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CLIMATE CHANGE TREND AND EFFECTS ON VINE CULTIVATION IN DEALU MARE VINEYARD

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Abstract

The measurement and quantification of climate variability was carried out on the basis of the 27 climate indices (16 indices based on temperature and 11 precipitation indices) defined by the Climate Change Detection and Indices (ETCCDI), which mainly focus on both cold and hot extremes of daily minimum temperature (TN), maximum daily temperature (TX), precipitation (PR) and, also percentile-based thresholds. Compared to climatology 1990-2009, in 2010-2022 the frequency of cold nights decreases and the frequency of warm nights increases. Percentile-based indices measuring the frequency of "cold days" (TX10p) has decreased and "warm days" (TX90p) has increased. The fixed maximum temperature events, freezing days (TX < 0°C) and summer days (TX > 25°C), show decreasing and increasing trends, respectively by 22 days (2.09 days/year), (in line with the general warming trend), but these are generally statistically significant. The effects of climate change are manifested on the development of vegetative phenophases (budding, flowering, leaf, grape ripening) and the evolution of grape production and its quality.

***Key words**: ETCCDI indices, freezing days, summer days, vegetative phenophases.*

INTRODUCTION

In the Last Report of the IPCC (Intergovernmental Panel on Climate Change) it is mentioned that "the warming of the climate system is unequivocal, as it emerges from the observations on the increase in air and ocean temperatures, the massive melting of glaciers and on a global increase in the average level of the seas." (IPCC, 2007a, 2007b). The average annual air temperature increased in the period 1989-2021 by 1.3°C, compared to the average 1936-1988 (10.8°C), a value that exceeds the average global warming of 0.85°C in the last 100 years, according to the report AR 5 (IPCC, 2013).

The increase in the concentration of CO_2 in the atmosphere, the higher temperatures, the changes in the annual and seasonal precipitation regimes and the change in the frequency of extreme phenomena will affect the volume, quality and stability of grape production.

The production of grapes and its quality were influenced by the heating during the night and in the spring, where the reduction in the frequency of frosts determined an earlier start of the vine vegetation and implicitly a longer vegetation period.

Using a series of models to simulate climate conditions it can be concluded that the climate warming trend observed in wine growing regions all over the world will continue.

Wigley et al. (1983) suggest that in Europe due to climate warming the duration of the vine growing season will increase, along with this increase the quality of wines in certain wine growing regions.

By using the climate model HadCM3 (Hadley Center Climate Model) and the A2 model (Pope et al., 2000) regarding CO_2 emissions, (Jones, 2005a, 2005b; Lobell et al., 2006; Gordon, 2007) predicted an increase in average temperatures during the growing season by 1.3°C in the northern hemisphere and only 0.9°C in the southern hemisphere.

Examining the degree of change projected for the period 2000-2049, significant changes are expected in each wine-growing region with values ranging from 0.2 to 0.6°C/decade.

The warming of the climate in the wine-growing regions of Europe has induced changes in the phenology of the varieties, namely an earlier development by 6-25 days of the vegetative phenophases, especially the fallow phenophases veraison and the ripening of the grapes.

Croitoru et al. (2016) showed that increasing trends are stronger for heat wave indices defined on the basis of maximum temperature (at least three consecutive days when the maximum temperature exceeds the 90th percentile) compared to those obtained on the basis of minimum temperature (at least three days consecutive when the minimum temperature exceeds the 90th percentile).

Other examples of using the identification methodology with thresholds defined by percentiles are indices that can quantify thermal extremes are those calculated according to the procedure recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI) (Alexander et al. 2006; Zhang, et al., 2006). Global observed changes in daily climate extremes of temperature and precipitation.

Based on the climate data recorded in the period 1956-2006 in the Cotnari vineyard, a slight warming trend of the climate was evident due to the increase of both minimum and maximum daily temperatures (Chiriac, 2007).

Similar to climate changes at the global level, changes in the regime of extreme thermal values were also highlighted in our country, namely: the increase in the annual frequency of tropical days (daily maximum >30°C) and the decrease in the annual frequency of winter days (daily maximum <0°C), the significant increase in the average summer minimum temperature and the winter and summer maximum temperature, the increase in duration of sunshine. The phenomena of temperature increase became more acute after the year 2000, the winter of 2006-2007 being the warmest winter.

