Meaghen O’Rourke & Bill Clayson
ES 482- Professor Jamie E. Trammell
1/28/21

Climate Adaptation Plan
Colvin Timbers, Lake County, Oregon

Introduction

Colvin Timbers is a stand of deciduous and evergreen forest overlooking Abert Lake, near the small town of Paisley in Lake County in south central Oregon. Colvin Timbers is situated within the Abert Rim Wilderness Study Area, which is managed by the Bureau of Land Management, America’s longest continuous fault scarp that contains an unusual ponderosa pine (*Pinus ponderosa*) dominant community for that elevation and region. Located approximately five miles from the other forested stands, the Timbers, which has not been commercially logged, contains a diverse group of trees including western white pine (*Pinus monticola*), whitebark pine (*Pinus albicaulis*), white fir (*Abies concolor*), quaking aspen (*Populus tremuloides*), willow (*Salix sp.*), and red alder (*Alnus rubrus*). This Climate Adaptation Plan aims at determining the vulnerability of the *Pinus ponderosa* and *Populus tremuloides* species in the face of climate change.

Figure 1. Location of Colvin Timbers, Lake County Oregon

Ponderosa pine and quaking aspen are native and commonly found in mountain and plateau regions of the American west. Reaching maturity at around 300-400 years, Ponderosa Pine is capable of living through long drought periods due to their large tap root (Utah State). Aspen (*Populus tremula*) are deciduous trees that can grow in a number of conditions such as dry mountain tops, shallow and deep soil, and moist streams (U.S. Forest Service). More research is needed to determine if the drop in precipitation or changes in the climate in Lake County will result in an impact for the Ponderosa Pine population within the Colvin Timbers stand.

Summary For Past and Present Climate- Lake County Oregon

Using data from the past 125 years, it can be observed that temperature has steadily increased in the area. From 1895 the average temperature was 40.9°F and it climbed to a peak of 47.8°F by 1934[Figure 1], resulting in a 6.9°F difference in just 39 years. After this peak, temperatures began to lower and 14 years later in 1948 the average temperature for the year was recorded at 41.6°F[Figure 2]. It took less than half the amount of time to drop than it did to raise around the same amount in the 1895 to 1934 time period. Lake County temperatures remain relatively stable, showing only one to two degree changes through to 1985. This year (1985) had the recorded average temperature of 42.5°F and in the following 36 years, recorded average temperatures had larger variations than past years. Since 1993 temperatures steadily increased and in 2020 the average temperature was recorded at 46.7°F.

Past and present data show that Lake County has experienced a 5.8°F increase in the last 125 years. These patterns seen in Lake County are also seen in the state of Oregon as a whole. Oregon demonstrated these patterns, however they started off at a slightly higher temperature of 45.6°F in 1895 and rose to 48.8°F by 2020. This is an increase of 3.2°F in the last 125 years which is less of an increase than we saw in our area of study.

Looking at more recent climatic anomaly data, it can be observed that temperature anomalies are coinciding with the temperature data from the previous graph. Just observing the last thirty eight years, temperature anomalies from 1982 to 1986 were demonstrating shifts both up and down by a few degrees. This mimics the temperature data from Figure 1, the years through 1995 to 2002 remain somewhat stable (relative to what was previously discussed) and after 2003 when 2.7°F was recorded, anomalies dropped to zero by 2011[Figure 4]. Directly after this drop however, is an increasing record of high temperature anomalies, by 2015 a peak of 3.8°F is achieved before dropping somewhat to 2.7°F by 2020[Figure 4].

In addition to temperatures and anomalies, precipitation is also an important factor to consider when studying an area's climate. Past data demonstrates that Lake county had lower levels of precipitation overall, but maintained the patterns seen at a state level. In 1895 Lake County received 13.92 inches of precipitation, when compared to the state as a whole, Oregon received 30.05 inches that same year[Figure 2]. Lake County is starting out about 16.13 inches lower than the state of Oregon in 1895. In 1930 Lake County dropped to 10.05 inches and the state saw a decrease as well, losing up to 7 inches of precipitation from the previous year [Figure 2]. It took fifty three years to bounce back and exceed these numbers. By 1983 Lake County was at a high of 23.36 inches and Oregon over 40 inches[Figure 2].

By 2000 Lake County had 15.33 inches and remained within this same range for the next four years until peaking in 2005 at a recorded 19.03 inches[Figure 3]. After 2005 average precipitation continued to drop until the last recorded year of 2020 at 9.86 inches[Figure 3]. From 1895 to 2020, Lake County overall experienced a decline in precipitation by 4.06 inches in the 125 years. In 2000 the state as a whole had the average precipitation of 27.91 inches and remained relatively consistent. By 2020, just like Lake County, Oregon precipitation average dropped to 28.87 inches, a decline of 1.18 inches over the last 125 years.

Temperatures in Lake County rose throughout the 2000's right around the same time when in 2005 precipitation began to lower. For Lake County, temperature and precipitation both had larger changes take place than in both present and past data for the state of Oregon as a whole. In the last 125 years Lake County has gotten about 5.8°F warmer and seen a decrease in precipitation by about 4.06 inches. Oregon in the last 125 years has gotten about 3.2°F warmer and only seen a decline in precipitation of 1.18 inches. With this information, we can conclude that although similar patterns in temperature and precipitation can be seen throughout the state and Lake County, Lake County has experienced a greater change within the last 125 years than Oregon as a whole.

