

CLIMATE TRENDS IN OLTENIA. CASE STUDY: DĂBULENI WINE CENTRE

Cristian MĂRĂCINEANU¹, Maria BĂJENARU², Aurelia DIACONU²,
Nicolae GIUGEA¹, Ramona CĂPRUCIU¹

¹University of Craiova, Faculty of Horticulture, 13. A. I. Cuza Str, Craiova, Romania

²Research and Development Station for Plant Culture on Sandy Soils Dăbuleni, Romania

Corresponding author email: mariaciuca92@yahoo.ro

Abstract

The Dăbuleni viticultural centre differs from other centres in Oltenia by the nature of the ecological factors. Located near the extreme south of Romania, it is characterized by sandy soils, high temperatures and a reduced rainfall regime. Under these conditions, viticulture acquires a series of particularities about culture technology and the choice of varieties for planting. All of these can be influenced by climate change. Meteorological data provided by the Research and Development Station for Plant Culture on sandy soils in Dăbuleni (Romania) for 10 years were interpreted to show the current viticultural climate and its trend. For this, several statistical indices were calculated (e.g. arithmetic mean, standard deviation, coefficient of variation), the Martonne aridity index was calculated, and the climagram of the period was made. The results were included in tables and represented graphically and show the evolution of the climate that characterizes viticulture on sands, in the Oltenia region (Romania).

Key words: climate, monitoring, trend, agroecology.

INTRODUCTION

Climate change directly or indirectly affects society, with significant risks for state or private enterprises; most targeted are the tourism, energy, agriculture, and food sectors, with direct repercussions on the national and global economy (Cheval et al., 2022; Falcescu et al., 2024). The annual instability of agricultural production due to climate change may threaten local and global food security (Lesk et al., 2016; Piticar et al., 2024). The yield of agricultural products would be higher if climate change had not intensified over the last decade, climate factors being the main environmental elements influencing the evolution and productivity of crops (Popescu et al., 2023). In 2018, Northern and Eastern Europe experienced high crop losses associated with extremely low rainfall and high temperatures between March and August (Brillouin et al., 2020). For example, low or erratic rainfall during the tuber development phase can lead to yield losses (Oseni & Masarirambi, 2011).

Understanding the regional dynamics of terrestrial water resources depends on several factors: snow phenology (timing of snow onset

and snow melt) studied by Amihăsesei et al., 2024, shows different dynamics between altitude bands and Koeppen-Geiger climatic regions in Romania with impact on water resources distribution and hydrological cycle, precipitation regime, orography complexity (Necula et al., 2024).

In the Oltenia region, there is a clear altitudinal zonation of vegetation as altitudes increase from south (about 3 m) to north (2519 m), which means a decrease in temperatures and, to some extent, an increase in precipitation (Vlăduț et al., 2017). Climate change in recent years in southern Romania stands out as persistent heat waves and prolonged droughts. Heat waves are extreme phenomena amplified by climate change, with critical implications for the human and environmental systems they affect (Pardo & Paredes-Fortuny, 2024). Changes in precipitation, evapotranspiration, and thus changes in the climatic water balance, are imminent effects of climate warming (Prăvălie et al., 2019).

Average temperatures in Romania have increased by more than 1.5°C in the last thirty years, with industrial pollutants being the main driving causes (Șmuleac et al., 2020; Ciornei et al., 2023; van Daalen et al., 2024). The

European Union (EU) is taking significant measures to face these challenges. The Green Deal Association aims to reduce greenhouse gas emissions in the EU by 55% by 2030 and achieve carbon neutrality by 2050 (Rant, 2024). If global temperatures reach +2°C, Central and Northern Europe will also become more prone to vegetation fires during droughts (El Garroussi et al., 2024). In particular, fire seasons are hypothesized to become more extreme and extend into more temperate northern latitude regions (Miller et al., 2024). Changes in global temperature and wind speed have varied in different months during 1989-2021, with their average rates of change being about 0.34°C/10a and 0.02 m/(s·10a), but they are much larger in some local regions (Vitasse et al., 2021; Fei et al., 2023). With growth rates of 0.003, 0.5°C and 5.5 mm per year, respectively, the interannual variation of NDVI (normalized difference vegetation index), temperature and precipitation showed a visible increasing trend (Nasiri et al., 2024). To assess the current climate, a large ensemble of multi-decadal simulations is needed to adequately sample internal climate variability, robustly identify model deficiencies, and convincingly demonstrate progress between climate model generations (Barbu et al., 2016; Jain et al., 2023). This variability stems from processes within the ocean-atmosphere-cryosphere-atmosphere-earth-biosphere system and external influences such as solar and orbital cycles, volcanic eruptions, and anthropogenic greenhouse gas emissions (Deser & Phillips, 2023).