MATERIALS AND METHODS

Climate data used in this analysis are for the Research Institute for Viticulture and Enology Valea Călugărească station for 1990 to 2022. The data consist of daily observations of the minimum and maximum temperature (TN, TX) and daily precipitation (PR).

The indices recommended by ETCCDI (http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml) are calculated based on daily observations of maximum and minimum temperatures and precipitation. According to the Climate Change Detection and Indices (ETCCDI) methodology, 27 climate indices were studied (16 indices based on temperature and 11 on precipitation). The indices for the station points were calculated using the CLIMPACT software.

The 16 indices based on temperature are: Summer days (SU25)-annual count when daily maximum TX>25°C (days); Ice days (ID0) - annual count when daily maximum TX<0°C (days); Tropical nights (TR20)-annual count when daily minimum TN>20°C (days); Frost days (FD0) - annual count when daily minimum TN<0°C (days); Max Tmax (TXx)-annual maximum value of daily maximum temperature (°C); Min Tmax (TXn)-annual minimum value of daily maximum temperature (°C); Max Tmin (TNx)-annual maximum value of daily minimum temperature (°C); Min Tmin (TNn)-annual minimum value of daily minimum temperature (°C); Warm days (TX90p)-percentage of the days when TX>90th percentile; Cool days (TX10p)-percentage of the days when TX<10th percentile; Cool nights (TN10p)-percentage of the days when TN<10th percentile;Warm nights (TN90p) percentage of the days when TN>90th percentile; Growing season length (GSL), days; Diurnal temperature range (DTR)-annual mean diference between TX and TN (°C); Warm spell duration indicator (WSDI)-annual count at least 6 days consecutive when TX>90th percentile (days); Cold spell duration indicator (CSDI)- annual count at least 6 days consecutive when TN<10th percentile (days).

The indices based on precipitation are: Max 1 day precipitation amount (RX1day), mm; Max 5 days precipitation amount (RX5day), mm; Simple daily intensity index (SDII)-PRCP>1.0mm; Number of heavy precipitation days (R10)-annual count of days when PRCP≥10 mm (days); Number of heavy precipitation days (R20)-annual count of days when PRCP≥20 mm (days); Number of heavy precipitation days (R25)-annual count of days when PRCP≥25 mm (days); Consecutive dry days (CDD)-maximum number of days with RR<1mm (days); Consecutive wet days (CWD)-maximum number of days with

RR≥1mm (days); Very wet days (R95p) annual total PRCP when RR>95th percentile; Annual total wet-dry precipitations (PRCPTOT), mm.

RESULTS AND DISCUSSIONS

Extreme temperature frequency indices showed that the frequency of cold nights (TN10p) and cold days (TX10p) decreased significantly during 2010-2022, with a decrease rate of 3.38% and 4.80%, respectively ($p < 0.05$), while the frequency of hot nights (TN90p) and hot days (TX90p) increased significantly, with an increase rate of 2.11% and 4.86%, respectively ($p < 0.05$) (Figure 1).

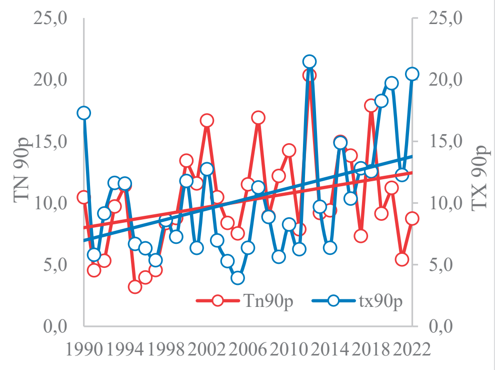

Figure 1. Frequency of warm nights (TN90p) and warm days (TX90p) from 1990-2022

The data obtained are consistent with the data obtained at the global level (Donat et al., 2013) indicating that the tendency of nocturnal extremes (TN10p and TN90p) were higher than those for daytime extremes (TX10p and TX90p).

