Effects of El Niño and the North Atlantic Oscillation on Zinfandel and Primitivo wine quality in Santa Rosa, California and Manduria, Italy

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Senior Integrative Exercise
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ABSTRACT

Sonoma County, California and Manduria, Italy are two of the world's largest producers of Zinfandel and Primitivo wine. In California, climate is affected by the El Niño-Southern Oscillation (ENSO) cycle, while Italy sees effects from the North Atlantic Oscillation (NAO). Climate data from 34 years were used to give average temperatures during the summer and winter months crucial to grape growth. Precipitation data for these months were also analyzed. These data were compared with documented El Niño years and years with a positive NAO index for evidence of climatic cyclicity. Using averaged wine quality ratings for California Zinfandel and Italian Primitivo, I compared years under the influence of one of these climate cycles with the wine produced in that year. This shows that neither El Niño nor NAO seem to be controlling the quality of wine produced in either of these regions, possibly due to human influence in the form of irrigation, an insufficient number of vintage charts, or the weakness of climatic cyclicity in the climate data.

Keywords: Zinfandel, Primitivo, El Niño, North Atlantic Oscillation, wine quality, cyclic climate change

INTRODUCTION

The flavor profile of a wine is dependent on many factors, some of which are variable, and some of which stay constant. The most important fixed factors are grape variety and soil type (Leeuwen et al., 2004; Stevenson, 1997). Of the variable factors that affect vintage, climate is the most important (Leeuwen et al., 2004; Rodó and Comín, 2000; Stevenson, 1997). For example, too much water in the berry will dilute flavor compounds, while sunshine and temperature affect the sugar and acid levels in the grapes (Hornsey, 2007). Among these climatic factors, studies show that the greatest effect comes from precipitation rather than temperature (Leeuwen et al., 2004), with wet years in general producing poorer quality wines. The preferred climate is hot during the day and cool nights with 10 or 11-day periods with little to no rain (Mero, 2007).

Because wine quality is linked so closely to climate, one might think that cyclic climate changes such as El Niño-Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) would have an effect on vintages. Previous studies have focused on the effects of El Niño and NAO on harvest dates (Souriau and Yiou, 2001) or the effects of these climatic cycles on wine quality in Spain (Rodó and Comín, 2000), but none has studied their effects on the Zinfandel and Primitivo wines grown in California and Italy.

Climate is, of course, not the only important influence on vintage. Another very important variable is the human influence. Everything that a vintner does, from irrigation to the aging process, can change the flavor of a wine (Mero, 2007; Stevenson, 1997). Because irrigation to some extent mitigates the effects of climate by compensating in years that are too dry it can even cancel out to some extent the influence of climate.

The goal of this study is to examine the effects that El Niño and NAO have on temperature and precipitation in California and Italy and correlate these data with vintage charts of wine grown in these areas. From this correlation, I will draw conclusions about the extent to which cyclic climate events affect wine quality.

WINE QUALITY RATINGS

Wine quality is judged on three factors: appearance or “eye,” smell or “nose,” and taste or “palate” (Stevenson, 1997). Several factors that affect the eye are clarity of the wine, viscosity (higher alcohol content leads to higher viscosity) and color. Color depends on grape variety, the ripeness of the grapes at harvest, age of the wine, and vinification methods (Stevenson, 1997).

Taste is, naturally, the most important factor in deciding wine quality (Stevenson, 1997). Because taste differs from person to person, any assessment of wine flavor will depend heavily on the person who is doing the tasting. The dominant flavor compounds in wine are tartaric and malic acid, arabinose (sugar), and ethyl alcohol (Hornsey, 2007). Each person has a different detection threshold and a different tolerance for each of these compounds, so even when two people are able to taste the same flavor, the wine will not appeal to each person equally (Stevenson, 1997).

A vintage chart is one person’s assessment of a particular region’s wine product from a specific year. Vintage charts are highly subjective and results vary from source to source. The wines may be rated on a scale of 100, 10 or 5 depending on the source, and some judges even give tips on how long to age the wine before consumption for optimal flavor.

ZINFANDEL/PRIMITIVO

Until recent years little was known about the origins of the Zinfandel grape of California or its connection to the Primitivo grape of Southern Italy (Mirošević and Meredith, 2000). There has been speculation about the relationship between Primitivo and Zinfandel since 1967, when a plant pathologist visited southern Italy and made a visual comparison between Primitivo plants growing in a vineyard and Zinfandel plants he had seen in California (Mirošević and Meredith, 2000). This connection eventually led Carole Meredith at University of California in Davis to perform a DNA analysis of Zinfandel and Primitivo (Mirošević and Meredith, 2000). Meredith found that Zinfandel and Primitivo are the same variety, with origins in Croatia (Maletia et al., 2004). A third cultivar, Plavac mali, from Croatia was also thought to be the same variety, but DNA testing confirmed that it is in fact the offspring of Zinfandel and yet another cultivar (Maletia et al., 2004). Now the connection between Zinfandel and Primitivo is widely acknowledged, and some Primitivo wine is even marketed as Primitivo/Zinfandel (Mero, 2007). Using Zinfandel and Primitivo as the wines in this study allows us to control for differences in flavor and quality due to different varietals that might react differently to climatic influences.

