Why Climate Change Matters for Lodi, California
Marisa Weinstock

In 2016, Lodi and it's produced wine pushed through, and even excelled, despite the many economic and environmental barriers. In fact, the wine revenue within the United States excelled, setting a record for its exports of wine. Saying as 90 percent of the 49.5 million cases of U.S. wine sold came from California[1], according to a report released this week by the California-based industry advocacy group. "Lodi wines are a huge part of it," said David Phillips, co-owner of Michael David Winery. Because the demand for wine abroad trumps that of the United States, economic benefit lies for California wineries, including Lodi, in the exportation of wine overseas. This results in a competition against wineries abroad and as said by Robert Koch, the Wine Institute's president and chief executive, "many of those places have much cheaper production costs than California does… In order to compete, Lodi wineries have to bring their best game." Despite Lodi's increased relevance as a hub for wine, its production is in trouble and our economy is at risk. Data from the National Oceanic and Atmospheric Administration 1930 to 1960 illustrates a statistically significant rise in minimum temperatures for October and December and an upward trend for September (for more information on the nature of this data, feel free to access my blog which offers further analysis here). This increase in minimum temperatures speaks to a rise in temperatures during the night.

Unfortunately, wide diurnal temperature swings are key to wine production and quality. The metabolism in grapes run quickly only under the optimal environmental conditions that are now at risk, which require warm dry days and cool nights[2]. Heat of day promotes ripeness and sugar development in the grapes and the cooler nights help the grapes to retain acidity and freshness, resulting in beautifully balanced flavors. To offset the sweetness given off by the warm sun, wines need the acidity metabolized when the cool night slows grape metabolism[3]. This supplies the tangy bite that helps cut the fatty taste when you eat steak. In addition, the brisk weather also promotes anthocyanins, which give wine both its red hue and astringency. This is why cooler night temperatures are a big factor in determining wine quality. Certainly, climate change results in much greater impacts for viticulture than just minimum temperatures, which are illustrated on my blog here.

Lodi's rise in minimum temperature from 1930 to 1960 is only the beginning of climate change's effects on the area. Climate change, with its generosity for heat waves[4], drought[5], and many other detrimental contributions, builds a stronger and stronger presence within the Central Valley with growing speed everyday[6]. Without mitigating our world's emission of greenhouse gasses, not only will our wine quality and quantity suffer, but the entirety of the Central Valley, the agricultural hub of our nation, will continue to be increasingly compromised, as well.

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[1] http://www.lodinews.com/news/article_03954168-f3fa-11e6-93b1-73ad69dc9f63.html
[2] http://horizon.ucsd.edu/maltmn/sasha/Heat%20waves%20and%20grapes%202010.pdf
[3] https://napavintners.com/napa_valley/life_cycle_of_a_grape.asp
[4] http://blog.ucsusa.org/roberto-mera/new-study-heat-extremes-californias-central-valley-climate-change-853
[5] Diffenbaugh, Noah S., Daniel L. Swain, and Danielle Touma. "Anthropogenic Warming Has Increased Drought Risk in California." *Proceedings of the National Academy of Sciences of the United States of America* 112.13 (2015): 3931–3936. *PMC*. Web. 22 Feb. 2017.
[6] https://riskybusiness.org/site/assets/uploads/2015/09/California-Report-WEB-3-30-15.pdf

