A Review of Advantageous and Challenging Factors for Cool Climate Viticulture in Michigan

Advanced Project
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DePaul University

Competence Statements

F11: Can design and produce a significant product that gives evidence of advanced competence.

F12: Can utilize research skills to assess environmental factors for suitability of growing wine grapes in cool, nontraditional climates.

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INTRODUCTION AND STATEMENT OF THE PROBLEM

Winemaking is a crazy business. There are multitude of factors stacked against the producer with many variables depending on the whims of weather and luck. Thus, it is essential for the tractable elements of the business to be well thought-out and carefully considered. One of the most pivotal decisions of starting a winemaking business is location. Topography, soil type, native vegetation, average climate, precipitation, wind intensity and direction can all have a significant effect on successful grape growing. The goal of this research is to understand the suitability and challenges of growing wine grapes in cool climate regions of the state of Michigan in the Midwestern United States.

Through the study of soil maps, temperature and climate history and projections, as well as the known needs of various grape varietals and other factors, I hope to gain insight which will prove helpful to me when I am looking for vineyard land to purchase. Additionally, this research and its conclusions will be of interest to investors as it demonstrates the thorough assessment of factors which have been taken into consideration when putting together my business. Local governments may also be interested in this project, as it may help direct them to ways to attract other small-scale agribusinesses to the Midwest.

This research will be limited to exploring environmental and geographical factors of suitability, with some attention paid to the economic impact of certain industry standards, but will not include consideration of commercial factors. The state of Michigan will be the primary area of exploration as it has an active commercial winemaking community, established American Viticultural Areas, and is the intended location of my future vineyard and winery business.

RESEARCH METHODOLOGY

My research approach for this project differed from previous methodologies because I did not depend on research guides for generating content or key words. I was aware, from my Research Seminar focus on climate change and viticulture, that there are studies relating the environment and wine grape growth and production in a very diverse range of geographic areas, thus my primary concern was finding adequate sources which were specific to Michigan.

I knew that my research would ideally focus on viticulture solely in this state, however, my initial research statement was focused on the Midwestern United States in order to cast a slightly wider net. Fortunately, after a conversation with my Professional Advisor, a winemaker in Northern Michigan, I was able to connect with a professor of Horticulture at Michigan State University who is focused on viticulture. A phone call with him, as well as a search for his name in the DePaul WorldCat search engine, yielded several scholarly articles, all of which were focused on Michigan. By reading these, as well as researching articles and authors from the references sections, I was able to tighten the focus of my research to only Michigan viticulture, as I had initially hoped.

As a result of my reverse-engineering approach, most of my content sources are scholarly in nature, and based in scientific knowledge. These fields encompass studies in climate change, geology, geography, and other earth sciences. My suspicion was correct, that terms related to geography and viticulture would be key, and yield subject material rooted in scientific fields, as opposed to business or economic articles.

My artifact is a map of suitable areas for grape growing in Michigan, encompassing soil science, climate, elevation and topography. This research was more focused on agriculture as a whole, with a vinicultural-angle when possible. Thus, my research encompassed search terms such as “soil health”, “soil fertility” and “topographical effects on agriculture” in addition to the more specific, “site selection”, “grape growing climate”, “American Viticultural Areas” and “Michigan”. These searches were conducted via the DePaul library environmental science and studies research guide, of which EnvironmentComplete and GEOBASE were the most pertinent.

LITERATURE REVIEW

Literature which examines the suitability and challenges of growing wine grapes in cool climate regions of the state of Michigan focuses on a combination of environmental and economic factors, and the interaction between them and specific geographic locale. A winemaker who can anticipate and understand behavior and trends for these variables, and manipulate and/or react to them successfully, creates a final wine which is the product of their land, personal style, and particular vintage.

