THE IMPACT OF CLIMATE CHANGE ON THE SUSTAINABILITY OF WINE PRODUCTION AND THE STRUCTURE OF WINE CONSUMPTION IN THE NORTHEAST REGION OF ROMANIA

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ABSTRACT. This study was carried out with the aim of investigating and analysing different aspects related to viticulture and wine production in the northeast region of Romania. The methodology focused on the use of statistical data and field research, with an emphasis on the impact of potential climate change on wine production and consumer preferences. The analysis of the evolution of vine cultivation in the northeast region of Romania was carried out using statistical data on grape harvest, area planted to vines and wine production. The results showed significant changes in these indicators over the period analysed (2013-2022), reflecting the dynamics of the wine industry in the region. A survey of a sample of 50 respondents provided relevant data on their preferences. Analysis of this data revealed information on preferred wine types, consumption habits and purchasing preferences. Although the population's preference for white wine is evident, climate change may pose a challenge for the region, and in the future, it may be necessary to adapt vineyard locations and cultivate vine varieties more suitable for red wine production. These issues have important implications for planning and developing the future of the wine industry in the northeast region.

Keywords: climate change; distribution; production; sustainability; wine.

INTRODUCTION

Climatic conditions are an essential element in the evolution and development

of vines, with direct control over the microclimate around the plants. These conditions influence the physiology and development of vines, affecting the quality and quantity of production. Although multiple atmospheric parameters can influence vine growth, such as solar radiation, wind and air humidity, two essential factors are temperature and water quantity (Ashenfelter, 2017).

Climate change poses a significant threat to the viability of vineyards, given that vines are a perennial crop with a productive lifespan of approximately 30–40 years (Rapcea and Nedealcov, 2014). Climate projections indicate significant long-term changes (Van Leeuwen *et al.*, 2019), and these changes can significantly affect the life cycle of vines. For example, they require both cold and warm periods to carry out their biological processes. Low temperatures are essential for plant hardening and fruiting, while high temperatures are important for fruiting (Marx *et al.*, 2017).

Traditional vine-growing areas, such as the northeast region of Romania, have a temperature range of 12–22ºC during the growing season (Ontel *et al.*, 2021). Daily values between 20 and 35ºC are optimal for vine development. The initiation of the growth cycle and the storage of carbohydrate reserves for the following year require low temperatures during winter. Adaptation to these specific climatic conditions is essential for obtaining quality and sustainable production in these wine-growing regions.

Drought is a constant and predictable concern, especially for vine growers in the northeast region of Romania. Although vines are relatively drought resistant compared to other crops, water shortages continue to affect vineyards. A significant increase in temperature can deteriorate the taste of the grapes (Ontel *et al.*, 2021). This problem becomes critical, as wine-growing regions face a constant increase in temperatures during the growing season and restrictions in the use of water for irrigation, limiting their ability to compensate for water shortages (Brabec *et al.*, 2020).

At present, the accelerating pace of climate change and the inability of agricultural sectors to adapt have led to the assessment of the specific impact of these changes on each branch, considering the specific climatic requirements of each crop. In the northeast region of Romania, significant changes over recent decades have affected agro-meteorological conditions, and research analysing the real impact of climate change on vineyards is limited. Neglect of cultivation technologies and land parcelisation have contributed to an unfavourable ecological situation, and the vine harvest has decreased considerably (Dumitrescu *et al.*, 2022).

Solutions to improve the efficiency of the wine sector may come from the promotion of wines with a geographical designation of origin, but this requires a current assessment of agro-climatic potential and the development of new methods for the efficient use of agro-climatic resources (Bentzen and Smith, 2018).

Romania's geographical location and topography offer favourable natural conditions for vine cultivation, which has led to the continuous development of viticulture, making it an important branch of agricultural production (Maruntelu, 2020). Romania stands out in the

European viticultural landscape, with approximately 180,000 hectares of land cultivated with vines. Only 28% of this area is found on the commercial market, while the rest of the land offers opportunities for new producers to enter the market. Wine-growing in Romania is concentrated in 8 major wine-growing regions, comprising a total of 37 vineyards and some 171 wine-growing centres. These regions are divided as follows:

