Summary of Climate Trends and Projections for Medford and Jackson County
for: Medford Climate Change Adaptation and Resilience Plan

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SUMMARY

A review of the historic climate trends and projections for Jackson County through the century assuming humanity continues the Business-as-Usual behavior of contributing increasing climate pollution to our atmosphere reveals that conditions by 2100 may approach an annual average nearly 10°F above the 1981-2010 baseline. Summers will likely warm more than the other seasons thus increasing evaporation. Precipitation will likely continue at the same overall annual average as historically with greater variability between wet and dry years. Winters will likely see an increase in precipitation with the summer dropping slightly and spring and fall declining marginally. The number of days annually over 100°F will likely rise, possibly reaching over 40 days by the end of the century. This will probably be accompanied by an increasing number of frost and freeze-free days and an expanded growing season though countered by reduced water availability during summer and fall.

Snowfall is expected to decline substantially during the century, dropping to near zero at lower elevations by its end, with precipitation falling as rain at lower elevations rather than snow at higher elevations. The reduced snowpack, with its reduced water content will likely reduce stream flow during late summer and fall and reduce water availability downstream for domestic, commercial/industrial, recreation, and agricultural use. With reduced stream flow, waters will likely be warmer and contain less oxygen compromising the habitat for aquatic species. As the climate warms through summer with little or no increase in annual precipitation, evaporative deficit will climb and both soil and vegetation moisture will decrease.

Among an array of problems generated, this combination of future conditions will compromise health, and water supplies, and elevate the risk of both drought and wildfires spreading rapidly once ignited.

The Historic Average. Those discussing climatic conditions frequently relate current conditions and hopes for the future to some normal or historically average condition. If there is one lesson to be learned from a review of the trends and projections for Medford and Jackson County climatic variables it is that hoping that current harsh conditions will return to historic patterns are unreasonably optimistic. Rather than thinking of our future in terms of some historic 'normal' or 'average' condition, we need to think in terms of the trends and what those trends indicate the future is likely to bring.

Introduction

This discussion of climate trends and projections and consequences is directed at Medford, but some sources, especially the USGS Climate Change Viewer which provides the projections, only narrow down to the county level. I have, therefore, attempted to compare Jackson County data with those for

Medford where such comparisons are available to assess whether the USGS Jackson County projections provide a reliable vision for what Medford is likely to experience in the future. Fortunately, they do.

As will be seen below, in general, the climate projections for Jackson County are simple continuations of the trends we have been experiencing over the last few decades. The following discussion of our potential future is based largely on United States Geological Survey (USGS) data on trends and projections. These are formulated from National Oceanic and Atmospheric Administration (NOAA) data and 20 climate models. Medford historic data are derived largely from the local NOAA Weather Service office and NOAA Climate at A Glance web pages where historic county and city data are displayed.

Graphs from the USGS website depict both recent historic trends and projections through the end of the century. The projections illustrate two scenarios. The red lines (Representative Concentration Pathway - RCP 8.5) depict a scenario that assumes we continue to consume fossil fuels at the accelerating rate we have exhibited to date, resulting in an accelerating pattern of greenhouse gas emissions. The impact of human activity is assessed in terms of the radiative forcing increase since 1750. Thus RCP8.5 represents a scenario where an increase of 8.5 watts per square meter average global surface warming is expected by the end of this century compared to the pre-industrial revolution average radiative forcing. While initially designated the 'Worst Case Scenario' because it was thought we would never achieve that trajectory, RCP 8.5 is now often called the Business as Usual (BAU) scenario because it is exactly the trajectory we are following. Meanwhile, the blue lines (RCP 4.5) assume we change that behavior and trajectory, and substantially slow the rate of accelerating fossil fuel use and GHG emissions by about 50% to increase by only a 4.5 watts per meter squared warming average increase from 1750 by 2100.

Temperature

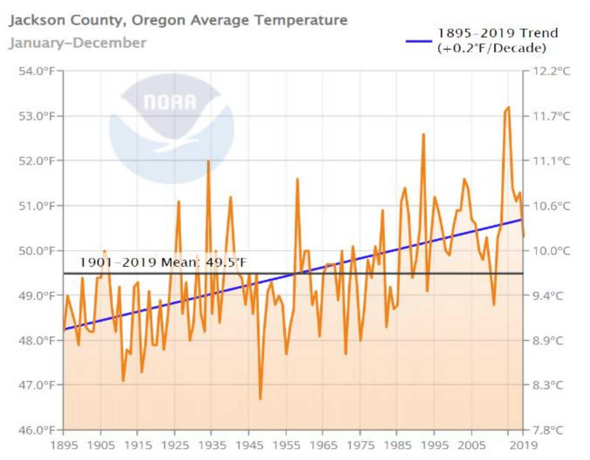

Figure 1. NOAA representation of warming trend in Jackson County, Oregon 1928-2019.
https://www.ncdc.noaa.gov/cag/county/time-series

According to NOAA, the annual mean temperature in Jackson County rose at the rate of 0.2ºF per decade (Figure 1) through the 20th century and up to 2019, signifying a rise of over 2ºF per century during that period. Meanwhile, the NOAA trend for Medford (Figure 2) suggests a warming during the period 1928-2019, the period for which data are available, of 0.4ºF per decade indicating an overall warming of a little more than the county, of some 4ºF per century.

Meanwhile, Figure 3 depicts the Medford temperature pattern as indicated by the local (Medford Airport) weather station from 1915 through 2021. These data suggest a local warming of 2.76ºF per century.

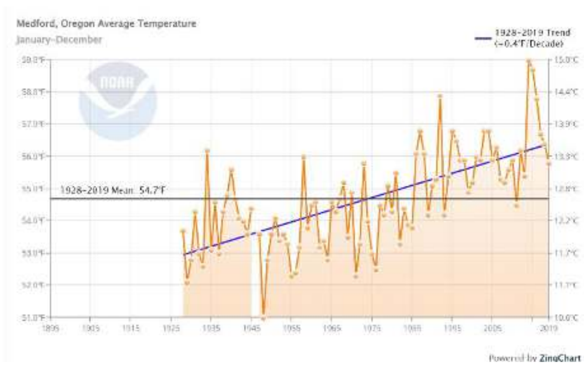

Figure 2. NOAA representation of warming trend in Medford, Oregon 1928-2019.
https://www.ncdc.noaa.gov/cag/city/time-series

USGS data for Jackson County mean temperature (Figure 4 lower graph) depict the historical trend and projections as suggested by the 20 models assessed. The county historical trend suggests a warming of some 1.5^{o}F from the 1981-2010 baseline to 2020, comparable to the range suggested by the Medford city historical data represented in Figures 1 -3.

The similarity between the actual data reported by NOAA and the model simulations developed by the USGS suggest that USGS projection models offer reasonable visions of our future. Thus, we could reasonably infer that the USGS projected Business-As-Usual (BAU, RCP 8.5) average seasonal temperature increase projections from the 1981-2010 baseline to the end of the century as depicted in Figure 4 for the county are reasonable indicators of what will happen in Medford assuming no serious collective effort to combat the cause for the crisis. It is worth parsing these projections among seasons, as depicted in Table 1. These projections reveal more severe warming during the summer (June – August) than other seasons. Meanwhile, by the end of the century, the warming for Jackson County will likely reach 9.4^{o}F above that 1981-2010 average. As will be discussed below, the implication of such a temperature change, should it occur, is alarming.

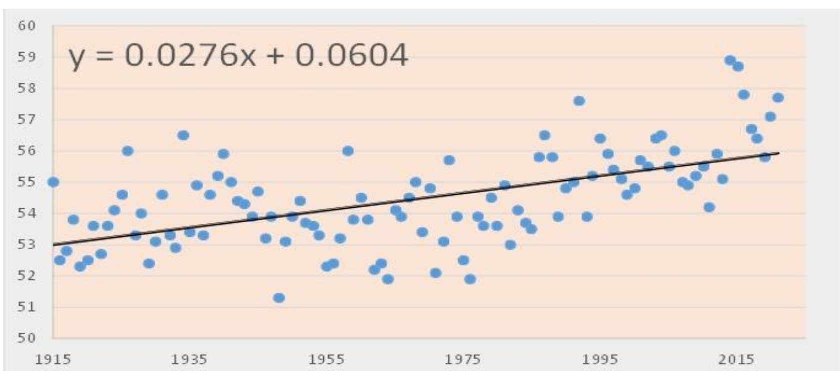

Figure 3. Medford temperature record from 1915 through 2021 from Weather Service data. http://xmacis.rcc-acis.org/

	1981-2010	2025-2049	Increase	2050 - 2074	Increase	2075-2099	Increase
Winter	37.78	40.58	2.8	43.1	5.32	44.75	6.97
Spring	47.61	49.69	2.08	51.0	3.39	53.57	5.96
Summer	64.95	68.42	3.47	71.07	6.11	73.35	8.39
Fall	51.95	54.55	2.6	57.68	5.73	58.5	6.56

Table 1. USGS Mean Historical seasonal 1981-2010 Temperature for Jackson County and projected temperatures and temperature increases for the periods 2025-2049, 2050-2074, and 2075-2099. Values are reported in ^{o}F; Data from - https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

