CURRENT TREND IN CLIMATE PARAMETER EVOLUTION AFFECTING VINEYARDS IN BUJORU VITICULTURAL AREAL

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Abstract

Climate change caused by global warming phenomena, cause important disturbances in all types of ecosystems, including vine growing areas. The current study presents the evolution of influential climate parameters for vine varieties at Bujoru viticultural area, located in south-eastern part of Romania. Climate analysis identified important changes on main climate indices that influence vegetative development and biological production yields specific to vine varieties. Results of the study confirm the climate parameter evolution with negative influences on traditional viticultural areas. Amplification of prolonged drought phenomenon was observed with recorded precipitation values below the multi-annual averages due to current climate change trends. Depletion of soil water reserves was helped by: an increase in the number of days with temperatures exceeding 30^0C, a change of the interval in which the highest air temperatures are recorded. Maximum air temperatures specific to the month of July have shifted towards the month of August. In winter months average temperatures have increased above before known reference levels. This study, through its results, confirms the current trend of intensifying extreme weather phenomena that can have significant effects on vine plantations, as well as pan-European trends for replacing traditional genotypes.

Key words: climate, parameter evolution, viticultural areal

Climate change has manifested as an increase in the frequency of extreme and uncertain climate events. World Meteorological Organization and Intergovernmental Panel on Climate Change warn that global climate trends are changing, whit unprecedented climate extremes (Fisher *et al*, 2013). Viticulture and winemaking have an important socioeconomic impact in many European countries. Climate characteristics are vital in defining terroir proprieties that in turn give specificity to a certain wine region. These climate indices are responsible for vine growth, vine physiology, yield, and berry composition and in turn determine wine typicity (Shimizu *et al*, 2022). Global warming phenomena have caused many disturbances in all types of ecosystems, viticultural areals not being left out.

The European continent, according to recent studies, is an especially responsive area to temperature rise induced by climate change, particularly during summer months (Giorgi, 2006). Grapevine is recognized as one of the most important crops cultivated across Europe, with the largest wine production and vineyard area in the world, is home to some of the most important and renowned wine-making regions and wines (OIV, 2019).

Climate change scenarios predict major influence on main viticultural choices or even alteration of geographical distribution for current grapevine varieties (Santos *et al*, 2020).

Grapevines are historically cultivated on six continents, between latitudes 4° and 51° in the Northern Hemisphere (NH) and between 6° and 45° in the Southern Hemisphere (SH), and across a large diversity of climates. Vine cultivation, mostly, being specific for climate regions (Tonietto, 1999). Viticulture is a key socioeconomic and cultural sector, with a high economic for many relevant industry branches of the supply and distribution chains. Setting aside the direct income from wine sales, which benefit the whole production chain (wine and subsidiary companies, their employees, viticulturists, and property owners), there are other indirect benefits provided, spreading from landscape and ecosystem services to tourism development (Lavalle *et al*, 1999).

Many individual atmospheric factors influence vine development and grape yield but meeting the required thermal and hydrological conditions remain among the most important aspects of a healthy productive plantation (Jones *et al*, 2005).

Grapevines require both adequately cold periods for hardening and fruitfulness followed by warm periods beneficial for the ripening process.

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Temperature is a crucial factor for the thermophilic heat-demanding grapevine (Fennel, 2014).

Vine cultivars are forced to modify their characteristic vegetation cycle, with often negative consequences on grape yield and quality indices of the resulting wines (Droulia & Charalampopoulos, 2022).

MATERIAL AND METHOD

Climate change monitoring in Bujoru viticultural areal was done for general and specific climate indices using a time line from 2010 to 2019 as reference, compared to the latest 2020-2023 interval. General climate analysis followed the variation of: Global heat balance, (Σt°g); Active thermal balance, (Σt°a); Useful heat balance, (Σt°u); Σ annual precipitation (mm); Average annual temperature °C; Average temperature for the month of : July, August and September °C; Average temperature from the first and second decades/ June °C; Mean maximum temperature values specific for August, °C; Relative air humidity (%); No. days with maximum temp. > 30°C; Bioactive period length (days); Real heliothermic; Hydrothermal coefficient index; "de Martonne" aridity index. Specific climatic vine indices were monitored: vine bioclimatic index; Oenoclimatic aptitude index (IAOe); Huglin helio thermic index (IH); Night cooling index (IF), in order to have a correct image of current climate influence on vine plantation.

RESULTS AND DISCUSSIONS

I. General climate indices analysis

Heat balance parameters: Global heat balance, (Σt°g); Active thermal balance, (Σt°a); Useful heat balance, (Σt°u) registered increases for 2020-2023 when compared to multiannual values.

