

The Balance of Water Availability and Economic Development Within a Changing Climate for the Wine Producing Region of the Valle de Guadalupe in Baja California

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Table of Key Stakeholders

Name	Association	Role
CONAGUA (La Comisión Nacional del Agua / National Water Commission)	Federal Government Agency	Oversees the nation's water resources, develops policies on use and quality, and issues subsidized funding
COTAS (El Comité Técnico de Aguas Subterráneas / Technical Committee on Groundwater)	Branch of CONAGUA	Measures and monitors aquifers
Secretaría de Agricultura y Desarrollo Rural / Secretary of Agriculture and Rural Development	Federal Government Agency	Oversees food, agriculture, natural resources, rural development, and related issues based on public policy and effective management
Secretaría de Turismo del Estado de Baja California / Secretary of Tourism of the State of Baja California	Regional Government Agency	Conducts the development policy for national tourist activity and promotes tourism activities, offerings, and campaigns
Provino Baja California / State Council of Wine Producers of Baja California	Civil society integrated by more than 50 wineries of the area	Promote the grape growing and wine industry of Baja California and organize productions that contribute to the promotion of the wine culture

EXECUTIVE SUMMARY

Abstract

Anthropogenic climate change has raised global temperatures and thrown standard weather patterns into disarray. For the Valle de Guadalupe, an agricultural region that specializes in vitis vinifera grapes used to make wine, impacts go much further than what's experienced above ground. Extraction from the area's aquifer and primary water source has increased significantly and become overexploited to meet infrastructural development demands for tourism. Natural rain-fed recharge rates have not kept up and the aquifer is experiencing a dramatic decline in water levels. Valle locals have implemented strategies to conserve and optimize water usage, but also stress the need to slow down the accelerated pace of development so it can be done sustainability and strategically. Interviews were conducted with Valle winemakers and employees to understand the issues and their perceptions of these topics first hand. These insights are presented throughout, as well as the adaptations and ongoing work of scientists and residents who work to preserve the longevity of this region.

Motivation

Choosing to focus on water availability impacts in a wine producing region was inspired by both what was and what was not being discussed as a global industry. The predominant conversation on climate change and viticultural impacts is often about responding to extreme weather events, like freezes or hail storms, and adapting to heat fluctuations and rising global temperatures. With any agricultural product, weather events vary every season, but seasonal irregularities caused by climate change complicate risk mitigation solutions. Furthermore, when it comes to rising temperatures, the average growing season for wine regions around the world has increased by 1.3° Celsius (2.34° Fahrenheit) between 1950-2000 (Veseth, 2018). There are two main methods for how winemakers and grape growers have been responding.

The first method involves incorporating new *vitis vinifera* subspecies, or winegrape varieties in specific growing areas. As shown in Figure 1 below, created by climatologist and wine researcher, Dr. Greg Jones, each type of winegrape thrives best in specific temperatures. If temperatures get too hot, grape quality can diminish or be ruined altogether. Should average growing season temperatures rise over 22° Celsius (72° Fahrenheit), conditions become too extreme to grow grapes successfully. As average growing season temperatures change, farmers could decide to plant more heat-tolerant grapes, with new or pre-existing rootstocks, as well as innovate with canopy management or additional cooling techniques (Veseth, 2018).

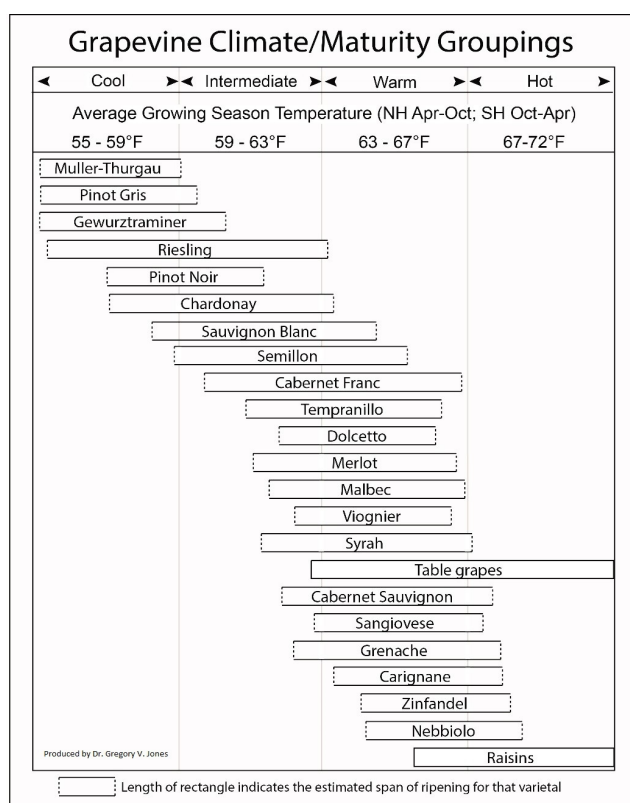


Figure 1: Compatibility of temperature and grape varieties from GuildSomm

The second method is moving to a new area higher in elevation or latitude. While there are dozens of factors that are considered for an area to be suitable for growing wine grapes, generally the most ideal areas are between 30-50° latitude (see Figure 2) on both sides of the equator due to the diurnal variation which occurs between the heat of the day and cooler temperatures at night. However, with global temperatures increasing, new winegrape growing areas are emerging above the 50° latitude

mark. England was considered too cold for the past several centuries for successful plantings, even though the country had a history of grape growing and winemaking when the early Romans brought grapes to the area (Berry, 2023). Several other countries including Sweden, Denmark, and Canada are now gaining momentum as areas producing quality wines. While it could be argued that this suitability shift provides an economic opportunity in places that haven't been able to produce wine in recent history, it's also an authentic representation of climate change impacts at work.

