

Climate Risk and Climate Analogies in Hungarian Viticulture

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Abstract. Though, according even to the most pessimistic forecasts, Hungary is expected to remain amongst the regions with good quality grapevine growing conditions in the future, the expected frequency and the impact of extreme climatic events are rather serious warning signs. In this study first some impactful climatic indicators are analyzed which are of high importance in grapevine production. Historic data are compared with regional climate model predictions of RegCM 3.1 with A1B scenario, concerning to the Central Hungarian grape growing regions. Then we introduce the method of spatial analogies with the help of which we find the regions which have a climate structure now that is similar to the one Hungary is predicted to have in the future.

Keywords: viticulture, climate change, data management, weather indicators, climate analogies

1. Introduction

Ecological demands of various plants are influenced different ways and in distinct extent by climate change since beneficial and unfavorable or detrimental effects of temperature, precipitation and other climatic factors are activated specifically (spatially and temporally) distributed. Therefore learning the distributions of the climatic parameters with emphasized importance of some main time intervals of the growing season specialized for plant species is of main interest.

In this study we consider the climatic conditions of grapevine growing regions in Central Hungary according to three different time scales: 1961-1990 as reference period, 2021-2050 and 2071-2100 as prediction time intervals. Regional studies have been enabled since global climate models have been downscaled to about 10 km grid points. We applied RegCM 3.1 (based on Hadley Centre's HadCM3 model) which was downscaled to 10 km grid points at Eötvös Loránd University, Budapest, Department of Meteorology for A1B scenario (Solymosi et al., 2008; Bartholy et al., 2009; Torma et al., 2008, 2011).

2. Materials and methods

Risk assessment was made for each of the 17 subregions of Pest County. The most important climatic factors of grape growing are the distributions of temperature and precipitation (Duchêne and Schneider, 2005; Jones and Davis, 2000; Jones, 2006; Schultz, 2000; Stock et al., 2003; Winkler et al., 1974). Thus some indicators of considerable impact were focused.

2.1. Effective degree days and Huglin Index with further climatic indicators

The effective degree days (EDD, °C) are calculated as the cumulated sum of daily mean temperatures above the base temperature (10°C) between the 1st of April and 30th of September. Grape varieties can be grouped according to their effective degree days demands up to full ripening (Gladstones, 2000).

We also calculated the widely applied Huglin Index (HI, °C, Huglin, 1978) which takes the maximal daily temperatures into consideration as well:

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$$HI = k * \frac{\sum_{1.Apr.}^{30.Sept.} \max((T_{mean} - 10); 0) + \sum_{1.Apr.}^{30.Sept.} \max((T_{max} - 10); 0)}{2}$$

where T_{mean} and T_{max} are the daily mean and maximal temperatures and k is a latitude coefficient that takes into account increasing day lengths from 35° to 50°, starting with 1.00 at 35°, ending with 1.06 at 50° and is based upon day lengths using Julian day and latitude as inputs. In case of Hungary $k=1.05$ was applied.

Moreover, the nine further indicators were calculated:

- the number of days with maximal daily temperature above 30°C (C30, days)
- the number of days with maximal daily temperature above 35°C (C35, days)
- the number of frosty days (below -1°C) after the 1st of April (F-1, days)
- the number of days with minimal daily temperature below -15°C (days)
- the number of days with minimal daily temperature below -18°C (days)
- the first, second and third maximal lengths of consecutive days with precipitation less than 1 mm (D1, D2, D3, days)
- the maximal length of consecutive days with precipitation more than 5 mm (days)
- yearly precipitation sum (mm)
- precipitation sum of the growing season (1st of April – 30th of September) (mm)

With a software developed specially for our aims all the 13 indicators above were calculated for each year of the three time series with 30 years and each of the 17 subregion grid points.

The data from three wine regions (Cegléd of Kunsági wine region, Budaörs from Etyek-Budai wine region and Veresegyház of Mátrai wine region) were analyzed and compared.

2.2. Climate analogies based on TYN CL 2.0 database

After having examined the expected changes of the climatic conditions of Central Hungarian grapevine production with respect to middle and long term scales, we can put the question: does there exist a region in Europe which has very similar climate condition now to the one Central Hungarian region is expected to have in the future? To find such kind of region and to learn its production structure, training system, variety assortment with growing experience can give us invaluable information which we can benefit in the decision on our long term management strategy.

For defining and finding analogue regions baseline climate data were taken from the OMSZ (Hungarian Meteorological Office) database. For the European base climatology (1961-1990) the TYN CL 2.0 database was used, which contains 10 minutes spatial resolution grid data for 5 climatic parameters (Mitchell et al., 2003). From these only the monthly temperature and precipitation data were used. We used the well-known, internationally used emission scenarios – A1, A2, B1, B2 – from the Hadley Centre's HadCM3 model.