1. Transylvanian Plateau (I) - with 5 vineyards.

2. Hills of Moldavia (II) - with 12 vineyards.

3. Hills of Muntenia and Oltenia (III) - with 8 vineyards.

4. Banat Hills (IV) - the exact number of vineyards is not specified.

5. Hills of Crişana and Maramureş (V) - with 4 vineyards.

6. Dobrogea Hills (VI) - with 3 vineyards.

7. Terraces Danube (VII) - with 2 vineyards.

8. The region of sands and other favourable soils in the south of the country (VIII) - with 3 vineyards.

Within the European Union, 5 wine-growing areas have been defined: A, B, C I, C II and C III (CR, 2008). This classification considers the wine-growing regions and the categories of wines, and each area has specific requirements regarding the minimum natural potential of grape varieties and the possibilities for must enrichment. From this point of view, the wine-growing regions of Romania have been defined as follows:

1. Zone B - this zone comprises the wine-growing region of the Transylvanian Plateau.

2. Zone C I - this zone comprises the regions of Hills of Moldavia, Hills of Banat, Hills of Crişana and Maramureş, and Hills of Muntenia and Oltenia, including the vineyards of Stefanesti-Arges, Samburesti, Dragasani and Hills of Craiova.

3. Zone C II - this zone comprises the regions of the Muntenia and Oltenia Hills, including the vineyards of the Buzaului, Dealu Mare, Severinului, Plaiurile Drancei and Dobrogea Hills, as well as the Danube Terraces, the sands and other favourable land in the south of the country (*Figure 1*).

This classification is important for the regulation and labelling of wines, ensuring that they meet the standards and quality required at the European level. The wine-growing region of northeast Romania comprises 5 wine-growing centres: Cotnari, Iaşi, Bohotin, Huşi and Iana (*Figure 2*).

The Cotnari wine region stretches between parallels 47º17' and 47º35' north latitude and is located in Iasi and Botoşani counties. This region is known for its production of quality wines and has important wine centres in Cotnari, Hârlău, Cucuteni and Frumuşica.

The Bohotin vineyard is located in the area of the Central Moldovan Plateau, known for its relatively uniform slopes with gentle slopes and altitudes that do not exceed 300 metres. The emblematic variety for this region, which develops its maximum quality potential, is Busuioaca de Bohotin. This variety is famous for its peculiarities, being unique in Romania for producing aromatic wines with shades of pink to red.

Romanian main wine sub-regions & key premium wine producers:
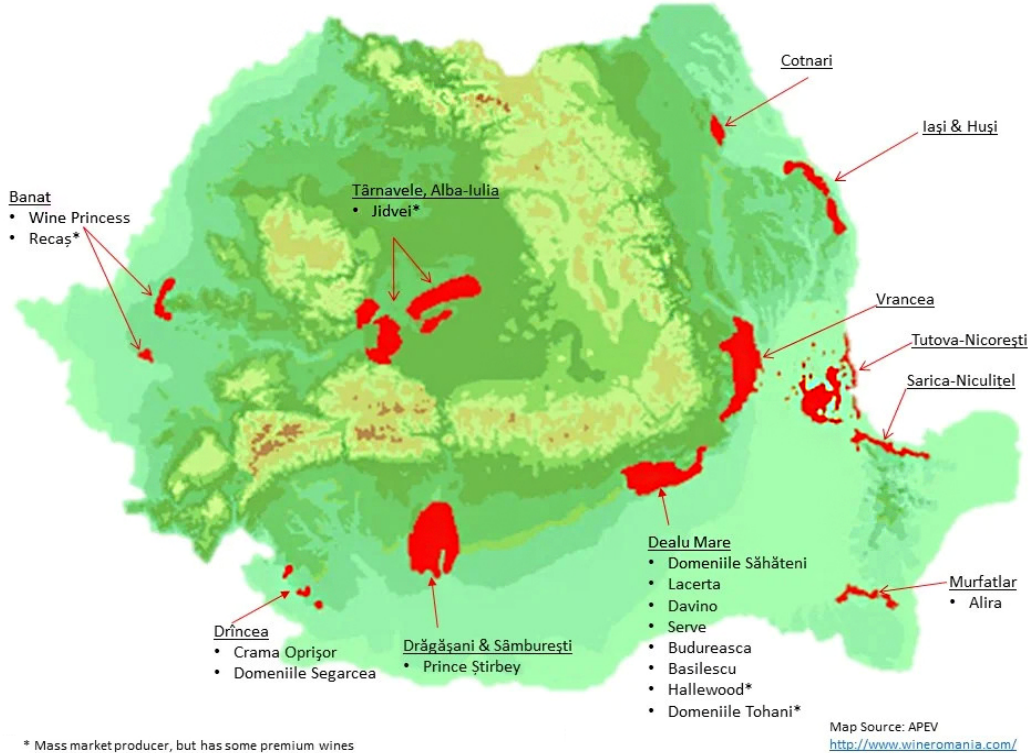
Figure 1 – Romanian main wine and sub-regions
Source: APEV
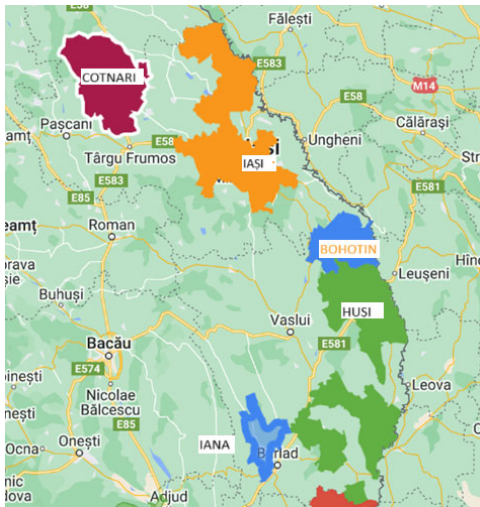
Figure 2 – Wine-growing regions
in the northeast region of Romania