The changes in Romania's hydropneumatic regime since 1960 have been more or less significant regarding the annual flow regime. Thus, increasing trends in winter correlated with the increase in air temperature and liquid precipitation at the expense of snowfall, decreasing trends in summer based on general warming increased evaporation and increasing trends in fall flow (Zaharia et al., 2020). To identify the anomalies and trends associated with high (annual and seasonal) flows of rivers in eastern Romania, two methods are applied: quantile perturbation method (QPM) and partial perturbation trend method (PMT) (Minea et Chelariu, 2021). The use of interpolation techniques and statistical tools in the

determination of various climatic data (temperature, precipitation and reference evapotranspiration) to explore the impact of climate change on Romanian forests after 1987 was fast by Prăvălie et al., 2022, the results highlighting the general trends of forest greening at the national level.

Many studies have linked climate change to urban development over the last century: rising urban air temperature, energy consumption rates, increased use of raw materials, pollution and waste generation, conversion of agricultural land to developed land, loss of biodiversity and water scarcity (Shahmohamadi et al., 2011). An analysis of the effects of temperature change on heating and cooling demand in Europe up to 2050 is carried out by Larsen et al., 2020, investigating trend changes (10-year average) and extremes (10-year min./max.). And the results of Micu et al., 2021, show a significant warming trend, well characterized by a sharp decrease in frost days and a significant increase in absolute maximum temperatures, summer days and the duration of drought periods. The impact of climate change on offshore wind resources in Northern Europe in the 21st century is analyzed based on the latest societal development and land use scenarios, with results showing that reducing emissions as shown by current climate targets would mitigate the declining trend and also lead to a more stable resource (Martinez et al., 2023).

The increasing intensity and fecundity of extreme weather events in recent years are increasing the risks of multiple crop losses at regional, national or global levels (Tigheelaar et al., 2018; Furtak & Wolińska, 2023). Hydric and thermal stress in the context of climate change affects the agricultural and horticultural sectors, and an in-depth knowledge of the phenomenon is topical. Increasing evidence on the significant impacts of climate change on viticulture (Alikadic et al., 2019; Cichi et al., 2021; Costea & Capruciu, 2022; Keller, 2023; Andrade et al, 2024), pomiculture (Cosmulescu et al; 2010; Milošević & Milošević, 2023; Jamal et al, 2024), vegetable growing (Mekonnen et al., 2022; Dumitru et al., 2023; Soare et al., 2024), etc., requires scientific research to investigate the evolution of these effects and the measures that can be taken

shortly (Droulia et al., 2021). Establishing the relationship between climatic resources, soil and vine variety, and the biochemical processes occurring under their influence confirms the viticultural vocation of the area (Căpruciu et al., 2023).

The impact of climate change on crop pathogen biogeography, disease incidence and severity, and their effects on natural ecosystems, agriculture and food production are topical studies (Trebecki et al., 2020; Singh et al., 2023).

Climate change mitigation strategies, such as afforestation, reforestation, and sustainable forest management, offer promising solutions for climate change mitigation while yielding substantial co-benefits for human health (van den Bosch et al., 2024).

In this study, meteorological data from the last 10 years in the Dăbuleni area were interpreted to characterize sandy soils viticulture in the context of current climate change.