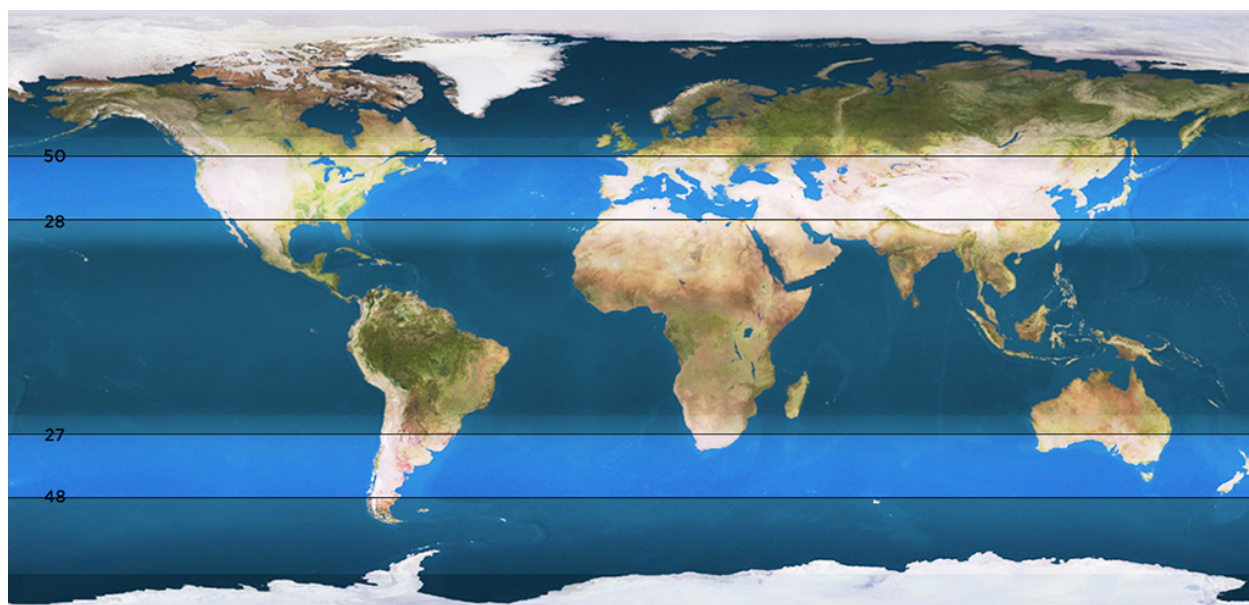


Figure 2: Ideal vitis vinifera growing areas between 30-50° latitude from Wine Shop at Home

These two adaptations are necessary when it comes to the longevity of the industry. The problem is that these methods are rarely properly articulated or acknowledged as what they truly are: short term solutions to the bigger issue of climate change. Any opportunity to showcase these topics as tangible examples on the urgency of climate change is lost. There's also equity and cultural concerns of long-established vineyards and people being expected to move to a new location to grow wine grapes to respond to an increasingly warming world. Many producers come from generations of winemakers who have grown grapes on the same land for decades if not hundreds of years. Giving up their land and moving elsewhere is often not feasible or desirable.

The topic of water availability isn't often a topic of conversation for the wine industry, but it enforces the urgency of climate change issues. Agricultural water stress from urban competition and extreme weather events has already been experienced and studied on a global scale, but rarely viewed from a viticultural perspective. Scientific literature and discussions were limited or nonexistent on what a future could look like for grapegrowers under conditions of low rainfall, urban growth competition, and severely declining freshwater sources. These topics impact individuals who often have worked and lived in an area their entire lives, if not for generations, and whose cultural and economic livelihoods were tied to those places. However, these hypotheticals were actually happening and effects being experienced first hand in Mexico's wine country of the Valle de Guadalupe.

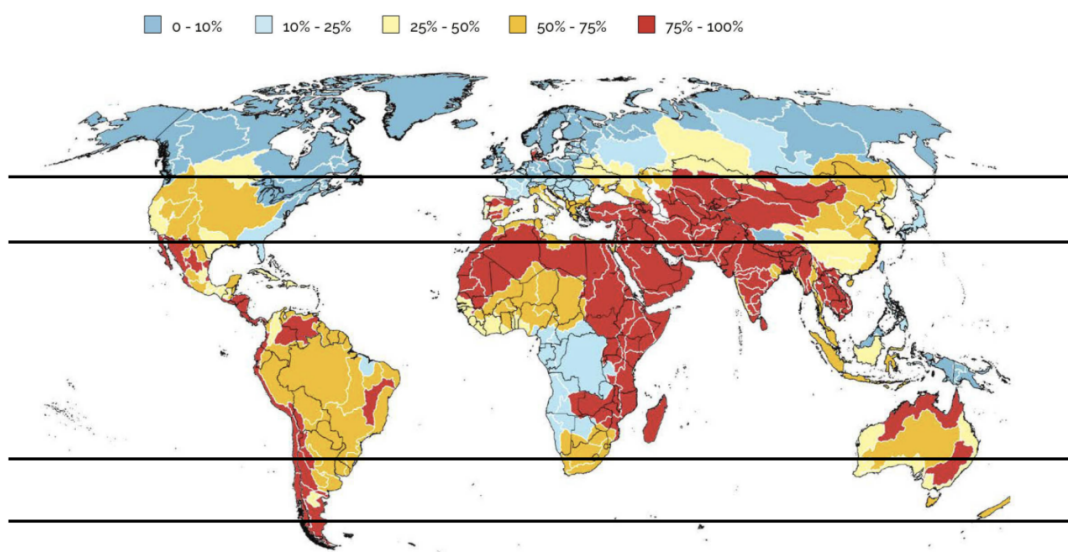


Figure 3: Water stress for agriculture in 2018 from Food and Agriculture Organization of the United Nations

Much of the information presented in this paper came from multiple trips to this region to meet and talk with Valle winemakers, vineyard owners, and employees. They will be referred to as “interviewees” throughout. Published papers and data were also used, but the main objective of this project was to incorporate the experiences and insights first hand from people who live and work in the Valle, especially in small scale wineries. Each of the interviewees have diverse histories of when they started growing grapes and making wine in the Valle, as well as the family ties to the surrounding area.