Figure 1 **Heat balance variation**

A Global heat value of 3483 was specific for 2022 representing an increase of 39 units but the maximum value of 3492 with an increase by 48 units was specific to 2023. Specific for temperate climate condition and Romanian vineyards global values are naturally situated in the rage of 2700-4000 Σt°g (Enache, 2013). Latest average values situated at the far end of the scale. Active thermal balance (Σt°a) values ranged from 3337(2020) to 3245(2023), highest value recorded was specific to 2020. An increase by 0.8% for active thermal balance parameter. Values of 1702 units for useful heat balance (Σt°u), seen in 2023, surpassed multiannual data situated at 1697 maximum values.

Temperature indices revealed important variations whit annual average temperatures registering increases compared to multiannual means. Data analysis revealed a 0.7^0 increase in 2022 and a more significant 1.5^0 increase for 2023. Although average temperatures reached 12.4 ℃ (2020), near the value of 2023, average temperatures decreased the following year below multiannual values.

Figure 2 **Average annual temperature variation**

Latest temperature values describe a change in before known trends whit the absence of colder years between hotter ones. Temperature changes associated with climate change are not homogeneous. Studies show that temperatures are currently 1 ℃ higher on average compared to pre-industrial revolution (IPCC, 2014)

Figure 3 **Average temperature indices in summer months**

Average temperatures for summer months show a developing trend of maximum average temperatures increases whit the same trend development as seen in average annual

temperature values. Beside the fact that new average air temperatures are achieved, data analysis shows a consecutive yearly increase in temperature. Most noticeable increase in temperature was specific to the month of August 2023 whit a maximum of 32.9^0C, 2.9^0C higher than 2010-2019 maximum values. July and August average temperatures also increased by 1.1 and 1.6^0C. June temperatures suffered declines from average values of 21^0C to a minimum of 17.8^0C (2021). European data show shifting climatic conditions due to climate change whit possible great impact on viticulture worldwide (Schultz *et al*, 2000).

Synergistic effects between projected precipitation decrease, and higher rates of evapotranspiration due to a warmer climate will likely increase water requirements, particularly during summer, in southern Europe (Cardell *et al*, 2019).

Figure 4 **Number of days with maximum temp. > 30°C, air humidity and bioactive period length**

Optimum photosynthetic temperature for the grapevine is between 25 and 35 °C (Kun *et al*, 2018). Increases in the length of bioactive periods have been especially characteristic for 2023 whit an extra 6 days longer than multiannual averages and 21 days more compared de 2022. These values are corroborated whit a rise in days that exceed average temperatures of 30^0C. Data has shown 55 days whit average values over 30^0C in 2022 whit a surge to 61 days in 2023.

Photosynthetic rates in grape leaves do not decrease significantly at 35 °C, but these processes are limited at temperatures of over 40 °C (Luo *et al*, 2011). A consecutive amplification of the number of days whit these values is starting to emerge. Air humidity is dropping whit latest data below mean values. 2022 registering a drop by 20.1 % and the lowest value for the time interval analyzed.

Figure 5 **Real heliothermic index and Hydrothermal coefficient values**

Important reductions of hydrothermal coefficient values were observed, lowest value being specific for 2023 (0.72), 0.23 units less compared to multiannual averages. Analysis of real heliothermic index show variations between 2.2 and 2.75 whit a value of 2.69 (2022) and 2.47 (2023) near multiannual values. Following climatic trend provided by other indices. New registered values surpassed known benchmarks for this specific climate region. A minimum of 0.44 unites compared to 2.25 value specific for late ripening varieties and maximum value of 1.44 unites compared to 1.25 value for early ripening varieties.

Figure 6 **Rainfall values**

A gradual decline of rainfall is emerging as a trend in the latest years. When compared to multiannual average values for 2010-2019 (526 mm), total amount for 2022 and 2023 of precipitation did not exceed 347 mm. The two consecutive years that registered the lowest precipitation values for the analyzed time line were also preceded by years whit declining inputs of water, 2020 (490.2 mm) and 2021 (447 mm).

Multiannual precipitation values of 526 mm were by 34 % higher compared to 2022 and 2023.

Precipitation ratios remain marginally close; 33% rainfall during vegetative periods for 2023 compared to 39% rainfall during vegetative resulted from multiannual data. Total soil water reserve is severely affected, whit lowering values for precipitations during vegetative periods, of 233 mm compared to multiannual values of 316 mm.