STUDY AREAS

Santa Rosa, California is located in Sonoma County, one of the preeminent wine-growing regions of the world (Stevenson, 1997). Located in Northern California, it is where much of California's Zinfandel wine is grown and produced (Fig. 1). All climate data for California reported in this study is from Santa Rosa.

Manduria, Italy is located in the Puglia Region of Southern Italy (Fig. 2). It is the primary source for Primitivo wine, which is sometimes called Primitivo di Manduria. All climate data for Italy in this study comes from Lecce, Italy. Lecce is 45 km east of Manduria, but Lecce and Manduria are on the coast with no large mountain ranges separating them, so I assume the climates are similar.

Figure 1. Location map for study site in Sonoma County, California.

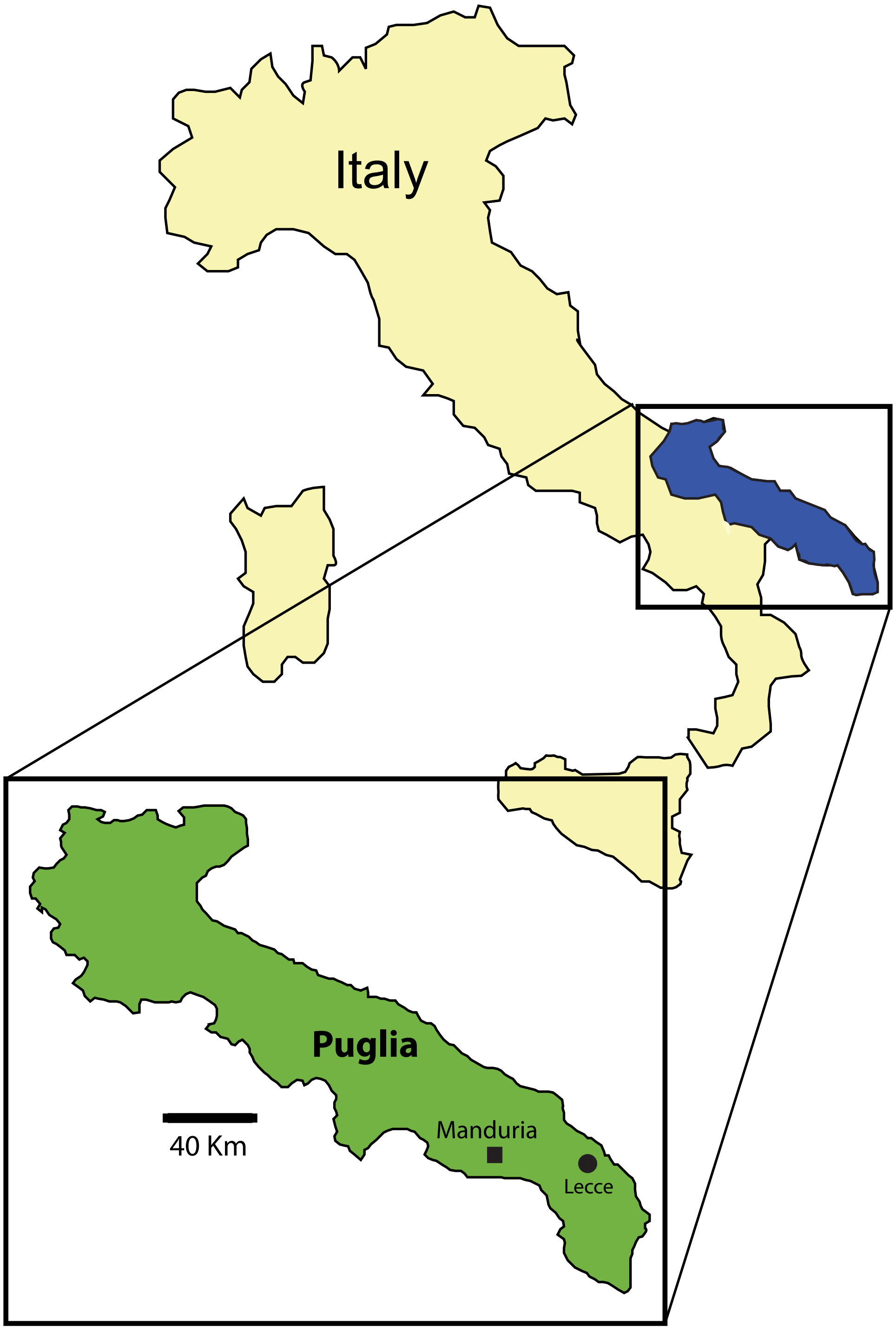

Figure 2. Location map of study area in the Puglia Region of Italy.

METHODS

Vintage charts are highly subjective, which means that they are not a concrete source of data. To account for the differences in opinion in vintage charts, this study uses the averaged results of 13 vintage charts of California Zinfandel and 6 vintage charts of Italian Primitivo. Since vintage charts from different sources use different rating systems, in this study I have converted all ratings to a scale of 10. The vintage charts used in this study come from multiple online sources (Appendix).