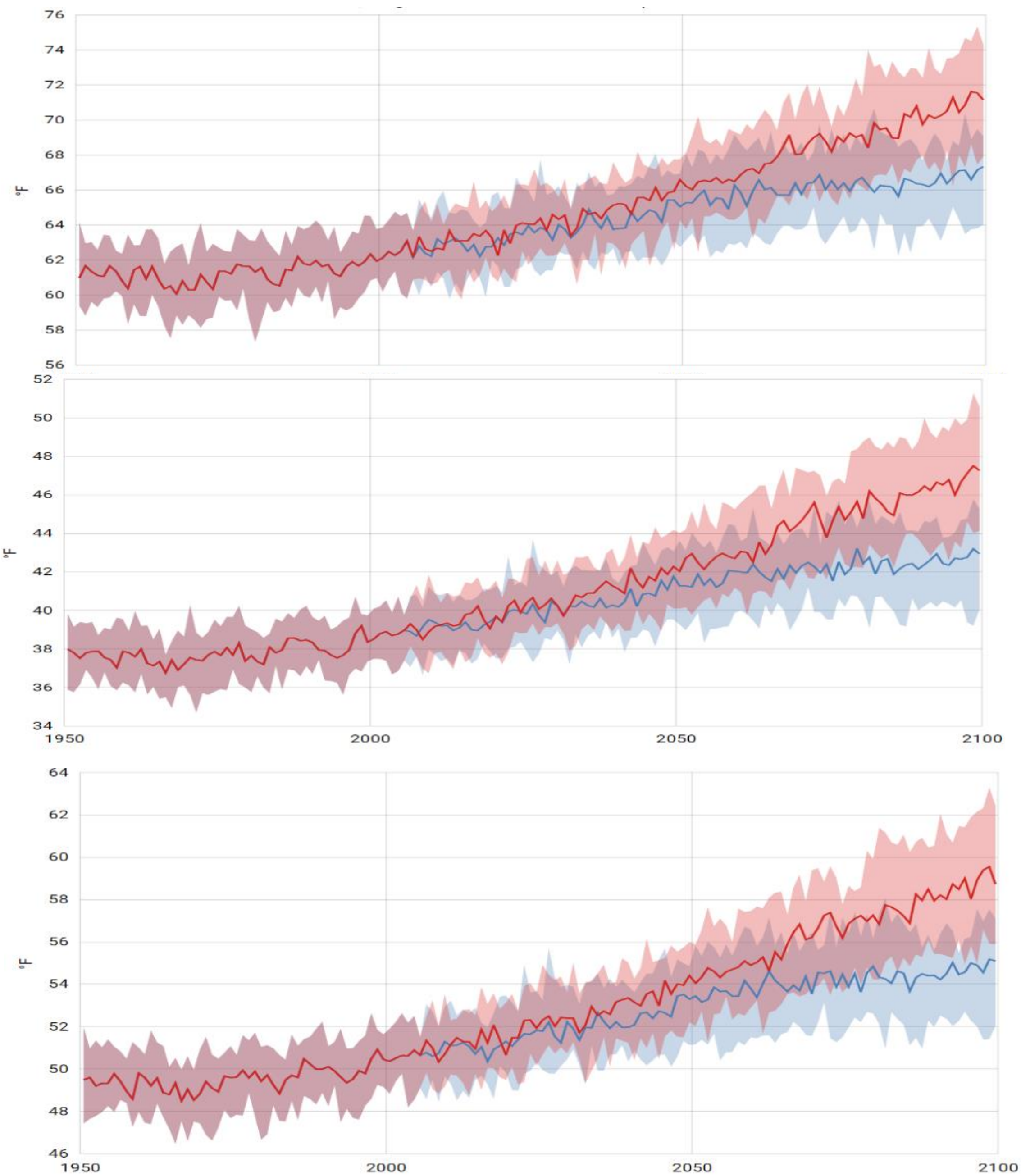

Figure 4. USGS Trends and Projections for Jackson County temperatures: maximum (top), minimum (middle), and mean (lower); red line= RCP 8.5, blue line = RCP 4.5. https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

Although temperature averages are important, equally relevant are extremes. For humans, as well as other organisms, a temperature over 100^{o}F imposes considerable heat burden. Figure 5 depicts the Medford actual trend in number of days annually over 100^{o}F according to the local Weather Service records. Although there is clearly much variability year-to-year, the data indicate an increase from about 7 days to some 11 days annually during the last century and the first two decades of this century. Rising at a rate of half a day a decade, this projection would reach 15 days by the end of the century. Meanwhile, projections from NOAA suggest that under the high emissions scenario, this number may

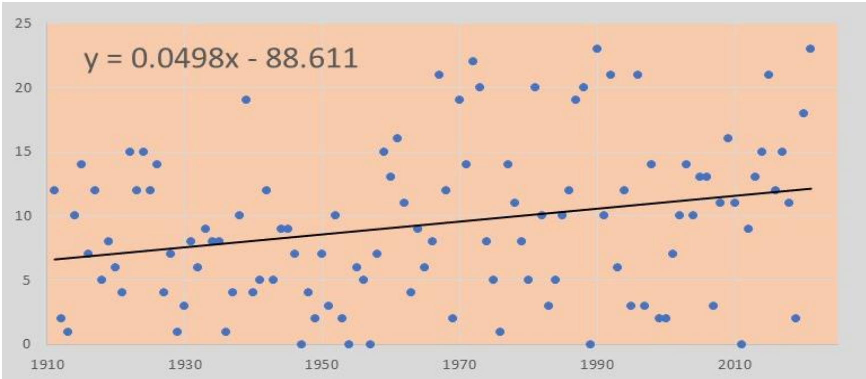

Figure 5. Trend in the number of days over 100°F from 1911- 2021.
http://xmacis.rcc-acis.org/

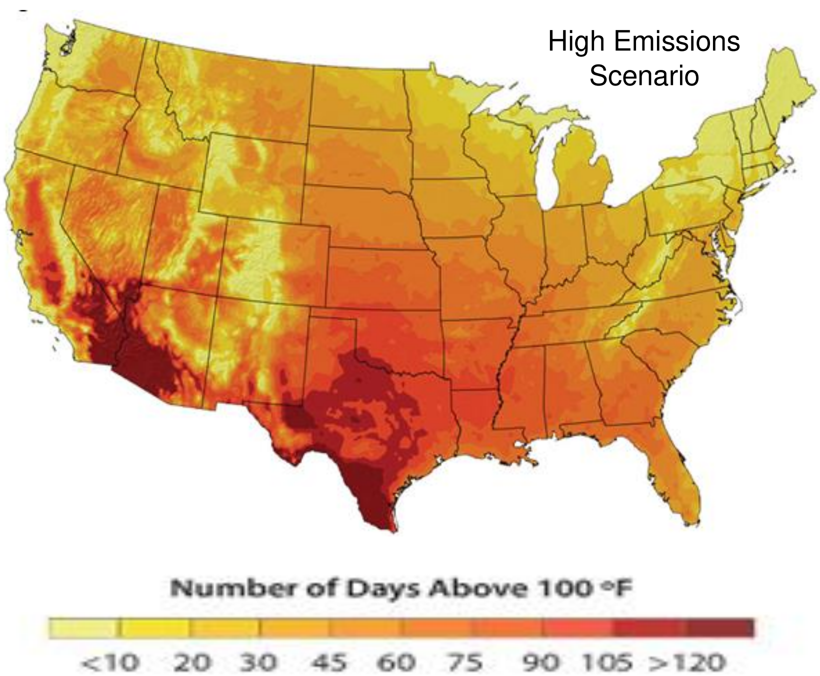

Figure 6. Projected number of days over 100°F by the end of the century under the high emissions scenario.
https://www.climate.gov/media/2879

reach some 45 days annually by the end of the century (Figure 6). A cautious approach might be to plan for the worst and hope for the best.

Degree Days

The concept of degree days is employed in studies of the growth and development of ectothermic (cold-blooded) flora and fauna, and in assessing human heating or cooling needs in construction.

In the biological context, the concept is based on the reality that the metabolic processes that drive growth and development of organisms are possible down to a critical temperature. Below that threshold, no development occurs. Naturally, it can be reported in Centigrade or Fahrenheit. Thus, if no development occurs below (for example) 51°F, and three consecutive days exhibit an average temperature of 53°F, the number of degree days is (53 – 51) = 2 (degrees) times 3 (days) = 6 DDs. In the construction arena, the cutoff is designated as 65°F. Thus, a temperature above that demands cooling and produces cooling degree days while temperatures below that demand heating and produce heating degree days. In a cooling climate the number of heating degree days would be expected to rise, while the number of cooling degree days would fall. The reverse is the case in a warming climate: cooling degree days increase and warming degree days decline.

Figure 7. Medford annual heating degree days trend; downloaded from NOAA Medford Regional Data Center http://xmacis.rcc-acis.org/

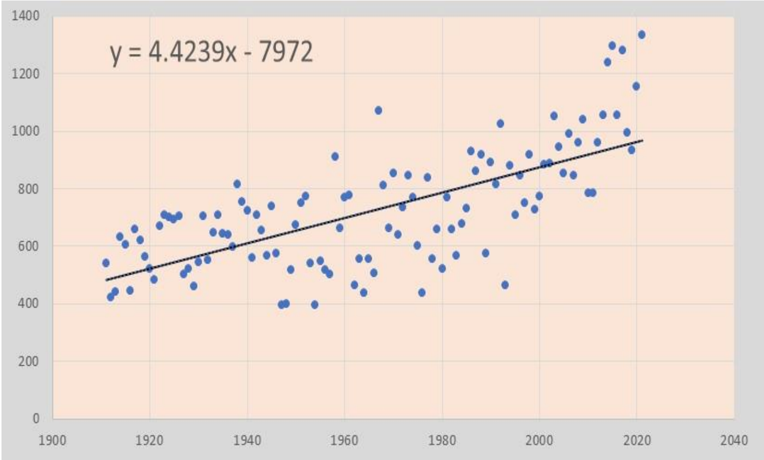

Figure 8. Medford annual cooling degree days trend; downloaded from NOAA Regional Data Center Medford. Data from http://xmacis.rcc-acis.org/

The historic trend in Medford, reveals exactly the pattern identified above for a warming climate. Indeed, heating degree days are falling at the annual rate of 5.8-degree days per year (Figure 7), while cooling degree days are climbing at 4.4-degree days per year (Figure 8). Undoubtedly, realization of the temperature projections depicted above will result in a continuation in the reduction in heating degree days and an increase in cooling degree days.