Climate Data and Analysis for Lodi, California

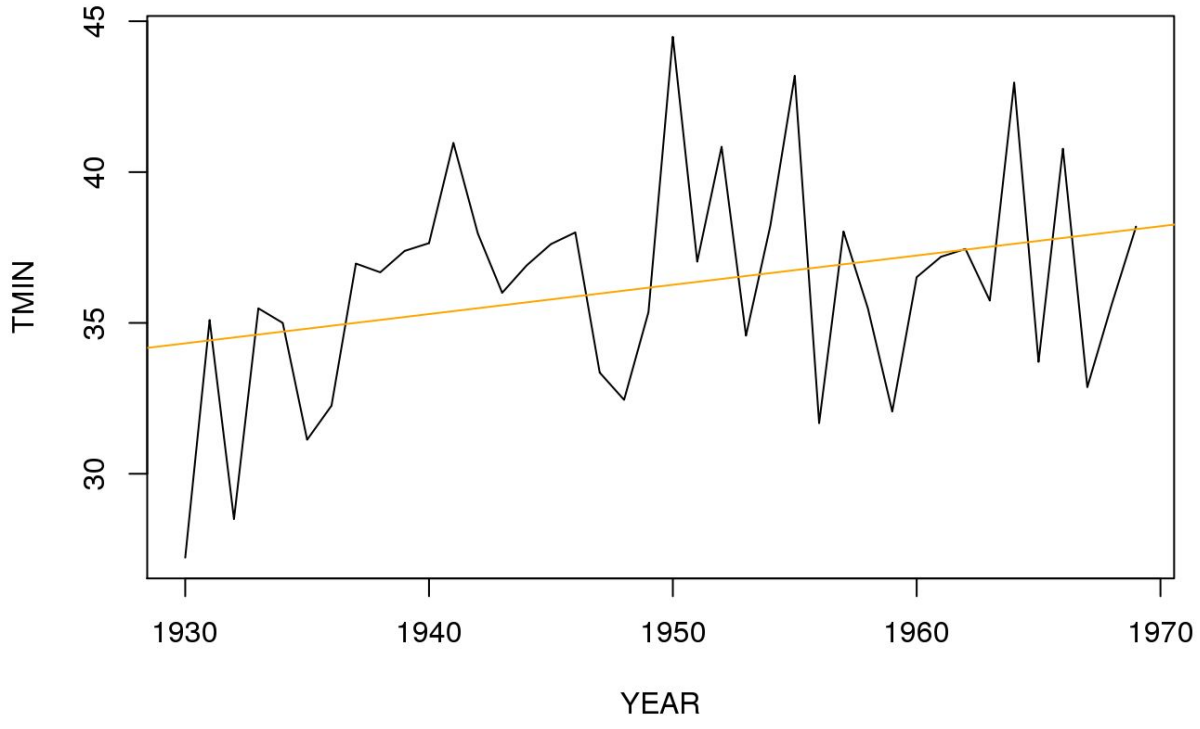
Marisa Weinstock

02/20/2017

Minimum Temperatures

The statistically significant increase in minimum temperatures in August, September, and October illustrate warming in Lodi.

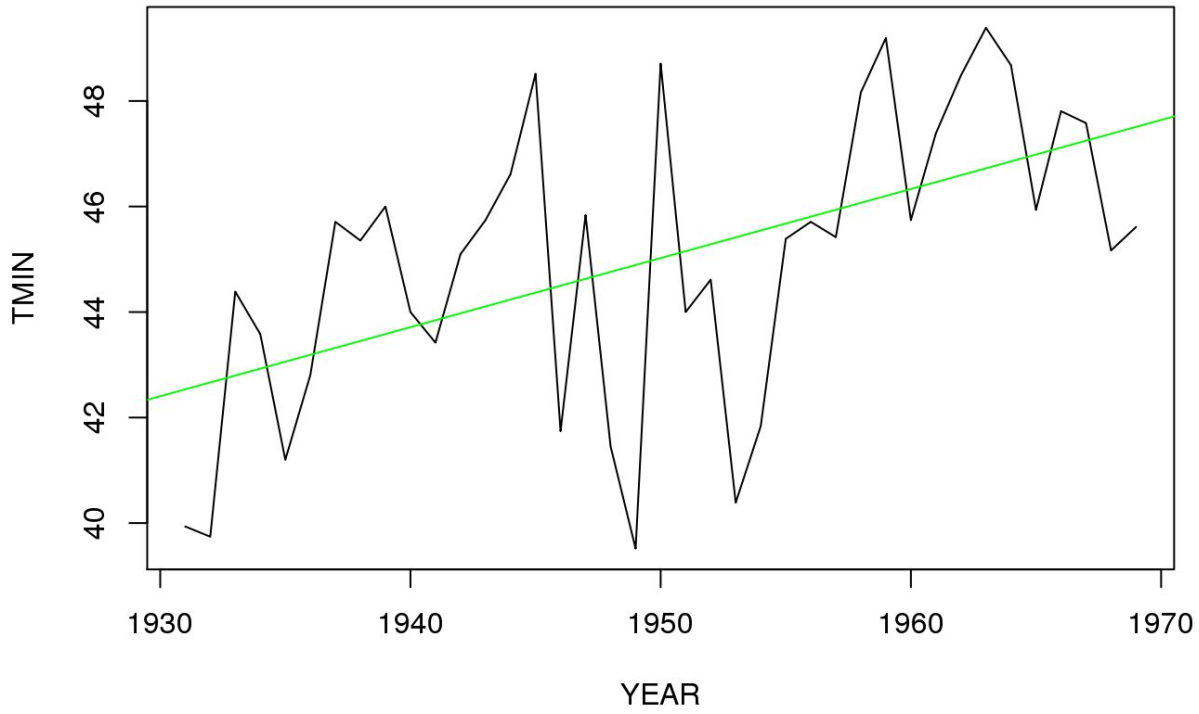
Minimum Temperature Increase in December



