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Internship Project

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Introduction

All agricultural activities are decidedly dependent upon and inherently interconnected to climate and weather; grapes are no different. Though grapes are grown worldwide, premium winegrape production occurs within very narrow climate ranges. Individual winegrape varieties have even narrower climate ranges. For optimum quality and production putting the cultivation of winegrapes is at greater risk from both short-term climate variability and long-term climate changes than other crops (Jones e Webb 2010). Climate's influence on agribusiness is at its most evident with viticulture and wine production where it is arguably the most critical aspect in ripening fruit to its optimum to produce the desired wine style.

There is a general acceptance by the scientific community of the reality of climate change in relation to human activities, especially concerning greenhouse gases (GHGs) emissions. Depending on the GHGs emissions scenario, it is expected an increase in global mean surface temperature from 1ºC to 3.7°C by the end of the century when compared to the reference period 1986-2005 (IPCC, IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 2007). The observed and projected climate changes have large impact on agricultural production in terms of various crop (Lobell 2008). This includes vine phenology and grapes composition, advanced harvest times, increased grape sugar concentrations and high alcohol level in wine (Orduña 2010). This is potentially a threat to the current, traditional wine regions but also makes other areas, e.g. located in north and central Europe, available for wine grapes cultivation. According to (Jones and White 2005), the regions of high-quality grapes production are at the margins of their climatic limits. For the other areas, e.g. in Central Europe, the observed changes in climate could push some regions into more optimal climate regimes for the production of wine grapes (Jones and White 2005). Several papers reported that earlier maturity was observed in typical regions of wine production, e.g. in Italy (Webb LB and Whetton PH 2012), and this was linked with the climate changes observed in recent years (Kryza and Szymanowski 2015).

Adverse effects of climate change include, among others, threats to traditional, regional wine grapes varieties (Bock A and Sparks T 2011), but the majority of the Western and Central European wine-producing regions have benefited from the observed trends in climate. The observed warmer season, e.g. in Lower Franconia, Germany (Bock A and Sparks T 2011), results in greater ripening potential of wine grapes but also has an impact on higher sugar content, and this alters the wine typicity. The changes in climate over the recent decades are also responsible for the increase of the area of land potentially suitable for grapevine cultivation.

Hence, in this project climatic anomalies over 21 years from 2001 to 2022 has been analyzed and comparison between current year and average of past years has been done in order to highlight changes and effects on wine production. Moreover, Standard Precipitation Index and some other bioclimatic indexes, which are also important and useful to assess the climatic potential of a region for viticulture, were evaluated for the Nizza Monferrato.

Climate change

Climate change refers to a change in the state of the climate that can be identified (e.g by using statistical tests) by changes in the mean and/or in the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as persistent anthropogenic changes in the composition of the atmosphere or in land use. In 2021, the annual global average temperature was about 0.84 C (Figure.1) hotter than pre-industrial levels (NASA s.d.) and it is confirmed by the world's scientists that the world could cross 1.5 C hotter as soon as 2030 (IPCC, Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways 2018). As it can be seen in Figure.1 the year 2020 tied with 2016 for the hottest year on record since recordkeeping began in 1880 and this year is on the way to a new record.

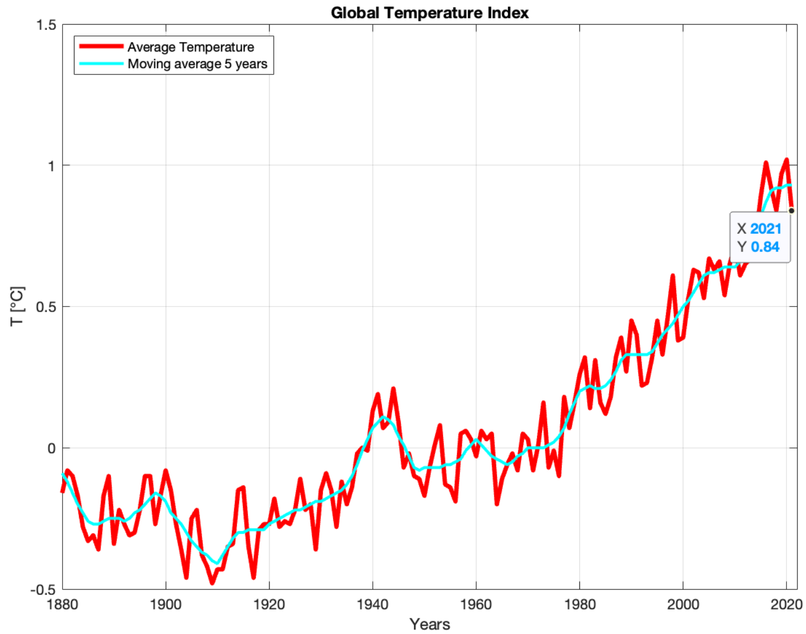

Figure 1 Global Temperature index (Annual average anomaly) (NASA s.d.)

Temperatures in Europe have increased at more than twice the global average over the past 30 years – the highest of any continent in the world. As the warming trend continues, exceptional heat, wildfires, floods and other climate change impacts will affect society, economies and ecosystems (WMO, World Meteorological Organization n.d.)[1].

Temperatures over Europe have warmed significantly over the 1991-2021 period, at an average rate of about +0.5 °C per decade (WMO, World Meteorological Organization n.d.). As a result, Alpine glaciers lost 30 meters in ice thickness from 1997 to 2021. The Greenland ice sheet is melting and contributing to accelerating sea level rise.
Figure.2 demonstrates mean temperatures for 2020 were above the 1981–2010 average across all of Europe. The largest positive anomalies occurred in northern and eastern areas, where the annual mean temperature

[1] World Meteorological Organization

was more than 2°C above average over a large region. The smallest anomalies were in the western and southern areas.