In addition to anticipated weather events in the near-future, wine grape growers tend to make the key decision of when to harvest based around three important factors of the grape berry: Brix[1], (°Bx), titratable acidity[2] and pH (Haggerty, 2012). The development of these variables is affected by climate and environment, as well as presence and development of pest and disease. Thus, in combination, they provide a clear picture of the grape berry's maturity, or ripeness, from which a winemaker can make educated assumptions regarding qualities of the final wine. All of these indicators, however, are predicated upon the winemaker's knowledge and familiarity with the nuances of their grape growing site. Successful wine grape growing is dependent upon a combination of macro-[3], meso-[4] and microclimate[5] (Galvez, Korus, Fernandez, Behn & Banjara, 2010) which help determine growing season (Bhadra, 2015), which helps determine which grapes to plant, and what style of wine to make (Haggerty, 2012). As for the land itself, one must consider soil type, color, nutrition & texture, degree of slope, aspect[6],

[1] Concentration of soluble sugars in a grape berry. 1° Brix is equivalent to 1% sugar – almost entirely glucose & fructose – by weight (Haggerty, 2012).
[2] "The major organic acids in the must are tartaric, malic, and citric. Of these three acids, tartaric and malic acids account for over 90% of the total acid constituents of the juice" (Iowa State University).
[3] "prevailing climate of a large geographic region (many square miles)" (Wolf & Boyer, 2003, p. 1).
[4] "local climate" (Wolf & Boyer, 2003, p. 2).
[5] "the specific environment within and immediately exterior to grapevine canopies" (Wolf & Boyer, 2003, p. 2).
[6] "the prevailing compass direction which the slope faces" (Wolf & Boyer, 2003, p. 16).

erosion, precipitation type, amount and timing, and previous land use (Mokma, Dersch & Kesselring, 2008).

Many industry participants, professionals and consumers believe that all of these factors conspire with the parent material of a site's soil to create a wine's *terroir*[7] (Cross, Plantinga & Stavins, 2011). For winemakers, there is a clear economic advantage to promoting this idea, for by tying their wine quality to their specific land, they allow no substitution for their product, ensuring its unique value (Maltman, 2008). In some countries, this idea is a government-certified concept, as wine-producing regions are given designation "based upon the geographic location of grape production" (Cross et al., 2008, p. 152), and in the United States these regions are certified as American Viticultural Areas (AVA) (Cross et al., 2008). Wine quality in many areas in the French *Appellation d'Origine Contrôlée* (AOC) are colloquially tied to the base material of bedrock from which their soils evolved (Cross et. al, 2011): "Champagne is commonly associated with chalk slopes, Chablis with Kimmeridgian limestone, Moselle wines with slate, Beaujolais with granite, etc" (Maltman, 2008, p. 2), but while these regions were initially defined by geologic boundaries, the status frequently ignores counter-dogma complications, such as the fact that chalk is only around 1/3 of the total surface area of the entire AOC region of Champagne (Maltman, 2008).

These ideas are further indirectly correlated when wine drinkers and professionals use geologically derived flavor descriptors, such as "earthy, stony and minerality" (Maltman, 2008, p. 2) to describe a wine. While vine roots can derive water from bedrock material, Maltman (2008) explains that "earth material is literally flavorless" (p. 10), and goes on to note that the same lithology, or type of rock, produces vastly different wines in different places around the

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[7] "from the French terre (meaning land), to refer to the special characteristics of a place that impart unique qualities to the wine produced" (Cross, 2011, p. 152).

world. He also explains that even if inorganic compounds were to contribute flavor, after a winemaker's fining and clarification processes they would make up a miniscule amount – about .2% - of a finished wine.

Scientists have, however, have found an academic connection between the effects of soil physical factors which are partially derived from breakdown and movement of underlying bedrock, and vine behavior (Maltman, 2008), and, as Maltman (2008) concedes, "the nature of this bedrock and its degree of weathering greatly influences the physical properties of the soil, an important influence on vine-root growth" (p. 3). Geology and landform fundamentally contribute to a grape vines' ability to flourish, as the resulting physical topography orchestrates air flow direction and speed, as well as influencing fungus, fruit set, frost, season length, cloud cover, vine damage, photosynthetic activity, berry acidity and berry sugar development (Maltman, 2008). Additionally, he explains, "the physical setting of a vineyard, ultimately due to bedrock geology…affects parameters such as…slope character, thermal properties and water availability, and these demonstrably influence vine growth and berry ripening" (p. 11). He concludes that the specific effects of bedrock on the flavor of a finished wine, when critically examined, are commonly exaggerated.

