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SPATIAL-TEMPORAL VARIABILITY ANALYSIS OF TEMPERATURE IN TWO VITICULTURE SITES IN SPAIN AND SLOVENIA

ABSTRACT

Objective of this research is to describe and compare the results of climate variables analyzed in two different viticulture sites; indeed, one study site is located in the Valencia wine region in Spain and the other is in the Goriška Brda region in Slovenia. The research includes the climate analysis for a period of five decades in both study sites, from 1965 to 2013, to follow temperature measured daily. In addition, the Huglin and Winkler indexes were calculated in the same research sites for the same time period. The analysis was conducted in four weather stations (two in Spanish site and two in Slovene site). The climate data analysis showed a considerable temporal variability with notable increase of temperatures; indeed, it showed also the significant spatial variability of climatic variables. The continent and sea influence created climate and spatial differences on the both study sites, which are comparable with the climate evolution in the study period. This preliminary work is encouraging and will be further developed. Moreover, the results of this paper will be used to elaborate a climate model for the 2015-2065 period in each site separately. The results of the climate comparison, will give us two different climate models, one for each study site, which will contribute to improve viticulture adaptation in the future.

Keywords: Temperature trends, climate change, Huglin index, Winkler index, and daily temperature.

INTRODUCTION

Agriculture and viticulture is severely affected by the climate change, particularly during the last decades. Changes in viticulture, especially in variety and changing position of vineyards, can be noticed worldwide. Additionally, the climate change has noticeable influence in micro-climate areas and it affects vineyard in it (Quénol, 2014). The consequences of climate change in viticulture areas affect wine quality and yield. The solution is the adaptation of vine. New varieties of vine have already been introduced and are expected to be introduced in the future (Fraga et al., 2012; Jones, 2005). Numerous analyses concerning

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climate change in viticulture on regional scales were already conducted. Nevertheless, only few analyses were made addressing the climate change in local scales (Quénol, 2014; Neethling et al., 2012; Bonnefoy et al., 2012).

In this paper, the spatial-temporal variability analysis of temperature is elaborated in local scale in two viticulture sites. The climate change along with global warming has a severe impact at regional scale. The climate parameters, especially temperature, have an important influence on vine growth and viticulture (Briche et al., 2014; Planchon et al., 2009). The viticulture is a sensitive culture, sensitive to climate change and it is an encouraging bio indicator of climate change (Jones et al., 2005). Therefore, the viticulture is a suitable crop in order to define the effects of climate changes. Moreover, the viticulture areas are concentrated in the Mediterranean climate regions, which present a large diversity of bio-species (Hannah et al., 2012; Van Leeuwen, 2013).

There are many bioclimatic indexes used for determination of characteristics of wine regions in function of grape varieties, nevertheless there are only few based on temperature (Huglin, 1986; Gladstones, 1992; Tonietto and Carbonneau, 2004). In this paper Huglin and Winkler bioclimatic indexes (Huglin, 1986) are applied to determine the progress of them in both viticulture study areas. The progress of precipitation and crop water can be described with Agro-hydrological models, considered an economic and simple tool for quantifying crop water requirements (Manzano, 2014), which will be used for the further analysis. The purpose of this study is to provide a critical analysis of temperature data during the research period in both study sites.

For this reason, the study sites with similar topography conditions were chosen. Each site benefit the climate influence from the Mediterranean sea (Figure 1) and are positioned within 70 kilometres from the coastline. There are 17 weather stations included in the doctoral research, 5 in Valencia site and 12 in Brda site. However, for the analysis purpose in this paper, four stations were used: two in Brda site and two in Valencia site. All four chosen meteorological stations share similar topographical features according to the other research site in order to optimize the comparison and they possess historical data of more years in comparison with the rest of the stations. The Huglin and Winkler bio indexes were calculated to analyse the evolution of them during the study period.

The objective is to present and compare the spatial-temporal variability analysis in two different viticulture sites and furthermore to define the correlations climate change during the last five decades that might exist between the both study sites.

MATERIAL AND METHODS

Goriška Brda, also known as Brda wine region, is located in Slovenia, next to the Slovenian-Italian border, about 20 kilometres northern from Italian city Trieste with the surface of 72 square kilometres. The climate is described as mild-Mediterranean, classified as ‘Cfa’ class, according to the Köppen Geiger system (Peel et al., 2007).