Temperature data for Santa Rosa came from the online database managed by the National Oceanic and Atmospheric Administration (NOAA) Satellite and Information Service and the National Climatic Data Center (NCDC) (NOAA and NCDC, 2007). The data give daily averages over a span of 34 years. For the purposes of this project, these data have been recalculated to give monthly averages for the 34 years, from 1973 - 2007. The precipitation data used in this study is from the Department of Water Resources California Data Exchange Center online (CDEC, 2007). It covers a span of 34 years in monthly averages, from 1973 - 2007.

Temperature data for Lecce also comes from the NOAA Satellite and Information Service database (NOAA and NCDC, 2007), while precipitation data comes from the EuroWeather website (Nautica, 1995). Reliable daily or monthly precipitation data for Lecce is not available for the period of time in this study. Therefore the precipitation data from Lecce in this study shows the average monthly amount of precipitation from 1961-1990.

Summer precipitation and winter temperatures and precipitation, have the most impact on wine growth (Hornsey, 2007). Therefore I have averaged temperature data together to give a winter average and a summer average for each year. For the purposes of this study, winter means the months of December, January, and February, and summer is June, July, and August.

The NAO indices used in this study come from the NOAA Climate Prediction Center website (NOAA, 2007). They give the monthly index, which in this study I have averaged into a yearly index (Fig. 3).

DISCUSSION

The current literature on El Niño events generally agrees on several major El Niño years: 1976-77, 1977-78, 1982-83, 1986-87, 1991-92, 1992-93, 1994-95, 1997-98, and 2002-03 (Alexander et al., 2002; Caviedes, 2001; D'Aleo and Grube, 2002; Diaz and Markgraf, 1992; Glantz, 2001; Molnar and Cane, 2007; Rodó and Comín, 2000). El Niño years are in general characterized by warm, wet winters on the west coast of the United States, and in California the winter storms often lead to landslides, flooding and erosion (Caviedes, 2001). However, no two El Niño events are the same (Molnar and Cane, 2007) and some El Niño years seem to be accompanied by minimal precipitation, such as the 1976-77 event (Kump et al., 2004).

This trend is reflected in the precipitation data from Santa Rosa (Fig. 4). For the most part, in this graph the documented El Niño years have some of the highest total precipitation, which means that El Niño is having an effect on precipitation in this area.

The temperature data from Santa Rosa responds less clearly to the El Niño trends. Among the average winter temperatures (Fig. 5a), some warm years correspond with El Niño years, but in fact some of the warmest years are not El Niño years, i.e. 1995/96 and 1996/97. The summer temperatures seem to respond a little more to El Niño (Fig. 6a).

Years in which the NAO index is positive typically result in warm wet winters in Northern Europe and dry conditions in the Mediterranean (Mekik, 2007). A negative