These changes in climate and precipitation are important for our understanding of the Colvin Timbers site and the effects on tree species. Due to the variety in growing conditions, more research will determine if the climate and precipitation changes in Lake County will affect the population of ponderosa pine (*Pinus ponderosa*) and aspen (*Populus tremuloides)* within the Colvin Timbers site.

Figures For Past and Present

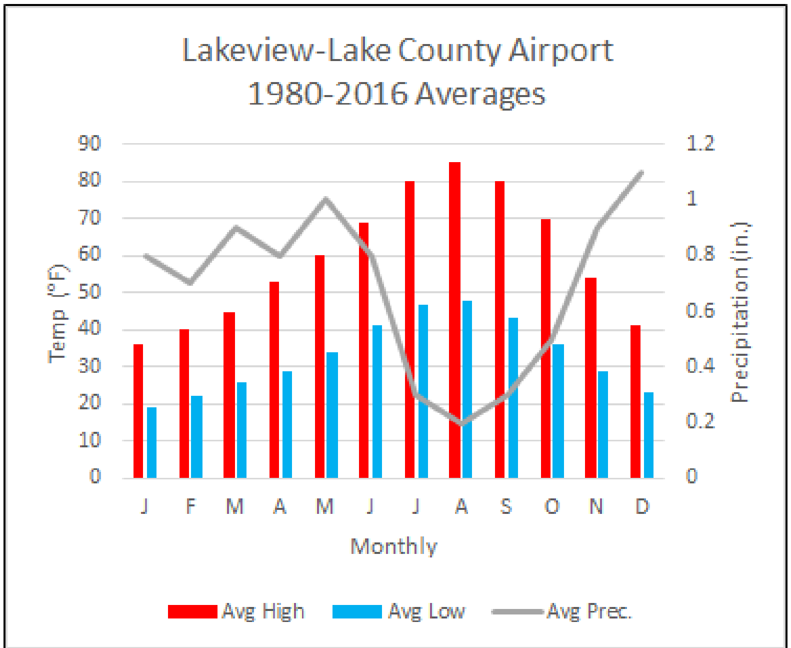

Figure 1. Recent climate averages, Lakeview-Lake County Airport. Source: wrcc.dri.edu/cgi-bin/cliMAIN.pl?or6426.

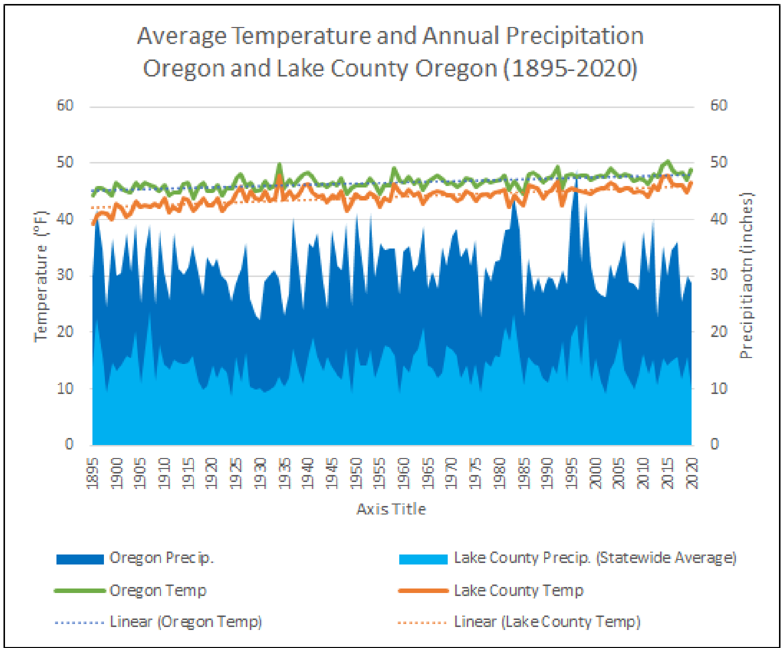

Figure 2. Average temperature and precipitation, Oregon and Lake County, 1895-2020. Although and drier on average, Lake County has paralleled the climate of the state as a whole. Source: NOAA National Center for Environmental Information, "Climate at a Glance," (www.ncdc.noaa.gov/cag/).