PART 1

Valle de Guadalupe Overview

The Valle de Guadalupe is located 145 kilometers (90 miles) south of San Diego in Baja California of northwest Mexico. Grapes were originally planted by Spanish missionaries for use in religious services in the 1600s, and now the Valle holds 90% of Mexico’s wine production (Nickles, 2020). Despite the lengthy history, the Valle has flown under the radar for many years compared to other globally acclaimed viticultural areas. The wine region has been growing in popularity and recognition, where it transformed from a small town to a popular vacation destination in a mere two decades. It’s home to over 100 wineries, 75% of which are small-scale family operations, and now represents significant investment for both agriculture and enotourism (Bernstein, 2021). Figures 4-6 below and Figure 9 on page 19 were made in ArcGIS Pro with data from the website of the Mexican Government Department of Agriculture and Rural Development.



Figure 4: Wide view of the Valle de Guadalupe in Northern Baja California

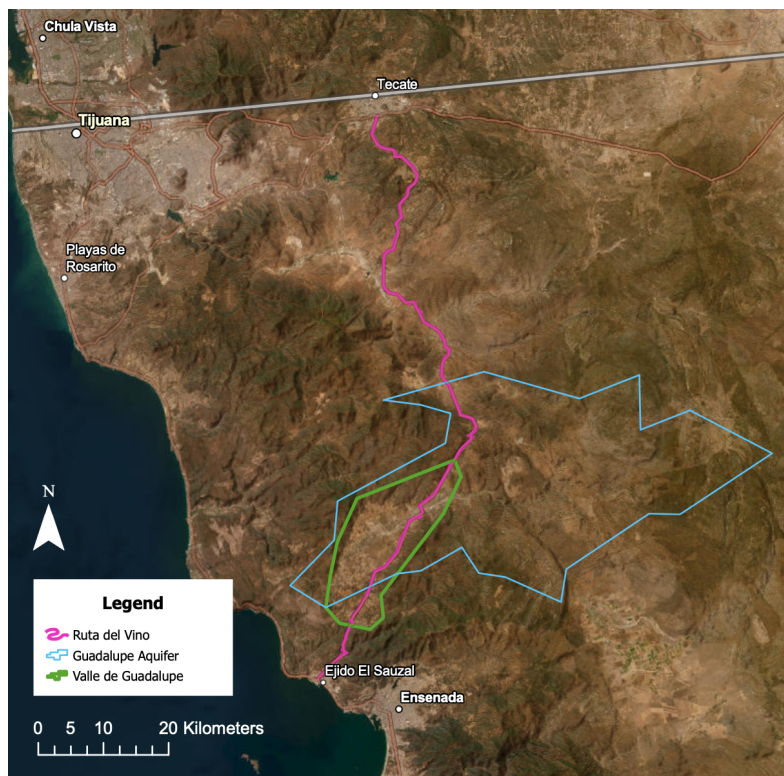


Figure 5: Administrative aquifer boundary lines in blue

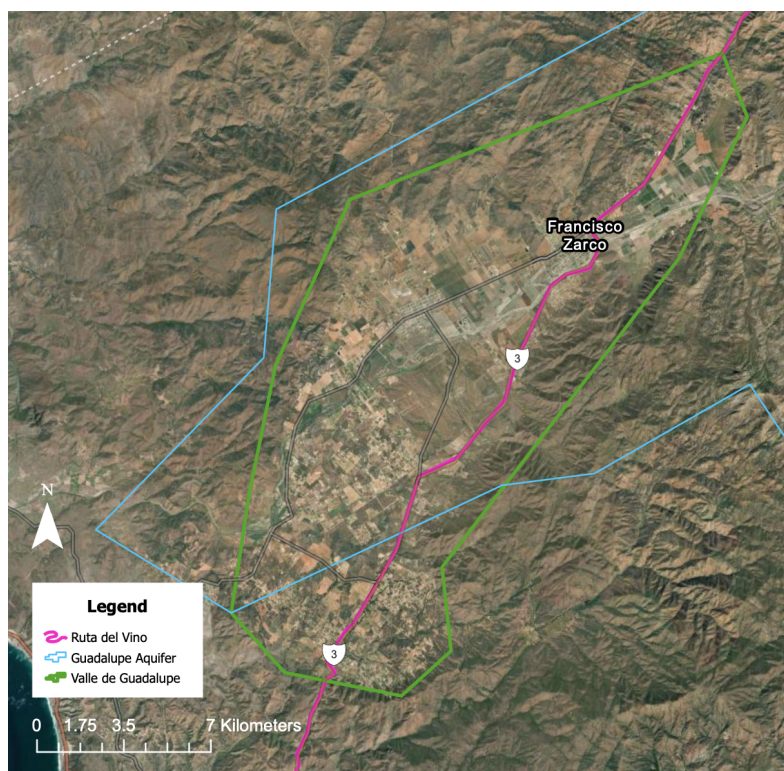


Figure 6: Zoomed view of the Valle de Guadalupe

From a grape growing perspective, the Valle's geographical advantage is its Mediterranean climate with hot, dry summers and mild, rainy winters, as well as elevations of over 305 meters (1,000 feet) (Nickles, 2020). It's located on the 32° latitude line, and experiences a maritime influence due to the close proximity to the Pacific Ocean where cool breezes often flow through the mountain tops. The landscape is lush and stunning, rolling mountains surround the valley, which brings to mind scenery from southeastern Europe. Unlike other wine grape growing areas of the world, Mexico doesn't have geographical indications or laws specifying what can be grown and blended together, so winemakers have full freedom of artistic expression in their products (Bernstein, 2020).

Average rainfall is low, with about 254 millimeters (10 inches) a year, so most water used in irrigation and wine production is sourced from the area's aquifer (Figure 5). Aquifer levels are fed by rainfall and is the sole water supply of the Valle. However, the aquifer has been overexploited for years and is currently experiencing a dramatic decline in water levels due to increased human activity and ongoing periods of drought. Establishing "La Ruta del Vino" (Figure 5), the region's official wine route, helped bring attention to the area. As more people came to the Valle to make wines and improve techniques, the momentum also attracted restaurateurs, chefs, and external business investors seeking to maximize the growth potential of the area and establish infrastructure and events to attract visitors.