Figure 1: Location of Valencia and Brda wine region (Zulo, 2015)

Local climate enjoys frequent warm and humid air from south-west with average temperature of 3°C in January and average summer temperature of 24°C in August (Climate: Medana, 2015). The weather stations, chosen for analysis are two: Bilje is located 20 kilometers from the Mediterranean sea and Vojsko, which lies north-eastern from Bilje further more to the interior (Figure 2).

The second study site is Valencia wine region. It is located on the north from the Valencia city on the eastern Spanish coast. The local climate has mild winters with average high temperature of 14°C and long warm summers with average high temperature of 28°C in July and August (Climate: Llíria, 2015). There are two weather stations chosen for further analysis. Meteorological station Valencia airport lies 13 kilometers from the Mediterranean coastline and Albacete station is located 140 kilometers further more in the interior of the Valencia airport. For the research, the daily temperature data sets from weather stations in the study sites were used.

The weather stations are distributed in the area of the study site as observed on the Figure 2. On Spanish site were used Valencia aeropuerto and Albacete stations for daily temperature analysis. On Slovene site the station Bilje and Vojsko were used for daily temperature analysis. For the daily temperature analysis the data set were recorded from 1965 until 2013. Stations Bilje and Valencia aeropuerto were chosen due to similar topographical conditions for detailed spatial-temporal analysis. The same similarities were the reason for choosing the stations Albacete and Vojsko.

Daily mean temperature was calculated according to the three measurements during each day: at 7:00, 14:00 and 21:00 o’clock. The data of the Slovene weather stations were gathered from the Slovene Ministry of Environment and spatial planning.

The data set from the Spanish research site were gathered from the ‘European Climate Assessment and Dataset’ from the Spanish Ministry of agriculture, alimentation and environment, AEMET and from EU project Figaro, irrigation platform.

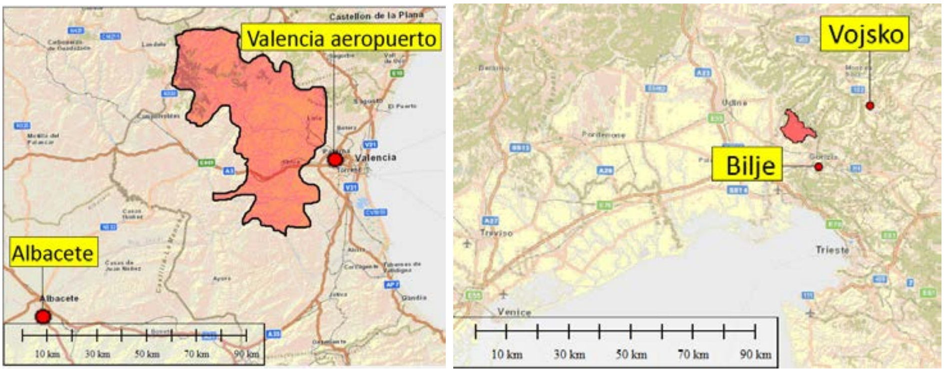


Figure 1: Location of four weather stations on the Valencia study site on the left and Brda study site on the right

In some cases, due to different reasons, some weather stations failed to record daily set of data for a certain period. In this case, the method of linear regression was used to determine the missing data**.** The Huglin index is calculated according to the formula on Table 1 for each year from April to September in the Northern Hemisphere.

Table 1: Formula and classes for Huglin index (Tonietto and Carbonneau, 2004)

Very cold	≤ 1500
Cold	1500-1800
Cool	1800-2100
Warm	2100-2400
Hot	2400-3000
Very hot	>3000

$$HI = \sum_{1\,apr}^{30\,sep} \frac{(Tmean - 10) + (Tmin - 10)}{2} \cdot k$$

The sum of the daily mean temperature (Tmean) and daily minimum temperature (Tmin) is superior to 10°C (Huglin 1978). The day length coefficient k, defined according to the latitude, is 1.02 for Valencia wine area and 1.04 for Goriška Brda wine site. The Winkler index estimates the characteristics of geographical zones and local adaptation of grape varieties (Huglin, 1986) and is classified in five regions and calculated according to the formula in Table 2 for each year from April to October. Daily mean temperature (Tmean) is measured daily and is considered in the calculation where superior to 10°C. Grapevines are not physiologically active if average temperature is inferior to 10°C (Huglin 1986). To calculate bioclimatic indexes Huglin in Winkler, the annual set of temperature data were used under the condition, that there were no more than 7 consecutive days with missing temperature data. In case of more than 7 consecutive days with missing data in one year, the bioclimatic indexes were not used for the same year.