MATERIALS AND METHODS

The analysis of climate trends in recent years indicates steady warming at the global and world levels with clear repercussions on quality in the wine sector and beyond. Although the vine is highly adaptable to different environmental conditions, extremely high temperatures (over 35°C) in recent years or heat waves often associated with drought can affect vine physiology and yield. The increase in average temperatures in Romania (more than 1.5°C in the last thirty years, Ciornei et al., 2023) is unfavourable from an industrial point of view, and the wine sector is also being affected. This study aims to assess the current climate that characterizes sandy soil viticulture in Oltenia (Romania), the viticultural centre of Dăbuleni (Figure 1), using some climatic indicators relevant to viticulture (Martonne aridity index, Dantin-Ravenga index, other climatic indicators). They were calculated based on meteorological data recorded by RDSPCSS Dăbuleni in the period 2012-2023 and were interpreted by the information in the literature (Mărcăineanu et al., 2011; Patriche, 2009; Satmari, 2010). A series of statistical indices (arithmetic mean, amplitude, relative amplitude, standard deviation, coefficient of

deviance) were calculated and graphs were realized to highlight the trend of the studied climatic factors.

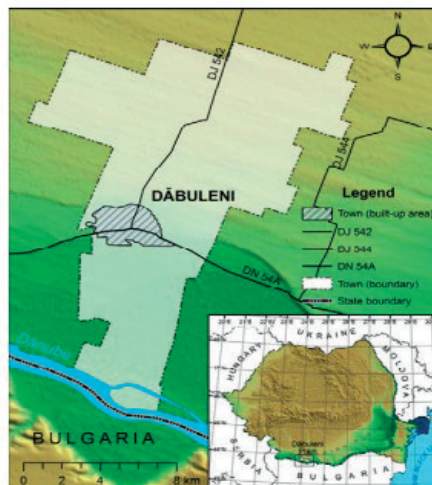


Figure 1. Location of the wine-growing center Dăbuleni (Achim et al., 2012)

The Excel program ensured fast and correct processing of meteorological data.

RESULTS AND DISCUSSIONS

Oltenia, a region located in the south-west of Romania, is important from an agricultural point of view due to the crops established (cereals, vines, vegetables), the climate evolution being defined for the quality of these crops (Mărcăineanu et al., 2021).

From a thermal point of view, the 2012-2023 period is characterized by a continuous upward trend in mean annual temperature. The maximum was recorded in 2020 with a value of 13.6°C, and the minimum in 2012 with a value of 11.6°C. The annual average calculated based on the 12 values indicates 12.7°C, which classifies the viticultural centre in the temperate type climate. A decreasing trend in the annual temperature amplitude values was observed (Figure 2). Basically, the difference between the annual maximum and minimum temperature has narrowed over the years of the study, due to warmer winter temperatures. Climatic observations also show a high number of tropical days ($t_{max} \geq 30^{\circ}\text{C}$), on average 79. In terms of mean temperature in July, values

are high, averaging 24.9°C, with extremes of 26.8°C (2012) and 23.1°C (2014), but dominant values fall between 25 and 26°C.

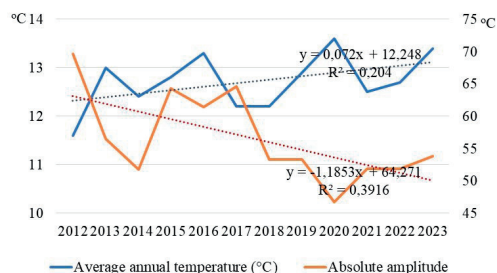


Figure 2. Annual mean temperature and amplitude evolution 2012-2023

Based on the excess heat factor and Antonescu et al. (2023) assess climate change for the near future 2021-2050, using the historical range 1971-2000 as a reference, the result of the study indicates that human exposure to heat waves will increase soon. The average temperature in July is a climatic indicator that orients the viticultural centre towards producing quality wines regarding carbohydrate accumulation. This is confirmed by interpreting the temperature and humidity values regarding the Seleaninov hydrothermal coefficient, the average for the period being 1. However, the quality of the wine must be proven by biochemical and organoleptic analysis, since excessive temperatures can negatively affect the quality indices of grape production and the wines. The evolution of another indicator, the overall heat balance, confirms the trend of increasing temperatures in this viticultural centre (Figure 3).