Annual precipitation and its distribution are critical. High soil water reserves are used during vine vegetative stages followed by dry and stable atmospheric conditions from flowering to berry ripening (Ramos *et al*, 2008). "De Martonne" aridity index suffered modification according to precipitation and temperature values. 2010-2019 average values of 24.9 were higher by 10 units, whit low values of 15.9 (2022) and 15.3 (2023). Values <22 are characteristic for extreme aridity areas and were characteristic to eastern periphery of Romanian Plain and Danube wetlands, which corresponds to the smallest annual quantity of rainfall <450 mm (Zaldea *et al*, 2021).

II. SPECIFIC VINE CLIMATE INDICES ANALYSIS

Specific vine climate indices offer hints on the health and suitability of the viticultural area (Fraga *et al*, 2013).

One of the most important parameters is cool night Index which represent the average of minimum night temperatures during ripening periods in order to improve evaluation of the qualitative potentials of wine in relation to the secondary metabolite accumulation in grapes (Piña-Rey *et al*, 2020).

Figure 7 **Vine bioclimatic and Night cooling index**

Both specific indices registered modifications according to previous general climate indices. Night cooling index was by 16.7% higher at its maximum value, 12.6-2023, than baseline values. Vine bioclimatic followed an ascending trend for the last two monitored years whit values of 10.67 and 10.96. Studies conducted in the Mediterranean wine making basin showed significant night cooling index variations, whit a developing trend for increasing values (Biasi *et al*, 2019). Other results Portugal vine growing centers also report higher night cooling indices (Blanco-Ward *et al*, 2019), confirming current trend at Bujoru viticultural area.

Oenoclimate aptitude index (IAOe) is another revealing climate suitability factor important in wine production under temperate climate conditions. In Romanian wine regions, IAOe is traditionally quite stable assuring certain types of wine production practices. In the last decades the IAOe values have increased (Irimia *et al*, 2017).

Bujoru multiannual values 2010-2019 show an average IAOe of 4758. According to data analysis 2020-2023, oenoclimate aptitude index has varied between 4950(2020) and 4460 (2021) whit consecutive increases for this index in 2022 and 2023 to 4856 respectively 4710. Values reflecting the impact of global warming phenomena when compared to previous measurements (Halbac-Cotoara-Zamfir *et al*, 2021).

Figure 8 **Oenoclimate aptitude and Huglin heliotermic index**

Huglin heliotermic index variations registered important variations between 2020-2023 whit a max of 2469 in 2020 followed by 2023 (2324) whit possible future ascending values. Higher huglin index, situates the territory as warm with cultivation possibilities suitable for late varieties situated in the $2100 < HI \leq 2400$ classification (Vizitiu *et al*, 2019).

CONCLUSIONS

Significant warming trends have been observed globally, with substantial implications for various sectors, including viticulture. Future warming phenomena will probably result in an eventual overall loss of viticultural suitability in the Mediterranean-like climatic areas of southern Europe, while in central and northern Europe, warming conditions will potentially benefit late ripening grapevine cultivation. Romania's diverse climate and varying geography mean that the impacts of climate change will be region-specific.

Low relative humidity combined with high temperatures can increase water stress in grapevines. This stress can affect the vines' ability to produce quality fruit and maintain overall health.

New climate parameters determine a raise in the number of dry years whit an interplay between reduced rainfall, higher maximum temperatures, and relative humidity having serious effects on vine plantations gown at Bujoru viticulture and winemaking research - development facility. Sustainable viticulture strategies are being developed in order to adapt and mitigate the effects of climate change seen in Bujoru viticultural areal.

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REFERENCES

Sanz-Sáez Á., Erice G., Aguirreolea J., Muñoz F., Sánchez-Diaz M., Irigoyen J.J., 2012 - *Alfalfa forage digestibility, quality and yield under future climate change scenarios vary with Sinorhizobium meliloti strain*. Journal of Plant Physiology, 169:782-788.

Shimizu H., Akamatsu F., Kamada A., Koyama K., Iwashita K. & Goto-Yamamoto N., 2022 - *Effects of variety and vintage on the minerals of grape juice from a single vineyard*. Journal of Food Composition and Analysis, 107:304-377.

Santos J. A., Fraga H., Malheiro A. C., Moutinho-Pereira J., Dinis L. T., Correia C. & Schultz H. R., 2020 - *A review of the potential climate change impacts and adaptation options for European viticulture*. Applied Sciences, 10(9) : 30-92.

Tonietto J., 1999 - Les Macroclimats Viticoles Mondiaux et l’Influence du Mésoclimat sur la Typicité de la Syrah et du Muscat de Hambourg dans le sud de la France: Méthodologie de Caractérisation. Ph.D. Thesis, Ecole Nationale Supérieure Agronomique, Montpellier, France; 233p

Lavalle C., Micale F., Houston T.D., Camia A., Hiederer R., Lazar C., Conte C., Amatulli G., Genovese G., 2009 - *Climate change in Europe. 3. Impact on agriculture and forestry. A review*. Agron. Sustain. Dev. 29: 433–446.