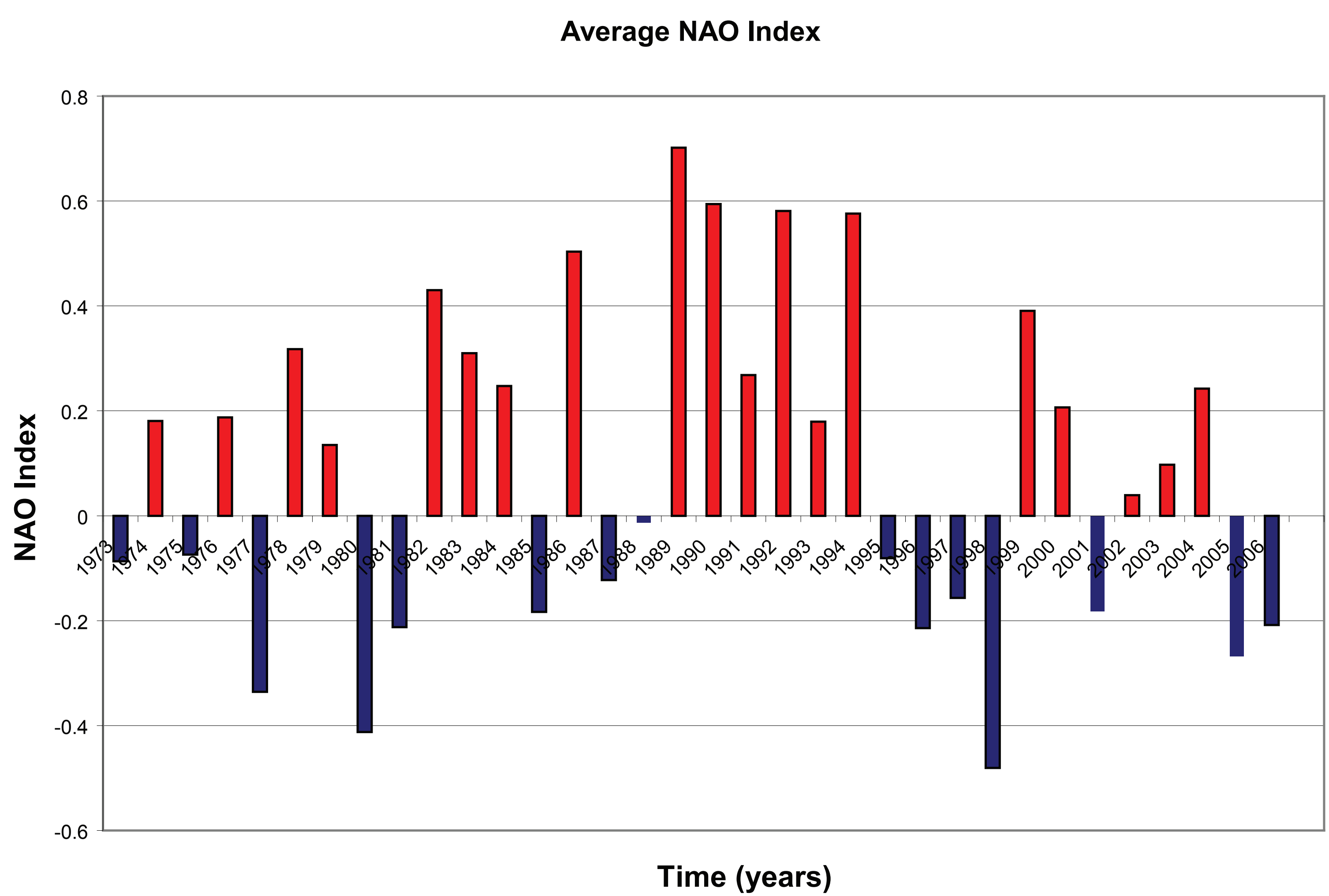

Figure 3. Average NAO indices. Red columns are years with a positive index, and blue columns are years with a negative index.

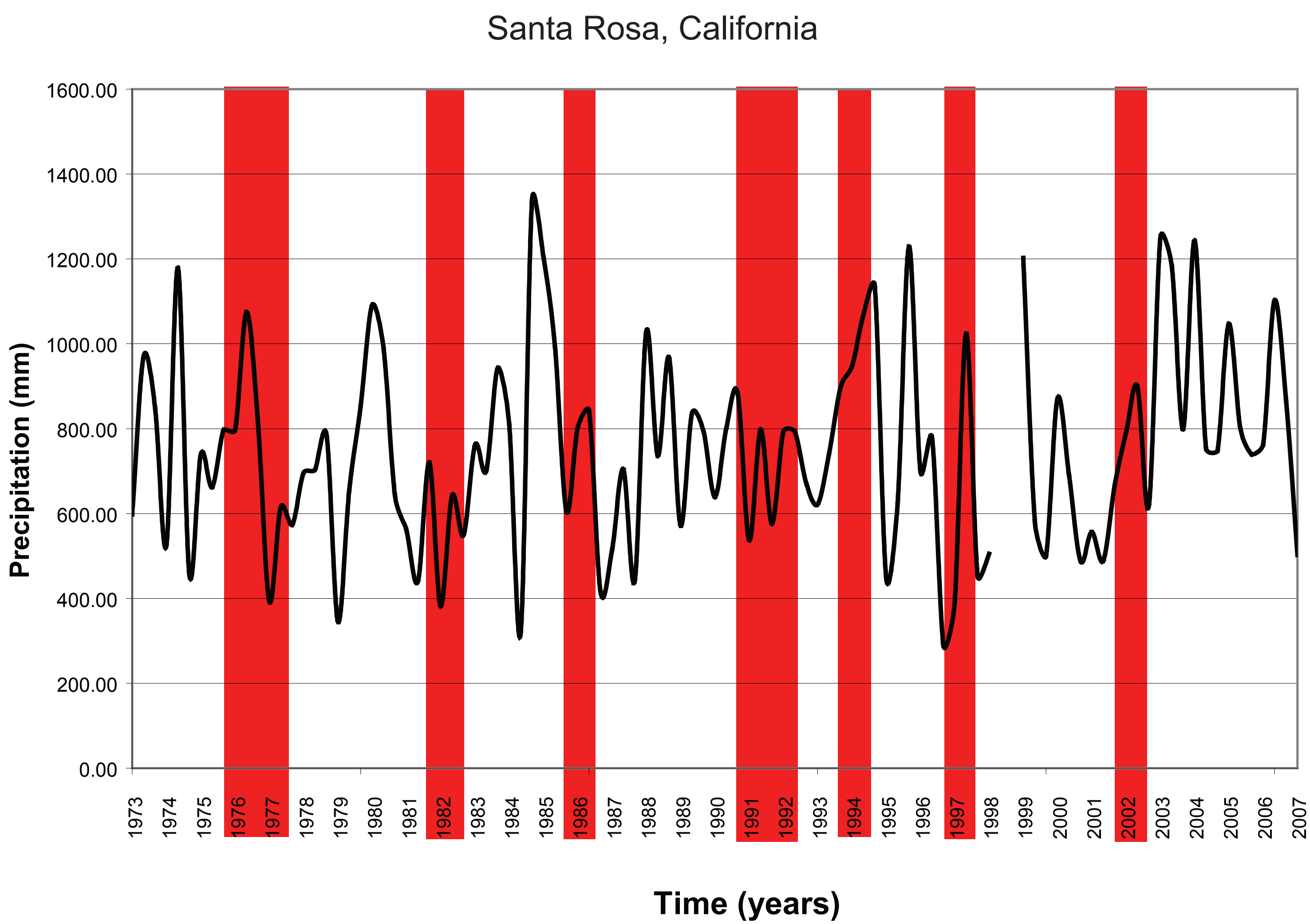

Figure 4. Total yearly precipitation for 102 years from Santa Rosa, California. The years marked in red are years in which El Niño is in effect.