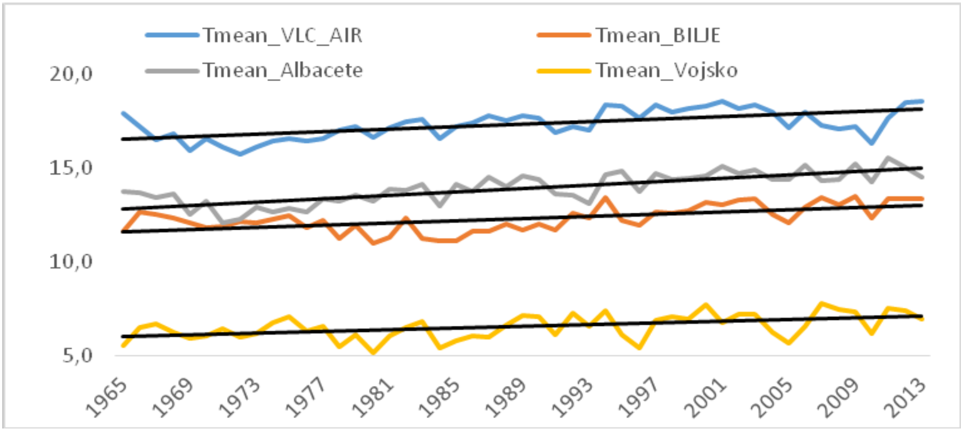
Table 2: Formula and classes for Winkler index (Tonietto and Carbonneau, 2004)

Region 1	850-1389
Region 2	1389-1667
Region 3	1671-1950
Region 4	1951-2220
Region 5	>2221

$$\mathbf{WI} = \sum_{1\,apr}^{31\,oct} (\mathbf{Tmean} - 10°C)$$

RESULTS AND DISCUSSION

With the temperature analysis, it was analysed the air temperature trend during the study period 1965 to 2013 at all four weather stations. The trend lines (Graph 1) clearly show the rise of the mean temperature during the study period at all four weather stations. The highest increase of the mean temperature during the period, was detected at the weather station Albacete. It recorded the growth of 2.17°C comparing to the station Vojsko, where the growth of the mean temperature was only 1.42°C as seen on the Table 3. The increase of the mean temperature at the Valencia airport weather station is superior in comparison with the weather Station Bilje.



Graph 1: Progress of mean temperature on all four weather stations during study period. VLC_AIR refers to the weather station Valencia airport (°C)

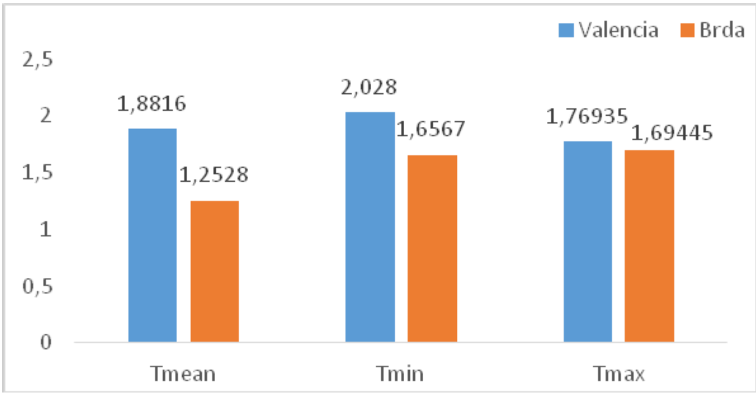
The annual growth of the mean temperature at the Valencia airport is 0.033°C, which is a superior value, than the annual growth comparing with the Vojsko (0.023°C per year) and Bilje (0.030°C) weather station. According to the results (Table 3), both of the Spanish weather stations recorded more intensive increase of mean temperature than the Slovene weather stations. The figures are showing the increase of mean temperature during the research period at station Albacete for 2.17°C , which is significantly higher than the increase of temperature at station Valencia airport, 1.59°C, located closer to the coastline.

The raise of the mean temperature during the research period at Bilje stations was 1.42°C and on Vojsko station, 1.09°C. The increase difference of minimum and maximum temperature at both weather stations is similar.

