current body of literature, and adds to the larger understanding of fire history in the Southwest Oregon region. Second, it provides data to stakeholders on how the regional literature may be referenced to make decisions concerning the AFRSP. The AFRSP is a multi-million dollar project that impacts key values held by the local community (USDA Forest Service, 2008). It is important that the decisions made by the AFRSP be made with the best and most thorough set of information available. Third, the AFRSP has managed to form a collaboration of stakeholders that historically have been at odds over best practices within public lands. The AFRSP could find use as a model for forest managers to engage stakeholders in other watersheds. To ensure that this model feasibly meets the goals of all stakeholders, a thorough assessment of all assumptions must be made.

We worked together with AFRSP to review the relevant literature on the Ashland watershed and other related regional basins. Over the past six months, we conducted research, data collection, data analyses, and prepared an overall conclusion of the findings. This required several group meetings, extensive research, and the cooperation of the AFRSP and our advisors Dr. Mark Shibley and Dr. Charles Welden. Findings from this research will be formally documented in this written report and presented at Southern Oregon Arts & Research 2014.

Appendix A: Timeline

Jan. 24th, 2014 - Formal proposal is delivered

Jan. 31st, 2014 - Systematic literature review begins

Mar. 14th, 2014 - First draft of final report is delivered

Apr. 4th, 2014 - Systematic literature review completed

Apr. 4th, 2014 - GIS data compilation begins

Apr. 15th, 2014 - GIS data compilation completed

Apr. 15th, 2014 - Analysis and interpretation of findings begins

Apr. 31st, 2014 - Analysis completed

May 14th-15th, 2014 - Public presentation of findings are presented at SOAR 2014

May 30th, 2014 - Final written report is delivered

Appendix B: Tables, Figures, Maps, and Graphs

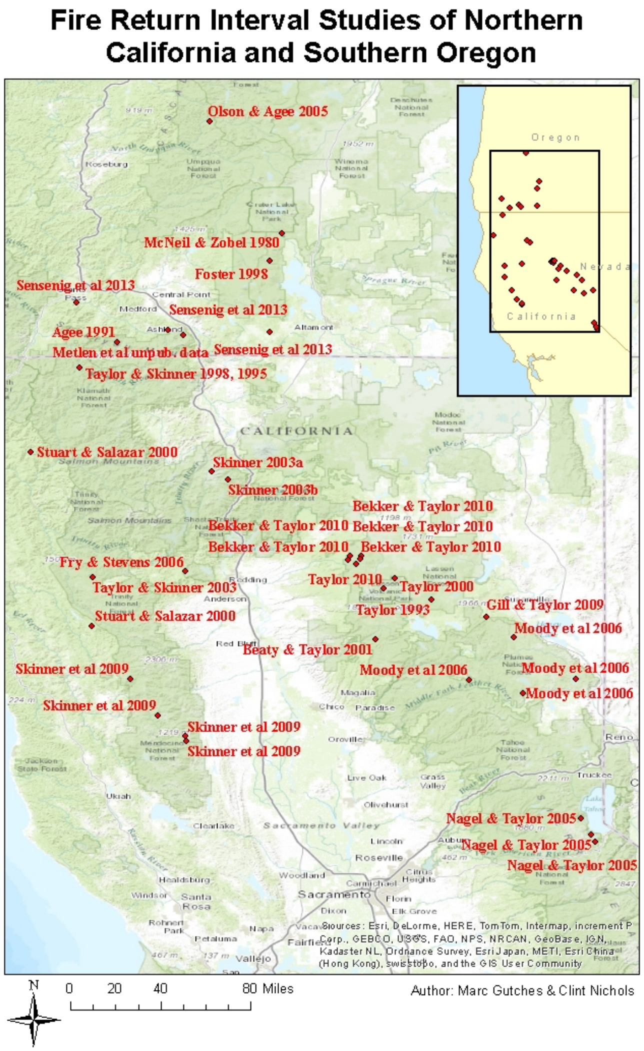


Figure 1: Map of all studies used for systematic literature review.