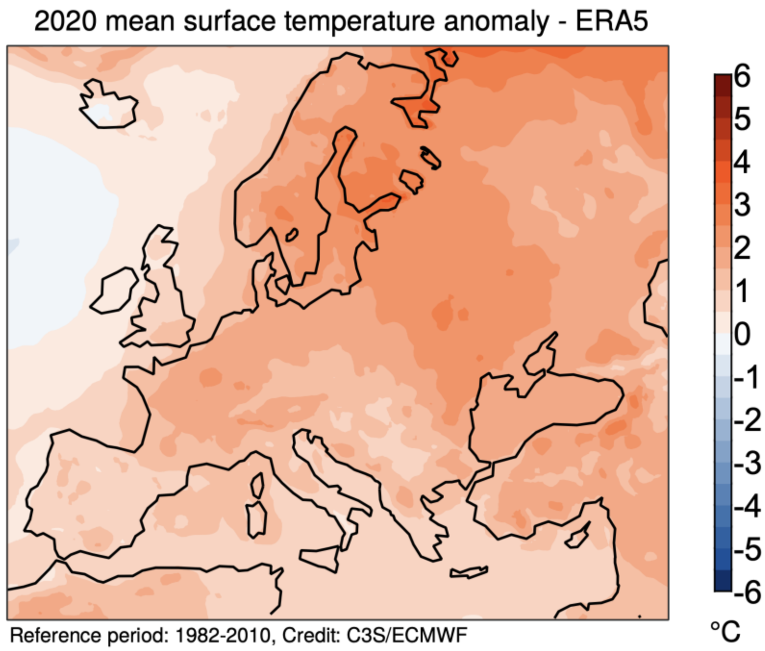

Figure 2 Average surface air temperature anomaly for 2020 relative to the 1981–2010 reference period. Data source: ERA5. Credit: C3S/ECMWF (Copernicus Climate EU n.d.)

In the Piemonte region of Italy In the last 60 years there has been an important increase in temperature, of about 2.1 ° C in the maximums and 1.5 ° C in the minimums: an increase that is much higher than what is measured globally. In the mountains, which make up 48% of the regional territory, the increase is even higher and reaches up to + 2.8 ° C in the highs and + 1.8 ° C in the lows (ARPA Piemonte 2021).

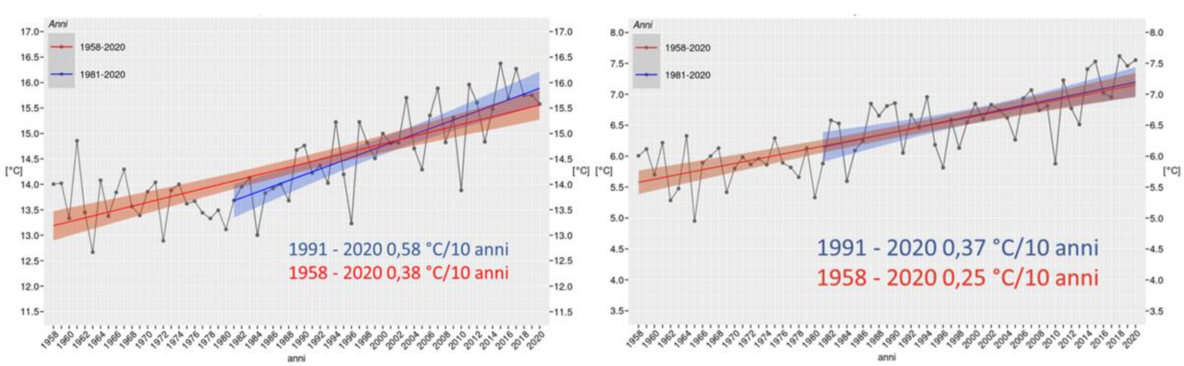

Figure 3 Annual average values of the maximum and minimum temperature from 1958 to 2020. The trend line referring to the years 1958-2020 is shown in red, the trend line referring to the period from 1991 to 2020 is shown in blue. The red and blue areas represent (ARPA Piemonte 2021)

The main effect of climate change is the increase in average temperature, which affects atmospheric circulation, other meteorological parameters such as precipitation, wind, humidity, and so on. In this project, some of these effects were analyzed for the interested area “Nizza Monferrato”.

Study area and Data

In this project, all the analysis has been done by collected data from the meteo station which is included in the network of stations belonging to the regional project "Innovative operational and dissemination services for the application of integrated and organic agricultural production techniques", entrusted to the grouping of companies consisting of "3a srl" of Turin and the "Foundation for research and innovation in agriculture - Agrion"in Manta (CN). The station has been activated on the first of January of 1997 near Nizza Monferrato with latitude: 44.757599, Longitude: 8.341372 (WGS84 reference system), and elevation: 179 m a.s.l. Nizza Monferrato is an Italian town of almost 10 thousand inhabitants in the province of Asti in Piedmont.

Although The station was activated on the first of January of 1997, due to some problems with sensors there were high numbers of gaps and missing data in the first 4 years. So, only data from 2001 to 2022 has been used. In all the analyses, years are considered as hydrological years (e.g: The hydrological year 2002 starts from the first day of October 2001 and ends on the last day of September of 2002).

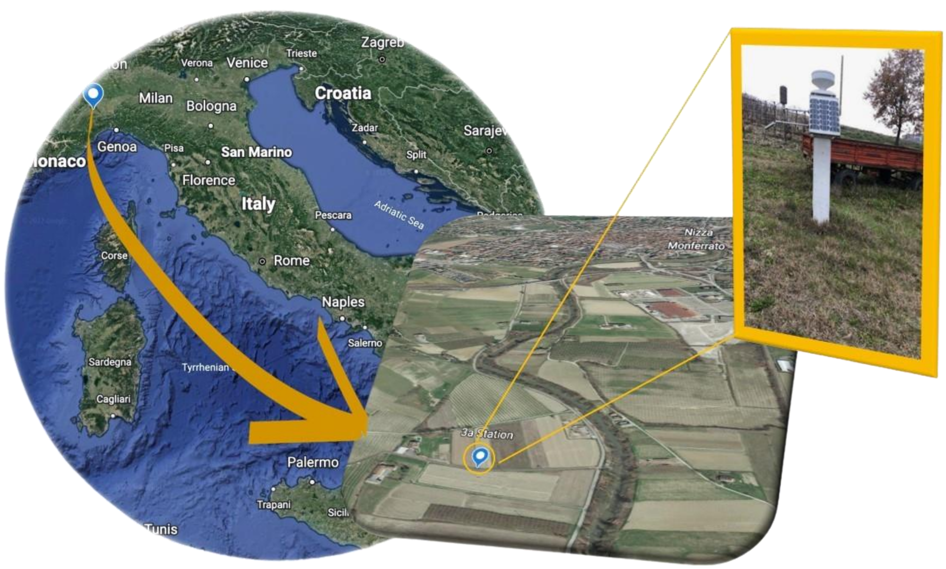

Figure 4 Photo of the station and its location taken from 3a website and google earth

Temperature

As it is mentioned before, one of the main effects of climate change is the change in average temperature. Hence, temperature analysis for the years between 2001 to 2022 of Nizza Monferrato, by considering the years as hydrological years, has been done.