The minimum temperatures within the month of December increase at a slope of 0.0970156 degress per year, with a statistically insignificant probability of 0.0516109. However, the 0.05 cutoff

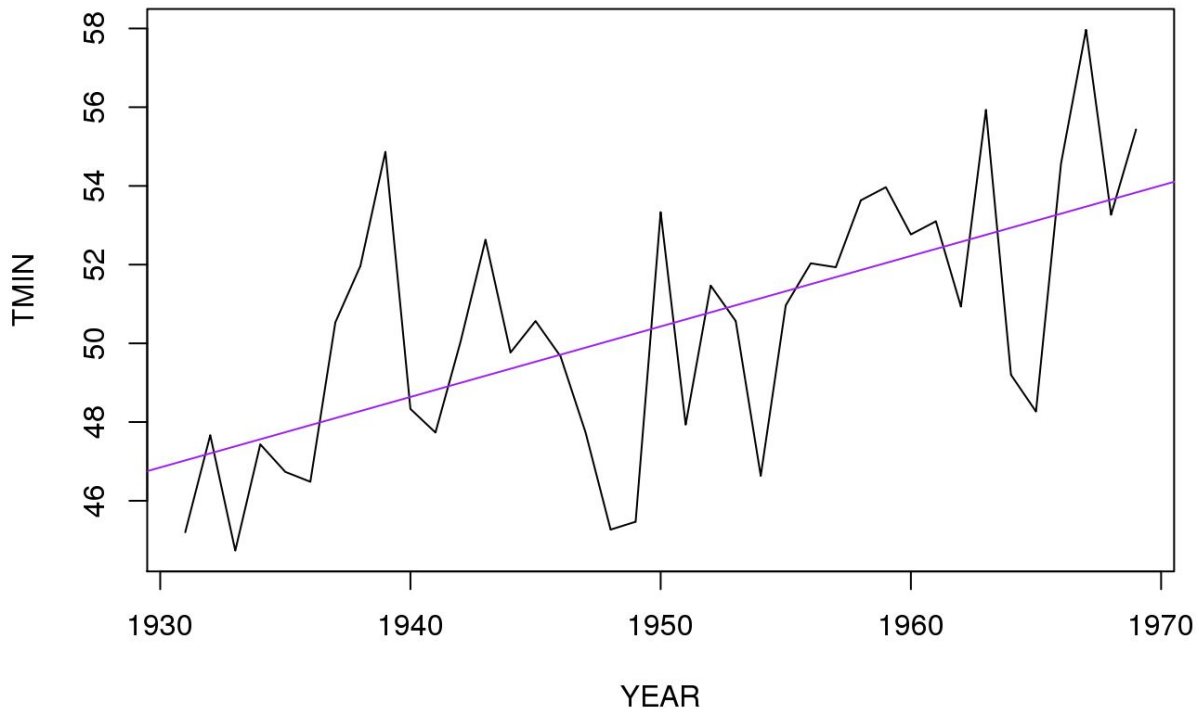
for statistical significance that this data almost reaches is arbitrary. In addition, this rise in minimum temperatures may be illustrating a trend that will continue with time to potentially create statistical significance down the line. As a trend, this heightening in minimum temperature in December relates to wine production because the cooling time in the coldest months holds great importance. An increase in minimum temperatures cripples grape production during a vital time.