The Huși vineyard has a history dating back to the reign of Ştefan cel Mare and is one of the oldest vineyards in the Moldavian Hills Region, located in the south-eastern part of the Central Moldavian Plateau, between the Crasnei Valley to the west and the Prutului Valley to the east, covering the administrative areas of Vaslui and Iaşi counties. The vineyards are located in hilly regions and on plateaus at altitudes ranging from 100 to 350 metres. Wine-growing centres in this vineyard include Huşi, Avereşti, Vutcani (Vaslui county) and Bohotin (Iaşi county). Known as an important wine-growing centre, the Iana area used to be part of the Tutova Hills Vineyard, a

designation and classification that is no longer used today. This vineyard is located in the south of the Moldavian Plateau, more precisely in the southeast of the Tutova Hills and in the northwest of the Covurlui Hills, separated by the valley of the Bârlad river.

The aim of this study was to assess the impact of climate change on the sustainability of wine production by highlighting the evolution of areas under vines from 2013 to 2021 with Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) status, grape production, the influence between vine area and grape production, and the structure of wine consumption in the northeast region of Romania.

This study was organised around three distinct research objectives, each addressing specific issues related to viticulture and wine production in the northeast region of Romania:

Objective O1: Analysis of the evolution of vine cultivation in the region. To achieve this objective, monitored quantities and time series of economic indicators specific to viticulture were examined. This analysis included aspects such as the area under vines, grape production, average yield per hectare, production costs and sales prices.

Objective O2: Analysis of consumer preferences for wine consumption in the region. To achieve this objective, a questionnaire was carried out on a sample of 50 respondents, which provided baseline data on consumer preferences, habits and behaviour regarding wine consumption in the northeast region of Romania.

Objective O3: Analyse the sustainability of potential climate change

in wine production in the region. This objective focused on the potential impact of climate change on viticulture and wine production. The Huglin Index, which models the future of viticulture by considering average and maximum daily temperatures, was used to assess this. In this way, an attempt was made to estimate how wine production in the northeast region of Romania could be affected by climate change.

By addressing these objectives, this study provides a comprehensive perspective on the evolution of viticulture in the northeast region of Romania, including economic aspects, consumer preferences and the potential impact of climate change on wine production. This interdisciplinary approach may provide valuable information for planning future strategies in the wine industry in this region.

The effects of climate change on wine production and consumption

Europe is the world's leading wine producer and has some of the most prestigious wine regions. These regions, particularly those in Italy, France and Spain, are considered the epicentres of global wine production (Ben Ameur *et al.*, 2022).

However, climate change has become an unavoidable reality in Europe, significantly influencing viticulture, and one of the most significant aspects of climate change is rising temperatures (Anderson and Witter, 2017). For example, in the Bordeaux region of France, the average annual temperature has increased by 2.1ºC in the past five decades, while in Veneto, Italy, there has been an increase in the average growing

season temperature by 2.3ºC from 2000 to present.