The result can be seen in Figure.5. The year 2022 with a record of 14.7 °C along with years 2015,2007 and 2003 are the hottest years in this period. A positive trend (0.48) was witnessed for the annual average temperature with an increase of 1.4 °C (Figure 6).

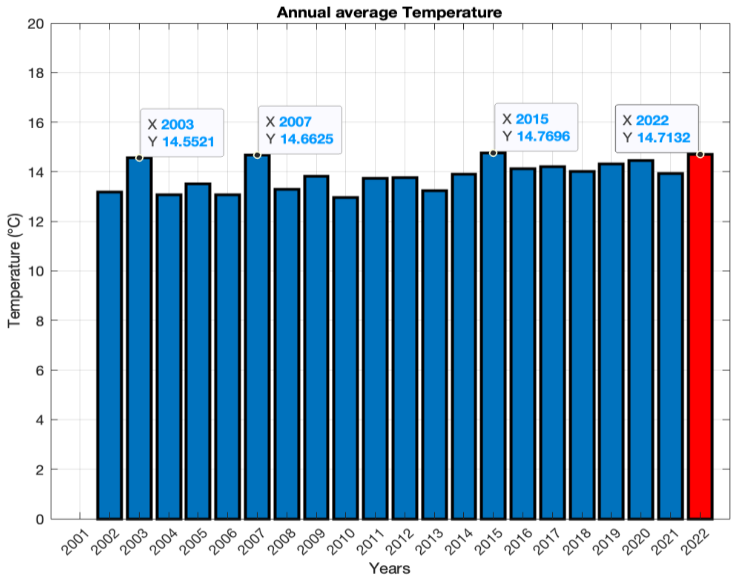

Figure 5 Annual average temperature of average daily data - Nizza Monferrato (Hydrological Years 2002-2022)

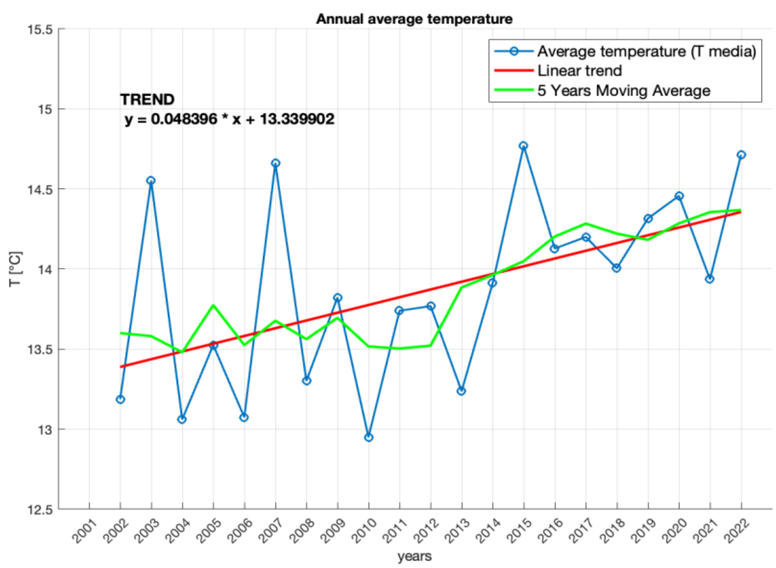

Figure 6 Trend of Annual average temperature of mean daily data - Nizza Monferrato (Hydrological Years 2002-2022)

Moreover, trend of maximum and minimum daily temperatures over last 21 years in Piedmont were considered, a statistically positive trend was observed (about 0.4 °C/10 years) for maximum temperature, which is lower than the regional trend mentioned before. So, it can be said that the maximum temperatures have increased by about +1.5 °C in 21 years. This increase seems to be more pronounced in mountainous areas.

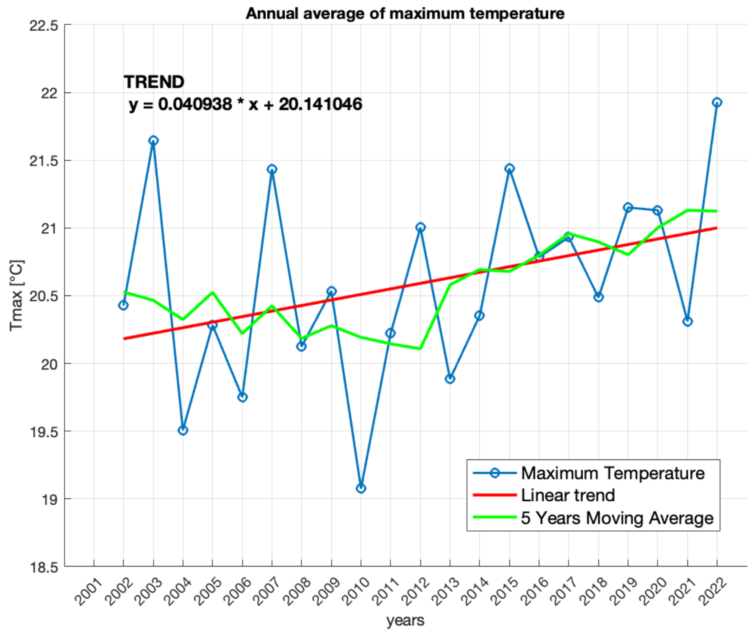

Figure 7 Trend of Annual average temperature of maximum daily data - Nizza Monferrato (Hydrological Years 2002-2022)

Even the minimum daily temperatures have undergone an increase, by around 1°C in 21 years with a trend of 0.48 °C/10 years.