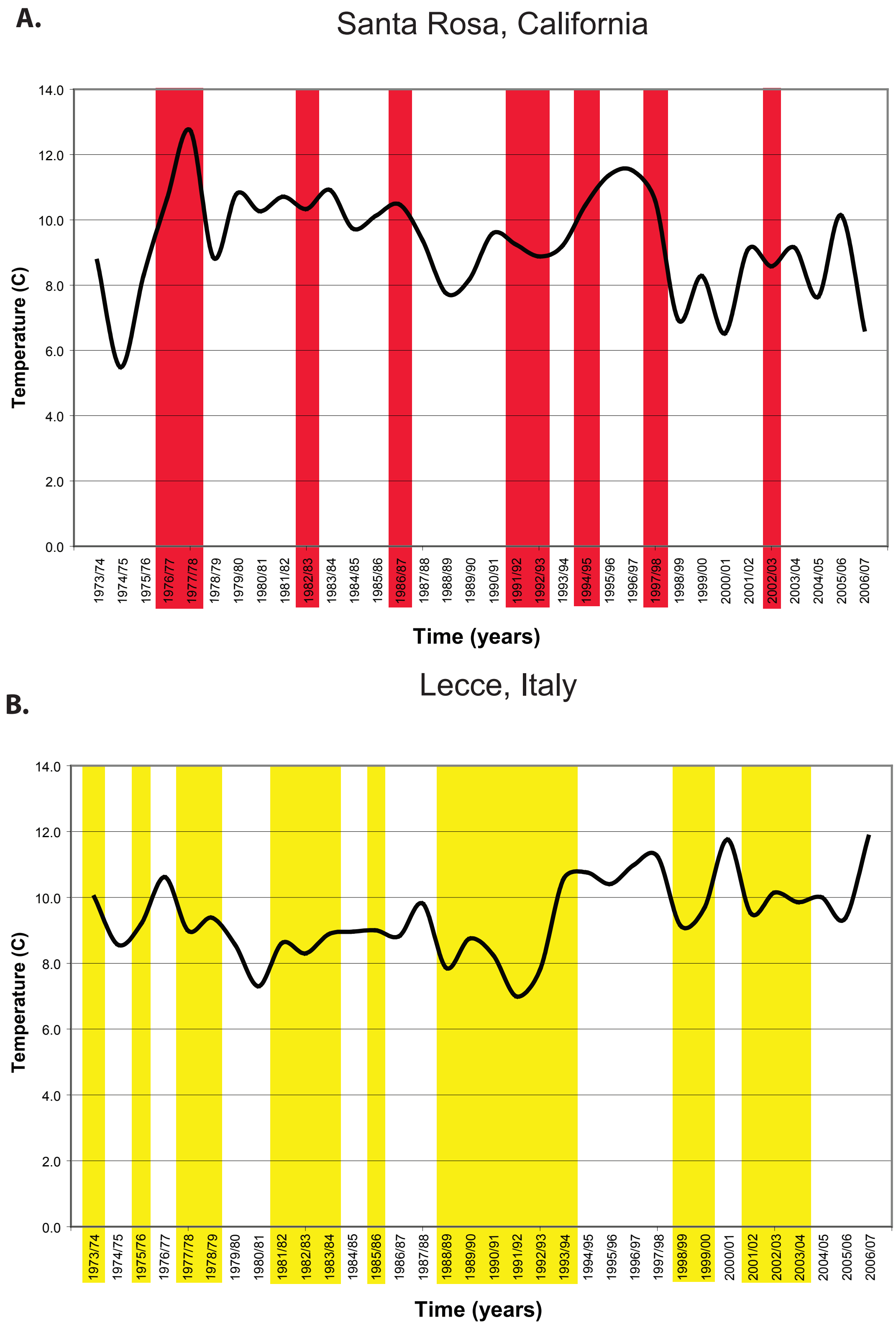

Figure 5. Average winter temperatures over 34 years. (*A*) Temperature data from Santa Rosa. Red indicates years in which ENSO is in effect. (*B*) Temperature data from Lecce. Yellow indicates years in which NAO index is positive.