As we do know that physical landforms and climate conspire to create different growing environments, Galvez et al. (2010) observed very little overlap between the varietal of cultivars[8] grown in the Midwestern United States, vs. along the American West coast. As Michigan is classified as a cool-climate viticultural region, the large majority of grapevines planted have historically been from the less well-known, but more cold-hardy, family *Vitis labrusca*, L. (Schultze, Sabbatini & Luo, 2016). These cultivars are generally well-equipped to withstand the

[8] "A plant variety that has been produced in cultivation by selective breeding" (Oxford).

harsh winters which characterize the region, and have fewer instances of damage from challenging spring and fall frosts which have the potential to injure or kill vines (Schultze et al. 2016). Seasonal conditions optimal for agricultural plant growth are measured by Growing Degree Days (GDD), a concept defined by Nielson in 2017 as “daily accumulations of heat”, which determine the amount of thermal time within a season available to plants for growth and development. These thresholds are unique to each species, and in 2016 Schultze et al. determined that the number of GDD for grapevines in Michigan had increased an average of 3.68 annually since 1980, with the most accelerated growth occurring between 2000 and 2010. Schultze, Sabbatini & Andresen (2014) corroborated this trend when they determined that the Michigan grapegrowing season had increased by 28 days between 1971 and 2011, with the most dramatic increase occurring over the last 11 years of their study. This trend has placed the region into what Schultze et al. (2016) describe as a “zone of transition” (p. 3), leading to “earlier budburst, shorter bloom periods and fruit reaching harvest maturity earlier” (Schultze et al., 2016, p. 10). This transition has created a dramatic effect on fruit quality, as measured by Schultze et al. 2016 as °Bx, and crop yield. These noted changes in regional climate over the last 40 years (Schultze et al. 2016) have led wine grape growers to increase plantings of the more tender and profitable *Vitis vinifera* L. grapes, as temperature increases have created longer and warmer growing seasons, allowing *vinifera* varieties, which take longer to develop full maturity, to achieve peak ripeness (Schultze et al. 2016).

An additional noted benefit of warmer trends in the region for wine grape growers is a shift in warm-weather precipitation events (Schultze et al. 2016). Historically, Michigan growers have received the majority of precipitation throughout 3 key months of the growing season: August, coinciding with *veraison*[9], September, during ripening, and October, when harvest typically takes place. If precipitation trends continue, however, Schultze et al. (2016) are predicting more rain in April & May, as budburst commences, and significantly less during the later part of the season, potentially leading to reduced instances of disease and rot, and a higher and more stable °Bx at harvest. Both of these changes could have a positive impact on wine quality and grape yield in the region.

As with all change in nature, however, a change in climate has had an effect on multiple environmental variables affecting Michigan viticulture. According to Friend, Trought, Stushnoff & Wells (2011), one of the most hazardous threats to survival of Michigan vines has been the potential damage of spring and fall frosts. They clarify that the extent of the damage varies among cultivars, with other factors such as the amount of environmental moisture, in the form of dew or surface moisture, at the time of the freezing event, and bud developmental stage, strongly influencing injury, and, as a result, yield. The authors note that frost is particularly hazardous to grapevines due to their physiological development practice of growing buds for the following year during *veraison* before harvest. Implications of this practice include vine injury, but also frost damage to flowers or leaves, which can negatively affect retention of carbohydrates – with sugars, the plant's energy source- and thus proper development, for the following years' yield (Friend et al. 2011).

In 2014 Schultze et al. determined the annual instance and risk of potential frost days (PFD), or days with a minimum temperature of -1°C, between 1971 and 2011 in Southwest and Northwest Michigan. By examining the effects of climatic trends on regional viticulture they discovered that frost risk, while lessening over the studied time period, and demonstrably lower

[9] A commonly used French term for the onset of ripening when sugar development begins to significantly increase (winefolly).

in both Southern Michigan and along the West coast of the state, as opposed to farther inland, continues to be a challenge for Michigan growers. They concluded that despite the fact that annual PFDs were decreasing over time, variation from year to year in this region can still be dramatic, and frost will always be a risk of grape production in the region.