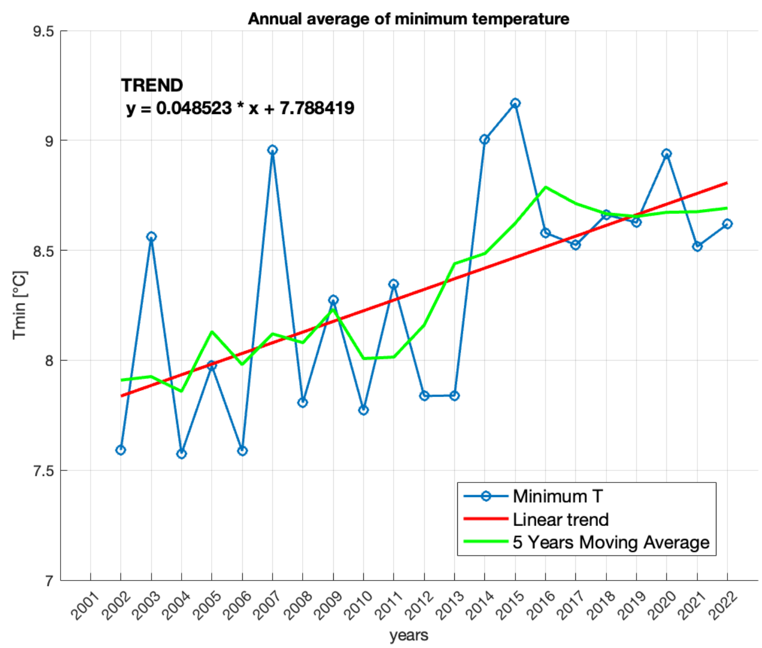

Figure 8 Trend of Annual average temperature of minimum daily data - Nizza Monferrato (Hydrological Years 2002-2022)

The maximum temperature trend for Nizza Monferrato is lower than the regional one (Piemonte) on the contrary, there is a higher trend for minimum temperature in comparison with the regional one.

By characterizing the mean temperature trend month by month and comparing the average of past years with 2022, it is possible to appreciate the monthly distribution of temperature (Figure 9). It can be observed that the increased value that we obtained before is distributed mostly in the growing season of grapes (May to August) which can directly affect the quality of the wine and harvesting or ripening time.

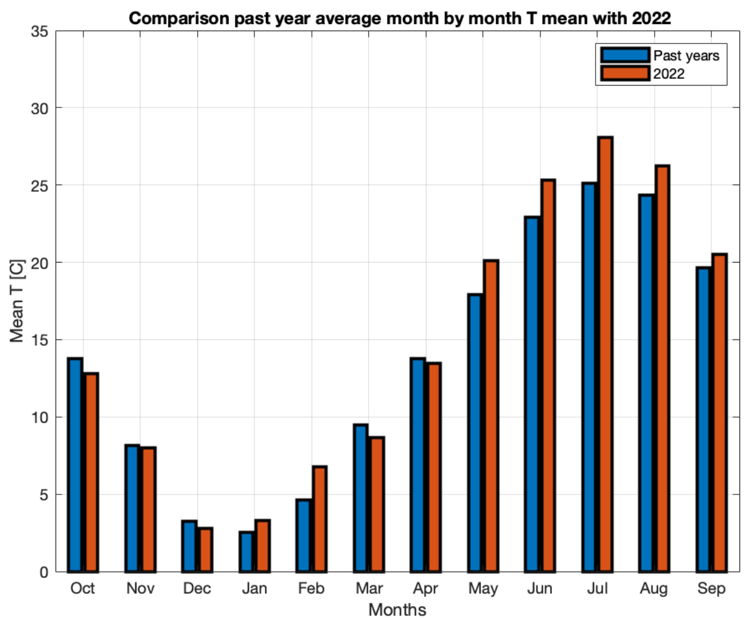

Figure 9 Month by month mean average temperature of the year 2022 in comparison with average of all the past years

Precipitation

Another analysis for Nizza Monferrato looked at the effects of climate change on precipitation in the interested area, which can affect grape growing and, intuitively wine production.
The amount of annual precipitation faced a huge decrease in 2022 and this year is the lowest year in the case of rainfall in the last 21 years with 515 mm of precipitation (Figure 10).

Month-by-month analysis has been done to compare the year 2022 with the average cumulative precipitation of the past years and as it is demonstrated in Figure.11 . All the months in 2022 have less precipitation in comparison with the average of previous years except June which has almost the same amount of precipitation and July which has a higher amount of precipitation in comparison with the average of last 20 years (2002-2021 hydrological year). This can cause drought in the area and can affect wine production.

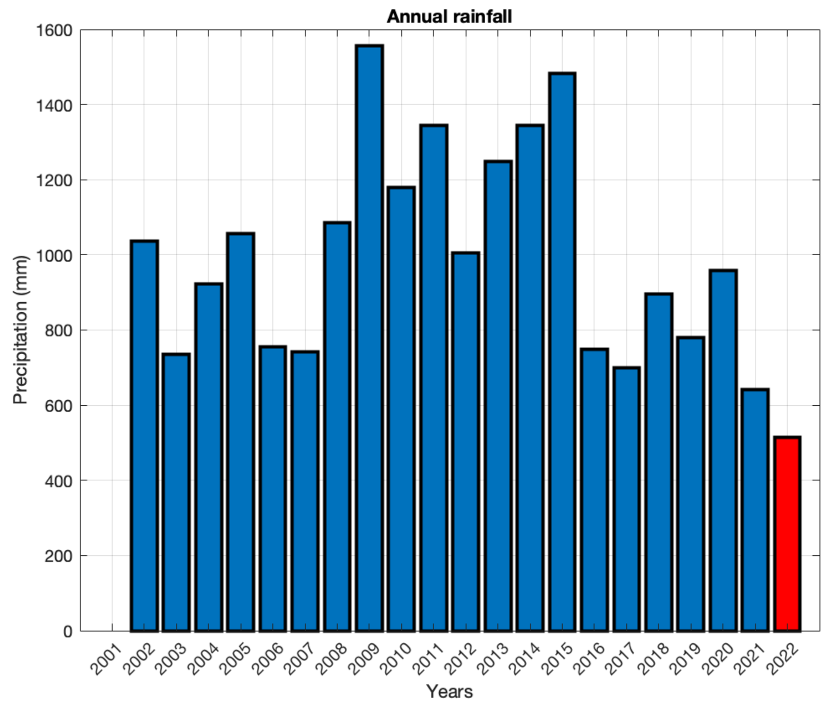

Figure 10 Annual Precipitation - Nizza Monferrato (Hydrological Years 2002-2022)