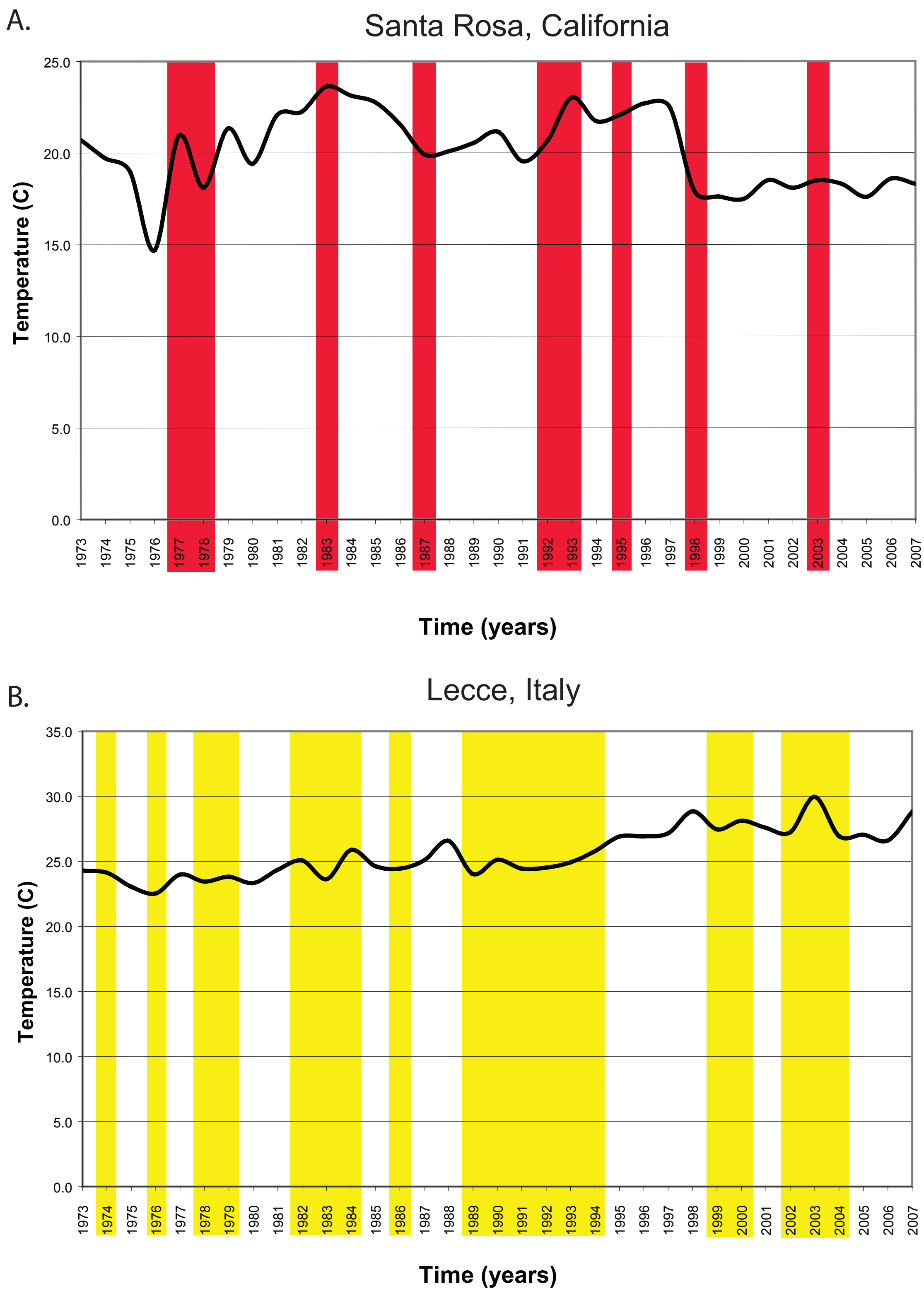

Figure 6. Average summer temperatures over 34 years. (*A*) Temperature data from Santa Rosa. Red indictes years affected by ENSO. (*B*) Temperature data from Lecce. Yellow indicates years with a positive NAO index.

NAO index corresponds to very cold conditions in Europe (D'Aleo and Grube, 2002), and also brings moisture to the Mediterranean (Bell and Visbeck, 2/20/2008). Using Figure 3, I can determine that 1976, 1978-1979, 1982-1984, 1986, 1989-1994, 1999-2000, 2002-2004, and 2007 were years with positive NAO indices.

When these results are compared to the winter temperature data from Lecce, Italy (Fig. 5b), we see that the temperature does not really seem to depend on the NAO index of that year. Some of the highest temperatures occur in years with a negative index, and some in years with a positive index. The same seems to be true for the summer temperatures (Fig. 6b), though there are more highs that match with positive NAO years than the winter temperature data.

Although I cannot compare precipitation data from Lecce with the NAO index, I can compare it to the average monthly precipitation from California (Fig. 7). Here we see that during the critical summer months, June, July, and August, California on average receives less total precipitation than Italy. As these are important months in grape development, less water is better (Hornsey, 2007). Conversely, during the critical winter months, December, January, and February, California receives more precipitation than Italy.

Table 1 compares each year's vintage quality to the dominant climate modifier for that region. In general, the vintages from California are of higher quality and have a much lower standard deviation than the Italian vintages. This is in keeping with the current literature on wines from Italy, which states that they tend to be of poorer quality than wines from other parts of the world (Stevenson, 1997).

