# PEDOCLIMATIC COMPARISON OF THREE VITICULTURAL AREAS OF ITALY DEVOTED TO HIGH-QUALITY AGLIANICO AND CABERNET SAUVIGNON PRODUCTION

Eugenia Monaco[1], Roberto De Mascellis[1], Giuliana Barbato[2,3], Paola Mercogliano[2,3], Maurizio Buonanno[1], Piero Manna[1,] Nadia Orefice[1], Anna Brook[4], Veronica De Micco[5], Antonello Bonfante[1]

[1]Institute for Mediterranean Agricultural and Forest Systems -CNR-ISAFOM, National Research Council, Via Patacca, 85, 80056 Ercolano NA, Italy
[2]Meteorology Laboratory, Centro Italiano Ricerche Aerospaziali (CIRA), Capua, (CE), Italy
[3]Regional Models and Geo-Hydrogeological Impacts Division, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Capua, (CE), Italy
[4]Spectroscopy & Remote Sensing Laboratory, Department of Geography and Environmental Studies, University of Haifa, Mount Carmel, 3498838, Israel
[5]Department of Agricultural Sciences, University of Naples Federico II, via Università 100, 80055, Portici (Naples), Italy

*Corresponding author: eugenia.monaco@isafom.cnr.it

## Abstract

**Aim:** The study aims to show how different pedo-climatic conditions (past, present, and future) in three Italian sites at different latitudes (from center to southern), affect the adaptation of two red grapevine cultivars: Aglianico and Cabernet Sauvignon.

**Methods and Results:** The pedoclimatic conditions of three experimental vineyards in three Italian regions (Campania, Molise and Sicily) were analyzed through a pedological survey to characterize the soils and to perform a climatic evaluation. The latter was based on local weather information and on the Regional Climate Model COSMO-CLM at high-resolution (8km x 8km) climate projections RCP 4.5 and RCP 8.5 (2010-2100) and Reference Climate (RC, 1971-2005). The degree of grapevine adaptation to future climatic scenarios in each experimental vineyard was evaluated through the use of bioclimatic indices (e.g., Amerine and Winkler).
Results showed how climate change will affect the cultivation of Aglianico and Cabernet Sauvignon, considering both the thermal and water needs of the cultivars in the analyzed viticultural areas. The RCP 8.5 scenario was the worst one for all experimental sites in terms of A&W but also for precipitation and extreme events, while RCP 4.5 highlighted differences among sites and time periods analyzed. For instance, for Aglianico, the thermal requirement (2110 GDD) will be reached in the RCP 4.5 in all experimental sites, while in the RCP 8.5 it will occur but mainly in a shorter time (~ 7 days less for 2070-100). Moreover, the increase in the frequency of extreme events during the grapevine season (i.e. maximum temperature >35°C, April-October) is expected to occur in the last time window of RCP 4.5 (2070-2100 with an increase of ~5%) and during the whole RCP 8.5 scenario. In this last scenario, the increase ranges from 15% (2010-2040) to 50% (2070-100) at all sites.

**Conclusion:** The present study explored how future climate scenarios will impact Aglianico and Cabernet Sauvignon vineyard cultivation in central and southern Italy, considering the specific thermal requirements of these two vineyards. The results, in terms of climatic requirements (Amerine and Winkler index) showed how the two vineyards could react to future climate change in three sites located in central and southern Italy.

**Significance and Impact of the Study:** The present work is the first example in southern Italy to evaluate the impact of climate change on two red grapevines varieties (indigenous cv and international one) to climate change. The degree of adaptation was evaluated by means of a thermal index widely used in viticulture, the Amerine and Winkler. This study has a direct impact at local and national scale, because it introduces a procedure that helps stakeholders to assess the adaptability of the wine-growing systems of territories.

**Keywords:** Pedo-climatic conditions, Aglianico, Cabernet Sauvignon, adaptation to climate change, thermal index

# PEDOCLIMATIC COMPARISON OF THREE VITICULTURAL AREAS OF ITALY DEVOTED TO HIGH-QUALITY AGLIANICO AND CABERNET SOUVIGNON PRODUCTION

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1)National Research Council of Italy (CNR), Institute for Mediterranean Agricultural and Forestry Systems (ISAFOM), Ercolano (NA), Italy;
2-3) CMCC-2 Meteorology Laboratory, Centro Italiano Ricerche Aerospaziali, Regional Models and Geo-Hydrogeological Impacts Division ; 4) University of Haifa, Israel, 5) Department of Agricultural Sciences, University of Naples Federico II
Corresponding author: eugenia.monaco@isafom.cnr.it

## OBJECTIVE

To evaluate how different pedo-climatic conditions (past, present, and future) in three Italian sites at different latitudes (from center to southern), affect the adaptation of two red grapevine cultivars

## STUDY AREAS

The experimental sites are placed in Italy at different latitudes.