Infrastructural development has taken the form of boutique hotels, housing projects used for vacation rentals, and spaces to hold events like concerts and weddings. These types of events can bring in hundreds of people for a short period of time, creating negative impacts to locals such as noise pollution, waste, traffic, and land destruction as planners dedicate space for people to park, temporarily host events, or even build more permanent infrastructure. It also dramatically increases the need for water. Valle inhabitants find themselves competing with each other and developers to build deeper wells in the hopes of obtaining necessary quantities for both agricultural and economic growth. Having access to fresh water was already a challenge, but with increased levels of tourism and development, the Valle's inhabitants find themselves in an even more complicated situation. Should these issues go unaddressed, they have the potential to escalate into long term impacts that could harm the future of the Valle.

Locals are afraid the scale of these activities could drain the aquifer entirely. Should that happen, the only other options would be to bring in imported water from Ensenada or Tijuana, which is incredibly expensive. If farmers don't have the capital to pay for water brought to the Valle, it could result in the decline of grape and wine production in the region, which was the original motivation that brought people and development to the area. Since most of the wineries in the Valle are small operations, they would be forced to close without water. As the Valle inhabitants seek to find a balance between financial benefits of tourism and preserving the area's tranquility and natural beauty, sustainable solutions need to be implemented before development projects continue to escalate.

Climate Change Impacts

Even for land-based agriculture, the interconnectedness of our planetary system from an atmospheric and oceanic perspective cannot be ignored. According to the United States National Oceanic and Atmospheric Administration, carbon dioxide quantities in the atmosphere have increased by 25% since the late 1950s, and 40% since the Industrial Revolution. As Figure 7 shows, rising global temperature increases due to anthropogenic burning of fossil fuels don't impact the planet uniformly. Temperature averages differ around the world due to wind circulation, atmospheric moisture and chemical makeup, and influential and slow changing oceans. The Valle is one of many areas that have increased in average temperature, especially within the last 30 years, which have been some of the most important years for its development. While heat increases are certainly an issue for grape suitability, the impacts go beyond what's happening above ground.

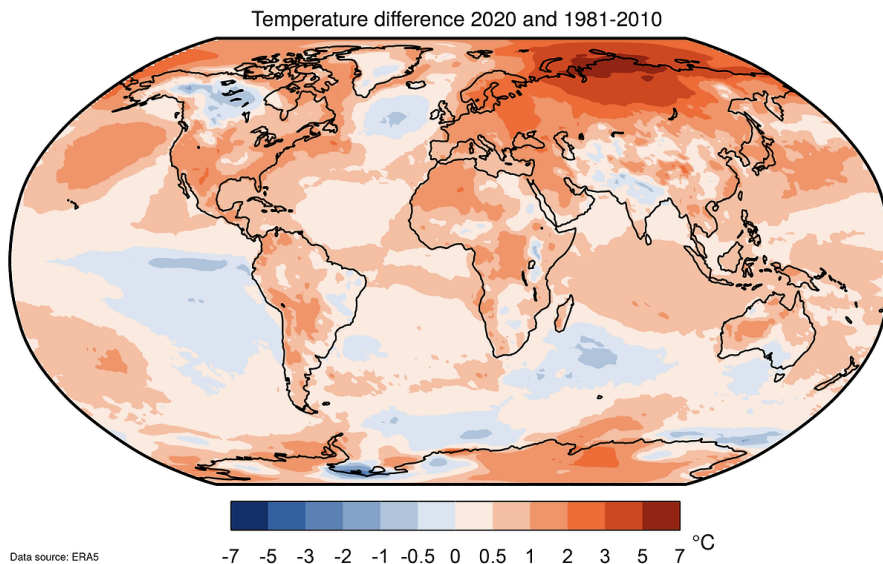


Figure 7: Temperature variation compared to 30-year averages from Copernicus Climate Change Service

A factor that is concerning for agriculture is the direct consequence climate change has on weather variability and unpredictability. When carbon dioxide and other greenhouse gasses are emitted, they linger in the atmosphere, trapping heat and increasing evapotranspiration from plants and surface bodies of water. Not only does this decrease moisture retention in soil, it also leads to an increase in water vapor in the atmosphere and significantly alters weather patterns. Extreme weather events come about as a result of added heat in the atmosphere which impacts wind speed, and when combined with extra water increases the strength of storms. The result could lead to more intense and longer lasting heat waves and changes in frequency and duration of precipitation. These processes directly contribute to the amount of water available on Earth's surface. For Baja California, these effects are currently being felt (Ezcurra et al., 2021).

Baja California already experiences low levels of rainfall, even without the added challenges of heat increases. Historically, rainfall is highest during the cool winter months, with 77% of the rain for the whole year occurring between December and March. 2% occurs in the summer, and the remaining 21% in the spring and fall (Del-Toro-Guerrero et al., 2022). The grape growing season for the northern hemisphere is from April to October, and for the Valle, this is the period where grapes need water the most to support the development of grape berries (Jones, 2015). While winter rain is beneficial in