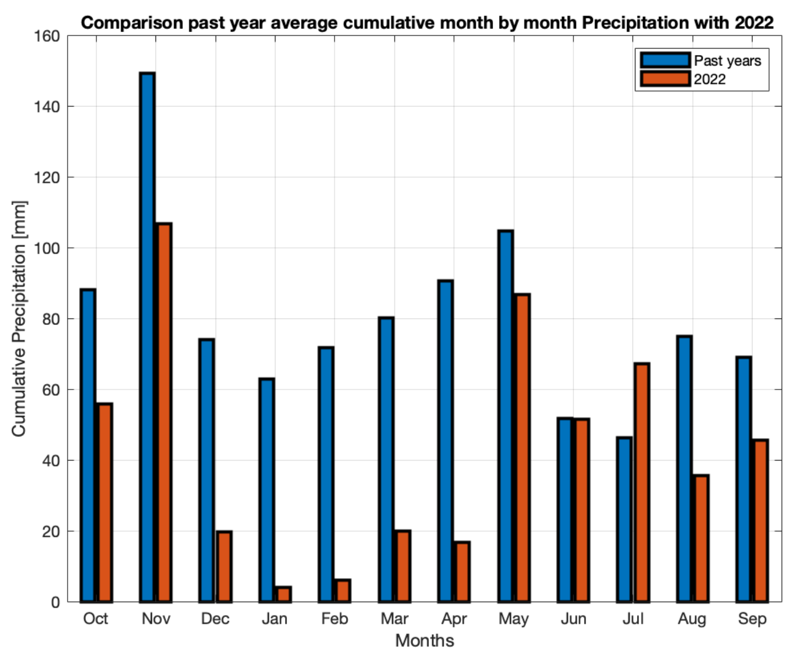

Figure 11 Month by month cumulative precipitation of the year 2022 in comparison with average of all the past years

Drought

Drought is an inevitable and recurring feature of the global water cycle that often leads to significant societal, economic, and ecological impacts. Numerous drought and dryness indices have been developed to describe the different types of droughts, including meteorological, agricultural, hydrological and socioeconomic. One of the most common indices is the Standardized Precipitation Index (SPI-n), which describes precipitation conditions relative to long-term climatology, and is known as an index of meteorological drought (Alireza Farahmand 2015).

Standardized Precipitation Index (SPI-n)

The Standardized Precipitation Index (SPI-n) is a statistical indicator comparing the total precipitation received at a particular location during a period of n months with the long-term rainfall distribution for the same period of time at that location. Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation (WMO, Standardized Precipitation Index 2015). Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI. The levels of severity of the events are classified following (MacKee, et al. 1993) (Table 1).

SPI is calculated on a monthly basis for a moving window of n months, where n indicates the rainfall accumulation period, which is typically 1, 3, 6, 9, 12, 24 or 48 months. The corresponding SPIs are denoted as SPI-1, SPI-3, SPI-6, etc. In order to allow for the statistical comparison of wetter and drier climates, SPI is based on a transformation of the accumulated precipitation into a standard normal variable with zero mean and variance equal to one. SPI results are given in units of standard deviation from the long-term mean of the standardized distribution. In 2009, WMO recommended SPI as the main meteorological drought index that countries should use to monitor and follow drought conditions (Hayes, et al. 2011) (JRC n.d.).

In this project, SPI-12 was calculated for the interested area (Nizza Monferrato) from the hydrological year 2002 to 2022 following procedure of (Alireza Farahmand 2015). Result can be found in the Figure 12. Since this index is based on the data of the previous 12 months so it is not calculable for the first year.

SPI Values	Drought Category
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Table 1 Level of severity classification based on the SPI values (MacKee, et al., 1993)