Of particular relevance to those engaged in agricultural activities is the length of the growing season. Depictions of the number of frost-free days (Figure 9), length of the frost-free season (Figure 10), number of freeze-free days (Figure 11), and length of the freeze-free season (Figure 12), indicate an increasing trend for all throughout the last century. The number of frost-free days is increasing at the rate of over 3 days per decade while the number of freeze-free days is increasing at nearly 3 per decade. There is no reason to expect other than these trends will continue. Summer drought, however, might negate the apparent benefits of this trend.

Figure 9. Medford - Number of frost-free days (> 36^{o}F) annually 1912 – 2021; data from http://xmacis.rcc-acis.org/

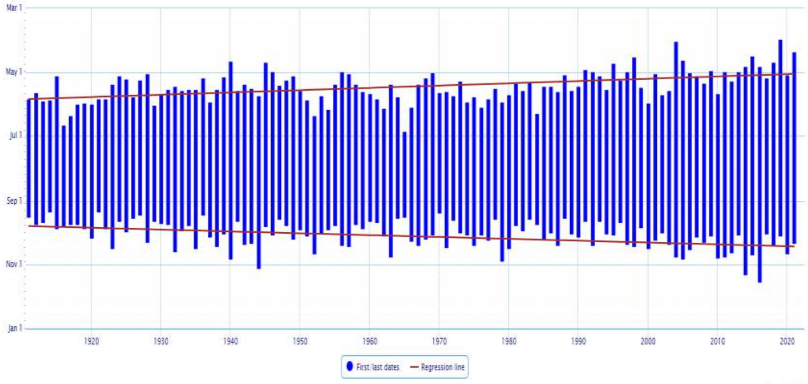

Figure 10. Medford - Length of frost-free season 1912 – 2021; data from http://xmacis.rcc-acis.org/

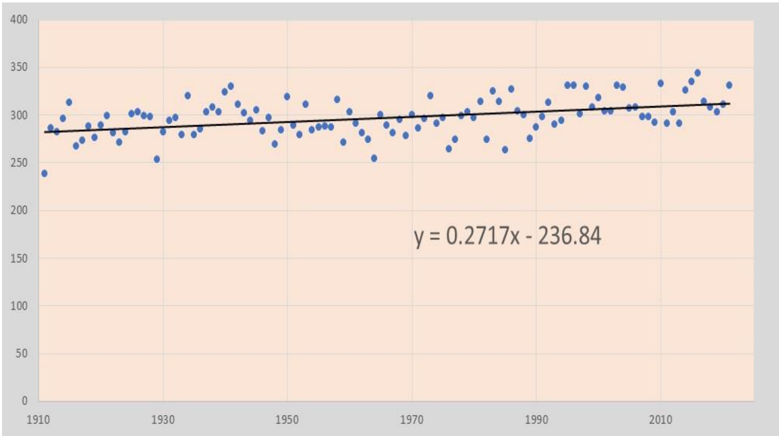

Figure 11. Medford - Number of freeze-free days annually 1912 – 2021; data from http://xmacis.rcc-acis.org/

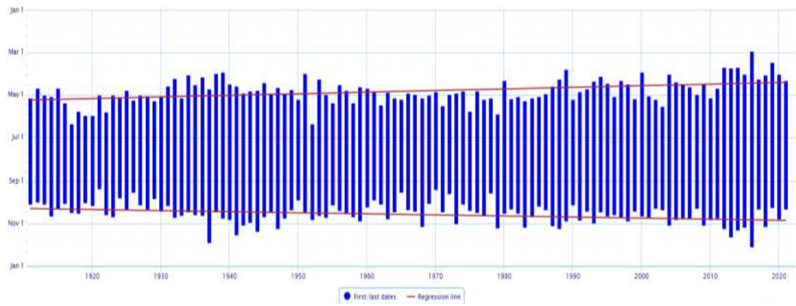

Figure 12. Medford - Length of freeze-free season 1912 – 2021; data from http://xmacis.rcc-acis.org/

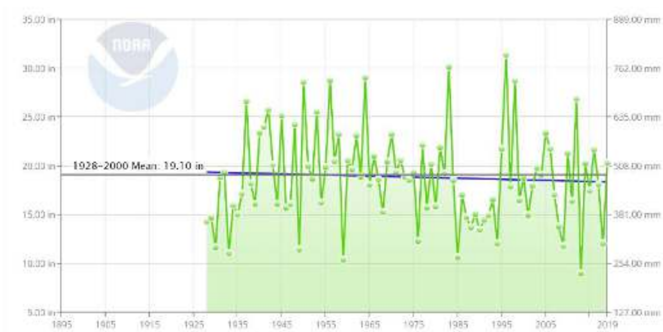

Figure 13. NOAA data on Mean annual precipitation for Medford from 1928 – 2019. https://www.ncdc.noaa.gov/cag/city/time-series/USW00024225/pcp/ann/7/1895-2019?base_prd=true&begbaseyear=1901&endbaseyear=2000&trend=true&trend_base=10&begtrendyear=1895&endtrendyear=2019

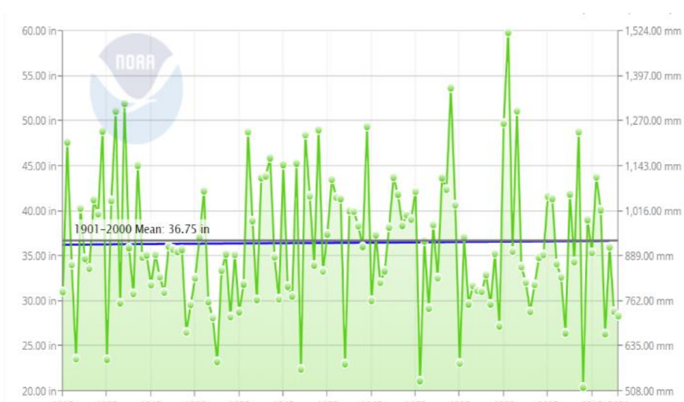

Figure 14. NOAA data on Mean annual precipitation for Jackson County from 1895 – 2021 https://www.ncdc.noaa.gov/cag/county/time-series/OR-029/pcp/ann/7/1895-2021?base_prd=true&begbaseyear=1901&endbaseyear=2000&trend=true&trend_base=10&begtrendyear=189

Precipitation

Historical precipitation data for Medford (1928-2019) and Jackson County (1895-2019) available from NOAA (Figures 13 and 14) reveal a pattern that exhibits no historical change. Although the Medford graph depicts a slight reduction (0.11 inches per decade) and the Jackson County graph depicts a slight increase (0.03 inches per decade), these lines are so close to horizontal as both to be statistically identical to flat.

By the same token, local weather station data (Figure 15) indicate a history of variability in annual precipitation in Medford, but neither an increasing nor decreasing trend.

Unsurprisingly, the USGS historical data and projections (Figure 16) reveal exactly the same pattern – no change in the past or through the coming century. This is evident for both the RCP 8.5 and RCP 4.5 scenarios. The only change that is evident in the future is a potential increase in variability, with wet years becoming wetter, and dry years drier

Of note from the county data (Table 2) is the seasonal trend. This indicates that winters will likely become slightly wetter, while all other seasons will likely become drier.

In addition, it is anticipated that precipitation will continue the trend towards rain falling on fewer days with larger downpours rather than the soil replenishing drizzle that has historically occurred.

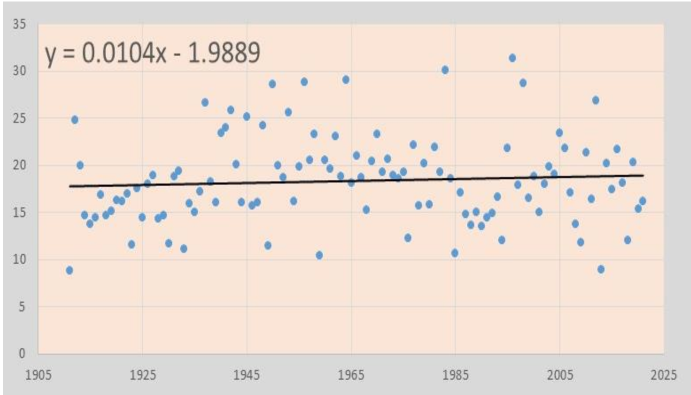

Figure 15. Medford annual precipitation data downloaded from NOAA Regional Data Center Medford http://xmacis.rcc-acis.org/

	1981-2010	2025-2049	Change	2050-2074	Change	2075-2099	Change
Winter	4.88	5.14	0.26	5.36	0.47	5.56	0.67
Spring	3.16	3.16	0	3.1	- 0.06	2.97	- 0.19
Summer	0.76	0.72	-0.04	0.72	- 0.03	0.7	- 0.06
Fall	2.91	2.89	-0.02	2.79	- 0.12	2.81	- 0.1

Table 2. USGS Mean historical seasonal 1981-2010 precipitation for Jackson County and projected precipitation and increases for the periods 2025-2049, 2050-2074, and 2075-2099. Values are reported in inches; Data from: https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