resupplying the groundwater aquifer table levels, it doesn't have much impact on grapevines that lie dormant during the cooler months and don't need an intake of water. It can also bring negative impacts including an influx of insects and wild predators, and the need for chemical or organic agents to ward off those threats to the plants.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	12.3 °C (54.1) °F	12.2 °C (54) °F	13.5 °C (56.2) °F	14.8 °C (58.6) °F	16.5 °C (61.7) °F	19.3 °C (66.7) °F	21.9 °C (71.5) °F	22.6 °C (72.8) °F	21.8 °C (71.3) °F	18.7 °C (65.6) °F	15.3 °C (59.5) °F	12.2 °C (54) °F
Min. Temperature °C (°F)	7.9 °C (46.2) °F	8.1 °C (46.5) °F	9.2 °C (48.6) °F	10.7 °C (51.2) °F	12.8 °C (55.1) °F	15.7 °C (60.3) °F	18.6 °C (65.6) °F	19.3 °C (66.8) °F	18.1 °C (64.6) °F	14.5 °C (58.1) °F	11 °C (51.8) °F	8 °C (46.5) °F
Max. Temperature °C (°F)	17.8 °C (64.1) °F	17.2 °C (63) °F	18.3 °C (64.9) °F	19.4 °C (67) °F	20.7 °C (69.2) °F	23.5 °C (74.3) °F	25.9 °C (78.7) °F	26.7 °C (80.1) °F	26.3 °C (79.4) °F	23.6 °C (74.4) °F	20.5 °C (69) °F	17.3 °C (63.2) °F
Precipitation / Rainfall mm (in)	61 (2.4)	74 (2.9)	48 (1.9)	22 (0.9)	9 (0.4)	1 (0.04)	1 (0.04)	2 (0.08)	4 (0.2)	14 (0.6)	23 (0.9)	48 (1.9)

Figure 8: Valle de Guadalupe data averaged over 1991-2021 from Climate-data.org

Del-Toro-Guerrero et al. conducted a study looking at temperatures and rainfall in the Valle during the period of 1992 to 2018. In drought years of high temperatures and low precipitation, not only do grapes and production suffer due to reduced supply and quality of water, but detriments extend to habitat degradation and economic disturbance. They found that compared to consecutive wet years, consecutive dry years were much more frequent. Dry years included 1995-1997, 1998-2000, 2001-2004, 2005-2009, and 2012-2016. The 2017/2018 hydrological year holds the record for the driest year with an annual precipitation of 58 mm (2.28 in). Needless to say, the Valle de Guadalupe area has undergone significant recent periods of low rainfall and warmer temperatures, putting strain on the aquifer's resources and putting the area at risk for other natural disasters.

These periods of drought also bring increased potential and consequences of wildfires, as has been heavily experienced throughout the western US and Mexico in the last few years. The 2019 and 2020 wildfire seasons in Baja California were particularly extreme. In 2020, fire fueled by strong winds burned over 8,500 hectares in the Valle before it was controlled and no longer considered active (Beyond Borders Gazette, 2020). The Valle's remote location and two lane roads further puts the area in a vulnerable position should fires occur and outside assistance be required (Rivlin-Nadler, 2019). These issues intensified by climate change will only worsen as global temperatures continue to rise.

PART 2

Water Availability & Use

Water management on a state or federal level is an incredibly complicated topic in any country, and is worthy of mention to understand the general structure. Water use and well permitting in Mexico is handled through the National Water Commission, or La Comisión Nacional del Agua (CONAGUA). As a federal agency, CONAGUA's role is to oversee the nation's water resources, develop policies on use and quality, and issue subsidized funding. Water extraction permits need to be purchased from CONAGUA before initial construction or expansion of wells. However, regulations for legal extraction are incredibly difficult to monitor and enforce on a federal level. Another key organization is the Technical Committee on Groundwater, or El Comité Técnico de Aguas Subterráneas (COTAS), a separate branch of CONAGUA that measures and monitors aquifers. COTAS helps manage water use, and builds programs and policies in areas with exploited aquifers (Gilabert-Alarcón et al., 2018).

In the Valle, issues of water supply are weakened by the persistent droughts and levels of extraction that have occurred for irrigation, wine production, and general use for other industries in the area. About 72% of the Valle's water supply goes to growing grapes, which is the same statistic for the amount of water dedicated to agriculture globally. 18% of Valle water is spent on public-urban use, 6% is for domestic use, and the remaining 4% is divided among livestock, other agricultural products, and industrial use (Del-Toro-Guerrero & Kretzschmar, 2016). The Valle's aquifer can hold a total volume of 218 million cubic meters (Mm³) of water (Daesslé et al., 2006), but current levels of water are difficult to determine. COTAS uses a technology called level loggers to document quantity and changes over time. However, measurements of the Valle's aquifer are inconsistent, which is a data constraint when comparing rates of extraction versus rates of replenishment.

One aspect that scientists and CONAGUA can agree on is that the aquifer is in a state of deficit. Deficit occurs when the amount of water extraction exceeds the rate of replenishment within

the system. A report from CONAGUA estimated that in 2018, 36.92 Mm³ was authorized to be extracted, 18.8 Mm³ was recharged based on average precipitation, which put the aquifer deficit at 18.22 Mm³ for the year (Saiz-Rodríguez et al., 2019). Another study cited a deficit at 12.04 Mm³ in 2013, 12.21 Mm³ in 2014, and 18.23 Mm³ in 2015 (Del-Toro-Guerrero & Kretzschmar, 2019). Between 1990 and 2009, it's estimated that an average of 28.2 Mm³ of water was extracted each year. Annual recharge for the Valle is solely dependant on annual rainfall, and depending on severity of a drought year, precipitation, temperature, and evapotranspiration from plants and surface waters could also play a part in how much water makes it into the groundwater reserves (Del-Toro-Guerrero & Kretzschmar, 2016).

While it may appear counterintuitive, wine grape growers strive for a level of water stress for their grapevines to promote deeper roots and grow fewer but stronger berry clusters on the vine. It's a challenging balance to strike. If any area worldwide receives less than 350 mm (13.78 in) of rainfall a year, water stress is considered extreme, and it could decrease photosynthesis, reduce pH levels, and result in an imbalance of sugar concentration and organic acids (Kretzschmar et al., 2012). Even though 350 mm of rain would be considered a good year for the Valle, it would still not be enough to replenish the aquifer with the amount of extraction taking place year over year. Being in an area already quenched for water, the Valle's water woes are consistently problematic due to the damaging impacts of drought duration and frequency. Should dry conditions continue for consecutive years, even moderate drought years have the potential to cause damaging impacts to an area (Del-Toro-Guerrero & Kretzschmar, 2016).