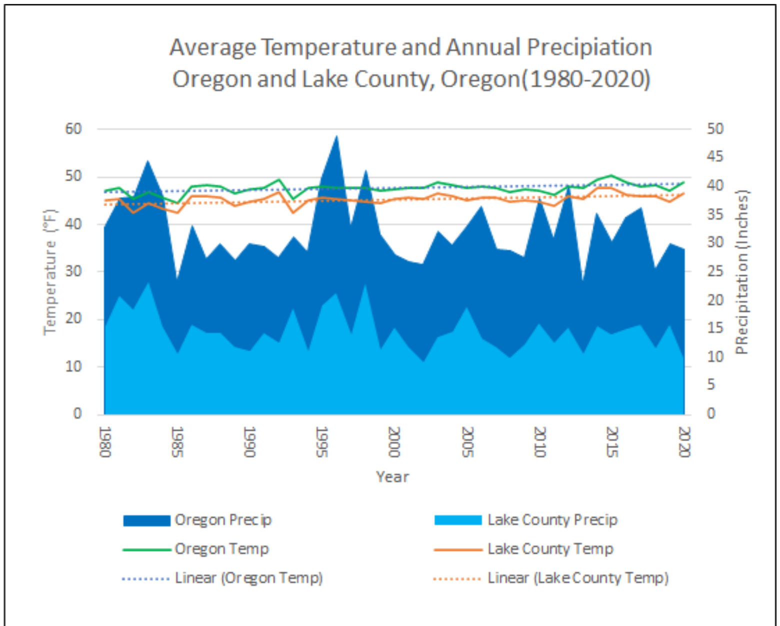

Figure 3. Average annual temperature and precipitation, Oregon and Lake County, since 1980. Source: NOAA National Center for Environmental Information, "Climate at a Glance," (www.ncdc.noaa.gov/cag/).

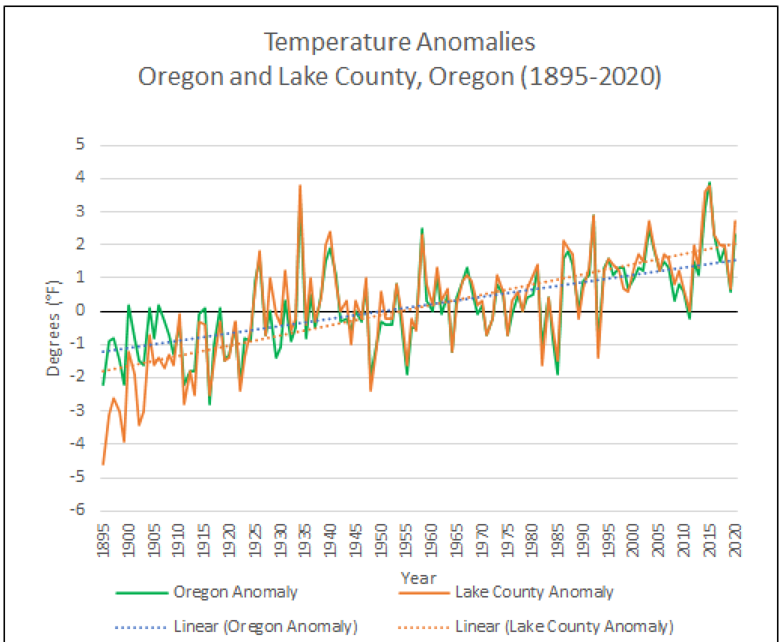

Figure 4. Temperature anomalies (measured as departures from the overall mean), Oregon and Lake County Oregon since 1895, reveal a steady upward climb in temperature. Source: NOAA National Center for Environmental Information, "Climate at a Glance," (www.ncdc.noaa.gov/cag/).

Summary of Climate Projections- Lake County Oregon

The following analysis will examine high and low RCP temperature, precipitation, and high and low days, in the Colvin Timbers region. Temperature and precipitation data from Paisley will be projected from 1980 into 2100 and has been statistically downscaled. The average daily maximum and minimum temperatures and total precipitation for Paisley are projected based on a range of climate models assuming that anthropogenic greenhouse gas emissions either continue to increase or stabilize. Representative Concentrated Pathways (RCP) are derived from estimates of methane (CH^4), sulfur dioxide (SO^2), and carbon dioxide (CO^2) atmospheric concentrations. Estimates in this projection include those derived from RCP 2.6, 4.5, and 8.5 models.

The RCP 8.6 model projects that Paisley may experience a daily maximum average temperature of 60°F and would increase by 8°F between 2020 and 2100 [Figure 1]. The weighted mean in the RCP 4.5 model projects Paisley may experience a maximum daily average temperature of 52 °F by 2100, an increase of 4°F [Figure1]. The weighted mean, in the higher RCP model for minimum temperature, projects that in the year 2020, Paisley would experience a daily minimum average temperature of 33°F and would increase by 7°F by 2100 [Figure 1]. The weighted mean RCP 2.6 model for minimum temperature, projects that in the year 2020, Paisley may experience a minimum daily average temperature of 32°F, an increase of 3°F by 2100 [Figure 1]. Historically, Lake County experienced a temperature of 45.1°F in 1980 and increased by 1.6°F by 2020. This is a much lower increase than what the models projected, as the high RCP was an increase of 8°F and the low RCP was an increase of 4°F.