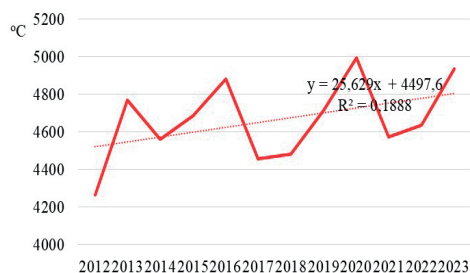


Figure 3. Heat Balance Evolution 2012-2023

A similar collection of information to that conducted in the study in relation to the extent

to which organizations use climate services, their perception of the benefits of using the services, the technical characteristics of the services and the future needs of stakeholders was conducted in Romania by Falcescu et al., 2024.

Existing Mediterranean viticultural areas have been found to respond to these climatic changes by redistributing vine-growing areas, probably as a result of a progressive shift towards the NNV from their original areas, concluding that increased warming and drought will most likely lead in the future to an eventual overall loss of viticultural suitability in the Mediterranean climate zones of southern Europe. In contrast, warming in central and northern Europe will potentially benefit vine growth (Droulia & Charalampopoulos, 2021).

Another limiting factor is soil. In terms of annual precipitation, it averages 649 l/m². From a climatic point of view, this value corresponds to the temperate climate, but there are exceptions, such as 2012 and 2013, when the recorded precipitation fell below 500 l/m² (dry climate). During the growing season, an average of 331.8 l/m² is distributed, but the trend is decreasing (Figure 4).

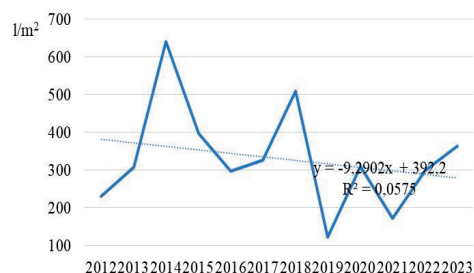


Figure 4. Annual Precipitation Evolution 2012-2023

As a result, the water supply to the vines is satisfied with a minimum of 250 l/m², but there are also situations when the precipitation volume falls below this critical value. Sometimes it reaches values below 150 l/m² (e.g. 2019 and 2021). Therefore, these sandy soils must monitor soil moisture status and supplement the water deficit.

The integration of the two important factors for the climatic characterization of a region resulted in Dăbuleni, the average of the 12 values of the Martonne aridity index, having a value of 28.6 (semi-humid climate). The

distribution of values indicates 2 years with a semi-arid climate, 5 years with a semi-humid climate and 5 years with a humid climate (Table 1). The climate characterization using the Dantin-Ravenga index confirms the name of Oltenia Sahara given to this area with sandy soil. Thus, 6 out of 12 years are semi-arid, 1 year is arid, and the rest have a humid climate.

Table 1. Evolution of climatic indicators in the wine-growing centre Dăbuleni

Martonne aridity index	Climate	Dantin-Ravenga index	Climate
17.8	semi-arid	3.02	Arid
19.6	semi-arid	2.88	semi-arid
44.4	humid	1.25	Humid
32.3	humid	1.74	Humid
30.8	humid	1.85	Humid
33.4	humid	1.64	Humid
41.6	humid	1.32	Humid
23.2	semi-humid	2.43	semi-arid
24.7	semi-humid	2.33	semi-arid
24.2	semi-humid	2.30	semi-arid
24.1	semi-humid	2.32	semi-arid
27.0	semi-humid	2.12	semi-arid
Average 28.6	semi-humid	Average 1.96	Humid

The mean value (1.96) is close to the value indicating a semi-arid climate. The values confirm the conclusion provided by the precipitation analysis regarding the danger of water deficit in sandy soil conditions. The climatogram for 2012-2023 shows a period of drought between summer and fall. Moderate drought during this period is useful from this point of view. This corresponds to the stage of grapes scorching and ripening (Figure 5). The statistical analysis of the main climatic parameters recorded in the Dăbuleni viticultural centre (Table 2) shows a more pronounced precipitation volume variation than the mean annual temperature. For this, the calculated coefficient of variation shows a homogeneous series with a small variation. The situation is different if we refer to the annual precipitation amount, whose variation coefficient indicates a highly variable parameter. The amount of precipitation during the growing season has the highest value of the coefficient of variation, the series is heterogeneous. And Fonseca et al. (2024) conclude that understanding the spatial

variability of microclimate is essential for sustainable and optimized grape production within vineyard plots. The impact on the wine sector of warmer climatic conditions, with a higher frequency of extreme temperatures and a decreasing trend in precipitation, in recent years has been assessed by Faralli et al, 2024. The viticultural sector of the viticultural centre of Dăbuleni, one of southern Oltenia's most profitable agricultural sectors, is significantly affected by the ongoing climate changes (excessive temperature); the sandy soil is also a limiting factor.