Minimum Temperature Increase in October



The minimum temperatures within the month of January increase at a slope of 0.1309064 degress per year, with a very statistically significant probability of 3.96710^{-4}.

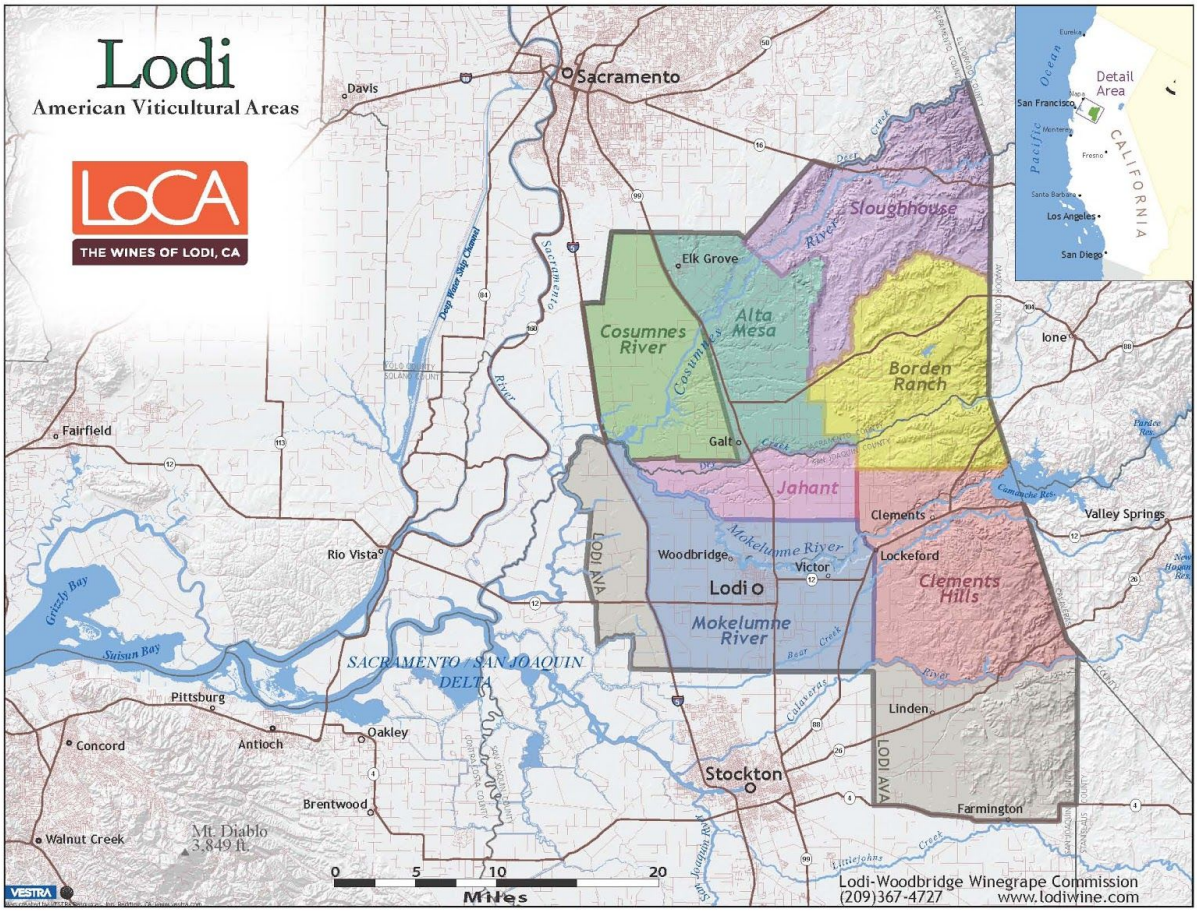
Minimum Temperature Increase in September