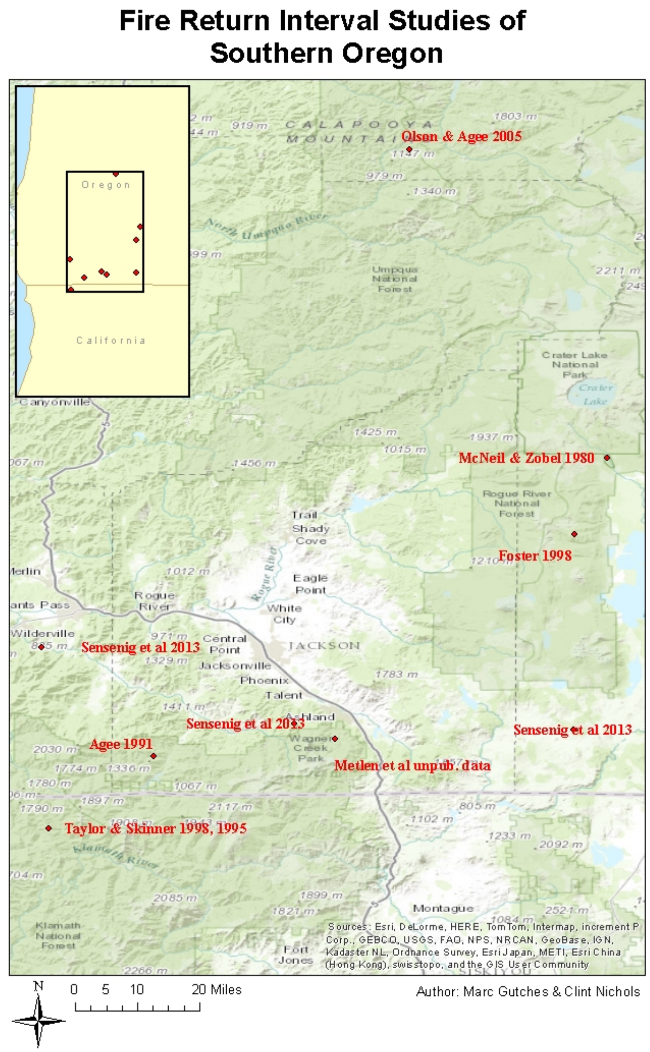


Figure 2: Southern Oregon studies used for systematic literature review.

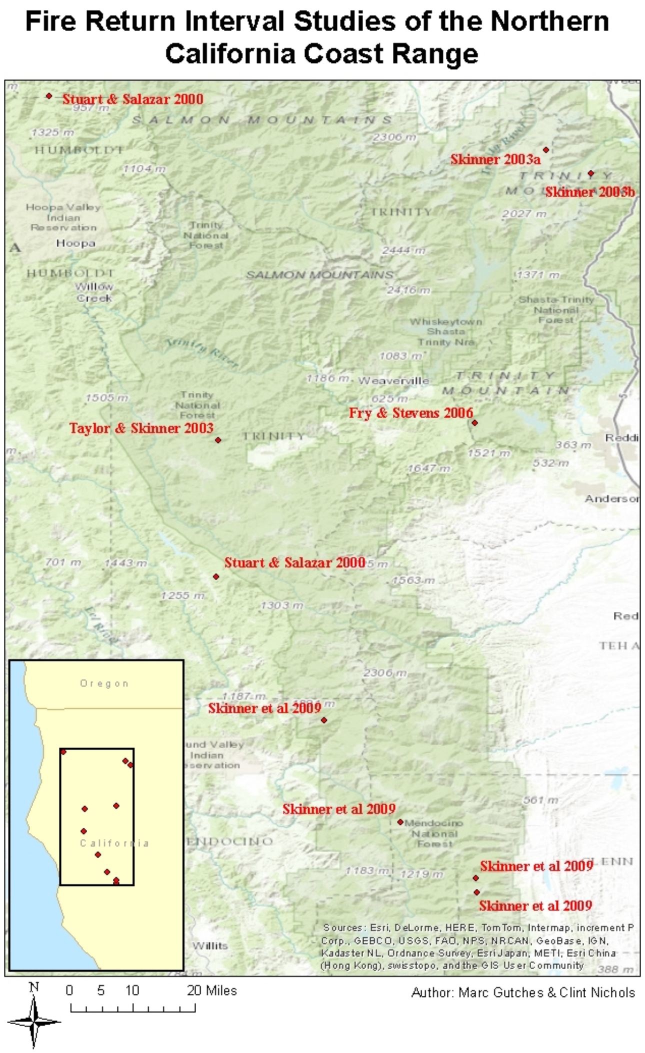


Figure 3: Northern California Coast studies used for systematic literature review.