Regarding the indices of thermal extremes that define frost days expressed by the number of days per year with the minimum temperature below 0°C (FDO) and the number of days per year with the maximum temperature below 0°C (IDO), the tendency is to decrease with 5.17 days/year, respectively 8.9 days/year ($p<0.05$) (Figure 2).

While the cold indices (FDO and IDO) showed decreasing trends, the warm indices (SU) showed increasing trends.

The indices of summer days (SU) recorded increasing trends, with rates of 1.72 days/year in the period 2010-2022 ($p < 0.05$) (Figure 3).

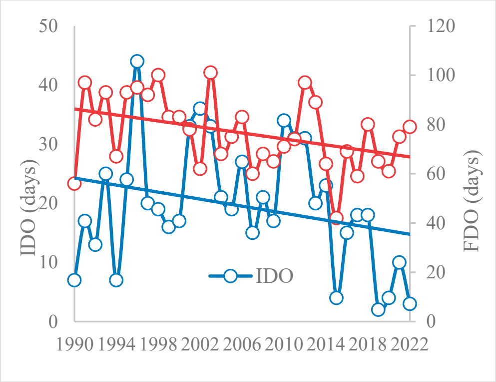

Figure 2. The annual Ice days (IDO) and Frost days (FD0) from 1990-2022

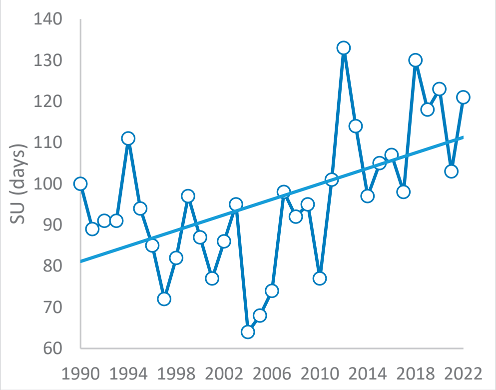

Figure 3. The daily maximum TX>25°C (SU) from 1990-2022

The warm spell duration index (WSDI) showed a significant increasing trend with a rate of 15.2 days per 2010-2022 period ($p < 0.05$) (Figure 4).

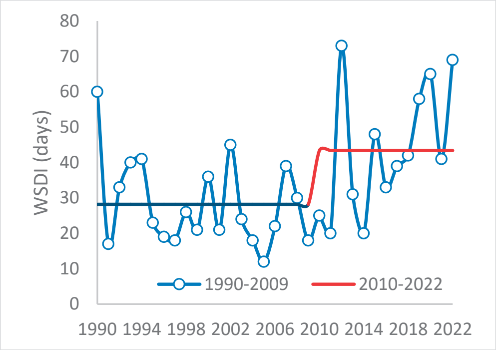

Figure 4. The warm spell duration indicator (WSDI) from 1990-2022

The cold spell duration indicator (CSDI)-annual count at least 6 days consecutive when TN<10th percentile showed a decrease, with a rate of 12.6 days/2010-2022 period ($p < 0.05$).

Among the indices based on precipitation Maximum 1-day precipitation (Rx1day) showed decreasing and obvious inter-decadal changes with increasing rates of 3.59 and respectively maximum 5-day precipitation (Rx5day) showed increasing trends 3.56 mm/2010-2022 period ($p<0.01$).

The Rx1day index had higher values in the period 1990-2009 and showed statistical significance ($p<0.05$), and the Rx5day index in the same period had lower values and did not present statistical significance (Figure 5).

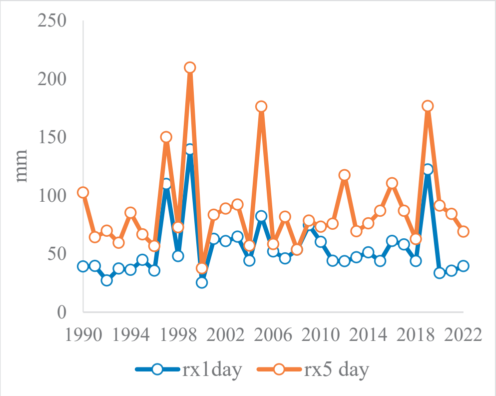

Figure 5. The rx1 day and rx5 day from 1990-2022

Methods for identifying signals in the configurations of precipitation-derived indices are also based on thresholds using specified values of precipitation amounts and thresholds using percentiles of the distribution of precipitation values.