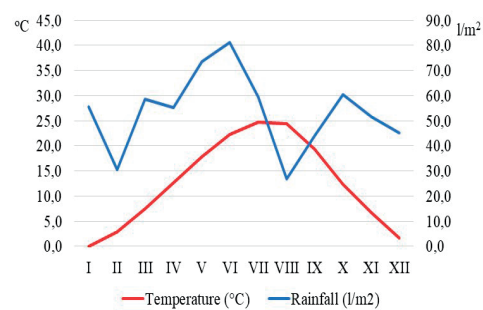


Figure 5. Dăbuleni Climatogram (2012-2023)

Table 2. Statistical results on the main climatic parameters recorded at Dăbuleni

Climate parameter / Statistical indicator	Annual average temperature (°C)	Annual precipitation (l/m²)	Precipitation during the growing season (l/m²)
Arithmetic average	12.7	649.0	331.8
Absolute amplitude	2.0	610.5	518
Relative amplitude (%)	15.7	94.1	156.1
Standard deviation	0.57	182.12	139.74
Coefficient of variation (%)	4.52	28.06	42.11

CONCLUSIONS

The ecological offer that characterizes the Dăbuleni viticultural centre has evolved in the last 12 years in the sense of increasing average annual temperature. Also, the higher temperatures in winter have steadily reduced the annual thermal amplitude and the amount of precipitation during the growing period of the vines has a decreasing trend. In this area, the limiting factors for vine-growing are water

scarcity, excessive temperatures and sandy, permeable soil with low fertility. Under these conditions, economically positive results can be obtained using a technology adapted to the existing ecological conditions.

ACKNOWLEDGEMENTS

To realise this work, we benefited from the support of the University of Craiova through the internal competition for awarding the results of scientific research, Research Gala.