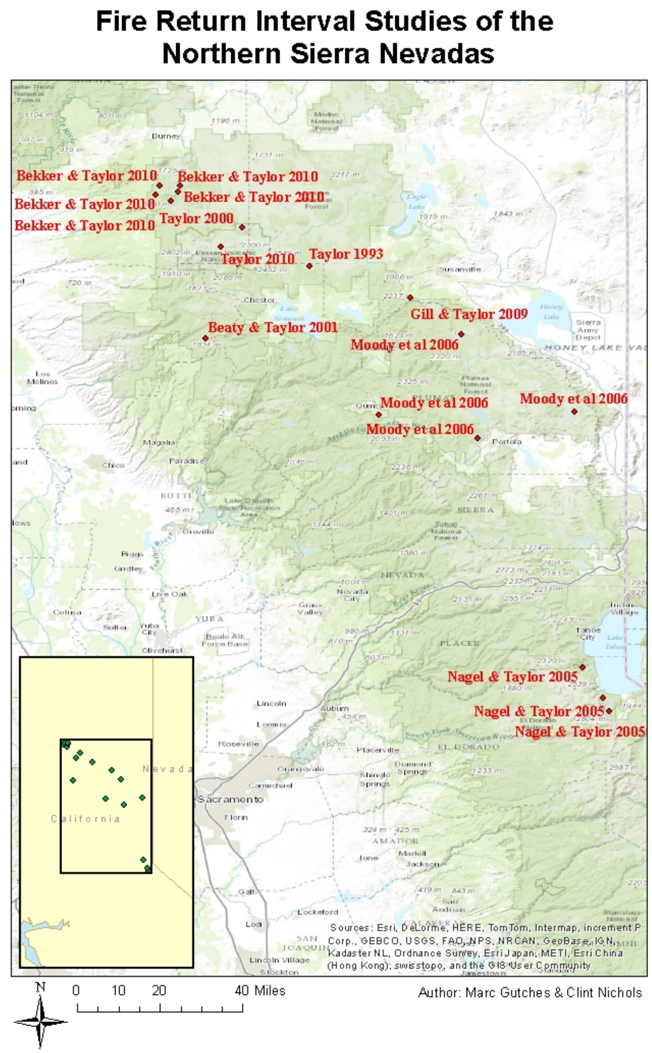
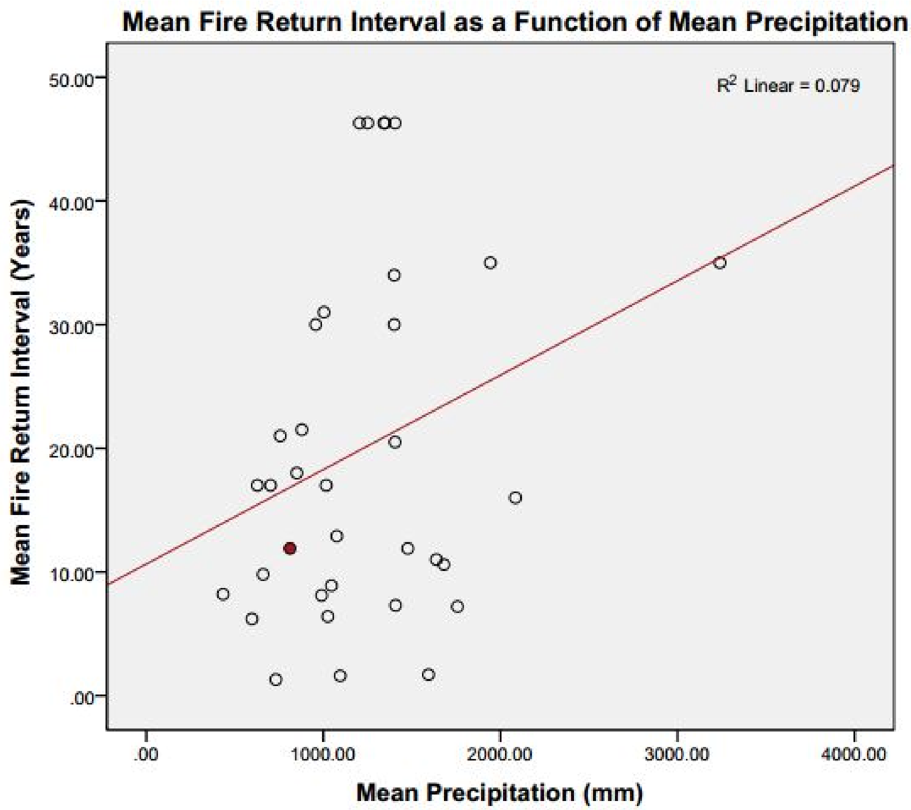


Figure 4: Northern Sierra Nevada studies used for systematic literature review.

Table 1: Studies used for systematic literature review and selected variables for each study. Note that some studies are listed more than once due to that study having more than one plot.