For the calculation of spatial analogy we used CLIMEX method. For each grid boxes the Euclidean distances of the climatic parameters were calculated. The similarity index for two climate datasets can be given with user defined parameter settings. The advantage of the method is that similarity rate does not depend on the number of grid points, and shows real similarity.

As a validation of the method the analogue regions for the baseline period were calculated and tested. The method was judged as appropriate if the spatial analogues of the examined region were also in the examined region.

3. Results

3.1. General characterization of Central Hungarian region

In Central Hungary mainly the early ripening varieties were expected to ripen appropriately in the reference time interval (1961-1990), the heat demands of the medium ripening varieties can be filled in the middle of the 21st century and the effective degree days demand of the late and very late ripening varieties can be reached at the end of the century.

According to the Huglin Index values Central Hungary region was belonging to the cool class in the last century and up to the middle of the 21st century it is expected to remain in the same class tending to be

warmer and warmer and it reaches the warm temperate class at the end of the century (Tonietto and Carbonneau, 2004). The increasing tendency of Huglin Index values (HI) together with the one of the effective degree days (EDD) can affect fairly beneficial.

The numbers of extreme warm days with maximum daily temperature above 30°C as well as of the extreme hot days with maximum daily temperature above 35°C are all estimated to increase intensively up to the end of the 21st century. The expected number of extreme warm days grows from about 14 days to about 31 days in the long run, compared to its value of the reference period 1961-1990. The expected number of extreme hot days is estimated to increase more drastically, from the yearly mean of about 1 day to about 2 days at medium term and to about 13 days at long term. The risk of extreme cold events is expected to decrease in Central Hungary region.

The yearly mean numbers of spring frost (2 days) and winter frost events (0.6 below -15°C – about once in two years; or 0.1 below -18°C – about once in ten years) are expected to decrease remarkably even in medium term; the frost risk becomes very low up to the end of the century with an only spring frost event expected in three years.

The precipitation sum demand of grapevine is satisfied in all the three time intervals (1961-1990, 2021-2050, 2071-2100) regarding for both the yearly and the vegetation period, according to the regional climate model RegCM 3.1. The amount of the yearly precipitation sum is expected to decrease slightly up to the middle of the 21st century and to increase thereafter. In the growing season there is only a decreasing trend detected up to a rate of about 10 % in a century.

The length of the longest dry period with consecutive days of daily precipitation less than 1 mm increases from an average of 22.4 to 26.7 in the long run, compared to the reference period 1961-1990. The lengths of the second and third longest dry periods are also estimated to increase. The increase is not significant, however, considering their approximate values in the reference period (above 20 days the first, above 15 days the second and above 12 days for the third longest period), a still existing risk of water stress is warned to remain for the future with a motivation for making efforts toward risk mitigation practices (Carbonneau, 1998).

According to the regional climate model RegCM 3.1 the length of the longest wet periods (3.2-3.4 days) with consecutive days of precipitation above 5 mm does not generate notable risk with an expected stagnancy in the future.

3.2. Analogue regions

The analogue regions obtained by the temperature ($\lambda=1$) and precipitation ($\lambda=0$) can be seen in Fig. 1. (for validation) and Figure 2. (for the future). If we accept the results of the climate models, the analogue regions of Central Hungary in the middle of the 21st century will be at Vojvodina region in Serbia, and South-Romania. It means about 100-300 km shifting to south, which corresponds to other international results. Nevertheless, for later time the scenarios predict more drastic change, the climate shifting will be 400-600 km to south.

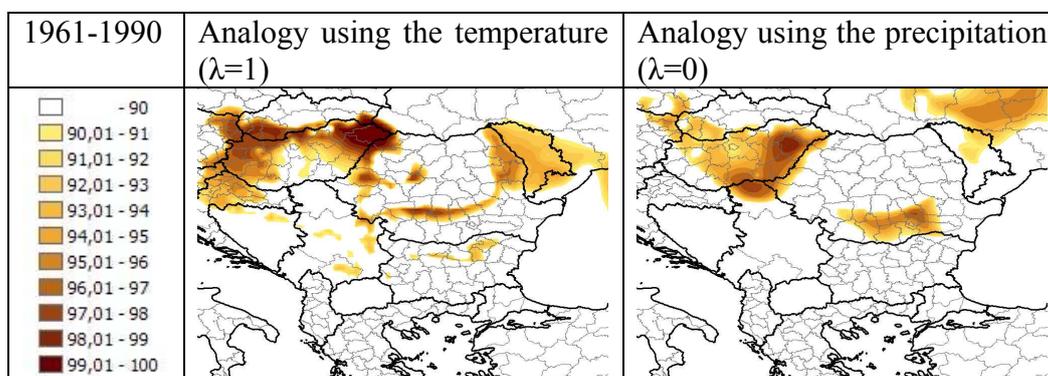


Fig. 1: Analogue regions of Central Hungary for the baseline period (validation) calculated by temperature and precipitation