Compared to the precipitation from the period 1990-2009, for the period 2010-2022, the trend is increasing with a rate of 1.64 mm/year, and for the precipitation during the vegetation period, the uneven distribution and the reduction of 2.27 mm/year can be observed (Figure 6).

Based on the results of annual trends in precipitation indices, an increasing trend of 0.21 mm/year was observed for the period 2010-2022, which may suggest that the annual number of days with heavy precipitation, number of days with dry and wet periods increased, compared to 1990-2009.

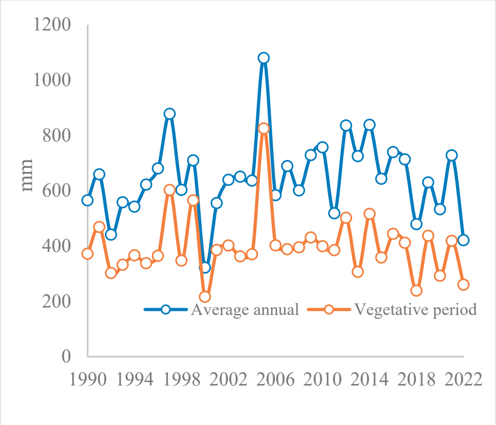

Figure 6. The annual amount and during the vegetation period of precipitation from the period 1990-2022

The indices R95p (Very Wet Days) and R99p (Extremely Wet Days) showed decreasing trends of 1.49 during 2010-2022, respectively, the increasing trend of 1.33 in R99p, data according to the literature (Donat et al., 2013a, 2013b; Zhou et al., 2016).

The maximum number of consecutive dry days (CDD) with RR<1mm and the maximum consecutive wet days with RR≥1mm (CWDrecorded in the period 2010-2022, also increasing values of 3.2 days, respectively 0.39 days (Figure 7).

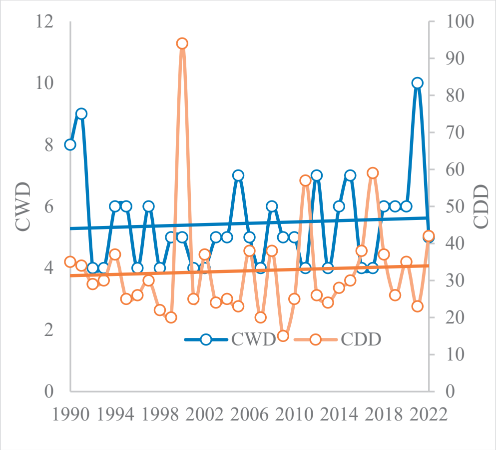

Figure 7. The CDD and CWN from 1990-2022

Due to the high temperature regime in the months of April and May, the flowering of the vines started earlier, by approximately 10-14 days compared to the normal period.

In general, flowering started almost simultaneously in all vinifera varieties, with differences of only 1-3 days between varieties.

The very high temperatures recorded in the air (which exceeded 35°C and even 40°C in the months of July and August) but especially those recorded on the surface of the soil which often exceeded 50°C and even 60°C determined a strong evaporation of water from the soil, leading to the phenomenon of pedological drought in the months of August and September.

The long period of drought associated with a high thermal regime and an air hygroscopicity of less than 40%, installed during the period of intense growth of shoots and grapes determined a drastic reduction in the growth of shoots, a pronounced debilitation of the buds and an early termination of grape growth (the weight of the grape, in most varieties, is lower by 40-50%). These changes in the wine-growing climate determined an advance development of the vegetative phenophases, especially of the fallow phenophases and the ripening of the grapes (by approximately 1-5 days), which influenced especially tfe quality of the grape production

Regarding the quality of grape production, the changes in the wine-growing climate led to an increase in the accumulation of sugars in the grapes, against the background of a drastic reduction in total acidity. This caused the glucoacidimetric index to take on high values, far above the optimal values for obtaining typical and high quality wines.