Addressing the influence of climate change on vineyards was highlighted by Candiago *et al.* (2022), who addressed ecosystem services for the study of viticultural landscapes in the context of climate change. Germanier and Moricciani (2023) explored the perceptions and adaptations of Tuscan vineyard owners to climate change. Rashidov *et al.* (2021) focused on assessing the long-term impact of a vine-training system on greenhouse gas (GHG) emissions in northern Tajikistan and examined how vine-growing practices can influence GHG emissions, thus providing essential information for understanding environmental impacts and identifying possible improvements.

Van Leeuwen *et al.* (2019) provided an update on the impact of climate change on viticulture and possible adaptations in their study addressing how climate change may affect grape quality and production, as well as potential adaptation methods to cope with these changes.

Germanier and Moricciani (2023) focused on climate change perception and adaptation from the perspective of wine-growing agritourism owners in Tuscany and explored how wine-growing agritourism owners in Tuscany perceived climate change and how they adapted to it. Navratilova *et al.* (2021) investigated the impact of climate change on the sugar content of grapes and the sustainability of their production in the Czech Republic, thus providing essential information on how climate change affects the quality and viability of the wine industry in this region. Other recent studies have highlighted factors such as quantifying and assessing trends and developments in research on climate change and viticulture (Marx *et al.*, 2017) and climate change's influence on grape quality and the sustainability outlook for wine production in the Czech Republic (Navratilova *et al.*, 2021). Deconinck and Swinnen (2019) focused on the analysis of applicable regulations in the wine industry and their impact on wine production and trade. Climatic conditions are a major factor in vine development and growth. They control the microclimate around the plants and influence vine physiology and development, as well as the quality and quantity of production. Nevertheless, while various atmospheric parameters can impact vine growth, including solar radiation, wind, and air humidity, two fundamental factors stand out: temperature and water availability (Ashenfelter, 2017).

Sustainable agriculture is a commitment to producing healthy and quality food while conserving natural resources and maintaining biodiversity (Navratilova *et al.*, 2021). According to Ashenfelter and Storchmann (2016), sustainability plays a crucial role in society, improving the quality of life in the long term and contributing to the harmonisation of economic growth, social development and environmental protection for the benefit of future generations. According to its principles, economic development should consider society and the environment not as obstacles but as incentives. According to Maruntelu (2020), sustainable development in agriculture involves careful programming of agricultural production to use natural resources and the environment reasonably, with the aim

of ensuring an adequate supply of food while maintaining high quality.

In the context of Romanian viticulture and grape production, it is essential to adopt sustainable agricultural practices. This involves the rational management of resources, such as water and soil, the efficient use of energy and the adoption of methods that reduce the impact on the environment. By pursuing sustainability in vine cultivation and grape production, both economic, social and ecological goals can be achieved.

Promoting sustainable agriculture not only meets current requirements but also prepares the ground for a sustainable future in harmony with the needs of the community, simultaneously protecting the environment and preserving biological diversity. It is essential that agricultural practices are directed towards a balance of present and future needs, ensuring a sustainable relationship between man and the environment.

MATERIALS AND METHODS

The methodology of this study mainly focused on the evaluation of statistical data related to viticulture and wine production in the northeast region of Romania, in parallel with an investigation of consumer preferences regarding wine consumption in this region. The data source used to create the time series of selected indicators related to viticulture and vineyards was obtained from Weather API (2023).

The climate data for 2013–2022 were obtained from https://www.map sdirections.info/ro/coordonate-gps.html and the GPS coordinates of localities were obtained from ONVPV (2023).

Protected Designations of Origin in Romania and their characteristics and general statistical data were obtained from the Romanian Ministry of Agriculture.

This study was based on the following research objectives.

O1 - Analysis of the evolution of vine cultivation in the northeast region of Romania

This objective focuses on the analysis of the evolution of the monitored quantities, as well as on the subsequent analysis of the time series of the specific indicators of economic performance in viticulture and wine production. These indicators included grape harvest, area under vines and wine production in the northeast region of Romania (Source: National Institute of Statistics). To describe the time series evolution of these key indicators related to viticulture and wine production in the northeast region of Romania, we used exponential smoothing methods. A model was created based on these data, and then this model was used to forecast the evaluated indicators (Angearu *et al.*, 2020; Candiago *et al.*, 2022; Navratilova *et al.*, 2021). The procedure assumed that the future value in the time series would be influenced by the previous one. However, the more recent value in time had a higher weight in the model (it is formally considered more important) than the older value (*Equations 1-2*).

$$\alpha_{Holt} = \alpha(2 - \alpha) \tag{1}$$

$$\gamma_{Holt} = \frac{\alpha}{2 - \alpha} \tag{2}$$

where α, γ, phi ∈ <0;1>.