The Valle experienced a fairly moist winter in the 2022-2023 season with 290 mm (11.42 in) of rainfall, but even those levels aren't enough to resolve the deficit that had been accumulating for the past several decades. Consistent drought periods have occurred between 1999-2009, 2013-2016, 2018-2019, and 2021-2022 with some odd wet years mixed in. Rainy years have been infrequent and were observed in 2005, 2009-2012, 2017, and 2020. However, the prolonged drought combined with levels of extraction prevented the aquifer from refilling the table levels out of a deficit (Del-Toro-Guerrero & Kretzschmar, 2019). The same situation applies to the recent winter rains of

2022-2023. It provided a much needed relief, but the long term replenishment is likely to be short lived should extraction rates continue and if the summer season brings high average temperatures.

When it comes to the wine industry, the main uses of water are for irrigation, cellar production, and sometimes mitigation of heat or frost. If restaurants or hotels are included in a winery's business model, the quantity of water needed continues to increase depending on the size of infrastructure, volume of guests, and if swimming pools or water features like fountains are incorporated. One of the queries in interviewing Valle winery owners and employees was about wine production size and an estimate of the amount of water needed annually. Answers of bottles produced a year ranged from 300 to 36,000. Irrigation typically occurs between April and October, corresponding with the seasonal growth of grapes, and the estimated amount of water needed for irrigation or total production varied during the 7 month period and are listed below.

Average Number of Bottles Produced Annually	Water Quantities Needed for Plant/Production
300	56 liters (14.8 gallons) to irrigate per plant
1,500	106 liters (28 gallons) to irrigate per plant
6,000	3,000 cubic meters for total production
36,000	8,000 cubic meters for total production

While estimates of water used in production have some value in contextualizing the volume required, exact quantities are incredibly challenging to calculate and can differ significantly by location and individual decisions of winemakers and staff. For example, apart from irrigation, one estimate states that around 22.7 liters (6 gallons) of water is used in cellar production to make 3.8 liters (1 gallon) of wine. Much of this amount is used in cleaning of equipment like barrels and fermentation tanks (Veseth, 2008). From growth to bottling, another study claims that for every 1 liter (0.3 gallons) of wine made, it takes approximately 870-960 liters (229.8-253.6 gallons) of water (The Porto Protocol, 2020). Even with efficient irrigation techniques and diligence with water consumption in other areas of production, this industry still requires a heavy quantity of water and further emphasizes the value of this limited resource in areas that are already stressed for water, like the Valle.

Economic Growth Challenges

Some of the interviewees have decades of experience in the Valle, but all have the commonality of being established in this region for at least 10 years. Throughout this time, the Valle has gone from having a single-digit number of wineries established in the 1980s, to now hosting more than 100. With the influx of wineries came restaurants and hotels to cater to a full experience for visitors. Promotional advertisements showcased the Valle's natural beauty, world-class wines, and top restaurants with chefs from Mexico City and Los Angeles, beckoning visitors to visit. This brought attention to the area not just for tourists from Mexico and the United States, but also people seeking business opportunities. It's not surprising considering a recent statistic stated that the local wine industry and resulting tourism accounts for 3.6 billion pesos (\$180 million USD) of revenue to the Baja region (Bautista, 2022).

Developers and investors from all over Mexico have observed the rise in popularity and sought to take advantage for themselves. While their goals and industries are all different, a common observation from the interviewees is that many want to find ways to make money quickly. Building hotels and housing takes much less time than setting up wineries or restaurants. There are limited quantitative statistics of how much infrastructure in the Valle has developed within the past 10 years, but Figure 9 below shows that developed areas have been accumulating. Locals who live and work in the Valle have felt the increase and have mixed thoughts on the matter. Increased tourism represents revenue for local businesses and an opportunity to share world-class wines through consumer advocacy. However, natural resources that support residents and current and future development projects are put in jeopardy to keep up with the growth.

