Analysis of climatic changes in different areas of Abruzzo region (Central Italy): implications for grape growing

Analyse des changements climatiques dans différents zones de la région des Abruzzes (Italie Centrale): implication pour la viticulture

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Summary

The dynamic evolution of some bioclimatic indices largely used to define the vocation of areas to grape growing was assessed over 43 years (1965-2007) in four sites of the Abruzzo Region (Central Italy). Nowadays Abruzzo has about 34.000 ha of vineyards mainly located in coastal areas running North-South along the Adriatic Sea, while the inland mountainous areas reduced their importance in the last 60 years.
In the maritime areas, represented by Lanciano and Nereto weather stations, rainfall amounts during vegetative period (from April to October) showed a reduction around 1980 while average growing degree days (GDD) remained stable until 1997, when a sudden increase (change point) of about 320 GDD was registered in Lanciano, but not in Nereto. This Northern maritime area became slightly cooler: average air minimum temperature during vegetative phase decreased in 1971-1977 period, and also air maximum temperature decreased after 1985. In the inland area (Sulmona), "change point" analysis revealed a sudden increase of average GDD, maximum and minimum air temperature around 1980, but no quick change in rainfall was assessed.
In Abruzzo Region, as already reported for other areas of Europe, changes of some climate parameters influencing grape ripening and composition occurred in these last decades, but with different modality according to the characteristics of the area.

Key words: viticulture, climate variability, climate indices

Introduction

Relationships between climate and grape growing have been extensively studied in the last century and several indices, mainly based on air temperature, have been proposed to describe region or site suitability to viticulture. The temperature criteria developed by Amerine and Wnkler (1944), measuring the available heat for growth over vegetative period (generally from April to October in the Northern emisphere), was used to define five climatic regions of California for grape growing. Amerine and Winkler index was criticized as being too simplistic, but it has been extensively applied to viticulture as reported by Gladstones (1992) and Jones and Davies (2000). This index assumes a linear relationships between temperature above 10°C and grapevine growth, while evidences reviewed by Gladstones (1992) suggest that vine growth reaches its maximum at mean temperatures around 23-25°C. On this basis Gladstones (1992) proposed a new index featuring a mean temperature cut off at 19°C. Recently Tonietto and Carbonneau (2004) combined three climatic indices to provide a classification of viticulture climates more universally valid. A Cool Night Index was proposed for describing climatic condition during maturation. The above mentioned indices have been generally used with a static approach and reported as average values of varying time periods.
Climatic changes have been observed over the last hundred years with different magnitude in the different areas (Werner et al., 2000). The impacts of climate change are likely to be not uniform across regions and varieties. Global warming might push a region outside of the optimum conditions for growing its traditional grape varieties. Abruzzo region, geographically situated in the East portion of

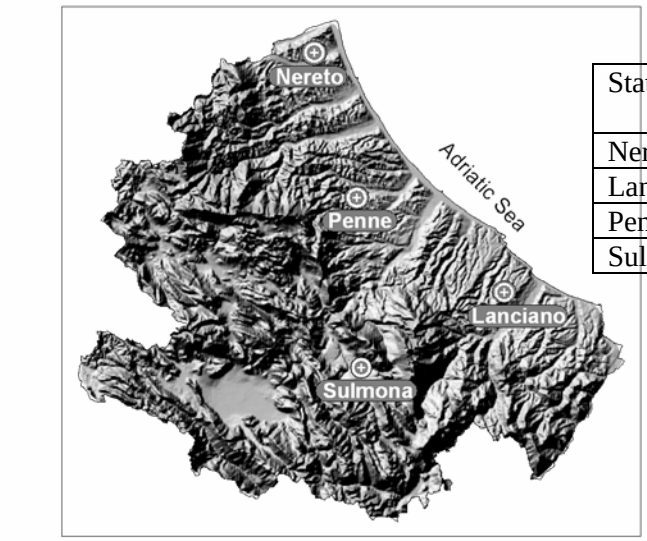
central Italy, extends over 10,794 km² with abundant viticultural areas mainly distributed in hills sloping to a narrow plain that runs North-South for most of the 129 kilometre long Adriatic coastline. The inland mountainous areas, accounting for almost two-thirds of the land, feature the highest Apennine peaks in Gran Sasso massif (2914m) and Maiella-group (2795m). Nowadays around 34.000 ha of vineyards are grown in Abruzzo and the viticultural importance of inland areas was reduced in the last 60 years.
Poor information are still available on climate of the Abruzzo Region and on its variability over time. The present paper report some climatic indices of four stations situated in grape growing areas of the Abruzzo as well as their evolution over a 43 years time period.