The mean absolute percentage error (MAPE) played a crucial role in the final selection of model coefficients (α, γ, phi).

The choice of model was guided by the co-monthly rule, which states that a prediction model is considered very good when the MAPE is below 5% and is considered satisfactory when it is below 10%. MAPE was calculated as follows (*Equation 3*):

$$MAPE = (1/n) * \Sigma |(y_i - u_i) / y_i \qquad (3)$$

where n is the number of data points in the time series, y_i is the observed empirical value in the series, and u_i is the estimated or theoretical value in the series.

This evaluation metric, MAPE, was used to assess how well the model fit to the observed data and to determine whether it provided an accurate prediction. MAPE values below 5% were considered indicative of a highly accurate model, while values below 10% were considered acceptable for a satisfactory level of accuracy.

O2 - Analysis of consumer interests regarding wine consumption in the northeast region of Romania

To investigate the research hypothesis regarding consumer interest in wine consumption in the northeast region of Romania, we conducted a questionnaire survey on a sample of 50 respondents. Our method of sample selection was purposive, and the criteria used in recruiting subjects included age, gender and previous experience in wine consumption. To ensure that our sample accurately reflected the target population, we selected respondents from different demographic and social groups in the northeast region. We opted for this approach to obtain as detailed and representative a picture as possible of the preferences and behaviour of wine consumers in this region. Subjects were recruited through convenience methods, such as distributing questionnaires at local events, in markets and through social media. This allowed us to attract a variety of respondents from different backgrounds and to obtain a wider range of perspectives and opinions.

To assess dependencies between selected questions in the questionnaire, the χ^2 test of independence based on Pearson's chi-square statistic was used (*Equation 4*):

$$\chi^2 = \Sigma [(n_{ij} - n'_{ij})^2 / n'_{ij}] \qquad (4)$$

where n_{ij} is the observed empirical frequency, n'_{ij} is the expected theoretical frequency, i ranges from 1 to r, where r is the number of categories of variable A, and j ranges from 1 to s, where s is the number of categories of variable B.

The χ^2 value is distributed according to the χ^2 distribution with $[(r-1)(s-1)]$ degrees of freedom. To determine whether there was a dependence between variables, we compared the p-value (probability value) with the chosen significance level, α (here α = 0.05). If the p-value was less than α, then it was considered to be significantly dependent at significance level α.

To measure the strength of the relationship between variables A and B, Cramér's contingency coefficient V was calculated as follows (*Equation 5*):

$$V = \sqrt{[\chi^2 / (n * q)]} \qquad (5)$$

where n is the sample size, q is the minimum value between r and s, and the coefficient V varies between 0 and 1.

O3 - Analysis of the sustainability of potential climate change on wine production in the northeast region of Romania

The aim of this objective was to investigate whether, despite the

preference of the population in the northeast region of Romania for white wine, potential climate change indicates the need for a significant shift of vineyard locations towards the more southern regions of Romania and consequently towards the cultivation of vine varieties suitable for red wine production (Maruntelu, 2020; Ontel *et al.*, 2021; Rapcea and Nedealcov, 2014).

Modelling the future of viticulture relies on the main climate indicator called the Huglin index, which uses a region's average and maximum daily temperature during the growing season (early April to late September). The formula for calculating the Huglin Index (HI) for the northern hemisphere, based on k (the day length coefficient), was calculated as follows (Huglin, 1978) (*Equation 6*):

$$\text{HI} = \sum_{01/04}^{30/9} \frac{(TG_i - 10) + (TX_i - 10)}{2} k \qquad (6)$$

where TG_i is the mean daily temperature and TX_i is the maximum daily temperature.

RESULTS AND DISCUSSION

In the northeastern region of Romania, the climate in the Cotnari wine-growing area is temperate-continental, with influences from the Dealul Mare Hârlău Coast.

The climatic characteristics include moderate temperatures, lying in a transition zone between two distinct climate types: the continental eastern European climate of the Moldavian Plain and the moderate central European climate of the Suceava Plateau.

In the Huși wine-growing region, the climate is defined as temperate continental, with excessive nuances, lying at the intersection between the moderate continental climate of the central Moldavian Plateau and the excessive continental climate of the Moldavian Plain.