Author & Date	Area (km2)	Region	Forest Type	Cross-Dating	Time Period	Mean Precip. (mm)	Mean Temp. (oC)	Min. Temp. (oC)	Max. Temp. (oC)	Mean FRI	Median FRI
Agee 1991	12.7	Siskiyou Mtns, OR	Mixed Evergreen	No	1746-1915	757	11.0	4.7	17.4	21.0	17.0
Beaty & Taylor 2001	17.4	Southern Cascade Mtns, CA	Mixed Conifer	Yes	1700-1904	1758	9.1	3.0	15.2	7.2	7.0
Bekker & Taylor 2010	2.4	Southern Cascade Mtns, CA	Mixed Conifer	No	1783-1913	1204	7.9	2.5	13.3	46.3	22.8
Bekker & Taylor 2010	4.9	Southern Cascade Mtns, CA	Mixed Conifer	No	1783-1913	1348	6.9	1.5	12.4	46.3	22.8
Bekker & Taylor 2010	3.0	Southern Cascade Mtns, CA	Mixed Conifer	No	1783-1913	1251	7.0	0.5	13.6	46.3	22.8
Bekker & Taylor 2010	4.4	Southern Cascade Mtns, CA	Mixed Conifer	No	1783-1913	1405	8.2	1.4	14.9	46.3	22.8
Bekker & Taylor 2010	1.2	Southern Cascade Mtns, CA	Mixed Conifer	No	1783-1913	1342	7.7	0.8	14.6	46.3	22.8
Foster 1998	82.7	Southern Cascade Mtns, OR	Mixed Conifer	No	1623-1910	1400	6.0	-0.2	12.2	30.0	23.0
Fry & Stevens 2006	2.4	Klamath Mtns, CA	Mixed Conifer	Yes	1750-1924	1594	12.1	6.2	17.9	1.7	1.0
Gill & Taylor 2009	132.6	Sierra Nevada Mtns, CA	Mixed Conifer	Yes	1600-1904	732	7.7	1.3	14.2	1.3	1.0
McNeil & Zobel 1980	8.4	Southern Cascade Mtns, OR	Mixed Conifer	Yes	1748-1902	850	6.5	-1.2	14.2	18.0	13.0
Metlen et al unpub. data	38.6	Siskiyou Mtns, OR	Mixed Conifer	Yes	1619-1911	812	9.9	4.5	15.2	11.9	11.0
Moody et al 2006	7.9	Sierra Nevada Mtns, CA	Mixed Conifer	Yes	1775-1849	1025	11.1	2.6	19.5	6.4	6.0
Moody et al 2006	6.9	Sierra Nevada Mtns, CA	Mixed Conifer	Yes	1775-1849	597	7.8	0.1	15.4	6.2	6.0
Moody et al 2006	5.7	Sierra Nevada Mtns, CA	Mixed Conifer	Yes	1775-1849	434	7.8	0.9	14.7	8.2	8.0
Moody et al 2006	5.2	Sierra Nevada Mtns, CA	Mixed Conifer	Yes	1775-1849	660	8.2	1.1	15.3	9.8	8.5
Nagel & Taylor 2005	2.2	Sierra Nevada Mtns, CA	Mixed Conifer / Chaparral	Yes	1714-1882	1004	6.5	-1.2	14.3	31.0	N/A
Nagel & Taylor 2005	4.1	Sierra Nevada Mtns, CA	Mixed Conifer / Chaparral	Yes	1714-1882	957	6.7	-0.5	13.9	30.0	N/A
Nagel & Taylor 2005	8.2	Sierra Nevada Mtns, CA	Mixed Conifer / Chaparral	Yes	1714-1882	879	6.8	-0.4	14.0	21.5	N/A
Olson & Agee 2005	18.6	Central Cascade Mtns, OR	Douglas Fir / Western Hemlock	Yes	1650-1900	1400	10.2	4.0	16.4	34.0	29.0
Sensenig et al 2013	298.8	So. Cascade, Siskiyou, Coast Mtns, OR	Mixed Conifer	No	1700-1900	628	7.8	0.7	14.9	17.0	N/A
Sensenig et al 2013	829.9	So. Cascade, Siskiyou, Coast Mtns, OR	Mixed Conifer	No	1700-1900	702	10.5	4.0	17.0	17.0	N/A
Sensenig et al 2013	178.1	So. Cascade, Siskiyou, Coast Mtns, OR	Mixed Conifer	No	1700-1900	1016	12.0	4.7	19.3	17.0	N/A
Skinner 2003a	39.6	Klamath Mtns, CA	Mixed Conifer	Yes	1525-1933	1519	6.6	1.1	12.1	N/A	14.5
Skinner 2003b	5.9	Klamath Mtns, CA	Mixed Conifer	Yes	1376-1941	1681	7.1	1.8	12.3	10.6	6.8
Skinner et al 2009	10.9	Coastal Mtns, CA	Mixed Conifer	Yes	1700-1900	990	12.2	7.2	17.2	8.1	4.0
Skinner et al 2009	7.2	Coastal Mtns, CA	Mixed Conifer	Yes	1700-1900	1046	10.4	6.0	14.7	8.9	4.0
Skinner et al 2009	8.8	Coastal Mtns, CA	Mixed Conifer	Yes	1700-1900	1477	10.2	5.0	15.5	11.9	5.5
Skinner et al 2009	6.4	Coastal Mtns, CA	Mixed Conifer	Yes	1700-1900	1638	11.6	5.7	17.6	11.0	8.0
Stuart & Salazar 2000	36.8	Coastal Mtns, CA	White Fir	No	1614-1944	3240	11.3	5.1	17.5	35.0	27.0
Stuart & Salazar 2000	39.8	Coastal Mtns, CA	White Fir	No	1614-1944	1944	10.6	4.2	17.0	35.0	27.0
Taylor & Skinner 1998, 1995	19.0	Klamath Mtns, CA	Mixed Conifer	Yes	1626-1904	1405	11.0	4.5	17.6	20.5	13.5
Taylor & Skinner 2003	13.1	Klamath Mtns, CA	Mixed Conifer	Yes	1628-1904	1095	11.8	3.9	19.6	1.6	3.0
Taylor 1993	10.8	Southern Cascade Mtns, CA	Red / White Fir	Yes	1740-1945	1076	6.6	-0.9	14.1	12.9	7.5
Taylor 2000	28.8	Southern Cascade Mtns, CA	Mixed Conifer	Yes	1750-1904	1408	6.3	0.5	12.2	7.3	31.8
Taylor 2010	12.5	Southern Cascade Mtns, CA	Ponderosa Pine	Yes	1750-1904	2085	6.2	-0.1	12.5	16.0	12.0