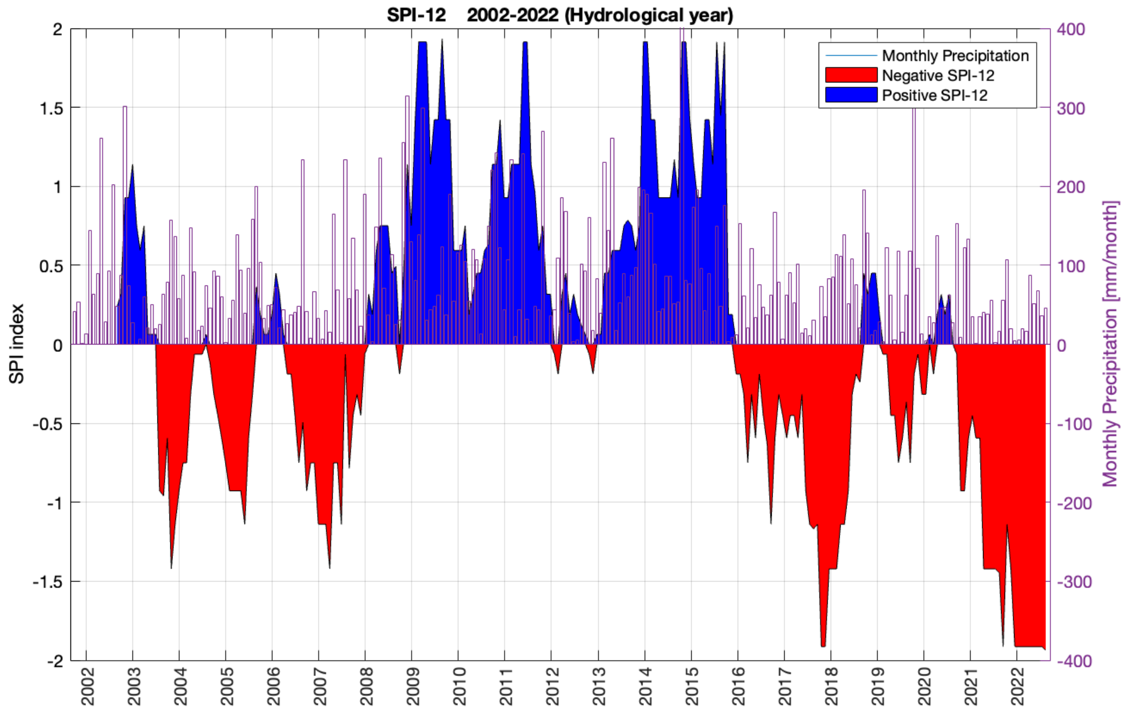

Figure 12 SPI-12 calculated by MATLAB code following the procedure of (Alireza Farahmand 2015) (Hydrological years 2002-2022)

Based on the analysis of the Nizza Monferrato station (Table.1) (Figure.12), it is determined that the SPI indicates near normal 70% of the time, moderately wet 10% of the time, moderately dry 10% of the time, very wet 5% of the time and, severely dry 5% of the time.
As the Figure.12 demonstrates, Nizza Monferrato over the period (2002-2022) faced 6 substantial drought periods and the last one is currently ongoing and can become the most prolonged drought over the years from 2002 to 2022.

Normalized Difference Moisture Index (NDMI):

The normalized difference moisture index (NDMI) is another index that can be used to determine vegetation water content and monitor drought. The value range of the NDMI is -1 to 1. Negative values of NDMI (values approaching -1) correspond to barren soil. Values around zero (-0.2 to 0.4) generally correspond to water stress. High, positive values represent high canopy without water stress (approximately 0.4 to 1). (Gao 1996)

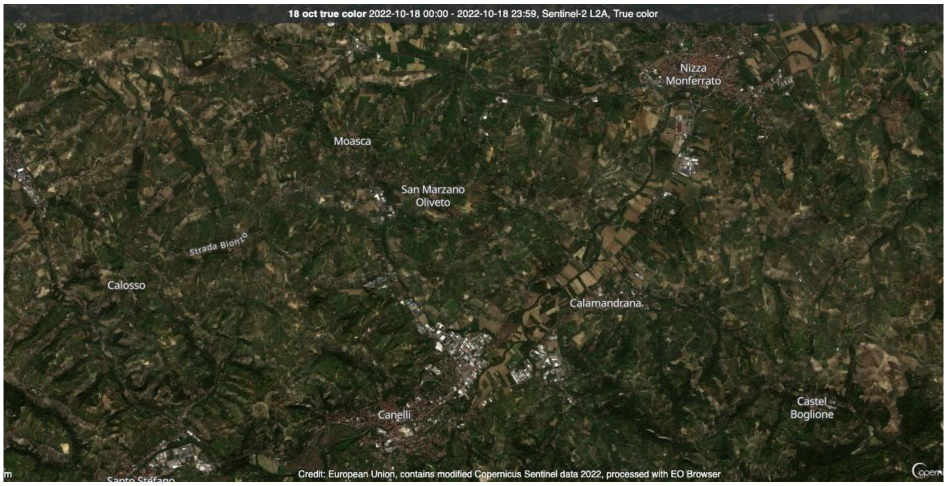

Figure 13 Satellite images from Sentinel-2 L2A (18.10.2022)

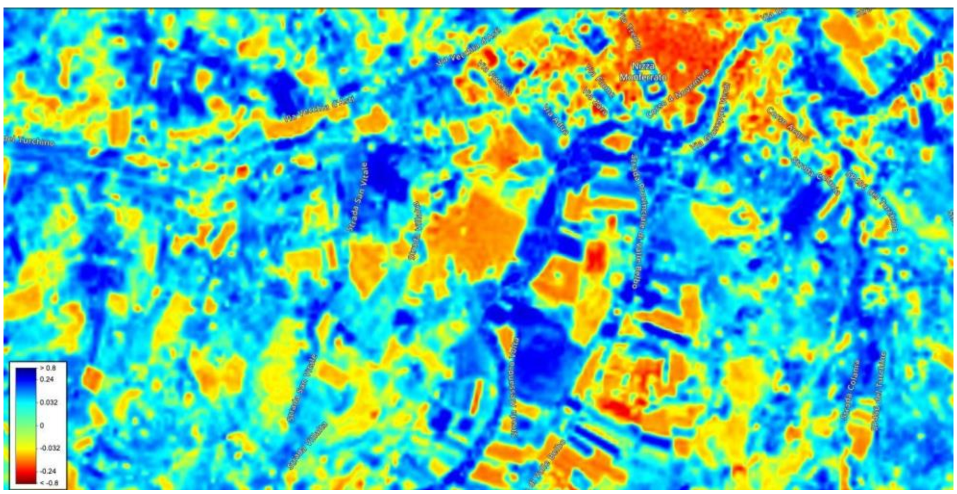

Figure 14 Satellite images from Sentinel-2 L2A (18.10.2022), proceed by (EO Browser n.d.)

The NDMI of the interested area (Nizza Monferrato and surrounding area) was acquired on 18.10.2022 from Sentinel-2 L2A and processed by EO Browser, demonstrating that the soil of some areas is barren and also there are some parts with water stress. It was only a single-day visualization it can be expanded to a multi-temporal analysis for the interested area in 3a future reports.

On the other hand, by looking at the ARPA Piemonte monthly hydrological report, evaluated SPI-12 give the picture of a context of water stress still present (Figure 15), which can be solved only by the rest of the rainy autumn and a winter full of snow.