Figure 3 shows the evolution of mean annual temperatures in the wine-growing regions of northeast Romania.
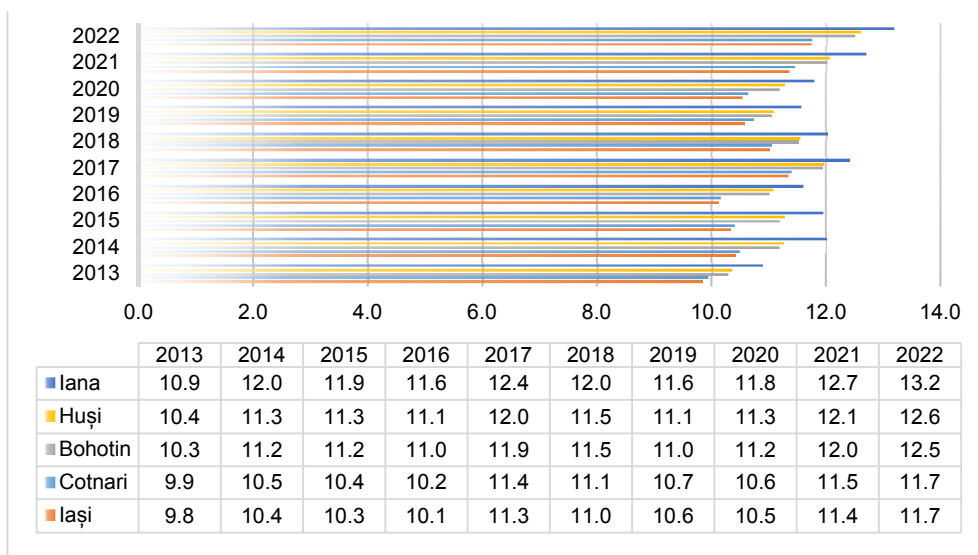

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Iana	10.9	12.0	11.9	11.6	12.4	12.0	11.6	11.8	12.7	13.2
Huși	10.4	11.3	11.3	11.1	12.0	11.5	11.1	11.3	12.1	12.6
Bohotin	10.3	11.2	11.2	11.0	11.9	11.5	11.0	11.2	12.0	12.5
Cotnari	9.9	10.5	10.4	10.2	11.4	11.1	10.7	10.6	11.5	11.7
Iași	9.8	10.4	10.3	10.1	11.3	11.0	10.6	10.5	11.4	11.7

Figure 3 – Evolution of mean annual temperatures (ºC)
in wine-growing regions of northeast Romania

In Cotnari, the mean annual temperatures ranged from 9.9ºC in 2013 to 11.7ºC in 2022, with minor fluctuations between these extremes. In Iasi, temperatures were generally similar to those in Cotnari, ranging from 9.8 to 11.7ºC over the same period.

The Bohotin region recorded slightly higher average annual temperatures than Cotnari and Iasi, ranging between 10.3 and 12.5ºC, while in Huși, temperatures were generally comparable to those in Bohotin, ranging between 10.4 and 12.6ºC. The highest evolution of annual average temperatures was recorded in the Iana region, with values between 10.9ºC in 2013 and 13.2ºC in 2022. This region seems to have had more pronounced increasing trends compared to the other regions of northeast Romania. Analysing these data,

all the wine-growing regions in northeast Romania experienced an increase in average annual temperatures during the period mentioned. This increase can have a significant impact on viticulture and wine production, influencing aspects such as the ripening period of the grapes, their chemical composition and, finally, the quality and quantity of the wines produced in these regions.

It is important for wine producers and researchers to consider these climate trends when planning and adapting agricultural and technological practices to effectively manage climate change and ensure the sustainability of the wine industry in northeast Romania.