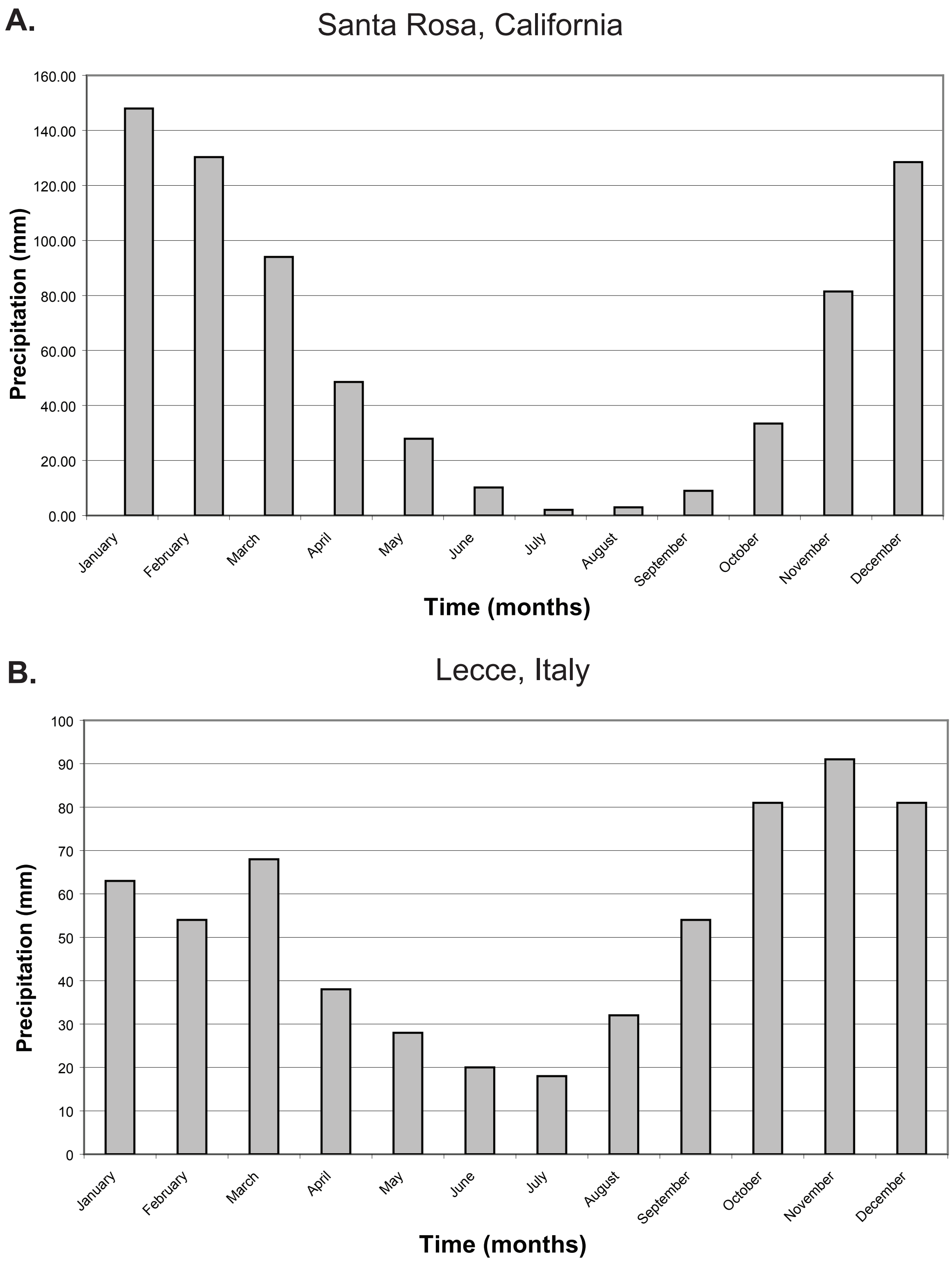

Figure 7. Graphs of average monthly precipitation at field sites. (A) Data from Santa Rosa, covering 34 years. (B) Data from Lecce, covering 29 years.

Table 1 : Vintage Charts

Year	ENSO	California	NAO	Italy
1975	no	8.8	negative	no data
1976	no	8.4	positive	no data
1977	yes	8.4	negative	no data
1978	yes	8.4	positive	9.0
1979	no	8.2	positive	no data
1980	no	8.1	negative	5.0
1981	no	8.1	negative	5.5
1982	no	8.0	positive	8.0
1983	yes	7.5	positive	6.5
1984	no	8.0	positive	2.0
1985	no	8.7	negative	8.5
1986	no	8.4	positive	6.5
1987	yes	8.8	negative	5.3
1988	no	8.2	negative	8.3
1989	no	8.0	positive	6.8
1990	no	8.9	positive	8.0
1991	no	9.1	positive	7.1
1992	yes	8.6	positive	6.7
1993	yes	8.2	positive	6.6
1994	no	8.6	positive	7.1
1995	yes	8.7	negative	6.5
1996	no	8.5	negative	8.2
1997	no	8.5	negative	8.9
1998	yes	8.0	negative	8.1
1999	no	8.6	positive	8.0
2000	no	7.9	positive	7.7
2001	no	8.8	negative	9.3
2002	no	8.7	positive	6.1
2003	yes	8.8	positive	8.3
2004	no	8.6	positive	8.5
2005	no	8.5	negative	8.7
2006	no	8.6	negative	7.0
2007	no	8.6	positive	no data

Notes: The years marked in gray show years with a positive NAO index, or years in which ENSO is in effect.