This being said, several techniques have been demonstrated to mitigate the extent of damage to vines. In 2011, Friend et al. attempted to delay budbreak of Chardonnay grapes, a more cold-hardy *vinifera* variety, until after the last spring frost, in order to determine the effects on yield. They accomplished this by the application of a sodium alginate[10] gel, sometimes painted on buds or sprayed by growers, which hardens over the bud growth cap (Friend et al. 2011). This is known to delay budbreak either because of its ability to physically limit budbreak, or because it slows down the metabolic rate of the plant (Friend et al., 2011). After application, a 5-hour frost event occurred. They reported that the more developmentally advanced buds sustained more damage than those in which budbreak was delayed. Their study also confirmed previous experiments by showing that, in vines which had been treated, when primary buds[11] were injured or died, secondary buds emerged to produce flowers and fruit. Schultze et al. (2014) note other frost protective strategies, including planting grapes on higher topographical features, improving cold air drainage and utilizing wind machines in the vineyard during frost events, in order to keep cold air from settling on vines and causing damage.

One significant advantage to growing grapes in a "'cool-cold' climate viticulture region of the world" (Schultze et al. 2016, p. 1) is the interruption of the life cycles of insects, making

[10] Sodium alginate is a hydrophobic biopolymer composed of two uronic acid polysaccharides. It is a FDA-approved edible coating and is also approved for use to prolong post-harvest shelf life and color of horticultural fruits, as well as inhibit microbial surface activity (Arrebola, 2015, p.255).

[11] A dormant grapevine bud is "a compound bud consisting of three growing points, sometimes referred to as the primary, secondary, and tertiary buds within one bud" (Hellman, 2015).

establishment of new pest populations a challenge (Galvez et al., 2010). Pertot et al. (2017), demonstrated that an increase in temperature has been positively correlated with insect population. In 2015, Bhadra noted that the shorter, humid growing season which is typical in the state make seasonal pests such as fungi, insects, bacteria and weeds a threat for healthy vines during the peak berry maturation period. It has historically been common for wine grape growers to combat these threats with an intensive spraying program which combined herbicide and pesticides, with fungicides accounting for the largest percentage of applications, and pesticide use typically significantly lower than in table grape production (Pertot et al. 2017).

Pertot et al. (2017) note that use of synthetic chemical insecticide is frequently determined to be the cause of environmental problems, and a known contributor to worker toxicity exposure. Thus, they explain, consumer demand for cleaner produce and practices is creating a demand for more environmentally sustainable spraying programs, as well as use of integrated pest management (IPM) techniques. These are defined by Bhadra (2015), as, "a systematic method for applying pesticides with the intention of minimizing risks to the environment and the agricultural economy" (p. 15), and also include sustainably oriented alternatives to spray programs, such as cover cropping and tillage techniques, among others (Pertot et al. 2017). The efficacy of these alternative programs has been challenged by the industry, as products are expensive to produce and sell, and market growth is smaller in the wine grape sector than in other agricultural areas (Pertot et al, 2017). One such recently developed alternative is the application of ozonated water on vines (Bhadra, 2015). A proponent of this idea, Bhadra touts its benefits as a lack of residue on plants and the fact that the ozone molecule, O_3, will naturally break down to a stable and harmless O_2 oxygen molecule when released into the atmosphere. Additionally, pests are unable to develop resistance to ozone as it destroys their cell-structure via oxidation reaction[12]. However, she also cites concerns by Cornell University viticulture director, Wayne Wilcox, about the limitations of ozone's ability to treat common grape berry diseases such as downy mildew, black rot and bitter rot, which occur inside the grape berry, where ozonated water does not penetrate. As seen in this table created by Petrot et al. 2017 (p. 75):

Table 1
Advantages and limitations linked to the use of microbial biofungicides.