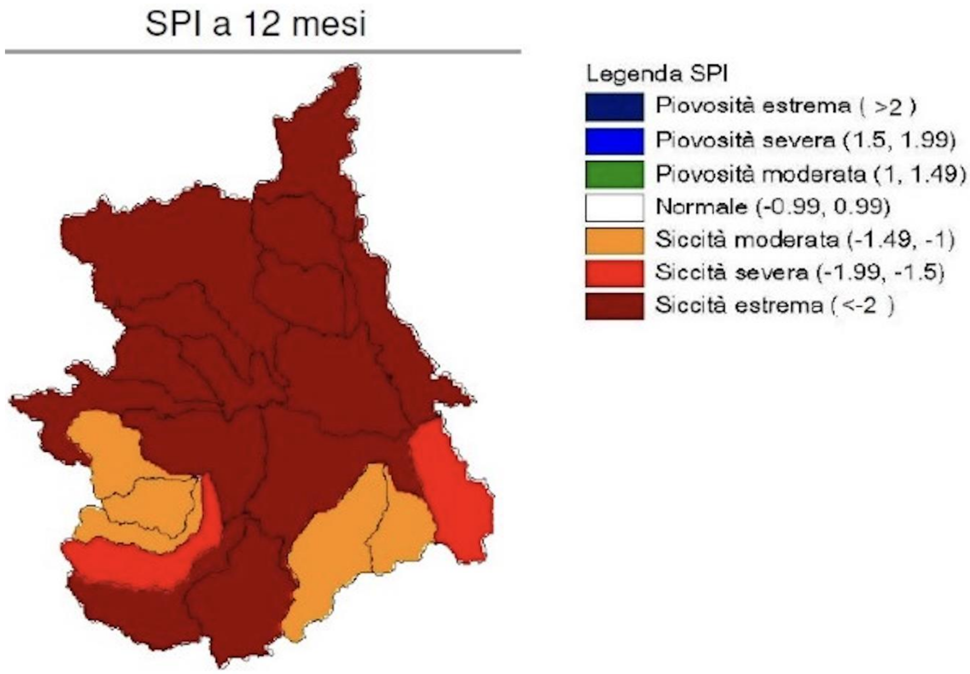

Figure 15 SPI-12 Calculated by Arpa Piemonte

Bioclimatic indices

Besides climate parameters such as the mean temperature or the accumulated precipitation over the grapevine growing season, bioclimatic indices have also been extensively supported as useful metrics to assess the climatic potential of a region for viticulture. In this project, some bioclimatic indices have been chosen and evaluated for specific months of the year 2022 and were compared with the average of the same month of previous years.

Growing degree days (GDD):

To predict vine growth stages such as bloom and, maturity, grape growers often use weather-based indicators, like GDD. Grapevine is a plant of a warm climate, which requires a sufficient amount of heat for its growth. Daily temperature strongly influences its development. Starting March 1st or April 1st of each year in the Northern Hemisphere, as the grapevines awaken from winter hibernation, farmers count GDD, or heat units, to estimate the growth and development of grapes. Research has shown that not only does GDD provide a more accurate physiological estimate than calendar days alone, but also helps farmers facilitate better management of a crop’s growth stage relative to pest and weed life cycles.

To calculate Growing Degree Days, the grapevine's threshold temperature of 10°C subtracted from the mean daily air temperature in any 24-hour period (the mean daily temperature adds together the high and low temperature for the day and divides that value by two). However, if the mean temperature is at or below the base temperature for a crop or pest of interest, the GDD value is zero. If the mean temperature is above the base temperature, then the GDD equals the value of the mean temperature minus the base temperature.

$$GDD = \sum_{January\ 1st}^{September\ 30th} \left(T_{avg} - 10^{\circ}\mathrm{C}\right) \qquad , T_{avg} \geq 10^{\circ}\mathrm{C}$$

GDD were evaluated for the year 2022 and the average of the previous year (from January 1st to September 30th). As it can be seen in the Figure.16 there is an increase in GDD of 2022 with respect to the reference period (16% increase at the end of September), which can change the time of ripening and harvesting grapes.

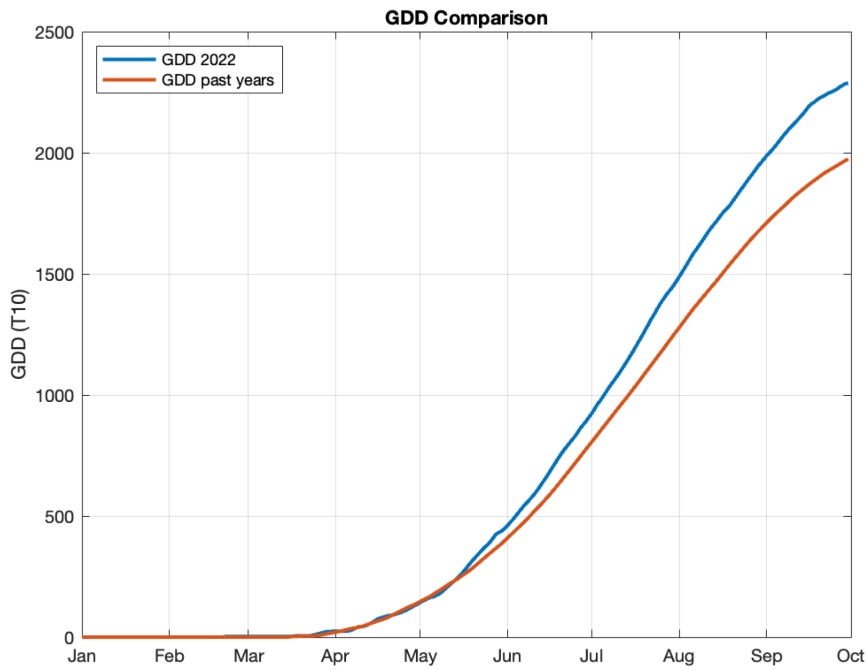

Figure 16 Calculated GDD index (1st January- 30th September)

Winkler (WI):

The Winkler index (WI) is the sum of the daily average temperatures above a threshold temperature of 10 °C considered the active grapevine temperature (the temperature above which it activates its vegetative cycle) along the growing season (1 April to end of October):

$$WI = \sum_{April\ 1st}^{October\ 31st} \left(T_{avg} - 10^{\circ}\mathrm{C}\right) \qquad , T_{avg} \geq 10\ ^{\circ}\mathrm{C}$$

Same as GDD, the Winkler index increased in 2022 with respect to the reference period (2002 to 2021 hydrological year) (Figure 17). Since any given variety usually is found to prefer only one narrow range of heat summation for optimum wine quality, winemakers will need to pay close attention to vineyard management during the seasonal heat input, which is concentrated in the vegetative and ripening phases of the grapes. This includes thinking about an early harvest, a different approach to managing the greenery (canopy), with special attention to leaf peeling, and thinning, in order to counterbalance an excessive production of sugars during maturation.