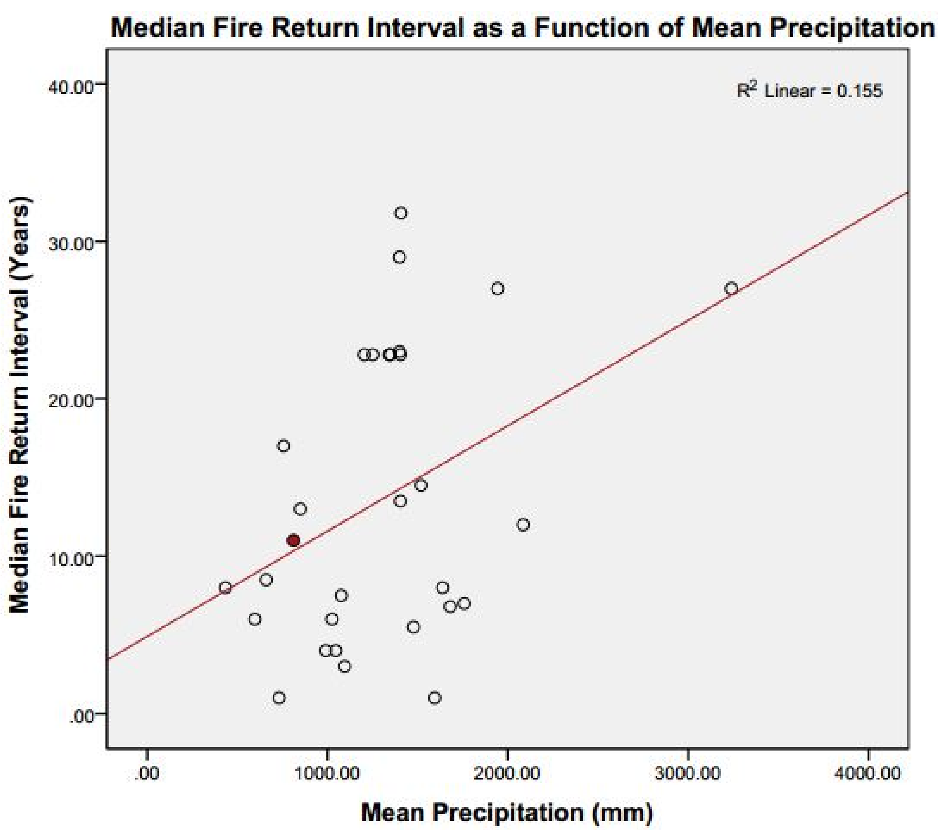
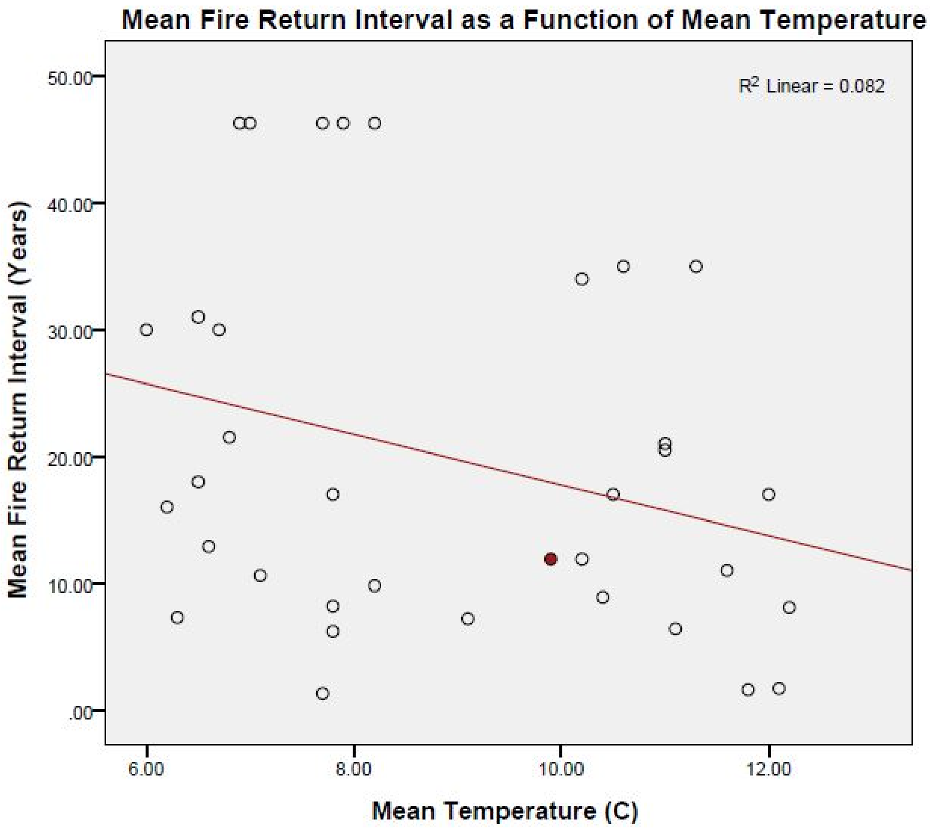


Figure 5: Mean and Median FRI as a function of precipitation (mean p value = 0.012, median p value = 0.031).