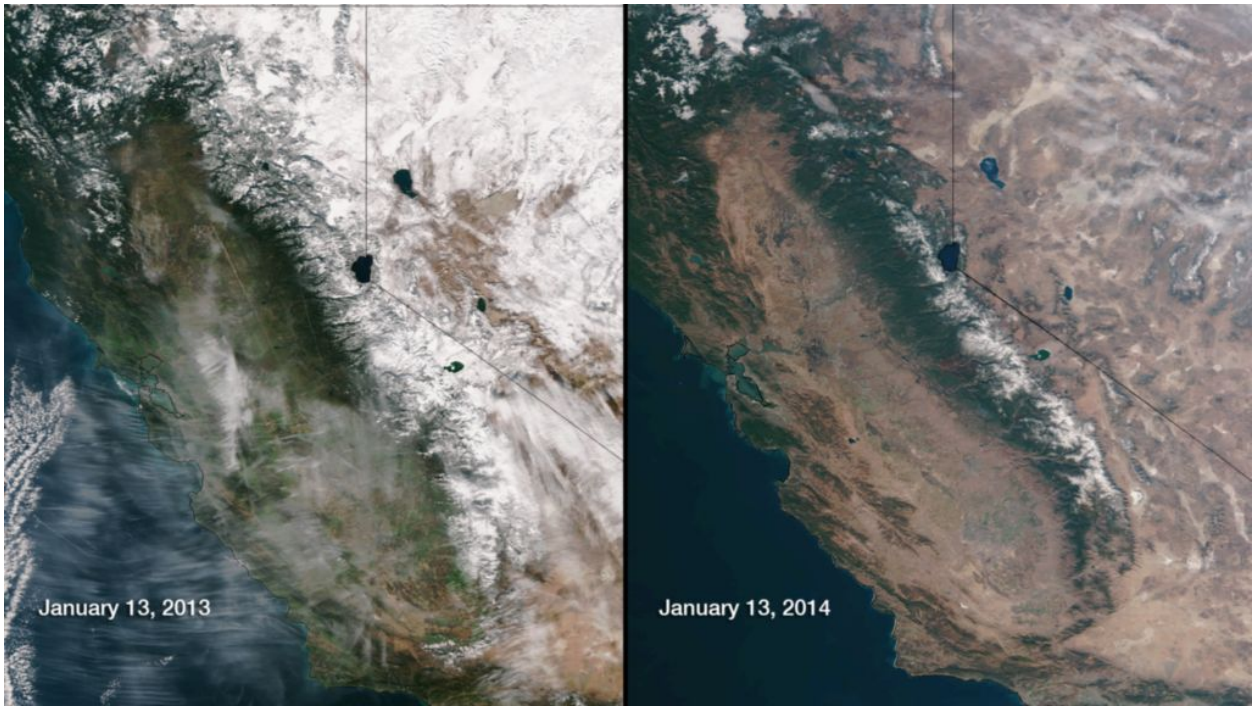
The minimum temperatures within the month of September increase at a slope of 0.17913 degrees per year, with a high statistically significant probability of 3.0410^{-5}.

Introduction to Lodi and its Water

Lodi is a city located in San Joaquin County, California, in the northern portion of California's Central Valley. Lodi is best known for being a center of winegrape production (the "Zinfandel Capital of the World"). Today, the Lodi area is home to several large manufacturing, general services, and agricultural companies.



East of Lodi is the Sacramento-San Joaquin Delta, a network of channels fed by freshwater flow from rivers, especially from the San Joaquin Rivers and Sacramento Rivers. In connection to the San Joaquin River is Mokelumne River, which travels from the Sierra Nevada mountain range to then curl along the city of Lodi. This eventually connects with the mouth of the Sacramento-San Joaquin Delta. Through an agreement with the Woodbridge Irrigation District made in 2003 and extending until 2047, Lodi purchases an average annual delivery of 2.345 billion gallons of surface water from the Mokelumne River per year for the city. Despite Lodi's deal with the Woodbridge Irrigation District, groundwater is the city's primary source of water. Groundwater, which is water held underground in the soil or in pores and crevices in rock, is irrigated for the city's usage through wells and also diverted for the purpose of agricultural irrigation.