Advantages	Limitations
They do not leave residues on berries	They have low persistency
They can be applied close to harvest	If not correctly applied their efficacy can be lower than chemicals
They do not interfere with fermentation	Their application needs more care (weather conditions, quality of water, etc.)
They are not (or less) toxic for humans and environment	In the case of high disease pressure they can be less effective
They are biodegradable	Their effect is often slower than chemicals
They are renewable	They are generally more expensive than chemicals
Their mechanism of action is complex and can be used in anti-resistance strategies	They cannot be tank-mixed with fungicides (with a few exceptions)
They are a useful tool in organic production and integrated pest management	Shelf-life is shorter than for chemicals
They are safe for workers	They have a strict expiry date
There is no (or a short) re-entry time after spraying	Some of them need to be stored at low temperature
They are not phytotoxic	Once open the box/bag should be re-sealed hermetically to prevent humidity
They can be applied with a normal atomizer	The suspension, once prepared, cannot be stored for a long time

the practical effects of these newer sprays have many benefits, as well as many challenges. As a whole, fungal biocontrol agents have been generally found to be too broad-spectrum in their application, and maintain poor efficiency (Pertot et al. 2017).

Other IPM techniques which do not include spraying different mediums are utilized by some growers (Pertot et al. 2017). The allure of these methods is their attention to the agricultural environment as a whole, and their view of vineyard health as a dynamic target composed of intersecting and interacting parts (Pertot et al. 2017). A relatively recent development in the academic viticulture world is the cultivation of disease-resistant and pest-tolerant hybrid grape varieties (Pertot et al. 2017). These varieties are economically and environmentally beneficial in that they require minimal spraying, and overall reduce cost, worker

[12] A chemical reaction classified by a loss of electrons, with an ensuing structural change at the molecular level (Wyman).

toxin exposure, soil compaction[13] and copper residue [14] on vines and soil, as well as contributing to the overall biodiversity, and thus strength and health, of a vineyard (Pertot et al. 2017). Challenges to their success in the industry include limited grower experience, lack of awareness and/or acceptance within the consumer market, and, in the case of place designation[15], legal limitations (Pertot et al. 2017).

In addition to challenges of disease, insects are a challenge to growers of all agricultural products. Bhadra (2015) notes that traditional pesticides have undesirable side effects, and are particularly problematic in that all pests are susceptible to developing resistance, creating an ineffective "chemical 'arms race" (p. 17). In a search for a more environmentally friendly and sustainable alternative to insecticides, some IPM-minded growers have experimented with placing reservoirs of semiochemicals[16], typically synthetic sex pheromones, around vineyard sites in order to deter or disrupt mating rituals among pests. The efficacy of this technique is inconsistent, due to its dependency on appropriate plant spacing and canopy, training systems, leaf density, and characteristics of the reservoirs themselves (Pertot et al. 2017). In situations where reservoirs were shown to be helpful in pest control, they lost efficacy above a certain pest population threshold, regardless of the number and placement of reservoirs (Pertot et al. 2017).

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[13] A result of physical pressure on the land over time, usually created by heavy machinery, which forms "a compacted layer [with] a high resistance to penetration" (White, 2009, p. 37) which can inhibit root growth and negatively affect the health of a soil's structure and its inhabitants.

[14] Copper-based fungicides are commonly applied in organically-certified viticultural spraying programs (Pertot et al. 2017).

[15] A designation of place or origin is a government-sanctioned pedigree status assigned to wine, cheese, and other value-added agriculture products which come from a particular geographic region and thus are seen as unique and unreproducible (Cross et al., 2011).

[16] "A pheromone or other chemical that conveys a signal from one organism to another so as to modify the behavior of the recipient organism" (Oxford).

Another complicated, but potentially viable, no-spray option includes the introduction of beneficial arthropods[17] (Pertot et al. 2017). These predators and parasitoids[18] are threatened by the use of pesticides, but as natural plant enemies their presence is typically an effective pest control, assuming their populations are maintained (Pertot et al. 2017). However, in addition to the challenges seen with the use of semiochemicals, Pertot et al. (2017) warn that "parasitoid survival & host searching can be affected by…the defense mechanisms of the host immune system" (p. 77), as well as sufficient host availability.