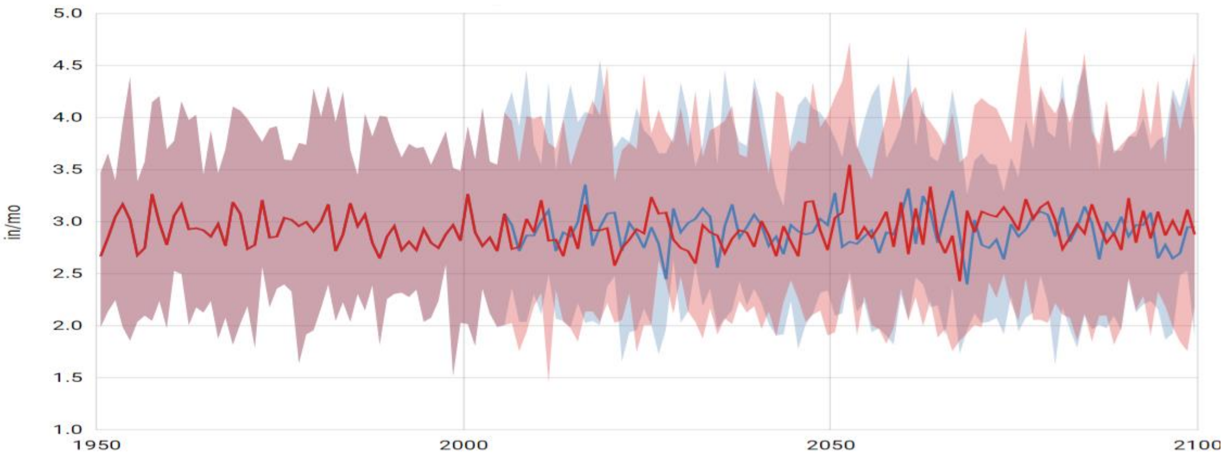

Figure 16. USGS depiction of precipitation history and projection for Jackson County. https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

Snowfall

While those who enjoy winter sports such as skiing and snowboarding are concerned about snowpack depth, from a biological perspective, the important element in winter snow accumulation is the water

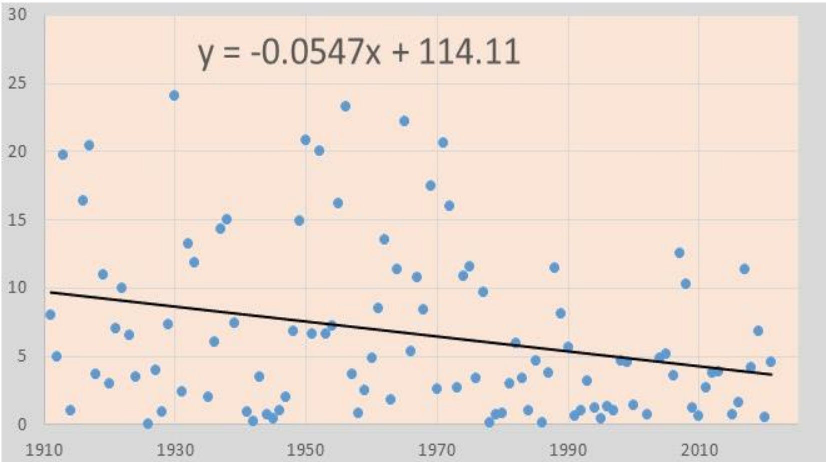

Figure 17. Medford annual snowfall in inches 1911-2021; data downloaded from NOAA Regional Data Center Medford http://xmacis.rcc-acis.org/

content of that snow, defined as Snow Water Equivalent. This amounts to about 10% of the actual snowfall, though some snow is wetter than other snow.

Figure 17 depicts Medford snowfall accumulation in inches during the last century. The pattern is clearly one of much variability among years, but overall substantial reduction at the rate of 0.5 inches per decade.

Meanwhile, the county trend in Snow Water Equivalent depicted in Figure 18 indicates recent reduction and a further substantial projected reduction by 2100. Indeed, the projections suggest that by the end of the century annual snow accumulation will likely approach zero under the RCP 8.5 scenario, with RCP 4.5 suggesting little better. Since these data average values across the county, it is important to appreciate that they probably mask the continued snowfall at high elevations, though this will be reducing assuming the downward trend in Figure 19 for Crater Lake snowpack continues.

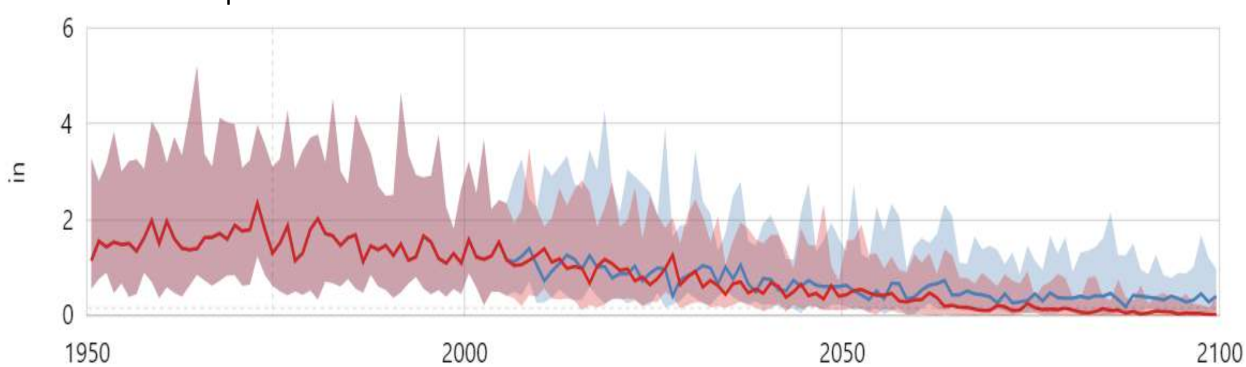

Figure 18. Mean annual snow (SWE), Jackson County. - https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

The expectation is that rather than reaching high elevations and falling as snow, precipitation will likely fall at lower elevations as rain. That this trend is already underway is illustrated by the snowpack data from Crater Lake (Figure 19) which clearly indicates that, while it’s variable, snowpack has been dwindling since the 1930s at the remarkable rate of over 2.5 inches per year.

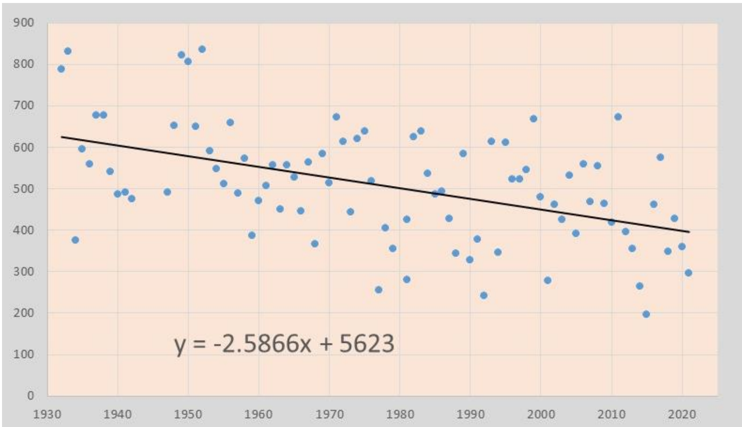

Figure 19. Snowfall at Crater Lake National Park from 1932/33 to 2020/21. Data from Crater Lake N.P.

Temperature Precipitation Consequences

While the temperature trend looks serious and the precipitation trend seems benign, the combination has dire consequences. As temperature increases, particularly during summer and fall, evaporation rate increases. Since precipitation is not projected to increase correspondingly, the consequence includes an increase in the evaporative deficit. This is a function of the difference between the amount of water that the prevailing temperature will potentially cause to evaporate, and the amount of water actually available to evaporate.

The evaporative deficit in the county (Figure 20) has been rising and is expected to continue to rise under both scenarios. The result of this trend is indicated in the soil moisture projection. The trend and projections for soil moisture (Figure 21) reveal a continuing decline through the century.

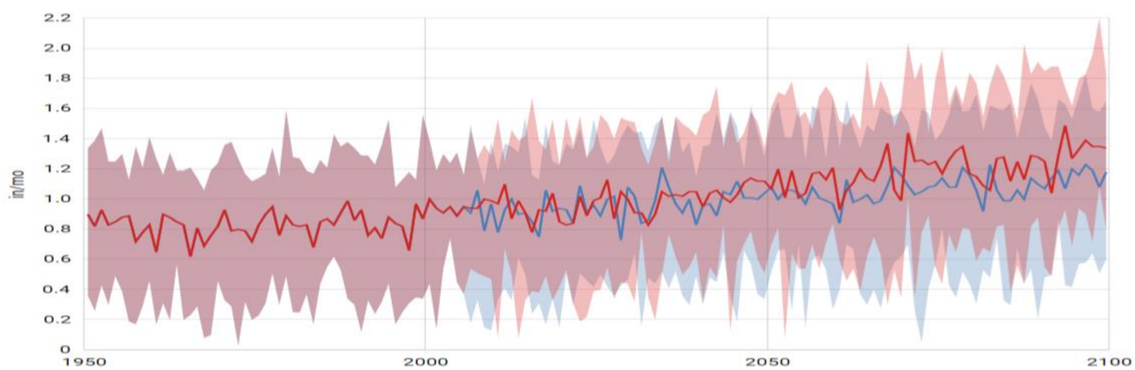

Figure 20. Recent historical and projected evaporative deficit in Jackson County through the century. https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