The site is in hilly area with an elevation of 605 m a.s.l. The slope is 5% with a North- East exposition


The site is in hilly area with an elevation of 280 m a.sl. The slope is 4% with a North exposition


The site is located on the Etna volcano at an elevation of 720 m a.s.l. The place is composed by terraces with a South-East exposition

## MATERIALS AND METHODS

**Climate change scenarios**: two different simulations were performed by employing two standard IPCC (Intergovernmental Panel on Climate Change) RCP 4.5 and RCP 8.5 greenhouse gas (GHG) concentrations. (Bucchignani et al 2015)

| RC | RCP 4.5 | RCP 8.5 | |
|---|---|---|---|
| 1971-2005 | 2010-2040 | 2040-2070 | 2070-2100 |

**Thermal index:** Amerine & Winkler index (1944)

$$GDD=\sum_{10/31}^{04/01}\frac{(Tmax+Tmin)}{2}-10$$

**Grapevine thermal requirements:**

Aglianico---2150 GDD (Bonfante et al., 2018)

Cabernet-Souvignon---1900 GDD (Turri et al,1987)

# RESULTS

## PEDOLOGICAL SURVEY

After a pedological survey, the representative soil profiles of each study area were identified, described, and sampled, as shown in the table and photos. For soil profile the dotted white line represent the delimitation of the soil horizons. The chemical and physical analyses were realized in the laboratory.

### Campania


P1 Cabernet


P2 Aglianico

| | Molise | | | |
|---|---|---|---|---|
| | P1 | | | |
| Soil profile (cm) | Ap1 0-5 | Ap2 5-30/45 | Bwk 30/40-80 | BC 80+ |
| pH | 7.94 | 8.25 | 8.47 | 8,50 |
| ECe | 0.230 | 0.142 | 0.122 | 0,105 |
| Coarse sand (g kg⁻¹) | 87 | 67 | 46 | 85 |
| Fine sand(g kg⁻¹) | 294 | 245 | 221 | 208 |
| Silt (g kg⁻¹) | 190 | 215 | 181 | 316 |
| Clay (g kg⁻¹) | 429 | 473 | 552 | 391 |
| Organic Carbon (g kg⁻¹) | 23.5 | 18.0 | 4.48 | 7,18 |
| Organic matter (g kg⁻¹) | 40.5 | 31.0 | 7.72 | 12,4 |
| Total N (g kg⁻¹) | 2.52 | 2.03 | 0.69 | 0,62 |
| Rate C/N | 9.3 | 8.9 | 6.5 | 11,6 |
| Available P ($P_2O_5$) (g kg⁻¹) | 104 | 42.4 | 6.93 | 7,45 |
| CSC (meq 100g⁻¹) | 33.9 | 32.5 | 29.7 | 27,9 |
| Exchangeable Ca (meq 100g⁻¹) | 28.9 | 27.1 | 24.5 | 25,80 |
| Exchangeable Mg (meq 100g⁻¹) | 2.42 | 3.22 | 3.71 | 1,03 |
| Exchangeable Na (meq 100g⁻¹) | 0.38 | 0.35 | 0.31 | 0,31 |
| Exchangeable K (meq 100g⁻¹) | 2.17 | 1.78 | 1.13 | 0,72 |
| Available Fe (mg kg⁻¹) | 13.7 | 15.7 | 14.4 | 9,76 |
| Available Cu (mg kg⁻¹) | 17.7 | 19.8 | 15.0 | 12 |
| Available Zn (mg kg⁻¹) | 3.13 | 2.85 | 2.38 | 1,87 |
| Available Mn (mg kg⁻¹) | 9.53 | 9.26 | 5.04 | 4,41 |