The weighted mean, in the higher RCP model for total precipitation, projects that in the year 2020, Paisley would experience an average of 14 inches (in) and would increase by 1in by 2100 [Figure2]. The weighted mean, in the lower RCP model for total precipitation, projects that in the year 2020, Paisley would experience an average of 15in and would decrease by 1in by 2100 [Figure 2]. Historically, Lake County experienced precipitation of 15.62 inches in 1980 and decreased by 5.76 inches by 2020. The high RCP model shows a 1 inch increase whereas the low RCP model shows a 1 inch decrease, thus both the RCP increase and decrease are still not as a dramatic change as the historical decrease in precipitation. The weighted mean, in the higher RCP model for days with greater than 1in of precipitation, projects that in the year 2020, Paisley would experience an average of .6in in 2020 and increase by .4in by 2100 [Figure 2]. The weighted mean, in the lower RCP model for days with greater than 1in of precipitation, projects that in the year 2020, Paisley would experience an average of .6in in 2020 and increase by .2in by 2100 [Figure 2]. The weighted mean, in the higher RCP model for days with greater than 3in of precipitation does not appear until the year 2064 at .1 [Figure 2]. By 2100 the days per year with more than 3 inches of precipitation is at 0 [Figure 2]. The weighted mean, in the lower RCP model for days with greater than 3in of precipitation does not appear until the year 2035 at .1, this same weighted mean does not appear in the year 2100 [Figure 2].

Under both the RCP 4.5 and 8.5 models, the area around Colvin Timbers can expect a steady decrease in days below 32°F through the remainder of the 21st century. The average number of days below 32°F by weighted mean will decline from 13.5 days in 2010 to 8.1 days in 2099 under RCP 4.5. The RCP 8.5 model predicts that the number of days below 32°F will decline to just 2.7. Under either scenario, the region may experience less than one freeze day per year.

In contrast, days above 95°F will become far more common as the century progresses. Under the RCP 4.5 model, days above 95°F will increase from the Colvin Timbers region from an average of 3.6 in 2010 to 18.3 by 2099, an average increase of 14.1 days per year through the end of the century . If the RCP 8.5 model comes to pass, the number of days above 95°F may increase to as many as 51 days per year, or an average 47 day increase through the century.

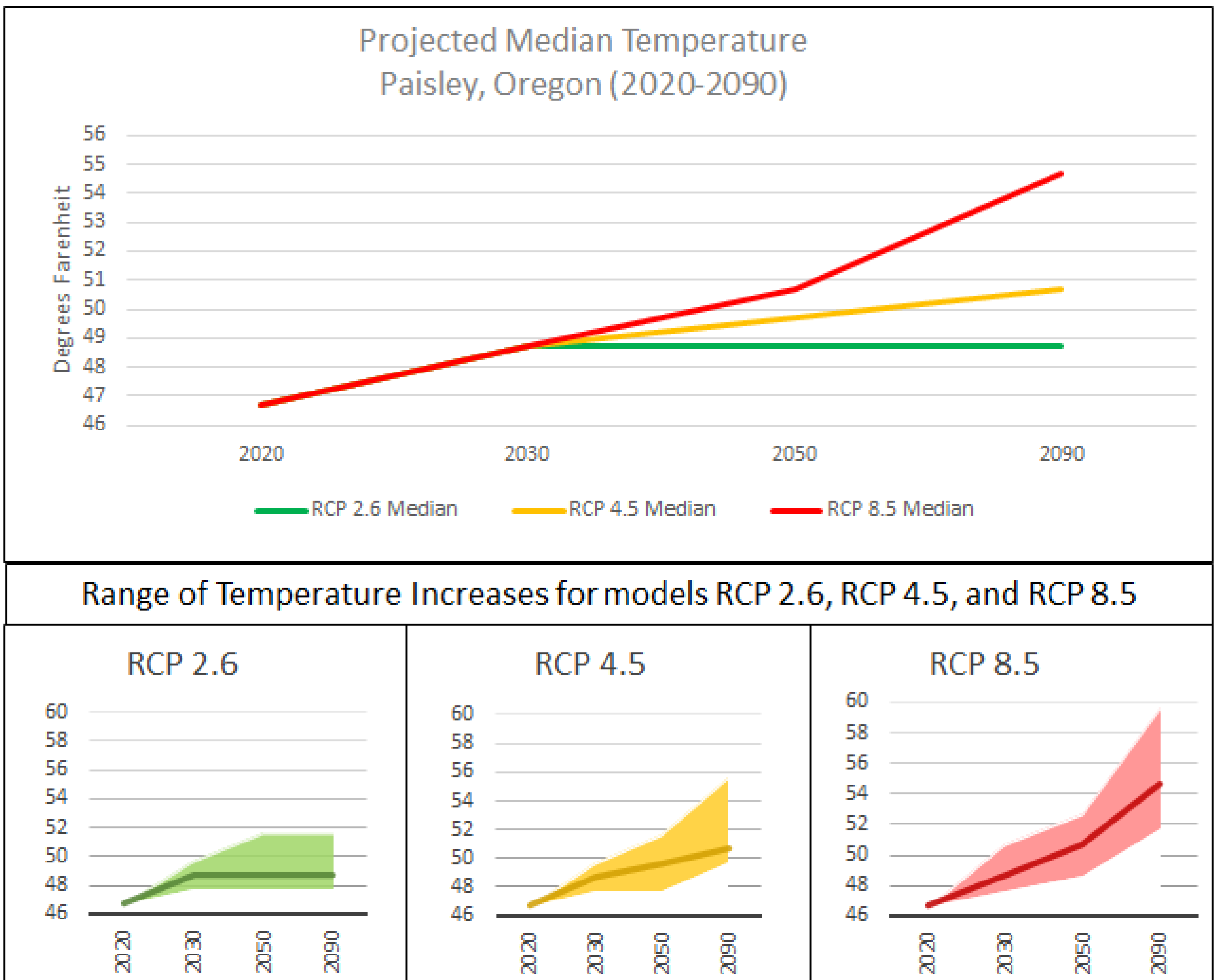

Figure 5. Projected annual median temperature increases and range of increases for RCP 2.6, 4.5 and 8.5 models. Temperature increase projections are based on data derived from statewide estimates provided by the Climate Impact Lab (http://www.impactlab.org/map/).