Comparing Sierra Nevada snowpack in two Januaries, illustrating the extremely dry conditions in early 2014. Source: NASA

Impact on Water Supply

Lodi and the city's surroundings use groundwater as their main source of water, which is used for residential and irrigational purposes. Anthropogenic warming dries up groundwater reserve and, in conjunction, ground-water pumpage, which greatly exceeds the natural recharge rate, has dramatically altered the ground-water flow in the Central Valley, as well. With significant cuts in managed water allocations in response to the drought, farmers, particularly those in the San Joaquin Valley, are forced to tap heavily into the already heavily depended on groundwater reserves in order to meet irrigation demands. The depletion of groundwater in the Central Valley caused the majority of the major water loss in the Sacramento and San Joaquin River Basins. Between October of 2003 and March of 2010, this showed a loss of 31.0 ± 2.7 mm/yr−1 equivalent in water height, resulting in an overall loss of 30.9 km3 for the entire study period of 78 months. The Central Valley lost 20.4 ± 3.9 mm yr−1 of groundwater during the 78-month period, or 20.3 km3 in volume. Given the already naturally low rates of groundwater recharge in the San Joaquin Valley and population growth, a continuance of groundwater depletion is expected (Famiglietti, 2011). Lodi's surrounding San Joaquin Valley relies more heavily on groundwater than its Sacramento counterpart because the drier climate results in more limited natural surface water available.

Streamflow within the Central Valley, an important factor in recharging the aquifer system, is influenced by precipitation in the mountains surrounding the valley. Due to the Sierra Nevada experiencing snowpack decline, earlier runoff, and reduced spring and summer streamflows, the Central Valley's reliance on the already overdrafted groundwater resource furthers (Cayan, 2004). Increased temperature and evapotranspiration will result in increased domestic water use within the city, as well. While Lodi itself does not provide water to agriculture, increased evapotranspiration

will increase agricultural water demand in the area, which will in turn affect groundwater supplies and economic growth.

Through anthropogenic warming, the regional climate of the Central Valley hits extremes, in particular with high extremes during the growing season (White, 2006). This change in the frequency of extreme temperatures has an extreme effect on biological and agricultural systems than changes in mean climate. As farmers' irrigation systems are threatened due to a lack of groundwater, soil moisture suffers. Soil moisture is an important control for heat and water transfer between the land and atmosphere, which in turn affects the development of extreme heat events (Lobell, 2008). Reduction in soil moisture has been shown to slow warming within the region, so this cutback of water usage actually contributes further to the local warming contributing to the drought in the first place (Lobell, 2008).

Impact on Water Quality

Sea level rise induces intrusion of saline water into the Delta, endangering water supply and agriculture in the reclaimed regions like Lodi that lie west and north west of the Delta region. The protective levees also threaten massive flooding with raising sea level (Vanderwarker, 2009). In addition, the temperature of surface water is rising. Water temperatures provide an important constraint on ecological function, such as fish spawning, swimming performance, metabolism, effects of aquatic invertebrates, and mortality (Source). Within the Sacramento-San Joaquin Delta, Chinook salmon are threatened by increased temperatures and drought years (Yates, 2008). These salmon, once in the Mokelumne River, transport biomass and nitrogen; this is key to stream and riparian ecosystem function (Merz, 2006). In fact, the studied native riparian vegetation in the Mokelumne River close to spawning sites received 18-25% of foliar nitrogen from marine sources (Merz, 2006). Loss of Pacific salmon damages riparian vegetation and local agriculture dependent on this ecosystem, affecting grape production in particular (Merz, 2006).

Impact on Viticulture

As previously stated, the now limited supply of irrigation water and foliar nitrogen from salmon due to a temperature increase will negatively impact viticulture. Not yet mentioned is the particular impact a decline in minimum temperatures holds for wine quantity and quality. The data illustrating a rise in minimum temperatures speaks to a rise in temperatures during the night. Unfortunately, wide diurnal temperature swings are key to wine production and quality. The metabolism in grapes run quickly only under the optimal environmental conditions that are now at risk, which require warm dry days and cool nights. Heat of day promotes ripeness and sugar development in the grapes and the cooler nights help the grapes to retain acidity and freshness, resulting in beautifully balanced flavors. To offset the sweetness given off by the warm sun, wines need the acidity metabolized when the cool night slows grape metabolism. This supplies the tangy bite that helps cut the fatty taste when you eat steak. In addition, the brisk weather also promotes anthocyanins, which give wine both its red hue and astringency.

In response to generally increased temperatures and increased prevalence of heat waves, attempts to maintain wine grape productivity and quality in the face of warming may be associated with increased water use for irrigation and the use of misting or sprinkling water in order to cool grapes.

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