### Molise


P1

| | Campania | | | | |
|---|---|---|---|---|---|
| | P1- Cabernet | | | P2- Aglianico | |
| Soil profile (cm) | Ap 0-40 | Bwk 40-60/70 | Cb 60-70/100 | Ap 0-50 | Bw 50+ |
| pH | 8.67 | 8.79 | 8.69 | 8.42 | 8.66 |
| ECe | 0.100 | 0.104 | 0.096 | 0.121 | 0.142 |
| Coarse sand (g kg⁻¹) | 206 | 127 | 151 | 141 | 114 |
| Fine sand(g kg⁻¹) | 325 | 352 | 305 | 191 | 226 |
| Silt (g kg⁻¹) | 269 | 301 | 358 | 171 | 177 |
| Clay (g kg⁻¹) | 200 | 220 | 186 | 497 | 483 |
| Organic Carbon (g kg⁻¹) | 4.50 | 1.47 | 1.38 | 8.14 | 4.99 |
| Organic matter (g kg⁻¹) | 7.77 | 2.54 | 2.39 | 14.0 | 8.60 |
| Total N (g kg⁻¹) | 0.58 | 0.29 | 0.29 | 0.80 | 0.61 |
| Rate C/N | 7.8 | 5.1 | 4.8 | 10.1 | 8.2 |
| Available P ($P_2O_5$) (g kg⁻¹) | 6.08 | 2.70 | 5.12 | 9.95 | 4.69 |
| CSC (meq 100g⁻¹) | 21.7 | 25.4 | 26.0 | 31.3 | 30.9 |
| Exchangeable Ca (meq 100g⁻¹) | 18.9 | 20.4 | 19.7 | 26.8 | 23.4 |
| Exchangeable Mg (meq 100g⁻¹) | 1.94 | 4.15 | 5.42 | 3.38 | 6.42 |
| Exchangeable Na (meq 100g⁻¹) | 0.14 | 0.12 | 0.15 | 0.26 | 0.28 |
| Exchangeable K (meq 100g⁻¹) | 0.68 | 0.65 | 0.65 | 0.86 | 0.80 |
| Available Fe (mg kg⁻¹) | 11.7 | 12.3 | 12.6 | 16.0 | 15.4 |
| Available Cu (mg kg⁻¹) | 7.52 | 3.09 | 2.91 | 13.5 | 11.9 |
| Available Zn (mg kg⁻¹) | 0.90 | 0.39 | 0.62 | 1.15 | 1.27 |
| Available Mn (mg kg⁻¹) | 4.04 | 2.25 | 2.81 | 6.00 | 4.37 |

### Sicilia


P1 Aglianico

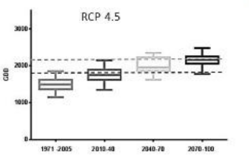

P2 Cabernet

| | Sicilia | | | | |
|---|---|---|---|---|---|
| | P1- Aglianico | | P2 - Cabernet | | |
| Soil profile (cm) | Ap 0-20 | Bw 20-40 | Ap1 0-20 | Ap2 20-45 | Bw 45+ |
| pH | 7.70 | 7.52 | 6.93 | 7.07 | 7.15 |
| ECe | 0.050 | 0.034 | 0.054 | 0.025 | 0.030 |
| Coarse sand (g kg⁻¹) | 646 | 678 | 463 | 342 | 476 |
| Fine sand(g kg⁻¹) | 315 | 293 | 468 | 577 | 439 |
| Silt (g kg⁻¹) | 34 | 18 | 49 | 63 | 78 |
| Clay (g kg⁻¹) | 5 | 11 | 22 | 18 | 7 |
| Organic Carbon (g kg⁻¹) | 13.3 | 7.95 | 27.1 | 22.0 | 25.7 |
| Organic matter (g kg⁻¹) | 22.9 | 13.7 | 46.8 | 37.9 | 44.4 |
| Total N (g kg⁻¹) | 1.43 | 0.66 | 2.52 | 1.97 | 2.43 |
| Rate C/N | 9.3 | 12.0 | 10.8 | 11.2 | 10.6 |
| Available P ($P_2O_5$) (g kg⁻¹) | 46.0 | 17.0 | 42.9 | 19.1 | 19.2 |
| CSC (meq 100g⁻¹) | 7.86 | 4.50 | 13.5 | 14.5 | 20.0 |
| Exchangeable Ca (meq 100g⁻¹) | 7.06 | 2.55 | 8.01 | 8.04 | 11.4 |
| Exchangeable Mg (meq 100g⁻¹) | 0.09 | 0.11 | 0.42 | 0.45 | 1.02 |
| Exchangeable Na (meq 100g⁻¹) | 0.08 | 0.05 | 0.10 | 0.12 | 0.19 |
| Exchangeable K (meq 100g⁻¹) | 0.38 | 0.21 | 0.80 | 0.59 | 0.57 |
| Available Fe (mg kg⁻¹) | 15.5 | 20.0 | 21.8 | 37.9 | 86.7 |
| Available Cu (mg kg⁻¹) | 4.55 | 8.36 | 5.21 | 6.74 | 3.31 |
| Available Zn (mg kg⁻¹) | 1.67 | 0.82 | 1.44 | 0.80 | 0.76 |
| Available Mn (mg kg⁻¹) | 0.54 | 0.54 | 0.70 | 0.46 | 0.46 |