Figures For Projections

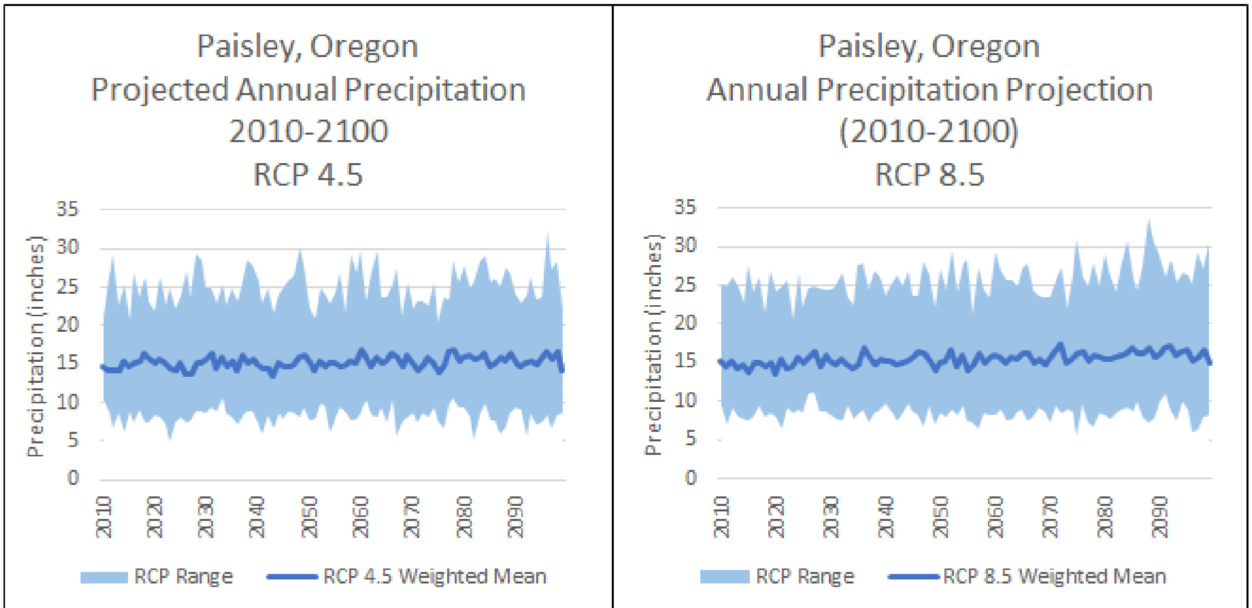

Figure 6. Projected annual precipitation for Paisley, Oregon, 2010-2100 under RCP 4.5 and 8.5 scenarios.

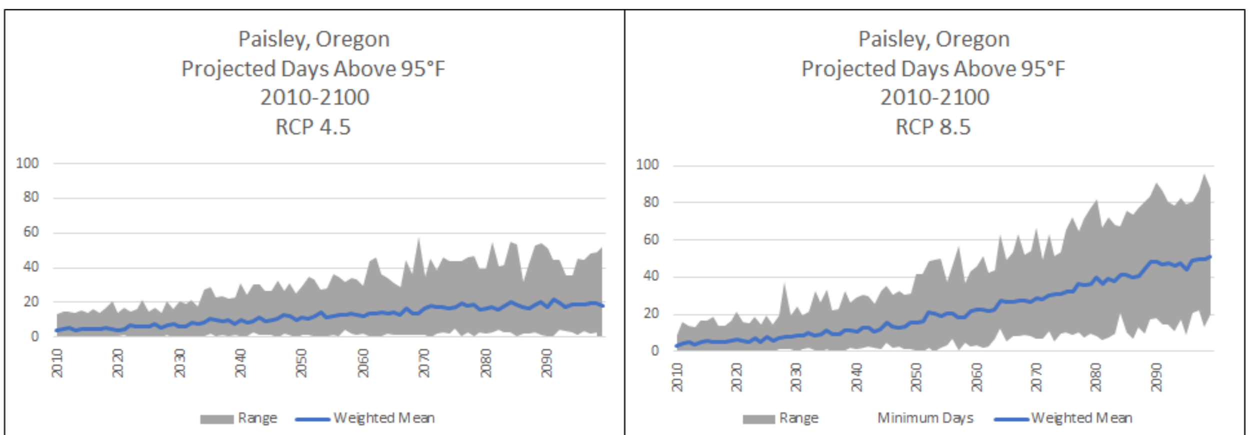

Figure 7. Days above 95° F for RCP 4.5 and RCP 8.5 climate projection models.