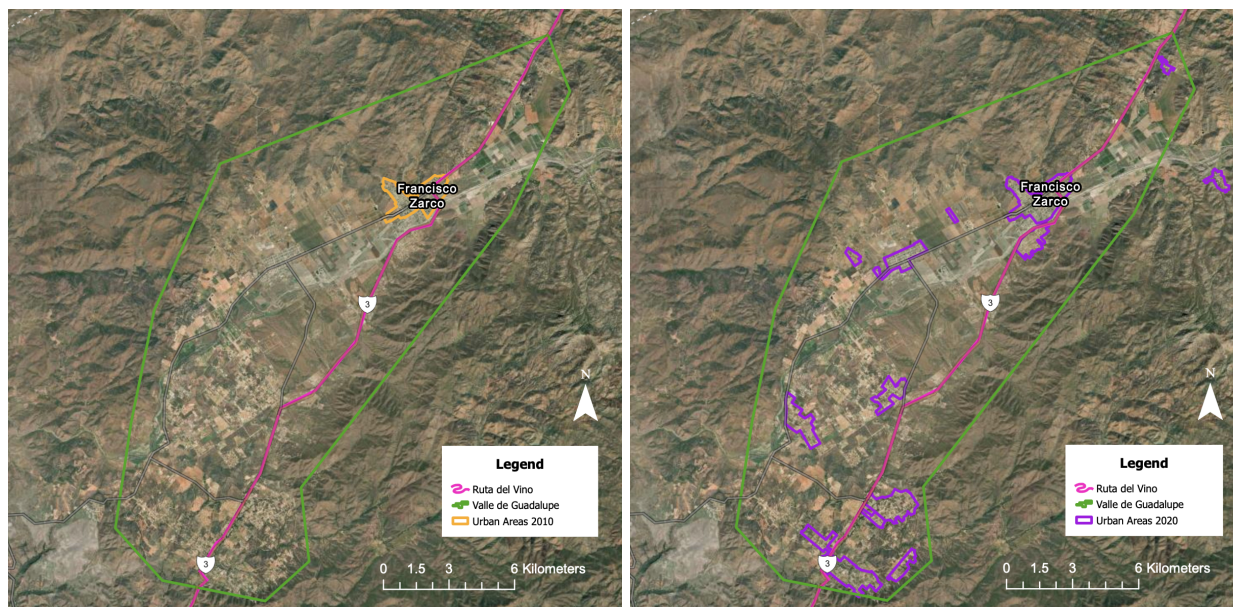


Figure 9: Developed areas in 2010 outlined in orange and 2020 outlined in purple

Locals have shown tenacity and influence in speaking out against enormous development projects and enacting local regulations that enforce weddings and concerts to conclude at midnight to not disrupt neighbors with noise. Many have also acknowledged the benefits of restaurants and hotels, but stress that ultimately, the main attraction and source of income comes from wine sales. The Valle is rooted in day-time activities, peace and quiet at night, and slow tourism, which is a form of travel all about experiencing culture and making conscious decisions for the environmental sustainability for local communities (Dickinson, 2023). That's the reputation locals want to preserve as the area continues to develop. Wine continues to be the most influential industry, and many of the interviewees feel that their perspectives are gradually being heard and understood by governmental representatives in the flight to protect the longevity of the Valle.

There are risks that should be considered before the Valle is built up too quickly. Factors that need to be addressed before further growth occurs include declining water supplies, road constrictions, historical site preservation, and environmental impact evaluations (Zárate Cornejo & Barragan Quintero, 2019). Understandably, groundwater supply is a high concern among locals. Daesslé et al. (2020) report that rainfall events lower than 100 mm (3.94 in) do not have much noticeable impact on aquifer recharge. If three or more months pass with little to no rainfall and extraction is not hindered,

water table levels can quickly diminish. This is what happened between 2011-2016, causing Valle aquifer levels to decrease by 30 meters, further proving how naturally occurring recharge is not enough to counterbalance overexploitation. Rapid growth and demands of tourism were cited as the main causes of the water reduction (Saiz-Rodríguez et al., 2019).

Despite the climate science, hydrological, and economic data that has been studied and published by professionals, what's missing is a unified plan of how to move forward. Santes-Alvarez (2017) writes about the importance of developing the Valle intelligently, improving governance processes, and involving local inhabitants to prevent ecological destruction and overuse of water. He argues that while national water policies and regulations are established with good intentions for localities, the centralized design of authority at the federal level hinders local governments to act differently than the laws dictate or adjust according to circumstances.

An example used is The National Water Law that was established in 1992 which sought to increase participation of local government and water users. The results weren't well received by the public as water governance was still ultimately tied to the federal level without much influence to smaller players, as was the original intention. Local users found themselves running into technical and administrative barriers, with no authority to make decisions, and no coordination to make their voices heard. Santes-Alvarez (2017) stresses that these problems continue to occur and won't change unless a regional agenda and goals can be established to manage natural resources and ensure water availability for Valle inhabitants.

PART 3

Implemented & Potential Adaptations

Valle grape growers and residents haven't been waiting for CONAGUA to come in and fix the problem. They've enacted multiple changes as individuals, not just to conserve water, but to benefit the ecology around them. For water management, many interviewees reported using drip irrigation, which slowly waters plants in small doses right at the soil. This saves water, optimizes soil moisture levels, and reduces chances of disease that could occur with too much moisture on the leaves. Additionally, vineyards and wineries use solar panels, compost food and other biodegradable materials, capture rainwater in tanks or ponds, and use organic farming practices for the good of the grapes, even though Mexico doesn't have a nationally recognized organic classification system. An interviewee from Tres Mujeres reported incorporating small islands of native plants interspersed among the grapevines to protect the soil from too much sun and provide natural shade for the vines.

Additional actions to address the issue of water security include bringing water in by truck, which has been done in severe seasons of drought. Water comes from other surrounding aquifers or from the Ensenada desalination plant which takes Pacific Ocean water and removes salt through reverse osmosis. Other water transportation systems through pipes have been proposed, but a network coming from Ensenada or Tijuana would be an expensive endeavor to construct. Some wineries have built surface water reservoirs for water capture, but this solution is dependent on available space and money, and has the risk of losing as much as 30% of total water stored to evaporation. Two engineers from Ensenada, who were motivated by water impacts and a desire to help people with this crisis, created a tool to reduce and optimize water use for agriculture. It consists of self-sustainable stations set up in fields that have sensors measuring nutrients, pH, and electrical conductivity in the soil for optimal plant growth, with all the information sent to a user's smartphone.

Large-scale solutions have been proposed from innovative technology to a complete policy overhaul. One team proposes using green infrastructure to construct water recharge areas throughout

the Valle where water could soak into the ground and replenish the aquifer. Areas could be established where water runoff is most prevalent and existing soil would retain water. This would involve more research to identify appropriate sites, and is further complicated by areas of natural vegetation loss due to agricultural land use (Saiz-Rodríguez et al., 2019). Another researcher writes that what's most needed is an entire review of national policy to ensure governing bodies focus beyond economic targets with inevitable harmful outcomes, and work to bring about sustainable social and environmental stability for the whole country. To do that, he argues that water must be officially recognized as a fundamental asset, ensure adequate water quality and quantity, bring about an end to overexploitation, and improve the communication between governing bodies and the citizens (Santes-Alvarez, 2017).

Interest has also accumulated to utilize reclaimed water due to the advantage of minerals and nutrients that could be used in agriculture. Reclaimed water is disposed of after residential or sometimes industrial use, treated in a processing plant, and then repurposed for watering crops and replenishing aquifers. Although not without its challenges, reclaimed water has been utilized in other areas of the world to address water exploitation and declining quality with the right planning and integration in place. According to Gilabert-Alarcón et al. (2018), for this to succeed, actions like the following examples would need to be taken through collaboration with researchers:

- Study the hydrogeology and water balance of the aquifer
- Analyze the legal framework regarding the treatment, disposal, and reuse of wastewater
- Set up pilot projects for aquifer recharge with reclaimed water
- Establish and enforce regulations for the efficient use of reclaimed water

Less than half the wastewater in Mexico is treated, leaving behind a large quantity of potential resources that could be utilized. Establishing even a local system within the Valle to repurpose reclaimed water would be an enormous undertaking, with a need to establish clear roles for the regulation and responsibilities of key players and solidify funding. However, that's not stopping a local group of scientists from striving to make this idea a reality.