Jones G.V., White M.A., Cooper O.R., Storchmann K., 2005 - *Climate change and global wine quality*. Clim. Change 73: 319–343.

Fennell A., 2014 - *Genomics and functional genomics of winter low temperature tolerance in temperate fruit crops*. Crit. Rev. Plant Sci. 33: 125–140.

OIV, 2019 - *Statistical Report on World Vitiviniculture*; International Organisation of Vine and Wine: Paris, France; Available online: https://www.oiv.int/public/medias/6782/oiv-2019-statistical-report-on-world- vitiviniculture.pdf

Giorgi F., 2006 - *Climate change hot-spots*. Geophys. Res. Lett., 33:87-107

Droulia F. & Charalampopoulos I., 2022 - *A review on the observed climate change in Europe and its impacts on viticulture*. Atmosphere, 13(5), 837.

IPCC, 2014 - *Climate Change Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Pachauri, R., Meyer, L., Eds.; IPCC: Geneva, Switzerland.

Schultz H.R., 2000 - *Climate change and viticulture: A European perspective on climatology, carbon dioxide and UV-B effects.* Aust. J. Grape Wine Res. 6: 2–12.

Kun Z., Bai-hong C., Yan H., Rui Y., Yu-an W., 2018 - *Effects of short-term heat stress on PSII and subsequent recovery for senescent leaves of Vitis vinifera L. cv. Red Globe*. J. Integr. Agric. 17: 2683–2693.

Luo H.B., Ma L., Xi H.F., Duan W., Li S.H., Loescher W., Wang J.F., Wang L.J., 2011 - *Photosynthetic responses to heat treatments at different temperatures and following recovery in grapevine (Vitis amurensis L.) leaves*. PLoS ONE, 6: 23-33.

Ramos M.C., Jones G.V., Martínez-Casasnovas J.A., 2008 - *Structure and trends in climate parameters affecting winegrape production in Northeast Spain*. Clim. Res., 38: 1–15.

Cardell M.F., Amengual A., Romero R., 2019 - *Future Effects of climate change on the suitability of wine grape production across Europe*. Reg. Environ. Chang. 19: 2299–2310.

Zaldea G., Nechita A., Damian D., Ghiur A. & Cotea V. V., 2021 - *Climate changes in recent decades, the evolution of the drought phenomenon and their influence on vineyards in North-Eastern Romania*. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 23:20-32

Fraga H., Malheiro A.C., Pereira J., Santos J.A., 2013 - *Future scenarios for viticultural zoning in Europe: Ensemble projections and uncertainties.* Int. J. Biometeorol. 57:909–925.

Piña-Rey A., González-Fernández E., Fernández-González M., Lorenzo M. N., & Rodríguez-Rajo F. J., 2020 - *Climate change impacts assessment on wine-growing bioclimatic transition areas.* Agriculture, 10(12): 605-615.

Biasi R., Brunori E., Ferrara C. Salvati L., 2019 - *Assessing impacts of Climate Change on phenology and quality traits of Vitis vinifera L.: The contribution of local knowledge*. Plants, 8:121-129.

Blanco-Ward Daniel A., Ribeiro David Barreales J., Castro J. Verdial M. Feliciano V., 2019 -

Climate change potential effects on grapevine bioclimatic indices: A case study for the Portuguese demarcated Douro Region (Portugal). In BIO Web of Conferences, 12: 1-13. EDP Sciences.

Irimia L. M., Patriche C. V. & Roșca B., 2017- *Changes in oenoclimate aptitude index characterizing climate suitability of Romanian wine growing regions.* Applied Ecology & Environmental Research, 15(4):10-19.

Enache V., 2013 - *Influenţa unor verigi tehnologice asupra dinamicii umidităţii solului, în condiţiile de secetă prelungită a anului 0 în Podgoria Dealu Bujorului-Romania*. In Horticultură, Viticultură şi vinificaţie, Silvicultură şi grădini publice, Protecţia plantelor, 36: 249-251.

Halbac-Cotoara-Zamfir R., Ferreira C. S. S., & Salvati L., 2021 - *Long-term urbanization dynamics and the evolution of green/blue areas in eastern europe: Insights from Romania.* Sustainability, 13(24):57-68.

Vizitiu D. E., Dinca L., Enache V., Donici A., Popa L., Cociorva D. & Murariu G., 2018 - *Identifying and describing the main climatic and stress factors that are affecting forest and viticultural ecosystems.* Horticulturae, 5:232-241.