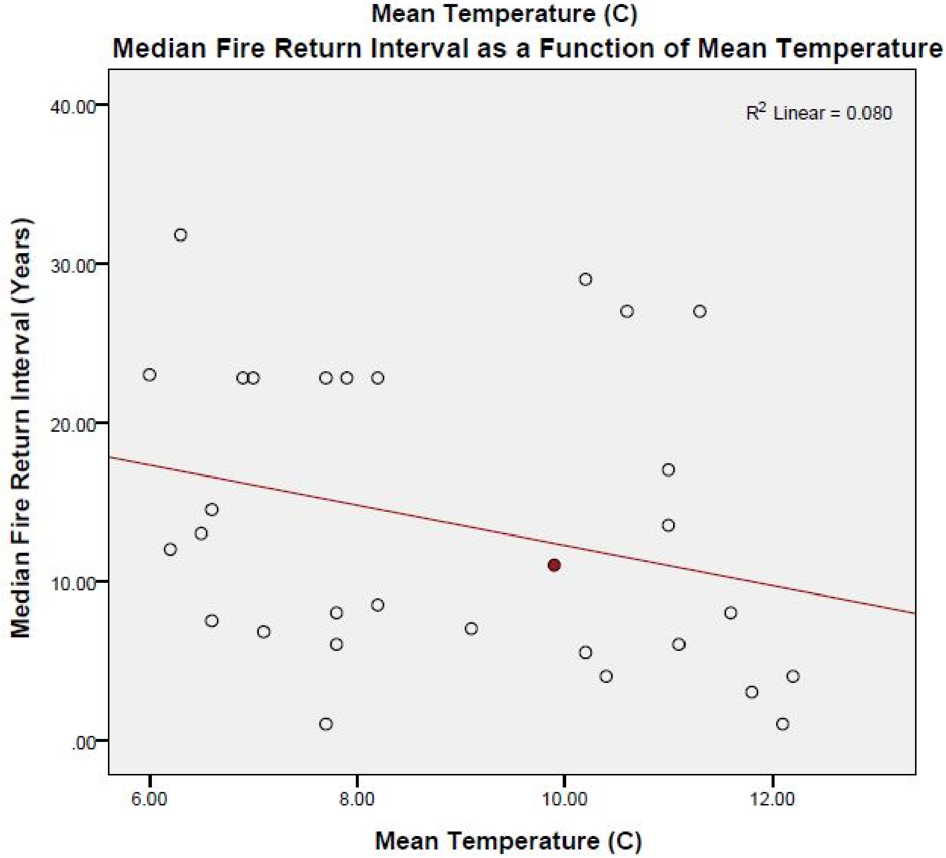


Figure 6: Mean and Median FRI as a function of mean temperature (mean p value = 0.095, median p value = 0.131).

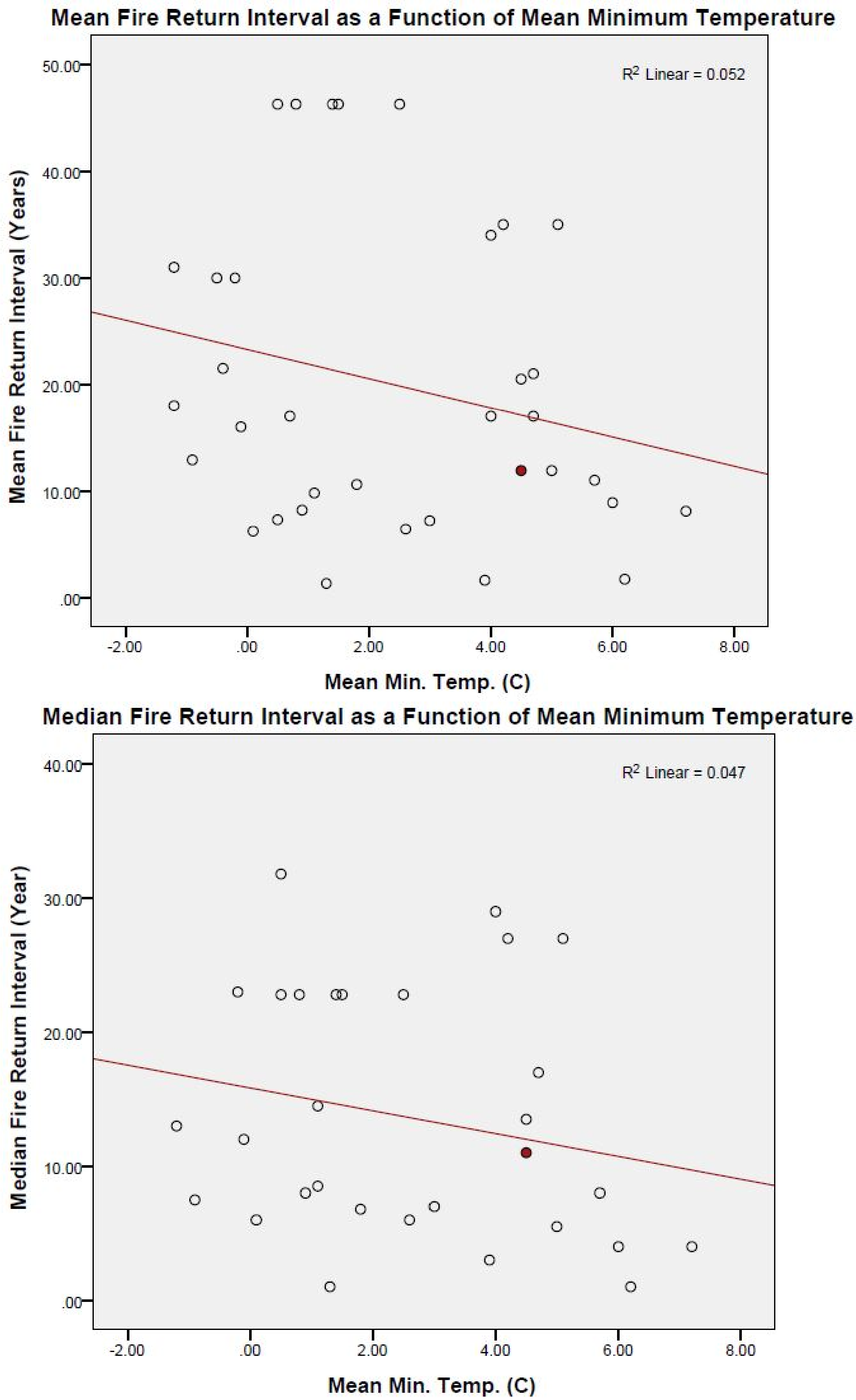
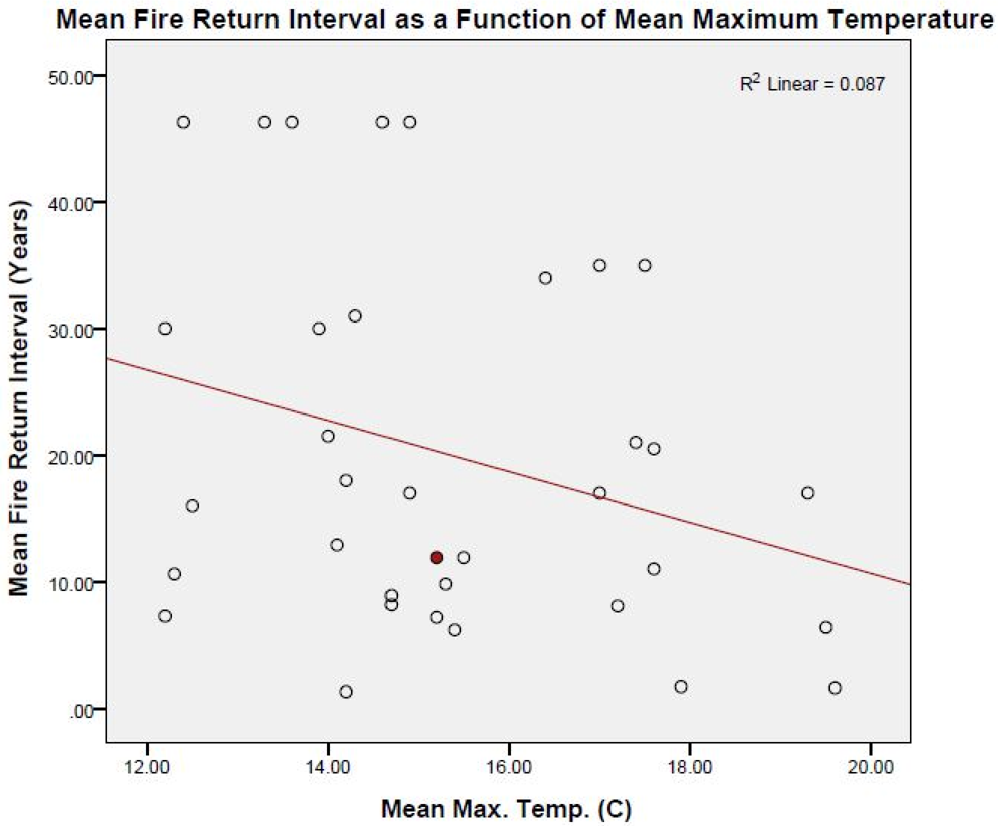