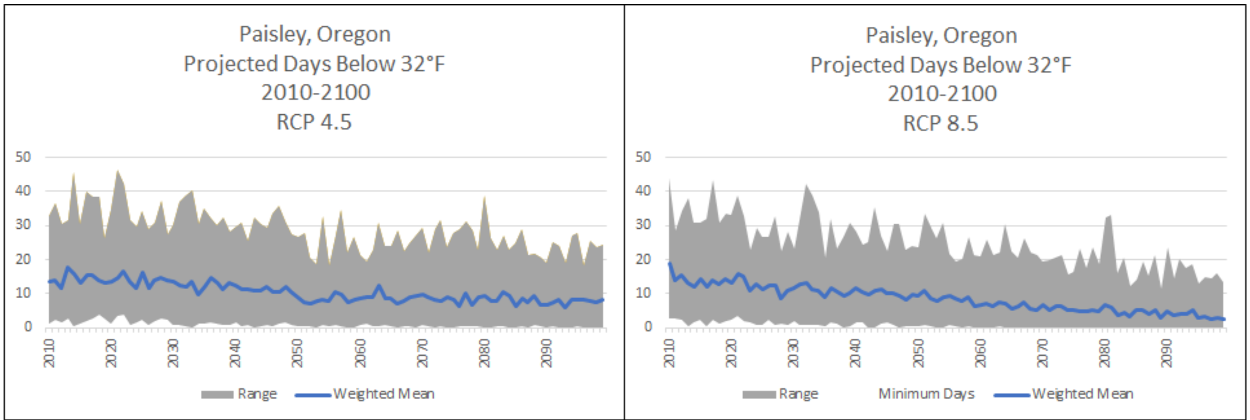

Figure 8. Days below 32° F for RCP 4.5 and RCP 8.5 climate projection models.

Summary of Vulnerabilities- Ponderosa Pine and Aspen

Pinus ponderosa, or ponderosa pine, is native to the Pacific Northwest of America and is vulnerable to temperature, drought, and fire. A study conducting ecological modeling estimated the vulnerability of fifteen tree species in Northwest North America to climate change, including ponderosa pine. Tree species become vulnerable to temperature changes as temperature can constrict the amount of photosynthesis that can be performed; thus affecting overall growth and health of the tree and leaving it vulnerable. This study used a combination of statistical and mechanistic models to evaluate where native tree species ranges may or may not become vulnerable (Coops, N. C., 2011). The areas that remained stable and or became vulnerable were defined by whether or not, "...more or less than half of the years fell within the originally defined limits." (Coops, N. C., 2011). The results varied by species and the study notes that ponderosa pine was classified as vulnerable with possible net shrinkage in range (Coops, N. C., 2011). This study helps to demonstrate that ponderosa pine is and will be vulnerable to increasing temperatures.

Another study directed towards long-term average climate and competition in relation to forest mortality used extensive aerial mortality surveys to assess California forests during an extreme four year long drought (2012-2015) (Young, D. J. N., 2017). The study showed that tree mortality, "increased by an order of magnitude, typically from tens to hundreds of dead trees per km2" (Young, D. J. N., 2017). The study notes that these mortality rates increased (statistically speaking) independently of the CWD and basal area. The results of tree mortality increased in a way that was disproportionate for areas that were both heavily populated and lacking in adequate water supply (Young, D. J. N., 2017). The results help determine that evergreen forests, and thus ponderosa pine, become vulnerable when crowded and faced with drought.

Both drought and temperature changes leave ponderosa pine vulnerable. When combined however, they further increase the pine's vulnerability to fire. A study examines the link between drought and fire intensities on ponderosa pine saplings. This study used watered and drought stressed saplings in two different fire intensity settings. What was found was that no matter what the pre-water looked like, high intensity fires killed the saplings (Partelli, et. al., 2020).

However, at low intensity burns, 70% of the well-watered saplings survived whereas the drought-stressed saplings all died (Partelli, et. al., 2020). It is noted that all saplings experienced reduced photosynthesis regardless of pre-fire water status. Saplings that recovered eventually regained a normal amount of photosynthesis compared to unburned plants (Partelli, et. al., 2020). Overall, this study shows that ponderosa pine saplings become further vulnerable to fire when drought induced stress is present as a pre-fire condition. For ponderosa pine, this could result in mobility and range restrictions as well as die-out, thus leaving the species vulnerable.

In their competition with species such as ponderosa pines, the quaking aspen (*Populus tremuloides*) found within Colvin Timbers will benefit in future decades from certain aspects of climate change, but aspen remain vulnerable due to drought mortalities. The aspen groves within Colvin Timbers stand at more than 6,000 feet within the Abert Rim Wilderness Study Area. The Abert Rim escarpment itself rises over 2,000 feet above the Abert Lake and the US 395 highway to the west. The location is noted for extreme remoteness and is managed by the BLM as a wilderness, meaning the roads within the location are no longer maintained or improved. (BLM, Abert Rim, 2021). Because aspen reproduce through both seeds and root sprouting, they generally rebound faster after fire disturbance than conifers. Aspen are also less susceptible to damage from other disturbances associated with climate change such as bark beetle infestations (Kulakowski, 2013).