One possible explanation for the difference in wine quality between the two study areas is irrigation. In Italy, it is against the wine-growing regulations to irrigate the grapes. Thus all water comes strictly from natural sources (Mero, 2007). In California, irrigation is standard practice in many vineyards, which greatly mitigates the effects of cyclic climate change on grape growth (Montanari, 2007).

The Italian wines are on average a 7 out of 10 in quality. Taken separately, the average quality for a year with a positive index is 7, while the average for years with a negative index is 7.4. Using a statistical analysis called a T-test to measure the strength of this difference shows that it is not statistically significant. This means that there is essentially no difference between the wines from years with a positive and a negative index. Although not significant, it is interesting to note that the highest ratings are from years in a negative NAO phase and the lowest ratings are during years in a positive NAO phase. This would seem to indicate that when the NAO is in a negative phase, it might actually be slightly more conducive to producing good quality wine.

One possible reason for which the difference in wine qualities is not significant is the limited sample size of quality ratings. The amount of information available about Italian Primitivo is very limited, which decreases the confidence in and accuracy of the results. With more ratings available, it is possible that the difference in qualities would prove to be significant.

In the case of Zinfandel wines from California, it is interesting to note is that the average quality for wines from El Niño years is the same as that for wines from non-El Niño years. This means that El Niño appears to have essentially no effect on wine quality in California whatsoever. Again this could be due to the small sample size of quality ratings, or it could be due to factors beyond the climate.

As stated before, California receives less rain, but has the ability to water in dry years. Essentially this means that growing conditions in California are rarely too wet, and when they are too dry, the vintner can compensate. Italy, on the other hand, does not have the option of irrigating, and has a wetter climate than California. Here this means that they are more likely to get too much rain, and they cannot compensate in years that are too dry. This could also account somewhat for the fact that the wine from California varies far less in quality than that in Italy, as well as its overall higher caliber. This might also be the explanation for the similarity of wines from El Niño and non- El Niño years in California.

RESULTS AND CONCLUSIONS

The results of this study indicate that neither El Niño nor the North Atlantic Oscillation affects wines produced in California and Italy. This is not in keeping with previous studies that have found that these climate cycles affect wine qualities in Spain (Rodó and Comín, 2000).

There are several possible explanations for this discrepancy. It could be that human interference in the form of irrigation is erasing the effects of El Niño in California. This would mean that the influence of humans in winemaking can be so great that it overcomes the effects of natural climatic events.

It is also possible that the flaw lies in the vintage charts. Since vintage charts are so highly variable and subjective, perhaps they are not a good basis for a study. Maybe with a more reliable and less subjective analysis of the wine, such as a chemical test, it would be possible to find a more direct connection between the climate changes and wine quality. Also, the small sample size of vintage charts limited the accuracy and dependability of their results. With a larger number of vintage charts available, it might have been possible to show a stronger correlation.

Another factor in weakening the connection between El Niño, NAO, and wine quality is the apparent weakness of the climate signal in the temperature and precipitation data for the two study areas. This could be due to poor data, or some factor that is preventing a clear El Niño or NAO signal from showing up. Perhaps both climatic cycles are affecting the data, but the interference between them makes it impossible to see either one clearly.

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APPENDIX

The vintage charts used in this study are as follows:

Zinfandel:

1. Robert Parker's wine vintage chart, accessed January 20, 2008, http://www.wine-pages.com/vintage.shtml#part2
2. WineSquire.com's vintage chart, adapted from Wine Enthusiast Magazine, accessed January 20, 2008, http://www.winesquire.com/articles/vchart.htm
3. The Wine Advocate Vintage Guide, accessed January 20, 2008, http://www.erobertparker.com/newsearch/vintageChart1.aspx
4. Wine Online, accessed January 20, 2008, http://www.wineonline.ie/cellar/charts.htm
5. Wine Enthusiast Magazine, accessed January 20, 2008, http://www.winemag.com/ME2/dirmod.asp?sid=DF51BF6739994DC7A29DF9D0C2BC5CF9&nm=Departments&type=Publishing&mod=Publications%3A%3AArticle&mid=8F3A7027421841978F18BE895F87F791&tier=4&id=8CE1A02B48A14A91BEFFC2D6B3108C76
6. Daniel Rogov's Vintage Chart from Strat's Place, accessed January 20, 2008, http://www.stratsplace.com/rogov/dr_vintage_usa.html
7. Enobytes Vintage Chart, accessed January 20, 2008, http://www.enobytes.com/Enobytes_Vintage_Chart_2007.pdf
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Primitivo

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3. Anthony Hawkin's World Wine Vintage Chart, accessed January 20, 2008, http://www.wineloverspage.com/wineguest/wine_vintage.html#itloc
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