Figure 7: Mean and Median FRI as a function of mean min. temperature (mean p value = 0.186, median p value = 0.252).



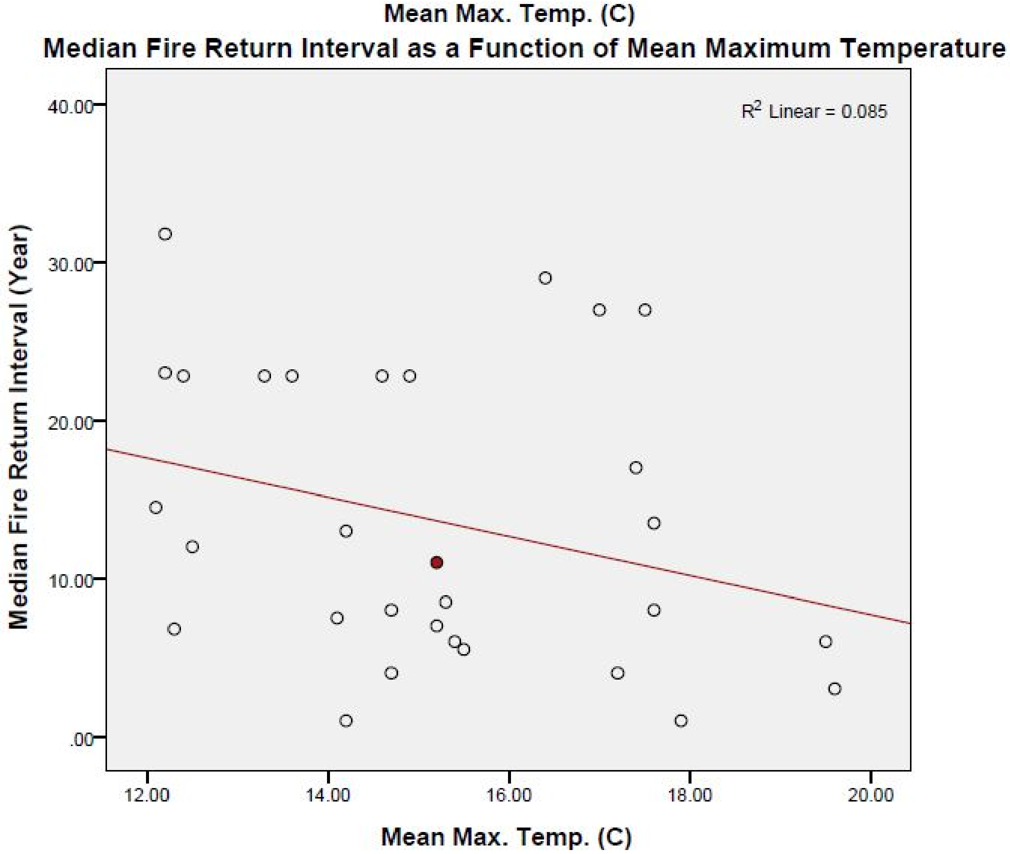


Figure 8: Mean and Median FRI as a function of mean max. temperature (mean p value = 0.086, median p value = 0.117).