Table 3. Mean temperature progress during the study period 1965-2013

Weather station	T mean in 1965 (°C)	T mean in 2013 (°C)	Increase of T mean trend values 1965-2013 (°C)	Increase of T mean trend values per year (°C)
VLC_air	16.54	18.13	1.59	0.03
Albacete	12.85	15.03	2.17	0.05
Bilje	11.61	13.03	1.42	0.030
Vojsko	6.01	7.10	1.09	0.02

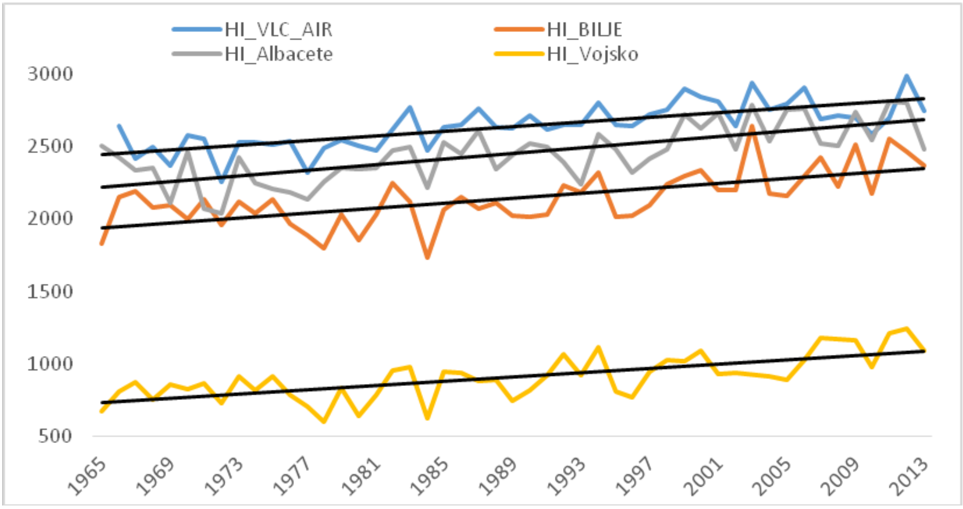
Comparing the both study sites, the increase temperature parameters was higher in Spain. On the Graph 2 can be observed the comparison of the progress of average mean temperature in both study sites. The progress results of average minimum and maximum temperature are included. The average Tmin (minimum temperature) growth is the highest, 2.028°C. It was measured at the Valencia study site. The increase of average mean temperature is the lowest increase during the period of research, 1.2528°C. It was measured in Brda study site. The highest difference of temperature growth in comparison with the two study site, was noticed in mean temperature. In the Valencia study site, the average mean temperature increased for 1.8816°C and in the Brda study site increased for 1,2528°C. Bioclimatic indexes were calculated from the temperature data, measured at the same four weather stations used for temperature measurements.



Graph 2. Increase of average Tmean,Tmin and Tmax
in Valencia and Brda study site (°C)

Since bioclimatic indexes are determined from the air temperature measurements during the growing season of the vine, the increase of Huglin and Winkler index was expected. As seen on the Graph 3, gradually increase of the Huglin index is detected. In the year 2003, the positive deviation of about 200 HI index points was detected at all weather stations, but not at Vojsko. Positive deviation in the year 2003 at the Vojsko station was not noticed, because there is no data available to calculate HI and neither WI index for year 2003 and 2008.

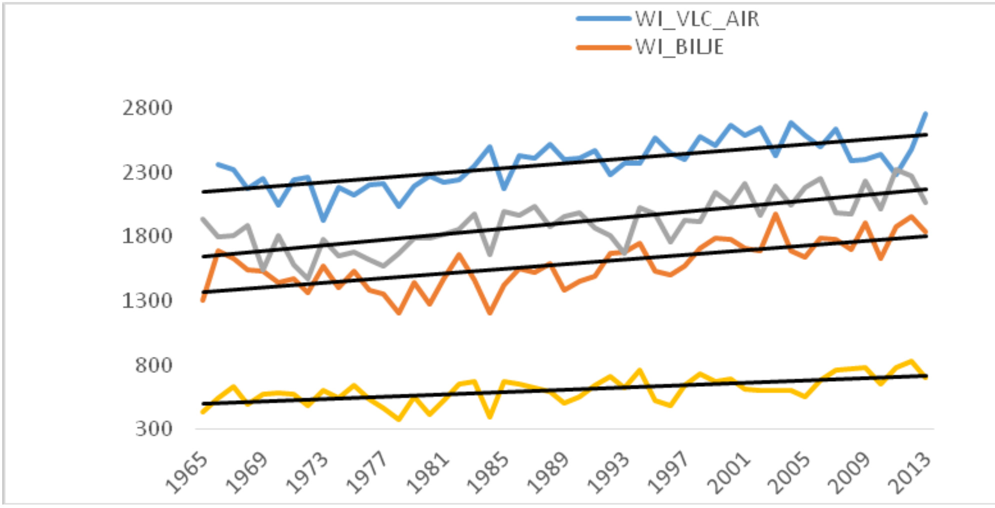
The second deviation was negative and it was detected in the year 1984 at all four stations. The highest increase of the Huglin index was detected at the Albacete weather station with 479.55 Huglin points. The lowest increase of Huglin index was detected at the Vojsko weather station with 357.48 Huglin points.