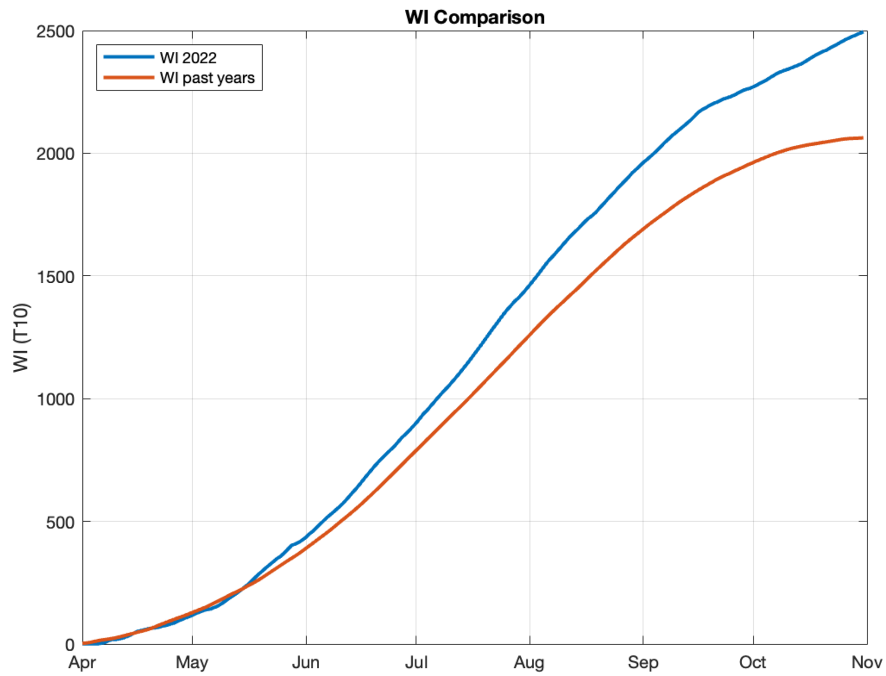

Figure 17 Calculated Winkler index (1st April- 31st October)

Huglin (HI):

The Huglin index (HI) provides information regarding heliothermic and sugar potential. It is very much correlated with the Thermal Index of Winkler but, according to (Jorge Tonietto and Alain Carbonneau 2004), is more relevant to the qualitative factors (e.g., berry sugar potential)

$$HI = \sum_{April\ 1st}^{September\ 30th} \frac{(T_{max} - 10°C) + (T_{avg} - 10°C)}{2} k \qquad T_{max} \geq 10°C$$

Where again, T_{avg} is the mean air temperature (°C), T_{max} is the maximum air temperature (°C), k is length of day coefficient ranging from 1.02 to 1.06 between 40° and 50° of latitude. A value of 1.04 was assumed for a latitude of Nizza Monferrato (44.757599).

As well as GDD and WI indices faced increase in the year 2022 compared to the reference period, associated to temperature increase, the Huglin index is also increased (+315) (Figure 18).

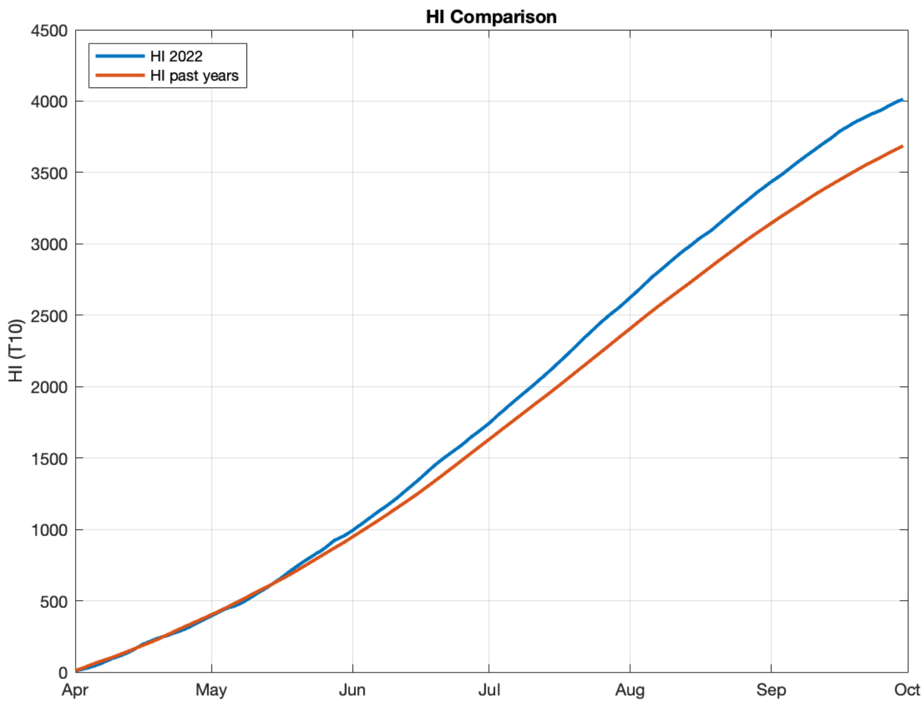

Figure 18 Calculated Huglin index (1st April - 30th September)

Conclusion

Increase in temperature and subsequently change in other parameters and increase in bioclimatic indices can have adverse effect or can have benefit for viticulture and this is related to the type of grape and location. The study is part of the climate analysis and modeling landscape to understand the impacts of anomalies on vineyards, an area that is gaining more and more interest. The assessment of the mutual influence between the vine and the surrounding environment requires the knowledge and good use of the physical factors of each wine region. The optimization of wine production and the management of field treatments must therefore be based, site by site, on a deep knowledge of the climates, always updated to the climatic changes in progress

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