Material and Methods

Analysis of climatic variability of Abruzzo was performed for four stations from 1965 to 2007 and data were obtained from "Servizio Idrografico del Genio Civile" in Pescara. The Nereto, Penne, Lanciano and Sulmona stations have not been relocated in the period of record. Nereto and Lanciano stations are representative of maritime grape growing areas of the Abruzzo, Sulmona is situated at the foothill of the Maiella mountain and is representative of the inland areas, while Penne sits in the hills between the Apennine Mountains and the Adriatic Sea (fig. 1). The climatic data consist of daily observations of maximun temperature (Tmax), minimum temperature (Tmin) and precipitation (P). Daily mean temperature was then calculated as T = (Tmax +Tmin)/2). The above mentioned climatic variables were used to calculate the following parameters:

- Average daily maximum temperature over vegetative period (TmaxVeg) calculated from April to October;
- Average daily minimum temperature over vegetative period (TminVeg) calculated from April to October;
- Growing Degree Days (GDD = T summation base 10°C from April to October);
- Raw Day Degree Summation above 10°C with 19°C cut off (RDDS = T summation from April to October, base 10°C ceiled at 19°C) as reported by Gladstone (1992);
- The number of days with extreme high temperatures (Dext), that is the number of days with Tmax>30°C as reported by Jones and Davies (2000);
- Cool night index (CNI), that is average minimum air temperature in September as reported by Tonietto and Carbonneau (2004);
- Average daily temperature range calculated for each month over vegetative period.
- Continentality Index (CI), that is the difference between T of the hottest and T of the coldest month, as reported by Gladstone (1992);
- Precipitation over vegetative period (Pveg = P summation from April to October);
- Precipitation over season (Ps = P summation from November to October of the next year);

Average values of each variable were calculated, then over time evolution of climatic parameters characterizing the four stations of the Abruzzo was assessed performing linear regression analysis. The slope (**β)** of regression line was estimated following the method reported by Hirsh *et al.* (1982). Statistical significance of each trend was evaluated by applying Mann – Kendall non parametric test (Kendall, 1962).
Change point analysis on 1965-2007 time series of studied variables and indices was carried out by means of the Strucchange library of R statistical software (http://www.r-project.org/) to detect occurrence of abrupt variation in climate



Station	Elevation (m)	Distance from the sea (km)
Nereto	163	9.5
Lanciano	283	10.0
Penne	438	19.4
Sulmona	420	51.0

Figure 1 Abruzzo region and location of the four station used in this study.

Results and Discussion

The four stations used in the analysis range from 163 to 438 m above sea level and from 9.5 to 50 km from the cost. Average values of growing season maximum air temperature (Tmaxveg) ranged from a minimum of 24.5°C recorded in maritime station of Lanciano to a maximum of 26.2°C recorded in the inland station of Sulmona, which showed the lowest average value of growing season air minimum temperature (13.2°C). These differences among areas in maximum and minimum air temperatures lead to small differentiation on daily mean temperatures over the growing season. As a consequence, the four sites showed similar heat summation over vegetative season: Growing Degree Days (GDD) ranged in fact from 1944 to 2130°C, values which fall in the range defined for region IV in California(Amerine and Winkler, 1944). Raw Day Degree Summation above 10°C with 19°C cut off (RDDS), suggested by Gladstone (1992) as a basis to predict maturity date, ranged from 1501 to 1599, thus confirming the abundant heat availability of the four Abruzzo grape growing areas, that are suitable to grow late maturity varieties. Occurrence of days with extreme high temperatures (Dext) was more frequent in inland station of Sulmona where 53 days per year daily maximum temperature exceeded 30°C (Tab.1). The inland area of Sulmona showed also cool nights during maturation, being its Cool Nigh Index (CNI) around 13.2°C (*i.e.* class CI+1 defined by Tonietto and Carbonneau, 2004), while the other three areas experienced temperate nights with CNI ranging from 15.5 to 16.1°C (*i.e.* class CI-1 defined by Tonietto and Carbonneau, 2004). Daily temperature variability of each month over vegetative season (data not shown) peaked in July and August when reached values around 9.70-10.14°C for Nereto, Lanciano and Penne stations. As expected, the inland area of Sulmona showed the largest daily temperature variability range, varying from a minimum of 10.59 in October to a maximum of 14.61 in August, and the highest Continentality Index (CI). In other words the inland mountainous area of Sulmona experiences cold winters and warm summers with large temperature variability between day and night. The mountainous Sulmona area showed the lowest precipitation amount during vegetative period and over all season, while Penne, in the hillside between the Apennine Mountains and the Adriatic Sea, showed the highest precipitation amounts (Tab. 1).