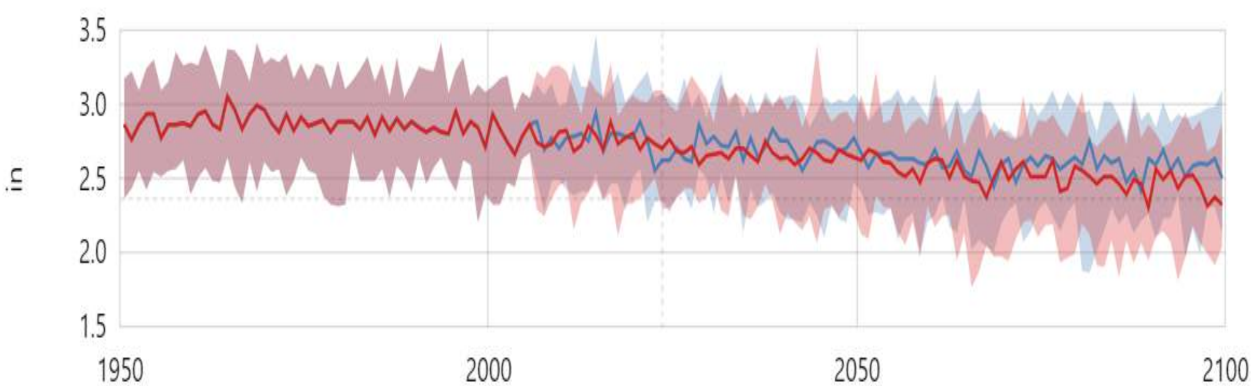

Figure 21. Mean annual soil moisture, Jackson County.
https://www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_counties.html

Potential Impacts

A reasonable consequence of this set of temperature, precipitation, snowpack, and evaporative deficit trends is drought. It is worth recalling that the temperature and precipitation patterns in this region are typical of a Mediterranean climate (Figure 22), named after that region in Europe where the same winter wet / summer dry conditions prevail. These unusual conditions occur in but six regions of the world. The consequence is that soils annually dry out, as does the vegetation. A common consequence of this is increased later summer/fall fire risk. Indeed, vegetation in such regions tends to be fire prone, fire adapted and fire dependent. This is certainly the case for the dry forests of Southern Oregon.

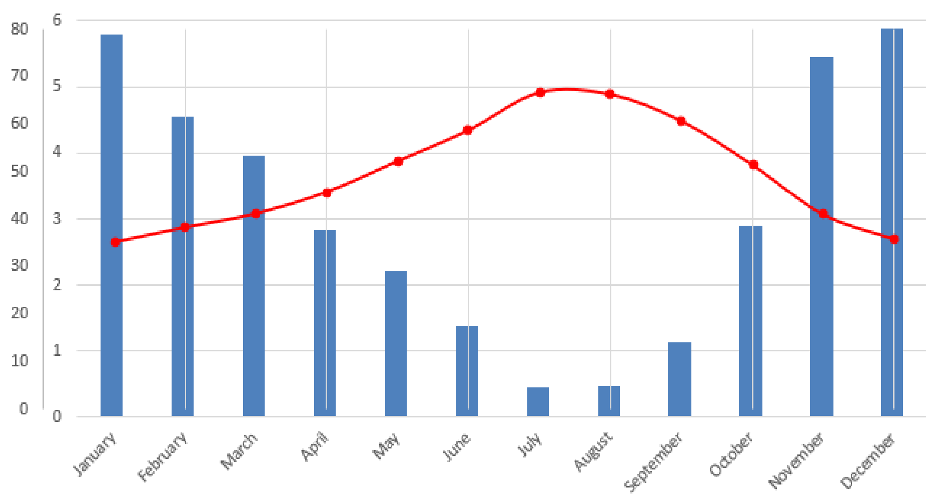

Figure 22. Patterns of temperature and precipitation in the Mediterranean climate of Jackson County; blue bars indicate monthly precipitation; the red line depicts the monthly temperature.

The trends in seasonal temperature increase and precipitation change suggest that summers will become drier through the century. This will increase the risk that fires, once ignited, will spread rapidly.

An analysis of drought potential for the Western United States (Ault *et al.* 2014) suggested that this region has a 40% – 50% chance of experiencing an 11-year drought, and a 20% – 50% chance of experiencing a 35-year mega-drought. Williams *et al.* (2022) recently reported that the Southwestern U.S. is experiencing the driest 22-year period since 800.

As growing season temperature rises, snowpack dwindles, and spring snowmelt arrives earlier, soils will likely dry out earlier and more extensively during summer, with the region anticipating substantially higher wildfire risk. Indeed, these are exactly the factors that correlate with higher fire risk (Westerling *et al.* 2006). Marlon *et al.* (2012), among others, suggest that the western U.S. is experiencing a substantial fire deficit as a result of regional global warming and changing precipitation patterns. Meanwhile, Melillo *et al.* (2014) argue that only a 2.2^{o}F temperature increase will result in a 300% increase in area burned. In addition to the recreational and economic losses, increased wildfire risk brings greater health risks from smoke and micro-particulates.

The impact of the array of climate trends anticipated for the region is troubling. In addition to the health effects, the combination suggests serious problems for agriculture, forestry, and natural systems because these are all profoundly influenced by the combination of temperature and precipitation patterns that the global warming trend disrupts both globally and regionally.

Should the variables discussed above shift to the extent suggested by the projections, the region will experience considerable disruption. It is recommended that we understand the potential impacts, do whatever we can to avert them, and simultaneously manage ourselves and our biological systems in such a way as to help us and them adapt to the changes that are a consequence of the emissions already released.

Heat Balance

One reality that is important to appreciate when considering biological effects is the heat balance of organisms. While humans, other mammals, and birds are endothermic – generating their own body heat and regulating body temperature physiologically, ectotherms (bacteria, protozoans, insects, fish, amphibians, reptiles, plants) are dependent on external ambient temperature. From a threshold below which no development occurs, up to a critical temperature, above which overheating and death occur rapidly, warming leads to increased metabolic rate, more rapid growth, and development, and thus larger populations. Most pathogens and infectious disease organisms fall into this category, as do their vectors. A warming climate thus leads their populations to overwinter more successfully, increase in numbers more rapidly and their range to expand towards the North and South Poles and up in elevation.

Natural Systems

Several decades ago, R.H. Whittaker (1970) developed a chart (modified in Figure 23) depicting the distribution of the world's natural ecosystems (biomes) in relation to average annual temperature and precipitation. The distribution of biomes around the world is determined largely by these two variables, acting in combination with soil characteristics. The message is that if these variables are modified, even minimally for biomes on the edge of current conditions, the survival of current biomes and the species of which they are composed will likely be severely undermined, potentially to the point of their being eliminated at least regionally and maybe globally. The biome edge likely to suffer most is the so-called 'trailing edge.' For example, if temperature is increasing, the trailing edge in Figure 23 would be communities at the warmer (lower) edge of the acceptable temperature range as the vertical axis 'shifts' up the graph. In the northern hemisphere the trailing edge is the southern (hotter) edge of the range, as temperatures increases southerly populations are increasingly compromised. As warming occurs, populations at the northern (leading) edge of their range become exposed to more conducive temperatures and can expand their range north or up in elevation.

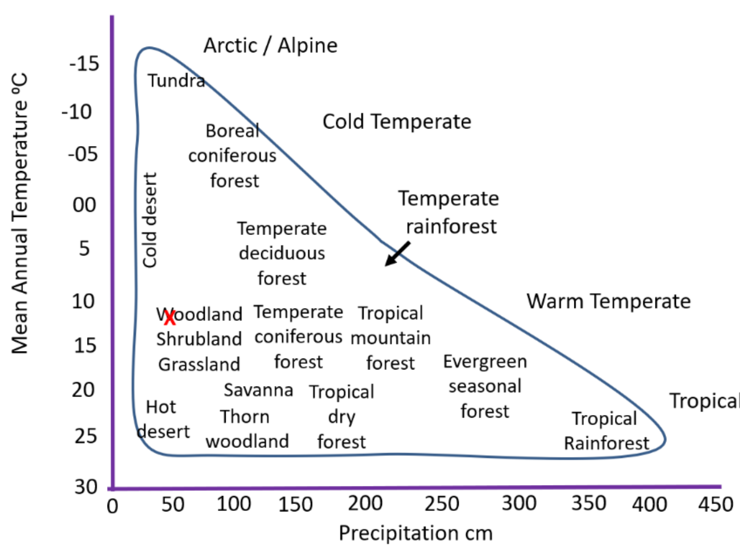

Figure 23. Distribution of natural ecosystems in relation to temperature and precipitation. (Modified from Whittaker 1970)

The relevance of threats posed by a changing climate is not limited to the loss of biodiversity (native flora and fauna / wildlife). In addition, our agriculture, outdoor recreation areas, critical watersheds, and valuable resources such as forests; will also be compromised. This is because human agriculture and forestry are dependent on exactly the same two variables (temperature and precipitation – water availability) that control the success of biomes. The best illustration of this is the fact that the American grain belt down the central tier of states of the U.S. exists where the natural biome of grassland / prairie historically existed. Thus, if we compromise natural biomes, we also compromise our agriculture, and our commercial forestry.