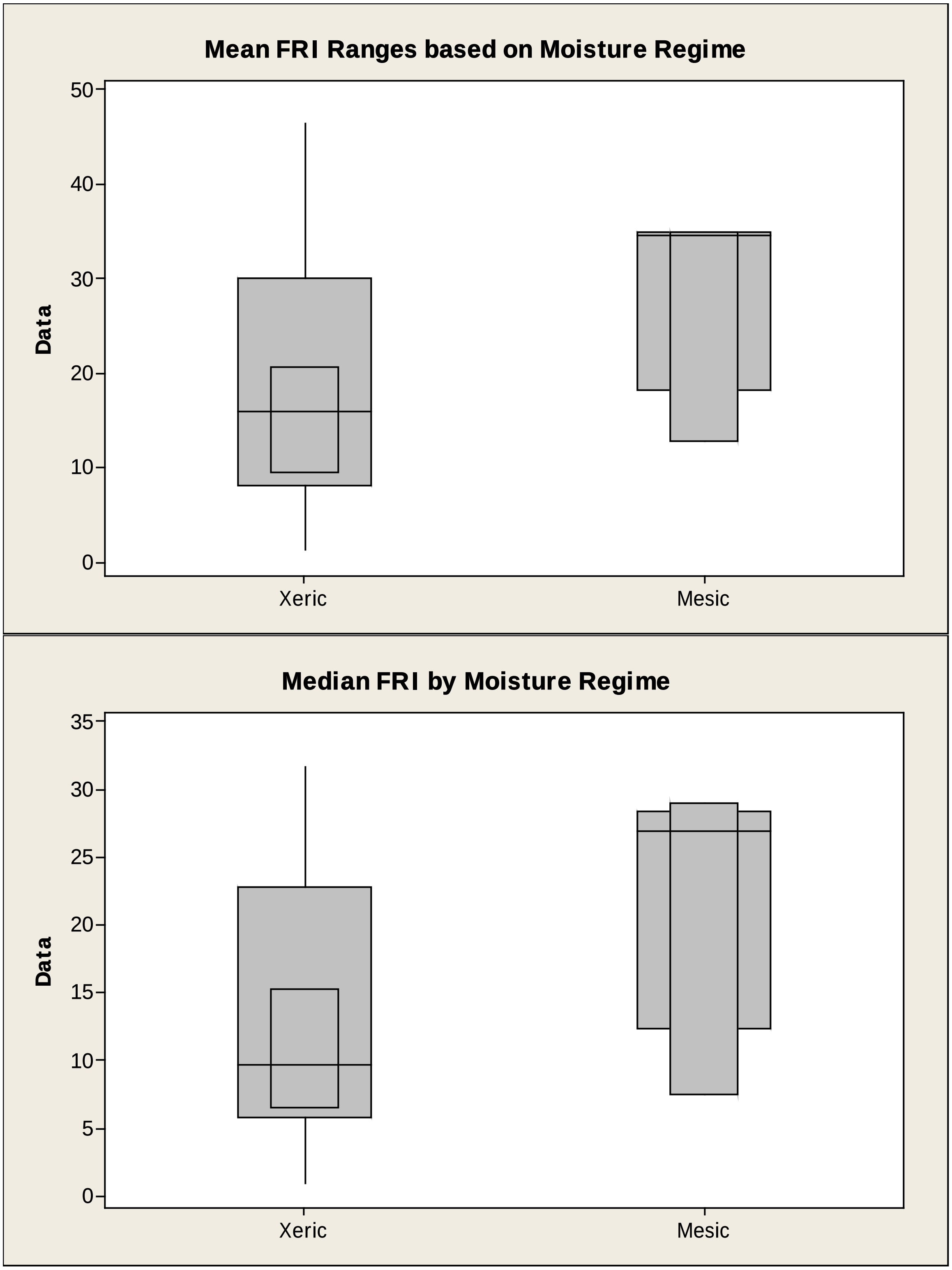


Figure 9: FRI ranges based on moisture regime. Smaller boxes represent the median confidence interval.

Table 2: Regression analysis of FRI and climate relationships

Relationship	R^2	Standard Error	Significance	Unstandardized Coefficient
Mean FRI ƒ Mean Pricip.	0.079	14.036	0.102	0.008
Median FRI ƒ Mean Pricip.	0.125	8.639	0.031	0.007
Mean FRI ƒ Mean Temp.	0.082	14.011	0.095	-1.996
Median FRI ƒ Mean Temp.	0.080	9.014	0.131	-1.267
Mean FRI ƒ Mean Min. Temp.	0.052	14.236	0.186	-1.371
Median FRI ƒ Mean Min. Temp.	0.047	9.175	0.252	-0.854
Mean FRI ƒ Mean Max. Temp.	0.087	13.978	0.086	-2.014
Median FRI ƒ Mean Max. Temp.	0.085	8.986	0.117	-1.241

Table 3: Descriptive statistics for moisture regime ranges.

Variable	N	N*	Mean	SE Mean	St Dev	Min	Q1	Median	Q3	Max	p-value	df
Mean FRI ƒ Xeric Forests	31	4	18.79	2.61	14.51	1.30	8.10	16.00	30.00	46.30		
Mean FRI ƒ Mesic Forests	4	31	29.22	5.45	10.89	12.90	18.18	34.50	35.00	35.00	0.177	33
Median FRI ƒ Xeric Forests	26	4	12.25	1.66	8.46	1.00	5.88	9.75	22.80	31.75		
Median FRI ƒ Mesic Forests	4	26	22.63	5.06	10.13	7.50	12.38	27.00	28.50	29.00	0.147	3

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