Station	Tmax °C	Tmin °C	GDD °C	RDDS °C	Dext No.	CNI °C	CI °C	Pveg mm	Ps mm
Nereto	25.2	15.8	2130	1599	35	16.1	19.3	388	685
Lanciano	24.5	15.2	2003	1552	27	15.5	18.8	387	750
Penne	24.5	15.5	2024	1562	31	16.0	18.7	479	825
Sulmona	26.2	13.2	1944	1501	53	13.2	20.6	311	612

Table 1 Average values of climate variables or indices for the four stations of the Abruzzo over 43 seasons (1965 to 2007).

Over time evolution of the above reported climate variables or indices was assessed by linear regression analysis and the trends are reported in Table 2. Average value of growing season minimum temperature significantly increased in all the four stations of the Abruzzo, while growing season maximum temperature considerably raised only in the inland mountainous station of Sulmona. The combined effects of over time variability of maximum and minimum temperature resulted in a significant increase of heat availability in the inland mountainous Sulmona area (10.23°C and 4.401°C increases respectively in GDD and RDDS) and in the maritime Lanciano area (7.42°C and 2.426°C increases respectively in GDD and RDDS). The Northern maritime Nereto area and Penne did not show any significant trend of GDD and RDDS in the last 43 years. Number of days with maximum temperature exceeding 30°C significantly increased only in inland Sulmona area (1 day per year). This mountainous inland area became warmer, but precipitation amounts and distribution seem to remain stable over the last 43 years as well as in Nereto and Penne areas. Maritime Lanciano area went through a significant decrease in rainfall amount during growing season (Tab. 2).

Station	Tmax °C	Tmin °C	GDD °C	RDDS °C	Dext No.	CNI °C	CI °C	Pveg mm	Ps mm
Nereto	-0.0032*	0.029*	-0.23 ns	-0.760 ns	-0.22 ns	-0.005 ns	0.037 ns	-2.94 ns	-4.68 ns
Lanciano	0.014 ns	0.050**	7.42*	2.426*	0.31 ns	0.019 ns	0.036 ns	-2.94**	-3.66 ns
Penne	-0.015 ns	0.024*	2.12 ns	0.740 ns	-0.11 ns	0.0003 ns	0.016 ns	-0.11 ns	-1.05 ns
Sulmona	0.075**	0.025*	10.23**	4.401**	1.00**	-0.013 ns	0.046 ns	-0.39 ns	0.23 ns

Table 2 Trends (beta coefficients) of the over time regressions (43 seasons, from 1965 to 2007) calculated for climate variables or indices for the four stations of the Abruzzo.

Trend analyses are largely used for model projections of future climate, but they are often affected by large data variability and do not take into account over time discontinuity and the occurrence of climatic phases, as reviewed by Mariani (2005). Change point analysis was then applied to find out the occurrence of sudden change in climate evolution of the four Abruzzo stations over the past 43 years. The results are summarized in Table 3, that report seasons of abrupt climate changes.