By modeling future conditions globally under different atmospheric greenhouse gas concentration scenarios, Williams and Jackson (2007) illustrated the problem clearly (Figure 24). They explored climate under future carbon dioxide concentrations of 850 and 550 ppm (parts per million) representing substantial increases from the historical (pre-industrial revolution) concentration of about 280 ppm,

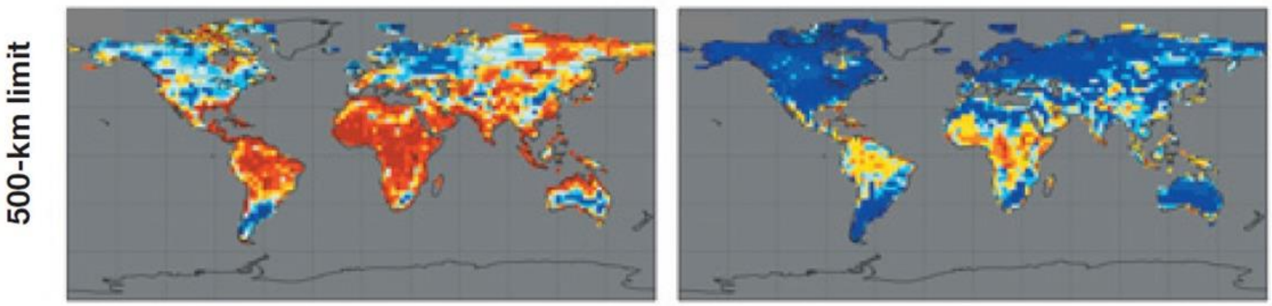

Figure 24. depictions of future biome survival probability under two atmospheric carbon dioxide concentration scenarios (left 850 ppm; right 550 ppm) from Williams and Jackson (2007)

comparing to the then current concentration, at that time approaching 400 ppm. The concentrations they chose represent where we might reach during this century according to the BAU scenario (850 ppm), as compared to the scenario comprising a less dramatic trajectory of rising emissions (550 ppm). Note that the problems are not imposed by the carbon dioxide concentrations but by the climate shifts the greenhouse gas imposes 5- 9^{o}F for 850ppm; 3.5 – 6.3 5^{o}F for 550 ppm). Areas that are red indicate there is no possibility that a biome will find a suitable location within the designated distance of 500 km, while blue areas indicate a probability of 100%.

While they also asked the question of whether there would be anywhere on the planet that climate would be suitable for current biomes, the more interesting question concerned possible climate availability within the depicted 500 km of the current location. This is a reasonable criterion for biomes since native flora and fauna have a limited capacity for dispersal to locations at great distance from that currently occupied. This distance is controlled by the dispersal capacity of propagules (seeds, juveniles and breeding adults). Additionally, human activities and infrastructure (agriculture, cities, roads etc.) now present barriers to the natural dispersal potential of many species.

It is critical to appreciate both that global warming and attendant climate change consequences are driving the climate projections, and that the projections refer to climate not where biomes will exist since there are many barriers to biome range shift. Rather, they map where climate will be appropriate for current biomes within 500 km. What these authors suggest is that under the 850ppm scenario most of northern (tropical / sub-tropical) South America and Africa will be devastated. Biomes of the coastal Southwestern and Southeastern United States and northern and southern Australia are similarly threatened as are the biomes of much of Asia. Most natural ecosystems in these regions will find nowhere within a reasonable dispersal distance that climate is suitable. Additionally, note the threat to the grassland biomes and the grain belt of the Central United States. See below for a discussion of potential impacts on Southern Oregon forest species and agriculture. While these outcomes are reported globally, the implications of this future are equally relevant to the natural ecosystems, agriculture, and forestry of Jackson County. The red ‘x’ on Figure 23, for example, identifies Medford’s climatic location and historic vegetation. A few degrees of warming can shift the climate away from that which supports the woodland / shrubland / grassland natural ecosystems of our region.

Forestry and Agriculture

The impact of future conditions on forests is of particular concern in SW Oregon. Westerling *et al.* (2006) identified warming during the growing season and timing of spring snowmelt as two variables that correlate with increased wildfire activity. As would be expected, warmer summers and earlier spring snowmelt correlate with high fire years since these lead to dryer conditions during already hot and dry late summer and fall.

Meanwhile, Rehfeldt *et al.* (2006 and http://charcoal.cnre.vt.edu/climate/species/) evaluated the impact of future conditions on the viability of western tree species. As an example, the current and future viability and range for Douglas fir and Ponderosa pine (Figures 25 and 26 respectively) in Oregon reveal a climate that will negatively affect viability. The color represents viability from 0 (grey), 0.5 (yellow) through 0.75 (green) to optimal - 1 (red). Both species are projected to exhibit range contraction in this region. The maps show the current distribution on the left and the future scenario, 90 years from now, on the right.

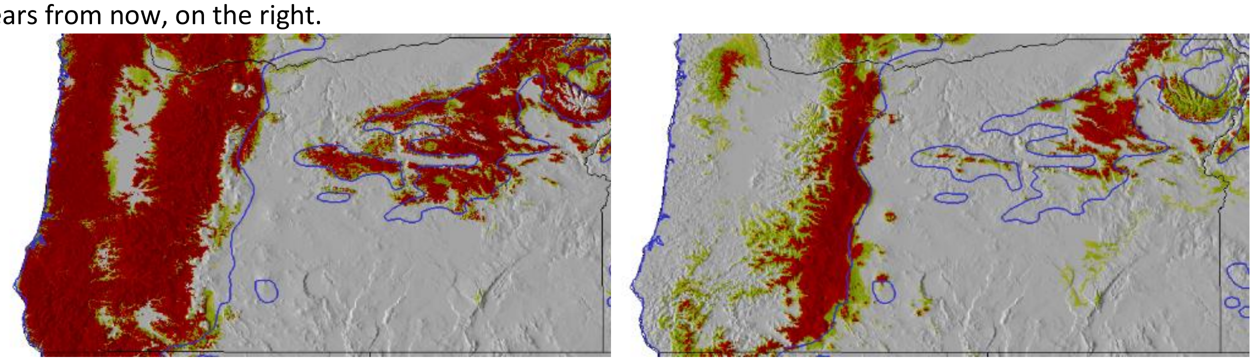

Figure 25. Douglas fir distribution and viability through 21st century.

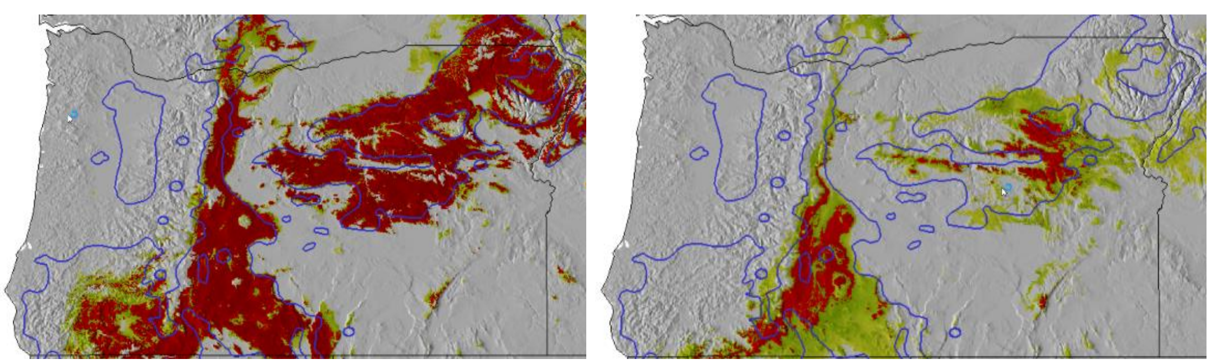

Figure 26. Ponderosa pine distribution and viability through the 21st Century:

In addition, according to Rehfeldt's models, by late century Oregon's climate will likely be completely outside the range of the Lodgepole pine, Sitka spruce, Engelmann spruce, and Subalpine fir. Many other ecologically and commercially important species will be severely compromised.

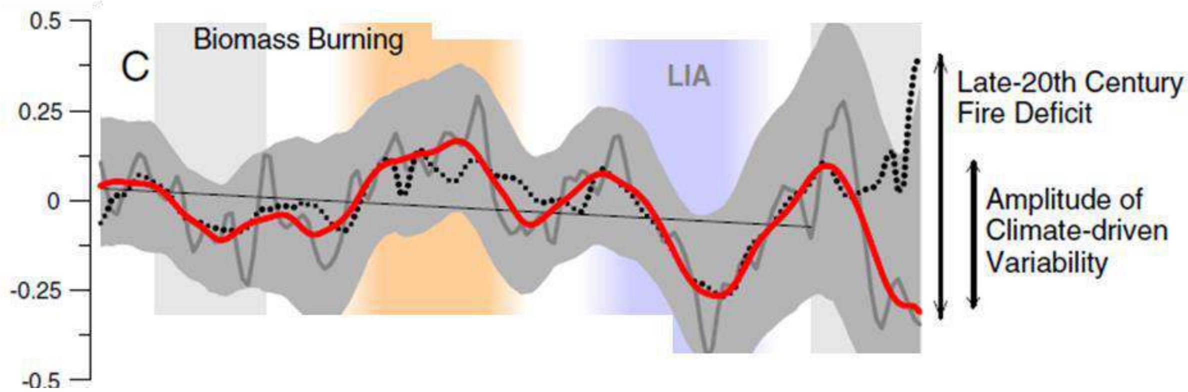

Figure 27. Relative changes in biomass burning in the Western United States for the past 3,000 years indicating the current fire deficit. Marlon *et al.* 2012

Given that many of the climate trends reported above can be traced back to the 1970s, it should be no surprise that the wildfire season in the Western states has expanded some three months since that time

(Kenward et al. 2016). Data from the Interagency Fire Center indicate that the number of wildland acres burned has increased since 1970 (Climate Central http://www.climatecentral.org/western-wildfire-trends). Meanwhile, reports suggest that both the number of western acres burning and the size of western fires has been increasing since the 1970s. However, analyses that include earlier decades and centuries yield a slightly different perspective. Marlon *et al.* 2012, for example, report (Figure 27) that we are currently experiencing an unusually low level of biomass burning. In fact, given the temperature and drought conditions present in the western forests, these authors conclude, that we are experiencing a profound fire deficit. Meanwhile, studies of burn scars in tree trunks reveal that the historical natural fire return interval (average period between fire events in a given location) through much of the dry forest of the Rogue Basin was less than a decade (Metlen *et al.* 2016). This represents a marked difference from current trends since the imposition of fire suppression in the last century. The fire return interval has lengthened to between 40 and 10,000 years (Metlen *et al.* 2015). With climate change, the tendency will be to return to the pattern of the earlier fire return intervals and extent as area burned increases.