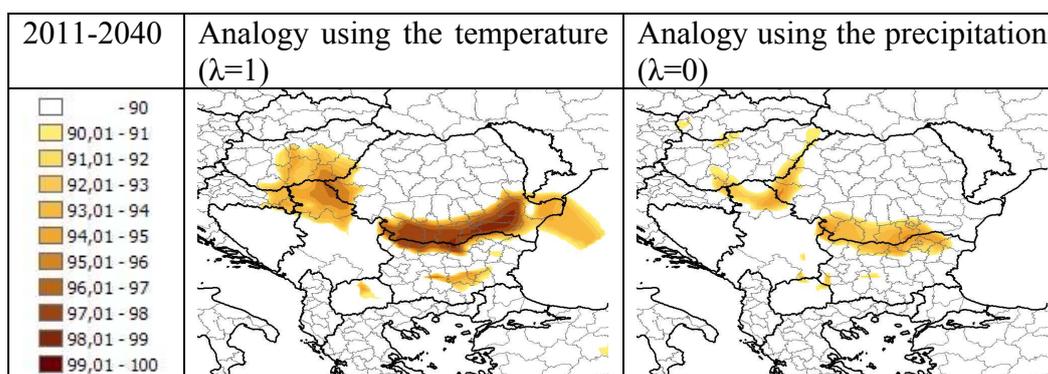


Fig. 1: Analogue regions of Central Hungary for 2011-40 calculated by temperature and precipitation

4. Conclusions

Considering the climatic indicators of Central Hungarian grape growing region we can state that in middle or even in long term with the increasing values of the temperature indices (effective degree days, Hugin Index) besides early and medium ripening varieties some late varieties can be introduced in the production in the subregions changing their cool climate class into temperate one. With warming the probabilities of spring and winter frost events are decreasing and therefore some frost sensitive table grape varieties can gain their higher security of crop production.

Nevertheless we stress the point that low probability events with high damage can still be very harmful. Low probability-high impact events are very complex to handle as their distributions are very difficult to estimate and even 10 km resolution regional climate model outputs have still too high error term to solve this problem appropriately.

The significantly decreased probability of frost events does not give enough reason to give up the research, breeding or application of frost resistant varieties especially in plain region viticulture regions with lower altitude or sites with cool collecting structure of terrain.

According to our results the significant increase of the number of warm and hot days involves both quantity (biomass increase) and quality risk of production (change of balance of sugars and acids). The structure of plantation, the system of cultural practices, especially the canopy manipulation and soil management practices have probably be modified and adjusted to the changed conditions in order to prevent the damages or mitigate the risk of loss. Moreover, we have to prepare for the possible modification of the characteristics of wines and the feature of some regions. The deviation between the results of the different years can moderate as the climate factors affect together with their interaction with the shifted phenological stages. The realized change of the character of a region is very difficult to prognosticate. Not only the change of the climate with its direct impact but also the effect of the modified edaphic factors, the plantation structure and the applied cultivation and practices with their interactions should be taken into consideration.

The water supply even with its possible decrease remains in the optimal range, considering the yearly precipitation sum, the risk of serious water stress is not high. The precipitation sum in the vegetation period tends to be near optimal. Moderate water stress, however can be caused by the longer and longer dry periods growing up to 27 days by the end of the 21st century. As a consequence of the increased aridity, we also have to prepare for unbalanced growing process.

We can state that regional climate model RegCM3.1 forecasts a warmer and dryer future in Central Hungary with respect to the long term mean distribution parameters which does not endanger the growing demands of grapevine producers. However, the increasing frequencies and seriousness of extreme events, especially warm and hot days as well as long dry periods bring us new risk factors to face which motivates us to find out new strategies such as modified or new plantation systems, vineyard establishment practices or viticultural management techniques. Since grapevine is planted for a long time (30-40 years), new plantations should be introduced considering the expected changes in the future.

We found that the method of the spatial analogy is a good tool understanding the effects of the climate change. Finding the analogue regions we can compare their training system, variety assortment, pest and

disease management and economic characteristics with the present ones in Hungary. Detailed analysis of the analogue regions can help us to adapt to the changing climate. This will be a good base for further research which leads to important information for decision makers to develop adaptation and mitigation strategies.

We conclude that both regional and subregional surveys are necessary to learn the present and the expected future situation of a region with the possible changes of its border. Responsible decisions on the modification of grape growing regions can be made according to the evaluations of the continuous monitoring and survey of Central Hungary and the ones we have found as analogous regions.

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