The primary vulnerability that confronts aspen due to climate change will likely be from changes in precipitation. Severe droughts have been associated with large and rapid aspen mortality in semiarid locations like Abert Rim. Cole (2020) compared aspen groves in humid versus arid climates. Aspen in Wisconsin, for example, have thrived despite climate change primarily due to high precipitation. Elsewhere, aspen die offs have become more common primarily due to drought. For Colvin Timbers specifically, future climate projections do not indicate large shifts in overall precipitation in coming decades (see Figure 2). Projections suggest, however, that the region will have more days of extreme heat and less frequent freezes (see Figures 3 and 4). These dynamics will lead to greater levels of evapotranspiration in summer months and faster snow melts, faster runoff, and less moisture retention in the soil, especially in intermittent streams or gulleys where aspen tend to thrive.

Summary of Adaptation- Ponderosa Pine and Aspen

As ponderosa pine is becoming increasingly vulnerable to temperature, drought, and fire, adaptation plans can be used to help alleviate these vulnerabilities and protect the species. There are multiple strategies in which to aid in the species adaptation. For temperature this section will look at two different strategies that focus on genetics and monitoring.

Firstly, as one source explains, increasing temperatures and severe droughts will affect forest cover and play a role in tree mortality rates (KOLB, E. 2017). Drought and intense burning are already causing deforestation within ponderosa pine forests, it is expected that this deforestation will increase, "...over the next century as atmospheric temperature and drought severity increase." (KOLB, E. 2017). Diverse genetics can help ponderosa pines adapt to these changing conditions, using arid-adapted genotypes will allow trees to be ready for future climates as, "...they will be more arid than today's climate…" (KOLB, E. 2017). After natural disasters, replanting efforts are common, in order to help ponderosa pine stands adapt for the future climate, planting arid-genotypes will achieve this goal as well as help mitigate the lost forest (KOLB, E. 2017). Overall, a better understanding of, "...the genetics and physiology of aridity adaptation of planted seedlings…" (KOLB, E. 2017) can lead to better restoration efforts and overall adaptation of the ponderosa pine species. Secondly, monitoring ponderosa pines is still vital to our understanding of the species and communities. It is important that we do not stop monitoring these species, even if we have adaptation plans going into practice. The reason for this is because habitats, ecosystems, and species are always in flux. Monitoring the ponderosa pine species throughout climatic changes will allow for better understanding of climatic effects and greater amounts of data that can be used in other studies (Temperate. n.d.). Monitoring also allows us to be aware of ponderosa pine habitat and track movements that may or may not be taking place (Temperate. n.d.). Tracking these movements will also keep our knowledge up to date which will lead to better policy and management decisions.

Adaptation strategies for drought in this section include genetic understanding and high moisture soil planting sites. First, genetic understanding is a great adaptation strategy for temperature, but it can also be used for drought. Genetic variability in ponderosa pine trees can allow for trees of the same species to be suited for different climatic conditions,especially around ecotonal areas at the edges of the species range. One study, "...used a greenhouse common garden to investigate phenotypic variations in growth," (Kolb, T. E., et. al. 2016) as well as experimentational drought and adaptive structural traits for ponderosa pine seedlings (Kolb, T. E., et. al. 2016). It was found that among maternal families within particular sites, phenotypic variability was a significant seedling trait. This suggests that there is, "...the potential for future evolution of stress tolerance in trailing-edge populations." (Kolb, T. E., et. al. 2016). When compared to geography, phenotypic variation had a negative relationship. This means that familial trees from low-elevation dry sites survived longer during extreme droughts (Kolb, T. E., et. al. 2016). Understanding the intraspecific variation will aid in the understanding of tree adaptation to drought, which is important for forest evaluations and management (Kolb, T. E., et. al. 2016). In addition to planting ponderosa pine trees that are genetically varied, replanting efforts should take into consideration soil moisture when choosing planting sites (Temperate. n.d.). Planting seedlings in areas of drought leads to stress and greater mortality rates. By planting them in areas with high moisture content, the saplings will have less drought induced stress and greater ability to grow and flourish.

Lastly, as fire vulnerability increases with temperature changes and drought severity, the use of monitoring will become increasingly important for understanding and management practices. One way that humans can help aid ponderosa pines in adapting is through the use of monitoring trends in climate and forest condition. By monitoring temperature changes, drought, and other related conditions, forest management plans can proactively identify areas that would be at higher risk of forest fires (Temperate. n.d.). Using this method in conjunction with drought and temperature studies will allow management to not only identify areas that are susceptible, but also areas that would be at a higher risk than others.

Recent research indicates that the primary cause of climate change, increased atmospheric CO_2 concentrations, may benefit aspen. Cole (2010) tested experimental aspen groves in a variety of locations to measure how increased atmospheric CO_2 has contributed to increased aspen production versus aspen in other locations or other species. The growth of aspen has increased by 53% in the past half-century in response to a 19.2% increase in ambient CO_2. Aspen forests in locations and times with higher precipitation have featured particularly robust growth rates (Cole, 2010).

Another key adaptation to changes in climate that will benefit aspen in the future is the species' ability to recover from major disturbances to forests. A study on aspen in forests in northwestern Colorado reveal the species' has greater resilience to disturbances than other three species. The region experienced a bark beetle outbreak in the 1940s, a series of harsh windstorms that knocked down vulnerable sections of forest in 1997, and severe fires in 2002. In each case, aspen stands were able to recover more quickly than other tree species if not affected by drought. Perhaps just as important to understanding the ecological significance of aspen is that other trees benefit from the presence of aspen during fire disturbances.