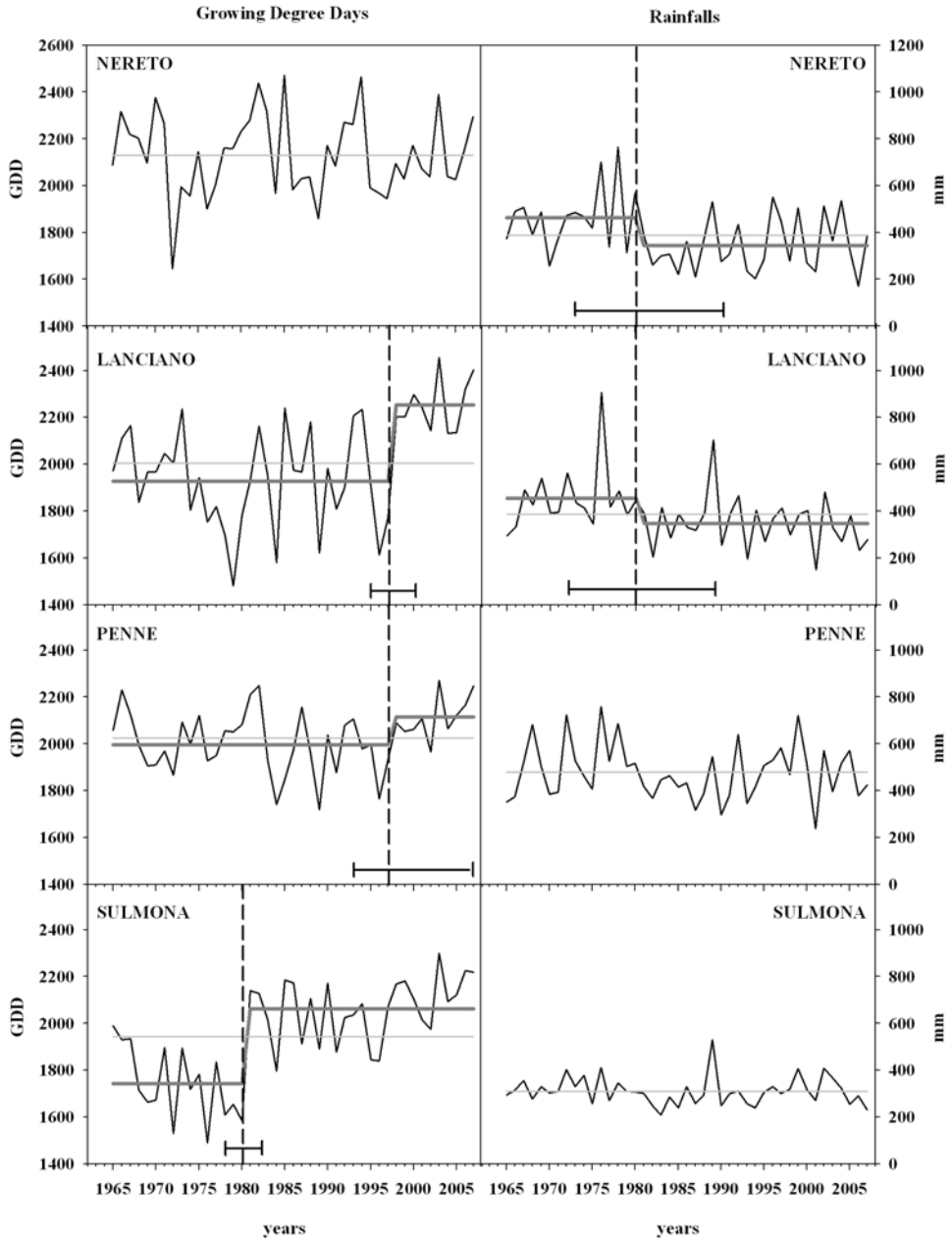


Figure 2 Change point analysis on Growing Degree Days (left) and Precipitations (right) for the four Abruzzo stations. Vertical dotted lines represent change point and horizontal lines in the bottom of each figure are the confidence interval. Horizontal thick lines represent the means of the two segments.

In the maritime Lanciano and Nereto areas, rainfall amounts during growing season showed a sudden reduction around 1980 while GDD remained stable until 1997, when a rapid increase (change points) of about 300 GDD was registered in Lanciano, but not in Nereto. This Northern maritime area became slightly cooler: average air minimum temperature during vegetative phase decreased in 1971-1977 period, and also air maximum temperature decreased after 1985.On the contrary, Lanciano Southern maritime area became warmer after 1997 and experienced extreme high temperatures in summertime: the number of days with temperatures exceeding 30°C raised from 24 to 37. Penne, in the hillside between the Apennine Mountains and the Adriatic Sea, was little affected by climate change: a small decrease in maximum air temperature was registered in 1983-1999 period, and the recent sudden increase of minimum air temperature was associated to a small raise in GDD (Fig. 2). In the inland mountainous area of Sulmona, "change point" analysis revealed a sudden increases of average GDD, maximum and minimum air temperature around 1980, but no quick change in rainfall was assessed. In Sulmona area number of days with temperatures exceeding 30°C raised from 39 to 65 after 1984.

Station	Tmax °C	Tmin °C	GDD °C	RDDS °C	Dext No.	CNI °C	CI °C	Pveg mm	Ps mm
Nereto	1985	1971 1977	_	_	_	1977	1999	1980	1981
Lanciano	1997	1997	1997	1997	1997	_	1979	1980	1989
Penne	1982; 1999	2001	1997	_	_	_	1973 1984	_	_
Sulmona	1971 1980	1980 1990 1997	1980	1980	1984	1999	1980	_	_

Table 3 Change point analysis applied to some viticultural indices of four stations of the Abruzzo over 43 seasons (1965 to 2007). Years of estimated sudden changes in the parameter are herein reported.

Conclusions

In Abruzzo Region, as already reported for other areas of Europe (Werner et al., 2000), changes of some climate parameters influencing grape ripening and composition occurred in these last decades, but with different modality according to the characteristics of the areas.

Acknowledgements

We thank Dr. Renato Zauri for his support in software R application to the data set and Dr. Paola Paoletti for the precious help in making the figures.

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