Figure 28 charts fire frequency and area burned for lands managed by Oregon's Department of Forestry from 1911 through 2020. Fire frequency displays variability but overall, a reasonable level trend. Meanwhile, area burned was clearly high during the early years of the last century, dropped from the 1940s through 1970/80s and then rose again. Two explanations have been proffered for this trend: (1) one suggests that fire suppression imposed during the early years of the last century and amplified by the Smokey Bear campaign successfully suppressed fires that were ignited – until the 1970s/1980s when an increased density of invading fire intolerant understory vegetation encroached into the system. This provided fuel that allowed fires, once ignited, to spread more rapidly. (2) The Pacific Decadal Oscillation, a phenomenon that switches periodically between warm dry conditions and cooler wetter conditions in Pacific Northwest influenced conditions conducive to fire. During the early years of the last century the warm phase prevailed, promoting enhanced fire conditions. This transformed to the cool phase about

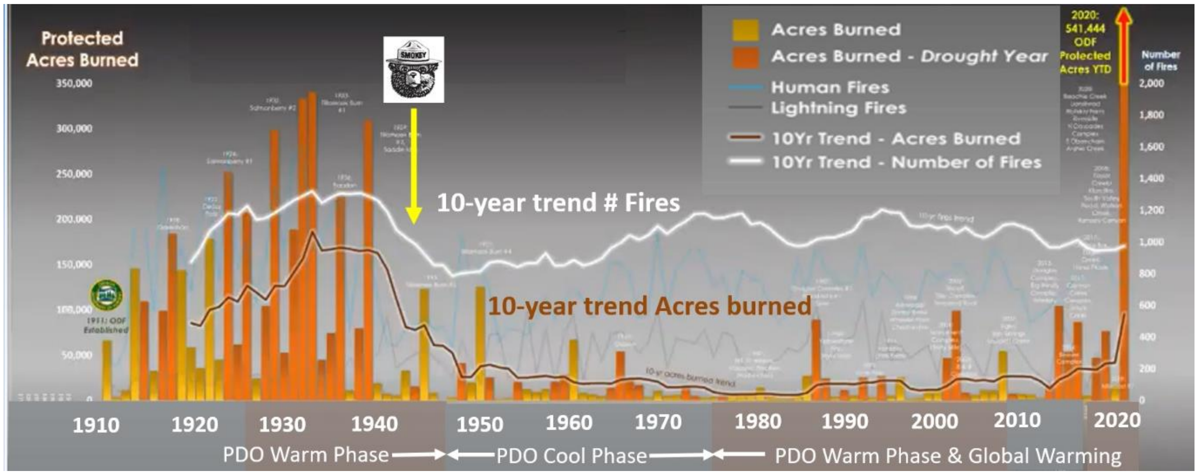

Figure 28. Oregon Department of Forestry Fire History 1911-2020
https://digital.osl.state.or.us/islandora/object/osl:938188

1940 inducing a reduction in fire conditions. This lasted until the 1970s, whereupon the dry phase returned stimulating fire conditions. The impact of the Pacific Decadal Oscillation phases was then superseded because global warming took over as the dominant climate influence throughout the region. Continued global warming thus will likely continue enhance wildfire risk throughout the western United States. The appalling events of 2020 are, as can be seen, “off the charts.” That the explanation comprises a combination of these ideas is possible

Regional Agriculture

Two examples will illustrate the potential impact of these climate trends on our local agriculture: grapes and pears.

Figure 29 depicts the growing season optimum temperatures for wine varietals grown in Southern Oregon (Jones 2006). On this, the late 20th Century 1961-1990 April to October growing season temperature average is superimposed for the growing season (blue line), along with the 2075-2099 projected average (red). The chart suggests the wisdom displayed by vintners who have adjusted to warming through the century by adopting warmer growing season varietals along with conservation irrigation and other dry farming management techniques. Unless extreme temperatures are achieved, warmer grape varietals can protect the wine industry. As is evident, the worst-case scenario is for the climate to change such that only table grapes and raisins can be grown here. The pattern among grape varietals where colder season varietals are being and will be further compromised can be generalized to other local agricultural crops and their varietals. Farmers and gardeners should study these trends and adapt accordingly.

While the warmer and drier conditions during the growing season are one potential problem facing crop production, another is the absence of a sufficient number of chilling hours during winter when the temperature is between 32 and 45 ^{o}F. The chill requirement is potentially a threat for perennial crops which need to meet that requirement in cool hours to allow the production of flower buds. The chill requirement for Bartlett pears, for example, is about 800 hours. While warming winters are not yet sufficient to pose problems for the spring development of pears, with continued warming, this could

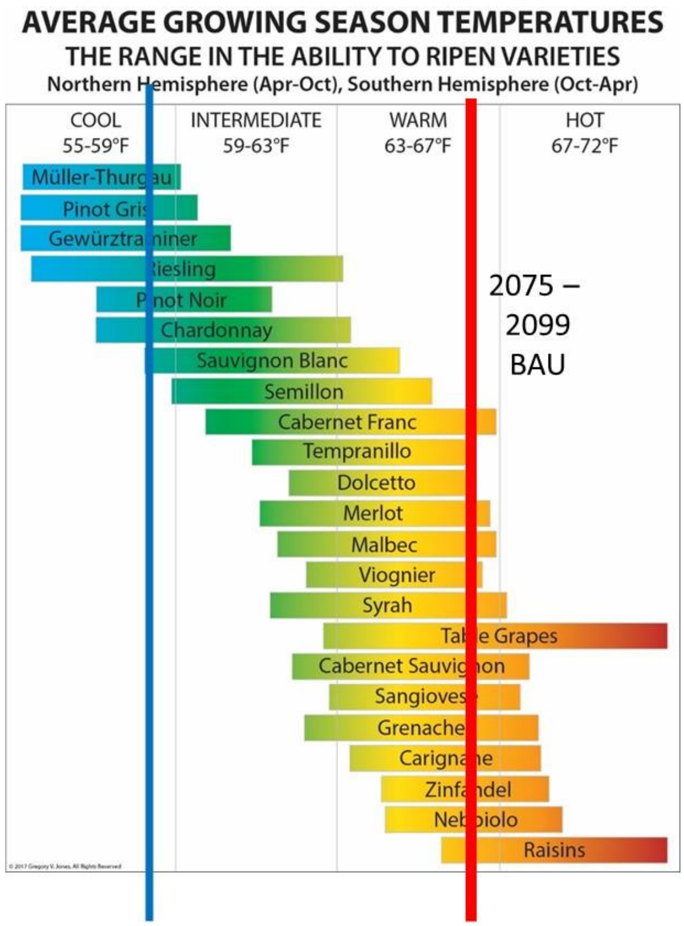

Figure 29. Optimal growing season temperatures for grape varietals typical of the Rogue Basin. Blue: 1960 – 1999 actual average temperature, Red 2075 – 2099 projected temperatures. Modified from Jones (2006). © Gregory V. Jones

become a concern in the future. This requirement explains the southern limit on successful pear growing region.

Freshwater Resources

The impact of the changing climate on our freshwater systems should also be considered. As Myer (2013) reported, the water quality in many of our streams is already compromised. Depleted flow and warming water can only make matters worse – threatening our iconic fish species and the health of our waters for irrigation and consumption. Warmer waters result in reduced oxygen concentration compromising fish and invertebrate species and causing massive fish kills. Warming waters also stimulate more rapid development conditions for water and vector borne disease organisms.

Salmon, for example require the following conditions that are likely to be compromised:

- Sufficient flow of cold water to facilitate successful migration upstream and healthy food supply which may be threatened by warmer waters
- Low flow for eggs and fry which may be threatened by heavy rains and flooding
- Cold water again for developing par is threatened as above
- Species that remain in the freshwater streams for more than a year require adequate food

Severe Weather

Studies have suggested that a primary factor inducing severe weather is the loop in the polar jet stream (e.g., Francis and Vavrus 2012, Screen and Simmonds 2014). Research indicates that the flow of the jet stream is influenced by the difference in temperature between the Arctic and Temperate regions. When this difference is large, the Jetstream tends to flow fast and direct (Figure 30 left). But when the difference is reduced, as is happening because the Arctic is warming faster than the temperate zone, the jet stream is slowed and the wave amplitude is increased (Figure 30 right). As a result, bursts of cold Arctic air sweep south (the polar vortex) and/or warm tropical/sub-tropical air sweeps north. In general,

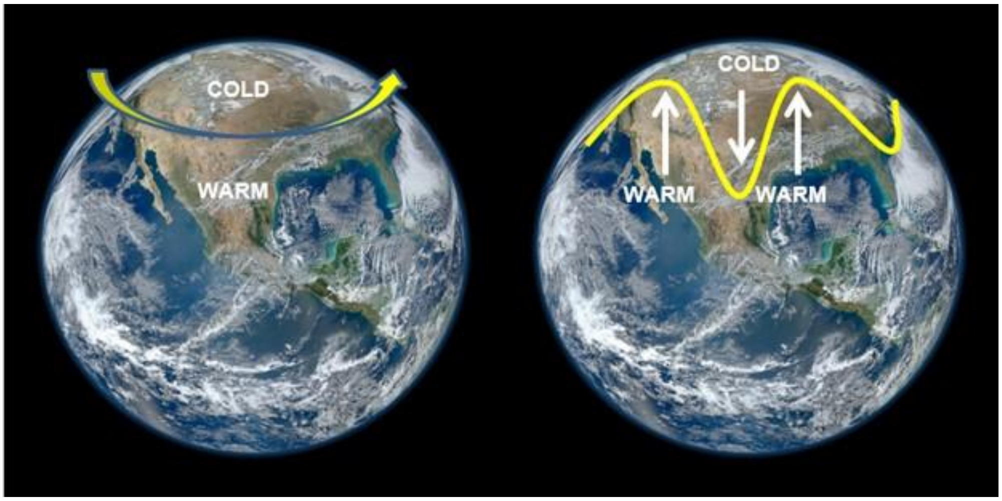

Figure 30. The Polar Jetstream adjustment

more bouts of extreme weather (storms, floods, heat waves, droughts, etc.) are experienced in temperate North America when the Jetstream wave amplitude increases. Since the warming Arctic is likely to reduce this temperature difference even further, Oregon should anticipate an increase in the frequency of extreme weather events.