Figure 4 shows the evolution of average annual rainfall (mm) recorded from 2013 to 2022 at the weather stations in Cotnari, Iași and Bacău.
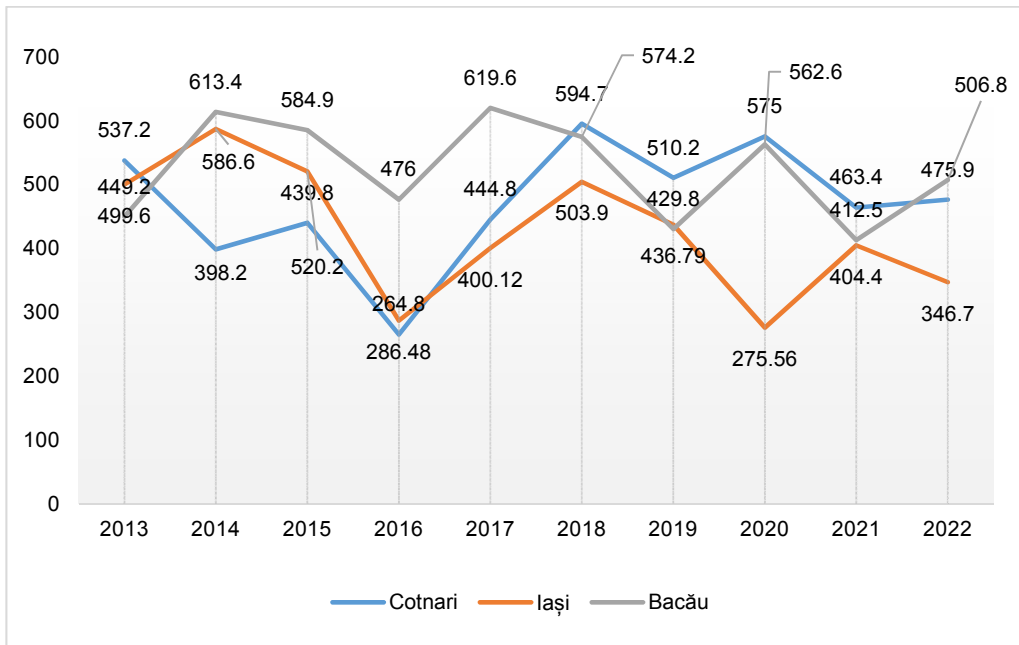
Figure 4 – Evolution of annual precipitation (mm)
recorded in the period 2013–2022 in the northeast region of Romania
Source: data processed from INS stations and annual reports of the institution

Annual rainfall is a key aspect of the regional climate and has a significant impact on the agricultural sector, particularly on viticulture and wine production, due to its role in the development of vine cultivation and in determining the yield and quality of the harvest.

In the Cotnari region, we observed a considerable variation in the amount of annual precipitation, with fluctuating values between 537.2 mm in 2013 and 475.9 mm in 2022. These variations can influence the development and quality of the grapevine crop each year. In Iasi and Cotnari, significant variations in annual rainfall were recorded, with values ranging from 275.56 mm in 2020 to 586.6 mm in 2014, and in Bacau, data also showed significant variations in annual rainfall, with values ranging from 412.5 mm in 2021 to 613.4 mm in 2014.

Analysing the evolution of annual rainfall in the northeast region of Romania in the mentioned period, a significant instability of this climatic factor was observed. This instability may have significant consequences on agricultural practices and water resources management strategies in the wine industry, highlighting the need for continuous adaptation to climate change and the implementation of risk management measures to ensure sustainable and quality viticulture and wine production in the northeast region of Romania.

Although the average temperature is predicted to increase by no more than 0.8ºC over the next 20 years, the change is more evident in terms of the sum of the average and maximum temperatures throughout the year (Ollat *et al*., 2016).

Equally significant were the annual variations in these temperatures and how large the extreme fluctuations were. In general, there was a continuing warming trend, leading to an increase in the value of the Huglin Index (*Figure 5*).

The economic performance of viticulture in the northeast region of Romania, represented by grape production and yield per hectare, did not show a significant development trend in the time series for 2013–2022. Moving averages were used to describe the trend for these indicators. Short-term forecasts are presented in *Figure 6* and *Figure 7*, showing the future development of the sustainable economic performance of viticulture and vine growing in the northeast region of Romania.

Thus, from 2013 to 2022, in the northeast region of Romania, many growers had to harvest earlier, especially the early varieties, due to the rise in temperatures and lack of rainfall. With an average yield of 4.9 tonnes per hectare, winegrowers harvested a total of 146.914 tonnes of grapes (*Figure 7*).

Winemakers agree that the 2013 harvest was marked by spring frosts, which irreparably destroyed most of the crops in certain areas of the northeast region of Romania. On average, vineyards in the northeast region of Romania recorded a loss of 22.10% of the harvest; however, the rest of the growing season was good for the vines, resulting in good quality harvested grapes, regardless of the varieties grown.

The average yield per hectare was about 5.7 tonnes in 2022, which was an increase of 3.7% compared to 2013, and the 10-year average yield per hectare is 5.3 tonnes.