Further research and advancements will hopefully continue to discover effective alternatives to spraying programs, and environmental trends noted by scientists will certainly have an effect on wine grape growers in the transitioning Michigan viticulture industry. Only time will tell which predictions were accurate, but we are sure to see this industry evolve over the coming decades, influencing and augmenting its suitability for wine grape production.

[17] "animals with segmented bodies, jointed appendages and a hard outer…exoskeleton" (Lowenfels & Lewis, 2010, p. 22). Common soil arthropods include spiders, mites, ticks, flies, termites, ants and moths, among many others (Lowenfels & Lewis, 2010).

[18] "an insect and especially a wasp that completes its larval development within the body of another insect eventually killing it and is free-living as an adult" (Merriam-Webster).

RESULTS AND CONCLUSION

My research shows that multiple factors related to climate and environment, paired with natural benefits of topography and geography, anticipate Michigan's suitability for wine production to continue and expand over the next century (Schultze, Sabbatini, Luo (2016); Schultze, Sabbatini, Andresen (2014). Due to changing climate trends, as well as a growing local and national demand, the state has seen a 300% increase in plantings of *Vitis vinifera* L. acreage between 2000 and 2011, a trend which is likely to continue (Schultze et. al, 2016). The same study anticipates beneficial shifts in regard to timing of precipitation events, season length, and growing season temperature, which Schultze et al. (2016) cite as, historically, the three primary barriers to *vinifera* growth in the region. In addition, the research indicates that our plan of producing a combination of hybrid and *vinifera* varieties in the state is a wise choice, and the timing of purchasing land within the next two years may be optimal due to what Schultze et al. (2016) term the state's "zone of transition" (p. 3).

As we see environmental shifts in the mesoclimate, the microclimate of a Michigan vineyard becomes paramount. As Schultze et al. (2014) determined, changes in microclimate can have a dynamic impact on vine health and yield, and the researchers found dramatic differences in suitability between land parcels a mere 20 miles apart. This shows us that site selection remains one of the most important decisions a new winery can make, particularly in a transitioning environment, and underscores the opportunity that this evolution will provide in the coming decades.

Land features highlighted by Mokma et al. (2008), such as soil texture, color & nutrition, degree of slope and aspect, risk of water or wind erosion, as well as crop history, are all major factors when selecting a vineyard site. Cross et al. show us that an AVA designation is helpful from an economic standpoint, but it's true resiliency depends largely on the consumer's perceived value and tasting knowledge. Currently, Michigan boasts five AVAs: Lake Michigan Shore and Fennville in the South, and Leelanau Peninsula, Old Mission Peninsula and Tip of the Mitt in the North. These are concentrated on the Western coast of the state, as research shows us frost risk is lower, temperature variability is stabilized by the warmth-holding depth of Lake Michigan, and large-scale losses are less frequent (Schultze et al., 2016). Additionally, the testing that scientists have administered throughout Michigan AVAs anticipate a coastal temperature increase of anywhere from +2.5 – +6ºC by the year 2100, and precipitation, while still occurring year-round, seems likely to be concentrated during April and May, rather than August and September, creating potential for reduced pest and disease impact, and a higher, more stable ºB at harvest (Schultze et al., 2016). These key changes add to the evidence that the Western coast will most likely become even more hospitable for *vinifera* production sooner than other parts of the state, though specific properties in other regions may also be well suited depending on microclimate.