REFERENCES

- Achim, E., Manea, G., Vijulie, I., Cocoș, O., & Laura, T. (2012). Ecological reconstruction of the plain areas prone to climate aridity through forest protection belts. Case study: Dăbuleni town, Oltenia Plain, Romania. *Procedia Environmental Sciences*, 14, 154-163.
- Alikadic, A., Pertot, I., Eccel, E., Dolcia, C., Zarbo, C., Caffarra, A., De Filippi, R., Furlanello, C. (2019). The impact of climate change on grapevine phenology and the influence of altitude: A regional study. *Agric. For. Meteorol.*, 271, 73–82.
- Amihăeșei, V. A., Micu, D. M., Cheval, S., Dumitrescu, A., Sfîcă, L., & Bîrsan, M. V. (2024). Changes in snow cover climatology and its elevation dependency over Romania (1961-2020). *Journal of Hydrology: Regional Studies*, 51, 101637.
- Andrade, C., Fonseca, A., Santos, J. A., Bois, B., & Jones, G. V. (2024). Historic changes and future projections in Köppen–Geiger Climate classifications in Major Wine regions Worldwide. *Climate*, 12(7), 94.
- Antonescu, B., Ene, D., Boldeanu, M., Andrei, S., Mărmureanu, L., Marin, C., & Pîrloagă, R. (2023). Future changes in heatwaves characteristics in Romania. *Theoretical and Applied Climatology*, 153(1), 525-538.
- Barbu N, Cuculeanu V, Stefan S (2016b). Investigation of the relationship between very warm days in Romania and large-scale atmospheric circulation using multiple linear regression approach. *Theor Appl Climatol*, 126(1-2): 273–284.
- Beillouin, D., Schauburger, B., Bastos, A., Ciais, P., & Makowski, D. (2020). Impact of extreme weather conditions on European crop production in 2018. *Philosophical Transactions of the Royal Society B*, 375(1810), 20190510.
- Cheval, S., Bulai, A., Croitoru, A. E., Dorondel, Ș., Micu, D., Mihăilă, D., ... & Țișcovschi, A. (2022). Climate change perception in Romania. *Theoretical and applied climatology*, 149(1), 253-272.
- Cichi, D.D., Căpruciu, R., Gheorghiu, N., & Stoica, F. (2023). Agrobiological and technological characteristics of table grapes varieties, grown in the temperate-continental climate from southwestern Romania. *Scientific Papers. Series B. Horticulture*, 67(1).
- Ciornei, L., Udrea, L., Munteanu, P., Simion, P. S., & Petcu, V. (2023). The Effects of Climate Change. Trends Regarding the Evolution of Temperature in Romania. *Annals of "Valahia" University of Târgoviște. Agriculture*, 15(2), 50-57.
- Căpruciu, R., Cichi, D. D., Mărăcineanu, L. C., & Stoica, F. (2023). Analysis of some biochemical compounds involved in adaptation mechanisms of vine to the minimum temperatures during the dormant season. *Scientific Papers. Series B. Horticulture*, 67(1).
- Cosmulescu, S., Baci, A., Cichi, M., & Gruia, M. (2010). The effect of climate changes on phenological phases in plum tree (*Prunus domestica* L.) in South-Western Romania. *South Western Journal of Horticulture, Biology and Environment*, 1(1), 9-20.
- Costea, D. C., & Căpruciu, R. (2022). The influence of environmental resources specific to the cultivation year over the grapevine growth and yield. *Annals of the University of Craiova-Agriculture Montanology Cadastre Series*, 52(1), 95-100.
- Deser, C., & Phillips, A. S. (2023). A range of outcomes: the combined effects of internal variability and anthropogenic forcing on regional climate trends over Europe. *Nonlinear Processes in Geophysics*, 30(1), 63-84.
- Dragotă CS, Dumitra cu M, Grigorescu I, Kucsicsa G. (2011). The Climatic Water Deficit in South Oltenia Using the Thornthwaite Method. *Forum geografic*; 10(1): 140-148.
- Droulia, F., & Charalampopoulos, I. (2021). Future climate change impacts on European viticulture: A review on recent scientific advances. *Atmosphere*, 12(4), 495.
- Dumitru, E. A., Berevoianu, R. L., Tudor, V. C., Teodorescu, F. R., Stoica, D., Giucă, A., ... & Sterie, C. M. (2023). Climate Change impacts on Vegetable crops: a systematic review. *Agriculture*, 13(10), 1891.
- El Garroussi, S., Di Giuseppe, F., Barnard, C., & Wetterhall, F. (2024). Europe faces up to tenfold increase in extreme fires in a warming climate. *npj Climate and Atmospheric Science*, 7(1), 30.
- Falcescu, V., Cheval, S., Micu, D. M., Dumitrescu, A., Roznoviețchi, I., Dumitrașcu, M., & Damian, N. (2024). Climate services in Romania - an analysis of stakeholders' perceptions and needs. *Climate Services*, 34, 100476.
- Faralli, M., Mallucci, S., Bignardi, A., Varner, M., & Bertamini, M. (2024). Four decades in the vineyard: the impact of climate change on grapevine phenology and wine quality in northern Italy. *OENO One*, 58(3).
- Fei, Y., Leigang, S., & Juanle, W. (2023). Monthly variation and correlation analysis of global temperature and wind resources under climate change. *Energy Conversion and Management*, 285, 116992.
- Fonseca, A., Cruz, J., Fraga, H., Andrade, C., Valente, J., Alves, F., Neto, A.C., Flores, R., Santos, J. A. (2024). Vineyard Microclimatic Zoning as a Tool to Promote Sustainable Viticulture under Climate Change. *Sustainability*, 16(8), 3477.