Monitoring and protection offer the most effective means to adapt the aspen in Colvin Timbers to future climate change. Monitoring programs can determine if the resilience aspen has shown toward recent climate change will continue, or if increased heat, drought, fire, and increased atmospheric CO_2 will come to threaten aspen as it does to other species. At the same time, continued ecosystem preservation efforts in locations like the Abert Rim Wilderness Study Area will help prevent further human caused damage to the aspen that reside in Colvin Timbers. Enhanced aspen growth has been shown to contribute to future forest resiliency following such disturbances.

Conclusion

Historically, Lake County has experienced a 5.8°F increase in the last 125 years, as well as a decrease in precipitation by about 4.06 inches. It is projected that within a high RCP model, temperatures will continue to increase by 8°F by 2100. The low RCP model shows an increase of only 4°F by 2100. Projections also show that Lake County may experience an increase in total precipitation by one inch within the high RCP model and or a decrease by one inch within the lower RCP model. With the historical data and projections, we can expect Lake County to become increasingly warmer and somewhat dryer.

Ponderosa pine trees will be vulnerable to these changes in temperature and precipitation, leaving them open to threats such as restricted photosynthesis, drought induced stress, and post-fire mortality increases. The aspen in Colvin Timbers may benefit from the increased atmospheric CO_2 that is the primary culprit of climate change. The primary vulnerability of aspen in the coming decades will be the potential for increased drought.

Adaptation plans that include monitoring and protection programs, genetically diverse sapling plantings, and site conditions, are vital to ponderosa pine adaptation. Monitoring programs and continued preservation efforts of forest ecosystems have the potential to benefit aspen groves to determine the potential for catastrophic loss due to drought or other disturbances. Overall, policy makers and forest management programs should take these plans into consideration when attempting to preserve this area.

References

Bureau of Land Management. "Abert Rim Wilderness Study Area." https://www.blm.gov/programs/national-conservation-lands/oregon-washington/abert-rim-wsa. Accessed March 8, 2020.

"Climate Explorer." https://crt-climate-explorer.nemac.org/. Accessed February 22, 2020.

Climate Impact Lab, "Climate Impact Map." http://www.impactlab.org/map/. Accessed 22 February 24, 2020.

Cole, Christopher T., Jon E. Anderson, Richard Lindroth, and Donald M. Waller. "Rising Concentrations of atmospheric Co2 have increased in natural stands of quaking aspen (*Populus tremuloides*)." *Global Change Biology* 16 (2010), 2186-2197.

Coops, N. C., & Waring, R. H. (2011). Estimating the vulnerability of fifteen tree species under changing climate in Northwest North America. Ecological Modelling, 222(13), 2119–2129. https://doi.org/10.1016/j.ecolmodel.2011.03.033

KOLB, E. (2017). ADAPTATION OF PONDEROSA PINE TO CLIMATE CHANGE. USDA Research, Education, Economic Information Systems. https://portal.nifa.usda.gov/web/crisprojectpages/1014222-adaptation-of-ponderosa-pine-to-climate-change.html

Kolb, T. E., Grady, K. C., McEttrick, M. P., & Herrero, A. (2016). Local-Scale Drought Adaptation of Ponderosa Pine Seedlings at Habitat Ecotones. Forest Science, 62(6), 641–651. https://doi.org/10.5849/forsci.16-049

Kulakowski, Dominik, Carol Matthews, Daniel Jarvis, and Thomas T. Veblen. "Compounded disturbances in sub-alpine forests in Colorado favour future dominance by quaking aspen (*Populus tremuloides*)." *Journal of Vegetation Science* 24 (2013), 168-176.

National Oceanic and Atmospheric Administration, National Centers for Environmental Information. "Climate at a Glance." https://www.ncdc.noaa.gov/cag/statewide/mapping . Accessed January 25, 2021.

Partelli-Feltrin, Raquel; Johnson, Daniel M.; Sparks, Aaron M.; Adams, Henry D.; Kolden, Crystal A.; Nelson, Andrew S.; Smith, Alistair M. S. 2020. Drought increases vulnerability of Pinus ponderosa saplings to fire-induced mortality. Fire 3(4):56. https://www.frames.gov/catalog/62038

Temperate. (n.d.). 2021 Adaptive Plan. Temperate. https://temperate.io/dashboard

United States Forest Service. (Na, Na Na). Aspen Ecology. U.S. Forest Service. https://www.fs.fed.us/wildflowers/beauty/aspen/ecology.shtml

Utah State University. (2017, Na Na). Range Plants of Utah. Ponderosa Pine. https://extension.usu.edu/rangeplants/shrubs-and-trees/PonderosaPine

Western Regional Climate Center. “Recent Climate in the West.” https://wrcc.dri.edu/ . Accessed January 21, 2021.

Young, D. J. N., Stevens, J. T., Earles, J. M., Moore, J., Ellis, A., Jirka, A. L., & Latimer, A. M. (2017). Long-term climate and competition explain forest mortality patterns under extreme drought. Ecology Letters, 20(1), 78–86. https://doi.org/10.1111/ele.12711