As a future owner of an agriculturally-based business, my concern for overall planet health and my desire to maintain an economically and environmentally sustainable business will lead to the utilization of IPM strategies for pest and disease control. Galvez (2010) and Pertot et al. (2017) show us that a changing climate means an altered threat of pest population as native species compete with new predators and inhabitants, demanding that grape growers intelligently manage the indices of pest and disease for overall vine and vineyard health (Pertot et al. 2017). Additionally, Bhadra (2015) notes that the resistance race between pests and chemicals established by the current insecticide industry is unsustainable, however, environmental concerns and a growing consumer demand for cleaner practices by growers make finding an alternative a priority. Best practices for how to go about this are, however, unclear. For example, it was not evident from the research whether it would be more effective overall to utilize smaller amounts of a more effective, but less sustainable, spraying program, or use more of a less effective, but more environmentally-friendly, agent. The advantages of growing resistant and tolerate cultivars have been demonstrated in a research environment, but this may not be the most effective solution from a business standpoint, due to lack of marketability and consumer awareness of these new varieties (Pertot et al. 2017). Either way, the current research recommends a multi-pronged approach involving natural pest enemies, plant architecture techniques such as cover cropping and lighter tillage methods, and planning inter-row crop planting effectively. These IPM-oriented techniques are beneficial in that they frequently support enhanced biodiversity in a vineyard, with the added benefit of increased soil health and fertility (Pertot et al. 2017).

In addition to proper pest management, and despite generally warming temperatures, current research shows that all Michigan grape growers will continue to be challenged by the potential of frost damage. While it is encouraging that Schultze et al. (2014) found a negative trending of PFD in the Southern sections of the state and closer to the lake over time, they conclude, along with Schultze et al. (2016), that early spring and late fall frosts will continue, as variability from year to year persists and, potentially, worsens.

In conclusion, the existing suitability of Michigan to cold-climate wine grape growing is anticipated to benefit from recent changes to the state's climate. This increased suitability has the potential to, in particular, support better quality and yield from plantings of *vinifera* cultivars, building a more stable and profitable local wine market, despite continuing challenges of frost, pest population, and disease. The year to year variation among these threats may lead to intriguing vintage differentiation for wineries, and could continue to develop distinct flavor profiles of the region as a result, a potential advantage for new winemakers.

ARTIFACT

The map I have created as an artifact effectively provides support in answering my initial research question as it illustrates the interaction of major wine-grape growing suitability variables for the state of Michigan. By looking at the indices of topography and elevation, soil type and temperature, in combination with current AVA locations and locations of existing wineries, we can compare these maps and identify viable areas for competitive and successful site selection for a new winery in Michigan.

LEARNING STATEMENT

Entering into the Advanced Project with a concrete post-graduation goal was advantageous for me because it narrowed the possibilities of what I might research to topics that are directly applicable to my winery plan. Before I solidified my research question I anticipated that this class would be an opportunity for me to display my growth in academic reading, writing and researching, time management, communication, networking, and collaboration. These are skills which have consistently been the focus of SNL classes, regardless of topic, and as this class represents the capstone experience for SNL it seemed appropriate to have a final opportunity to showcase my development.

In choosing my research question I was steadfast in my goal of researching topics which would support my next steps as a vineyard and winery owner. My research broadened my knowledge base in three key areas: Michigan's climate and the environment, vineyard site selection, and threats and challenges to growing grapes in cold climates. While all aspects are somewhat codependent, my understanding of each of these variables will be helpful at different points as a new farmer and winemaker. Site selection is arguably the most important decision that I will make, so competence in this area will help me as I look for land and weigh advantages and challenges of different properties. Understanding threats to cold-climate viticulture will help me make smart decisions regarding vineyard design and varietal selection, and a sense of Michigan's climate and environment will help me plan an effective vineyard management strategy and determine the style of my wines.

Many of the skills which I developed and deployed throughout the process of this project will enhance my career. Communication, networking and collaboration will be crucial to my success as a newcomer in an established winemaking community, and continue my role of mentee to my Professional Advisor and Externship winemaker. Analysis of my sources and the opportunity to compare conclusions of scholars allowed me to engage in critical thinking which will support problem-solving and decision-making as an entrepreneur. Further, feeling comfortable researching and interpreting academic articles will allow me to stay current within my field and continue to learn from experts. Thus, learning at this level has allowed me to develop tools to successfully navigate future challenges by seeking out and taking advantage of resources, asking for help when I need it, thinking creatively, remaining open to new ideas and concepts, and incorporating lifelong learning into my role as a business owner.

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