- Furtak, K., & Wolińska, A. (2023). The impact of extreme weather events as a consequence of climate change on the soil moisture and on the quality of the soil environment and agriculture - A review. *Catena*, 231, 107378.
- Jain, S., Scaife, A. A., Shepherd, T. G., Deser, C., Dunstone, N., Schmidt, G. A., ... & Turkington, T. (2023). Importance of internal variability for climate model assessment. *npj Climate and Atmospheric Science*, 6(1), 68.
- Jamal, M. U., Bilal, M., Durani, A., Waseem, M., & Jabarkhil, A. K. (2024). Effects of Climate Change on Horticulture Sector Productivity: A Review. *Nangarhar University International Journal of Biosciences*, 231-236.
- Keller, M. (2023). Climate Change Impacts on Vineyards in Warm and Dry Areas: Challenges and Opportunities: From the ASEV Climate Change Symposium Part 1-Viticulture. *American Journal of Enology and Viticulture*, 74(2).
- Larsen, M. A., Petrović, S., Radoszynski, A. M., McKenna, R., & Balyk, O. (2020). Climate change impacts on trends and extremes in future heating and cooling demands over Europe. *Energy and Buildings*, 226, 110397.
- Lesk C, Rowhani P, Ramankutty N. 2016 Influence of extreme weather disasters on global crop production. *Nature*, 529, 84-87.
- Martinez, A., Murphy, L., & Iglesias, G. (2023). Evolution of offshore wind resources in Northern Europe under climate change. *Energy*, 269, 126655.
- Mărăcineanu L.C. (2011). *Aplicații ale ecologiei în viticultură*. Ed. Universitaria Craiova.
- Mărăcineanu, C., Giugea, N., Mărăcineanu, E., & Căpruciu, R. (2021). Climate trends in Oltenia. Case study: Craiova-Banu Mărăcine, *Scientific Papers. Series B, Horticulture. Vol. LXV*, No. 1, 762-766
- Mekonnen, T. W., Gerrano, A. S., Mbuma, N. W., & Labuschagne, M. T. (2022). Breeding of vegetable cowpea for nutrition and climate resilience in Sub-Saharan Africa: progress, opportunities, and challenges. *Plants*, 11(12), 1583.
- Micu, D. M., Amihaesci, V. A., Milian, N., & Cheval, S. (2021). Recent changes in temperature and precipitation indices in the Southern Carpathians, Romania (1961-2018). *Theoretical and Applied Climatology*, 144(1), 691-710.
- Miller, J., Böhmisch, A., Ludwig, R., & Brunner, M. I. (2024). Climate change impacts on regional fire weather in heterogeneous landscapes of central Europe. *Natural Hazards and Earth System Sciences*, 24(2), 411-428.
- Milošević, N., & Milošević, T. (2023). Impact of climate change on plum (*Prunus domestica* L.). In *Cultivation for Climate Change Resilience, Volume 2* (pp. 257-278). CRC Press.
- Minca, I., & Chelariu, O. E. (2021). Anomalies and trends of high river flow under temperate climatic conditions in north-eastern Romania. *Journal of water and climate change*, 12(2), 552-565.
- Nasiri, V., Rahmanian, S., Aslani, Z. H., Maftai, C., & Vaseashta, A. (2024). Spatial Trend Analysis of Vegetation Dynamics and Their Responses to Climate Change on Black Sea Coasts, Romania From 2000 to 2021. In *Modeling and Monitoring Extreme Hydrometeorological Events* (pp. 162-184). IGI Global.
- Necula, C., Stefan, S., Birsan, M. V., Barbu, N., & Nita, I. A. (2024). Maximum winter temperature over Romania in connection to atmospheric circulation. *Theoretical and Applied Climatology*, 1-10.
- Oseni T and Masarirambi M. (2011) Effect of climate change on maize (*Zea mays*) production and food security in Swaziland. *Change*, 2: 3.
- Pardo, S. K., & Paredes-Fortuny, L. (2024). Uneven evolution of regional European summer heatwaves under climate change. *Weather and Climate Extremes*, 43, 100648.
- Patriche, C.V. (2009). *Metode statistice aplicate în climatologie*. Ed. Terra Nostra, Iași.
- Piticar, A., Andrei, S., & Tudor, A. (2024). Spatiotemporal Variability of Convective Events in Romania Based on METAR Data. *Sustainability*, 16(8), 3243.
- Popescu, A., Dinu, T. A., Stoian, E., & Șerban, V. (2023). Climate change and its impact on wheat, maize and sunflower yield in Romania in the period 2017-2021. *Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development*, 23(1).
- Prăvălie, R., Sirodoev, I., Nita, I. A., Patriche, C., Dumitrașcu, M., Roșca, B., ... & Birsan, M. V. (2022). NDVI-based ecological dynamics of forest vegetation and its relationship to climate change in Romania during 1987-2018. *Ecological Indicators*, 136, 108629.
- Prăvălie, R., Piticar, A., Roșca, B., Sfîcă, L., Bandoc, G., Tiscovschi, A., & Patriche, C. (2019). Spatio-temporal changes of the climatic water balance in Romania as a response to precipitation and reference evapotranspiration trends during 1961-2013. *Catena*, 172, 295-312.
- Rant, V. (2024). Regulating Sustainable Finance and the Green Transition in the EU. In *Handbook of Environmental and Green Finance: Toward a Sustainable Future* (pp. 359-405).
- Satmari A. (2010). *Lucrări practice de biogeografie*. Edit. Eurobit. Timișoara
- Shahmohamadi, P.; Che-Ani, A.I.; Maulud, K.N.A.; Tawil, N.M.; Abdullah, N.A.G. (2011). The Impact of Anthropogenic Heat on Formation of Urban Heat Island and Energy Consumption Balance. *Urban Stud. Res.*, 497524.
- Singh, B. K., Delgado-Baquerizo, M., Egidi, E., Guirado, E., Leach, J. E., Liu, H., & Trivedi, P. (2023). Climate change impacts on plant pathogens, food security and paths forward. *Nature Reviews Microbiology*, 21(10), 640-656.
- Soare, R., Dinu, M., Babeanu, C., Niculescu, M., Soare, M., & Botu, M. (2024). Quantitative and Qualitative Production of Species *Cucumis metuliferus* and the Potential for Adaptation in the Context of Current Climate Change. *Plants*, 13(13), 1854.
- Șmuleac, L., Rușescu, C., Șmuleac, A., Imbrea, F., Radulov, I., Manea, D., ... & Pașcalău, R. (2020).