CONCLUSIONS

Annual increasing trends were recorded namely: TNn, TNx, TXx, ID, and SU, while decreasing trends were observed in three indices (ie, TXx and FD).

The frequency indices of nocturnal extremes (TN10p and TN90p) were higher than those for daytime extremes (TX10p and TX90p), ($p<0.05$).

While all indices suggest a constant heating of both minimum and maximum temperatures, a decrease in TXn may suggest that the coldest daytime temperature has decreased annually. In conclusion, we can say that the warming trend of the viticultural climate manifested by the recording of excessive temperatures since April and until the ripening of the grapes led to an advance triggering of all the vegetative phenophases and to a standardization of the moment of their triggering in the vinifera varieties.The grape production has been influenced by climate change. High temperatures and precipitation in lower quantities have affected grape production and vegetative growth is lower.

REFERENCES

Alexander, L.V., Zhang, X., Peterson, T.C., et al. (2006). Global observed changes in daily climate extremes of temperature and precipitation. *J. Geophys. Res*. 111.

Chiriac, C. (2007). Influence of climate change upon environment in the Cotnari Vineyard, Annals of Stephan the Great University, Romania, XVI, http://www.atlas. usv.ro/www/anale/datagrid.

Croitoru, A.E., A. Piticar, A.F. Ciupertea, and C.F. Roşca. (2016). Changes in Heat Waves Indices in Romania over the Period 1961–2015, *Global and Planetary Change*, 146:109–21.

Donat, M.G., Alexander, L.V., Yang, H., et al. (2013a). Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century the HadEX2 dataset. *J. Geophys*. Res: Atmosphere 118, 2098e2118.

Donat, M.G., Alexander, L.V., Yang, H., et al., (2013b). Global land-based datasets for monitoring climatic extremes. *Bull. Am. Meteorol. Soc.* 94, 997e1006.

and New York.

Gordon, C., C. Cooper, C. A. Senior, H. Banks, J. M. Gregory, T. C. Johns, J. F. B. Mitchell, and R. A. Wood (2000). The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments, Climate Dynamics, vol 16, p147-168.

IPCC (2007a) IPCC Fourth Assessment Report: Climate Change 2007 (AR4). Working Group I Report. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2007b) IPCC Fourth Assessment Report: Climate Change 2007 Synthesis Report, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 52.

IPCC (2013). Climate Change 2013: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Jones, G. V., (2005a). Climate and terroir: Impacts of climate variability and change on wine. *GeoScience Canada*, Terroir Series (in press).

Jones, G. V. (2005b). Climate change in the western United States grape growing regions. *Proceedings of the 7th International Symposium on Grapevine Physiology and Biotechnology*. Davis, California, June 2004. In press: *Acta Horticulturae.*

Lobell, B.B., Field, C.B., Cahill, K.N., Bonfils, C. (2006). Impact of future climate change on California perennial crop Yields: Model projections with climate and crop uncertainties, *Agricultural and Forest Meteorology*, vol. 141, Issues 2-4, 208-218.

Morak, S., G.G. Hegerl, J. Kenyon (2011). Detectable regional changes in the number of warm nights, *Geophysical Research Letters*, 38, L17703.

Pope, V. D., Gallani, M. L., Rowntree, P. R. & Stratton, R. A. (2000). The impact of new physical parametrizations in the Hadley Centre climate model - HadAM3. *Climate Dynamics*, vol 16, 123-146.

Zhang, X., FW Zwiers, G. Hegerl (2009). The influence of data precision on the calculation of temperature percentile indexes, *International Journal of Climatology*, 29, 321–327.

Zhang, X, L. Alexander, GC Heger, P. Jones, A. Klein Tank, TC Peterson, B. Trewin and FW Zwiers (2011). Indices for monitoring changes in extremes based on daily temperature and precipitation, *WIREs Climate Change*, 2, 851–870.

Zhou, B.T., Xu, Y., Wu, J., et al. (2016). Changes in temperature and precipitation extreme indices over China: analysis of a high-resolution grid dataset. Int. *J. Climatol*. 36, 1051e1066.

Wigley, T.M.L., Lough, J.M., Jones, P.D. (1983). Spatial patterns of precipitation in England and Wales, J. Climatol. (in press).

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