Ongoing Involvement

Scientific work continues to develop and actions implemented for sustainable growth in the Valle. There are numerous individuals dedicating time and resources to gather and process data, target the gaps in knowledge, and build projects to address challenges and support this region. Strategies must continue to be prioritized to conserve and optimize water usage while enhancing the monitorization and documentation of water use trends and weather patterns in the face of an aquifer deficit. Discontinuous data capture in the form of missed values or unrecorded information sometimes impede data verification throughout the wide network of weather stations of Baja California (Del-Toro-Guerrero & Kretzschmar, 2016). Without funding for monitoring and recording, progress could be jeopardized. Additionally, collaboration between government, researchers, and other stakeholders is a necessity to share information for decision making and effectively create change (Gilabert-Alarcón et al., 2018).

As of June 2023, scientists from Centro de Investigación Científica y de Educación Superior de Ensenada and Universidad Autónoma de Baja California have begun work on a government-authorized, multiyear project within the Valle to assess the aquifer's water budget, complete climate models to make predictions for the future, and build infrastructure to treat water for reuse in small wineries. This project will conduct long term monitoring of water quality and retention, and review local and land regulations to slow down extraction. Another goal is to improve data capture and share findings amongst a wide audience. The intention is for residents and scientists alike to be involved in water management and work collectively and self-sufficiently to address the issues of water shortages in a declining aquifer.

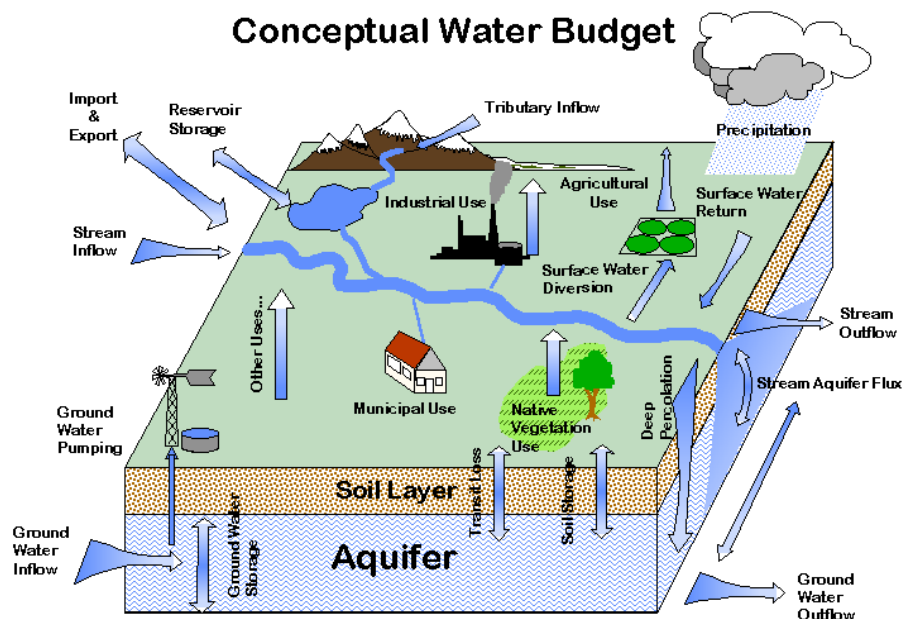


Figure 10: Examples of water sources that are assessed in water budgets from Know Your H2O

Sustainable and eco-tourism have slowly been gaining momentum in the Valle, but most of the interviewees agree that it hasn't become very common yet. When asked if many of their visitors are curious about climate change or sustainability impacts, the responses indicated that the answer was generally no. However, with the Valle's natural beauty being one of the draws and as popularity increases in the region, the future of eco-tourism and heightened awareness of environmental impact through slow tourism may not be too far behind. Valle winemakers as a community are committed to keep the area as an agricultural region first with a push for more education on water use and conservation. This philosophy combined with the ingenuity of residents and scientists who want to see this region continue to thrive indicates that there could be a shift in the expectations and offerings of what the Valle could provide as a tourist destination.

The Valle is an incredibly special and fascinating place, and there are multiple ways that wine lovers and tourists can support this region. First, by buying and drinking Mexican wine. The power of the dollar should never be underestimated, and by choosing Valle wines, consumers are experiencing hours of labor and passion from individuals who want the world to know about the Valle de Guadalupe. Secondly, interviewees encourage visiting the Valle to see the beauty, meet the individuals

who live and work in this area, and taste the food and wines. Ideally, tourists should spend time and money at the establishments who understand the environmental situation and take steps to find solutions. Visitors are also recommended to keep the peace of the rural region and avoid loud late-night activities. Finally, sharing the experience of visiting or drinking wines from the Valle de Guadalupe. The world deserves to know about the quality and caliber of wine grown and made in an area of the world that might not be on everyone's radar just yet.

As much as Baja California has grown as a culturally significant and exciting travel destination, interviewees express views of an unfair stigma tourists often have about Mexico being unsafe, which deter many people from crossing the border from the US. Wine made in the Valle is gradually making its way to the US and global markets, and represents an opportunity to bring attention and tell the stories of Baja to the world. Last year, Baja California hosted the 43rd World Congress of Vine and Wine of the International Organization of Vine and Wine (OIV) attracting many scientists and winemakers from different countries.

This is an area that has a rich wine-making history, has much to show travelers about the culture and food, and much to lose in the face of climate change. There are multiple challenges to address as this area rises to acclaim and responds to increases in visitors and demands for resources, but it's also proven that the land and people are resilient and resourceful. The Valle is a place worth investing time and attention so it can be preserved and thrive in the years ahead, and be an example to the world about the dangerous and devastating effects of climate change, and how local people can make strides to overcome those impacts.

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