- Impact of Climate Change in the Banat Plain, Western Romania, on the Accessibility of Water for Crop Production in Agriculture. *Agriculture*, 10(10), 437.
- Tigchelaar M, Battisti DS, Naylor RL, Ray DK. 2018 Future warming increases probability of globally synchronized maize production shocks. *Proc. Natl Acad. Sci. USA*, 115, 6644-6649
- Trebicki, P. (2020). Climate change and plant virus epidemiology. *Virus research*, 286, 198059.
- van Daalen, K. R., Tonne, C., Semenza, J. C., Rocklöv, J., Markandya, A., Dasandi, N. & Lowe, R. (2024). The 2024 Europe report of the Lancet Countdown on health and climate change: unprecedented warming demands unprecedented action. *The Lancet Public Health*.
- van den Bosch, M., Bartolomeu, M. L., Williams, S., Basnou, C., Hamilton, I., Nieuwenhuijsen, M., ... & Tonne, C. (2024). A scoping review of human health co-benefits of forest-based climate change mitigation in Europe. *Environment International*, 108593.
- Vitasse, Y., Ursenbacher, S., Klein, G., Bohnenstengel, T., Chittaro, Y., Delestrade, A., ... & Lenoir, J. (2021). Phenological and elevational shifts of plants, animals and fungi under climate change in the European Alps. *Biological Reviews*, 96(5), 1816-1835.
- Vlăduț, A., Nikolova N., Licurici M. (2017). Influence of climatic conditions on the territorial distribution of the main vegetation zones within Oltenia region, Romania. Muzeul Olteniei Craiova. Oltenia. *Studii și comunicări. Științele Naturii*, 33, 1, ISSN 1454-6914, 154-164.
- Zaharia, L., Ioana-Toroimac, G., & Perju, E. R. (2020). Hydrological impacts of climate changes in Romania. *Water Resources Management in Romania*, 309-351.