Health

It is possible that the direct effects of global warming and climate change on human health are among the most serious that we face in the short term; they are, reasonably, among the potential effects that generate most interest and concern among residents.

The following notes have been modified slightly from Oregon Heath Authority and the U.S. Global Change reports.

From Haggerty (2015) dealing with Oregon concerns:

Some communities will be affected more than others.

Climate change is likely to make health disparities worse.

- Some populations, like communities of color and low-income households, already bear a disproportionate burden of disease.
- These groups face more exposures to hazards and have fewer resources to recover from climate change related impacts.

Risk is higher among certain groups

- Native Americans risk further loss of cultural traditions, sustenance and way of life.
- Older adults are more at risk of heat-related illness and death.
- People in low-income urban neighborhoods are at greater risk of heat-related illness due to the urban heat island effect.
- People living on steep slopes are at risk of landslides and those living at the interface of wildlands are more at risk of wildfire.
- Residents on the coast are more at risk from extreme storms.
- Private well users may be at greater risk of water insecurity.
- People working outside, such as farmworkers and construction workers, are more at risk of negative health effects.

- People working on the front lines of emergencies, including firefighters and first responders, are more at risk of injury and death.
- Children face cumulative impacts over their lifetime, which will be greater than those of earlier generations.

We can work together to protect our families and communities.

Oregon's Public Health Division is taking action to reduce risks.

- Oregon's Public Health Division recognizes that climate affects health in many ways. They are working to further understand our risks and what we can do to prepare for the changes ahead.
- Addressing health disparities and prioritizing the needs of our most vulnerable communities will build Oregon's overall resilience.

Collaboration is essential to building our resilience.

- Taking action requires collaboration across agencies, sectors and cultures.
- Innovative solutions come from our many diverse communities.
- Adapting to climate change includes building local capacity and leadership in traditionally underrepresented communities.

Everyone has a role to play.

- Everyone has a role to play in protecting and improving our quality of life in Oregon. Learn more at: **www.healthoregon.org/climatechange.**

Meanwhile, USGCRP (2016), addressing national concerns, pointed out that: "Every American is vulnerable to the health impacts associated with climate change" (p. 3). They listed the major concerns nationally as follows:

- *Extreme Heat:* More frequent severe prolonged heat events cause elevated temperatures which lead to increases in heat related deaths and illness.
- *Outdoor Air Quality:* Increasing temperatures and changing precipitations patterns cause decreasing air quality (ozone, particulate matter, higher pollen counts) which lead to premature death, acute and chronic cardiovascular and respiratory illnesses.
- *Flooding:* Rising sea level and more frequent or intense extreme precipitation, severe storms, and storm surge events cause contaminated water, debris and disruptions to essential infrastructure which lead to drowning, injuries, mental health consequences and other illnesses.
- *Vector-Borne Infection:* Changes in temperature extremes and seasonal weather patterns cause earlier and geographically and seasonally expanded tick and mosquito range, leading to increased tick-borne diseases such as Lyme disease and mosquito borne diseases such as malaria.
- *Water-Related Infection:* Rising sea surface, stream, river, and lake temperature, changes in precipitation and runoff affecting coastal salinity cause contamination of recreational waters and marine and freshwater aquatic food which lead to diarrhea, intestinal illnesses, circulatory system infections, and death.
- *Food–Related Infection:* Increased temperature, humidity combined with an extended growing season lead to increased growth rate in pathogens accompanied by seasonal shifts in exposure

to such disease agents as *Salmonella* lead to increased risk of gastro-intestinal disease outbreaks – such as *Salmonella* poisoning.

- *Mental Health and Well-being:* Climate change induces increased temperatures and extreme weather events, which results in increased exposure to heat waves and traumatic events such as disasters. In turn, these result in distress, grief, behavioral health disorders (aggression) and impacts to social resilience.

Chapter 2 of the Medford Natural Hazards Mitigation Plan (DLCD 2017) discusses some of these issues.

More recently, the Oregon Health Authority's Oregon Climate and Health Profile Report (OHAPHD 2017) considers the following:

It starts with building our workforce capacity to promote the following:

• The plan includes case studies and videos that highlight how our public health workforce is already taking action to build community resilience.
• Our Climate and Health Program is leading a collaborative of local health departments across the state who are implementing resilience strategies.
• Climate and health strategies in the new Resilience Plan include:

*policie*s,

- Actively engaging with our diverse community partners and elevating the voices of our most vulnerable populations to inform policy priorities.
- Informing policies that affect air quality and reduce air pollution.
- Promoting policies that strengthen our local food systems.

systems,

- Conducting regular monitoring of climate and health indicators, and monitoring the progress made on our resilience strategies.
- Equipping our health care partners with the information they need to protect patients from climate-related health risks.
- Supporting community-driven climate adaptations that contribute to building an evidence base for effective climate and health interventions.

and environments,

- Promoting community improvements that encourage walking, biking and the use of public transit.
- Helping to ensure access to safe places for communities to gather, build community and take refuge.
- Prioritizing public health interventions that address the root causes of health inequities and preventable diseases in Oregon.

Figure 31. Outline image of S. Oregon and California indicating future Medford climate possibilities. Map: http://www.netstate.com/states/maps/images/ca_outlinebord.gif

A Living Reference Point

By mid-century, it is suggested the Medford summer climate (Figure 31) will resemble that currently experienced by Redding, CA (Mote 2015) with a July average high of 96.8^{o}F and an average January low of 38^{o}F , (http://www.bestplaces.net/climate/city/california/redding). Meanwhile, by 2100 Medford summer is likely to experience the current climatic conditions in Delano, CA (near Bakersfield) (http://www.climatecentral.org/news/summer-temperatures-co2-emissions-1001-cities-16583 with 10 inches of annual rainfall, 0.1 inches of annual snowfall, an average July high of 99.9^{o}F. (http://www.bestplaces.net/climate/city/california/delano).

Conclusion:

Since about 2012, we have frequently heard that 97% of climate scientists agree with the consensus that global warming is happening and that human-induced emissions are responsible. A recent analysis of climate science literature published after 2012 by Lynas et al (2021) suggests that the percentage of publishing climate scientists agreeing with the consensus has grown to at least 99%, and maybe 99.9%.

Since the FEMA definition of a natural hazard as: “a source of harm or difficulty created by a meteorological, environmental, or geological event” and the Homeland Security (2021) defines it as an event “which result from acts of nature, such as hurricanes, earthquakes, tornadoes, animal disease outbreak, pandemics, or epidemics” it seems that events resulting from global warming and the climate change disruptions that follow should be included in a Climate Change Adaptation and Resilience Plan. The consensus among climate scientists is that the major driver of the global warming that causes the climate disruptions discussed here is human-induced emissions of greenhouse gases.

Global warming and climate disruptions are currently causing, and will undoubtedly continue to cause an increasing frequency of hazardous events. It is worth noting that the main impact will probably be from both the basic advancing and destructive trends as much as from extreme events. Efforts should be directed to recognizing and preparing for these trends as much as preparing for the extreme events.

One of the clearest messages to be gleaned from the climate trends and projections is that planning should take into consideration what these trends and projections suggest about our future. While we are generally accustomed to relying on recent historic average as the norm which suggest what the next few years will reveal, we should abandon that approach and focus on trends. Unless some serious international effort is launched that diverts us from the Business-as-Usual trajectory, RCP8.5 is the trajectory we will probably follow – at least over the short term.

Evidence suggests at least the following should be embodied in a Medford Climate Change Adaptation and Resilience Plan:

1. Increasing temperatures and heat waves that will pose direct and short-term health risks especially to vulnerable communities suggesting consideration be given to preparing such communities for the threats and medical centers for the consequences.
2. Decreasing snowpack and increasing drought that pose threats to water supplies, agriculture and forestry – including wildfires with direct recreational economic and human health effects – suggesting a need for systems managers and extension advisers to be preparing for such eventualities.
3. Similar temperature trends increasing the risk of vector and water-borne disease epidemics suggests medical centers should be preparing for such events.
4. Increasing flood risk compromising infrastructure (roads, bridges, water /waste treatment facilities) suggests maintenance, repair and construction plans should account for these threats.
5. That temperature trends will cause problems for inhabitants of insufficiently well-constructed residences suggests consideration should be given to developing building codes that assure preparation for the forthcoming climatic conditions.
6. Since temperature and extreme events cause mental health stress community mental health agencies should be prepared to deal with this.

Acknowledgments

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