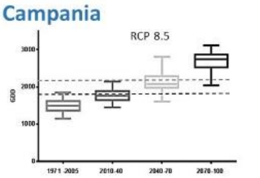
## THERMAL REGIMES UNDER CLIMATE CHANGE

Boxplot of A&W Index for each climate scenario and site. The dotlines in the chart are treshold for Cabernet (---1900 GDD) and Aglianico (---2150 GDD)

### Campania

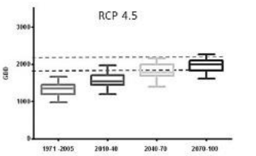



A&W ranges between **1582 and 2500 GDD.**

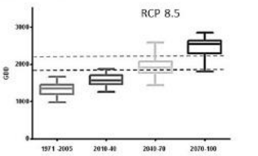



A&W ranges between 1700-3100 GDD

### Molise

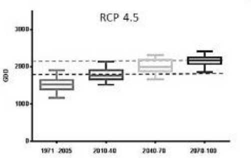



A&W ranges between 1401 and 2260 GDD.

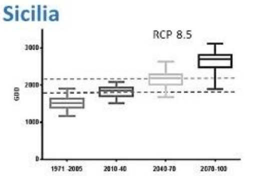



A&W ranges between 1500-2800 GDD

### Sicilia

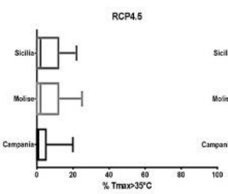


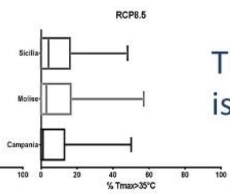

A&W ranges between **1900 and 2650 GDD.**




A&W ranges between **1960-3350 GDD**

## EVALUATION OF PRESENCE OF THERMAL EXTREME EVENTS

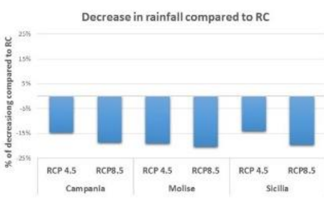



The occurrence of Tmax >35°C is about 3%

Thermal extreme events (April- October) were evaluated in agreement to Jones (2012). The occurrence of daily absolute maximum temperature over 35°C is reported.

## RAINFALL REGIME




Precipitation is expected to decrease compared to the reference period in all RCPs (4.5 and 8.5) and study sites

## CONCLUSIONS

- The variability of vine cultivars can be an excellent alternative to contrast the CC and not alter the hilly landscape;
- Climate plays a fundamental role in determining the thermal adaptability of a cultivar and the bioclimatic index of Amerine and Winkler can be an excellent indicator for detecting future trends;
- Cabernet Sauvignon has good chances of adaptation in the RCP 4.5 in all sites. For RCP 8.5 it is not very adaptable in the Sicilian site and in for the other two sites only in the first thirty years;
- For Aglianico there are high chances of adaptation in the RCP 4.5 in all sites. For 8.5 it is adaptable until the second time window (2040-70) in the Campania and Molise sites, while for Sicilian site Aglianico is not adaptable since 2040-70 because temperatures are too high compared to threshold;
- The maximum extreme temperatures will occur in all the sites for both scenarios; in RCP 8.5 (2070-100) these could represent a risk but only for the hilly site of Molise;
- In the future study, adaptability will also be determined taking into account the **hydraulic properties of the soils influenced by precipitation regime.**