Graph 3: Huglin index at the four weather stations during the study period. HI refers to Huglin index and VLC_AIR refers to weather station Valencia airport.

At the beginning of the study period, weather station Albacete, with 2221.60 Huglin index points was defined in the “Warm Huglin class”. During the research period, has reached the “Hot Huglin class”. Weather station Valencia airport did not change the class during the study period and remained in the ‘Hot’ Huglin class. Bilje weather station did change during the study period the Huglin class from Cool, with 1938.07 Huglin points, to Warm, with 2358.12 Huglin points. The Vojsko weather station remained in ‘Very cold’ Huglin class. The Valencia research site classified for two Huglin classes higher than the Brda study site during the study period. Similarities can be observer with the Winkler index regarding to the Huglin index. On the Graph 4, the progress of the Winkler index can be seen at all four weather stations during the research period.

All weather stations clearly show the increase of the Winkler index. The highest deviation was noticed in the year 1985 at all four weather stations. It was a negative deviation for about 200 Winkler points at all weather stations. Also at the Huglin index was noticed the negative deviation just one year after, in the year 1986. The lowest increase of the Winkler index is seen at the weather station Vojsko, at the Brda study site.



Graph 4: Winkler index at the four weather stations during the study period. WI refers to Winkler index and VLC_AIR refers to weather station Valencia airport.

The increase was only for 215.61 Winkler points in comparison with other stations, where the growth reached 531.36 Winkler index points at the Albacete weather station. The highest uptrend per year is noticed at the Albacete weather station. The highest increase was noticed at the Valencia study site. The Winkler index increased for 491.8540 Winkler points during the study period. The lowest increase is seen at the Winkler index at the Brda study site, 330.1823 Winkler points. Huglin index increased more at the Valencia study site. In this case, the difference between the study sites is lover, namely 40.55 Huglin points. As seen at the Winkler and Huglin index analysis, the Vojsko weather station was the least affected by the climate change in comparison with other three weather stations. The highest influence of the climate change was observed at the Albacete weather station.

CONCLUSIONS

The increase of air temperature on both study sites during the study period was expected as seen on the graphs of temperature progress in this paper. The conclusion is the increase of air temperature during the study period 1965 to 2013 at Valencia and Brda study sites. The Spanish study site was affected more by the climate change, than the Slovene site, which can be clearly seen on temperature progress during the study period, particularly the weather station Albacete. The measurements of minimum and maximum temperature show similar temperature increasing trend at both Spanish stations.

The reason of the lower increase of temperatures at Valencia aeropuerto station, which is located closer to the seacoast, is the influence of the Mediterranean Sea. The sea influence is decreasing with the greater distance from the seacoast, which can be observed on the weather data of the Albacete weather station. Nevertheless, the Mediterranean sea appears to have minor influence on Slovenia research site in comparison with Spanish site. On the weather station closer to the coastline of Mediterranean sea, Bilje, the mean temperature increase was significantly higher, than mean temperatures on the weather station Vojsko, located in interior of the land (Graph 2).

The difference of the progress of the air temperature on the both study sites can be found in several reasons. The topographical features of the weather stations closer to the sea, i.e., Valencia airport and Bilje, are similar. They are both located between 10 and 15 kilometres away from the coastline and the altitude above the sea level is between 30 and 70 meters.

The difference is the influence of the city Valencia, which is located between Valencia airport stations and the Mediterranean Sea. Between Bilje and the coastline, there is forrest and few small villages. Nevertheless, the weather stations Albacete and Vojsko have more differences in topographical characteristics. The same reasons are implied to the progress of the Huglin in Winkler index, since they derivate from temperature measurements. In conclusion, areas closer to coastline are affected with minor increase of the mean temperature in comparison with the weather stations further away from the coastline.

Topographic characteristics and the urban city affected the trend evolution temperature. With more weather data from other 17 weather stations at both study sites, will be elaborated a climate model for the future study period. With the contribution of the data gained in this paper and with the further climate analysis, we will be able to elaborate the future climate model for the next 50 years.

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