Figure 5 – Evolution of the Huglin Index (ºC) in the
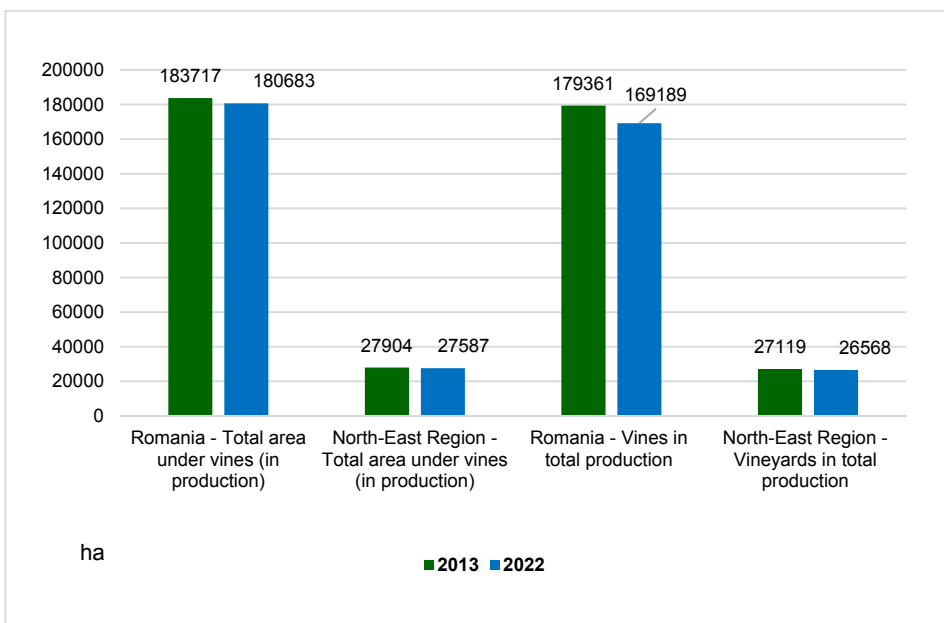wine-growing regions of northeast Romania from 2013 to 2022
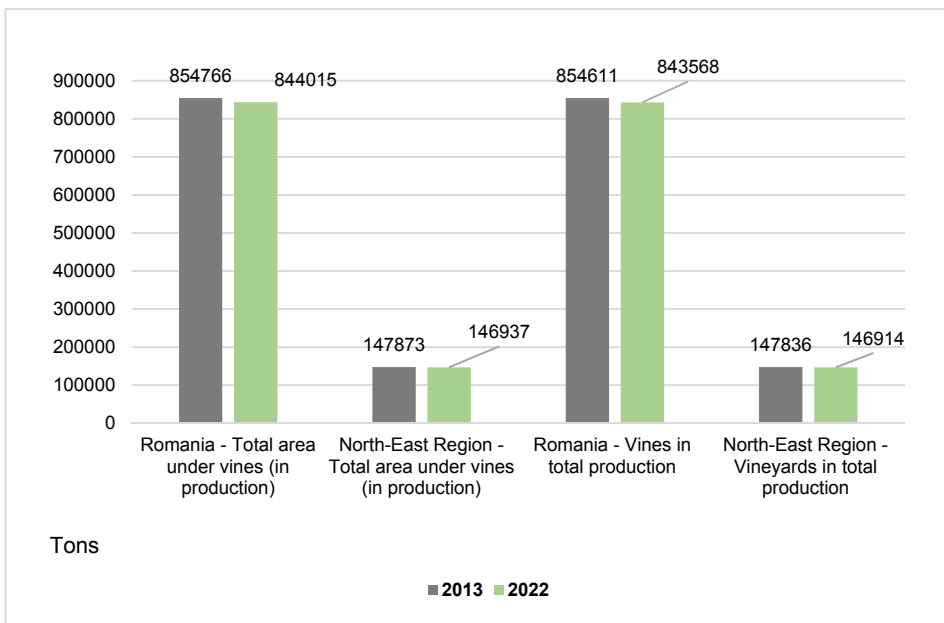
Figure 6 – Area under vines (ha)

Figure 7 – Grape production (tonnes)

The year 2019 brought an exceptionally good harvest for wines from the northeast region of Romania.

The unusual season, characterised by a very early harvest, gave the grapes different characteristics from normal

years, and the hot, dry summer increased the sugar content of the grapes, while acidity decreased, resulting in wines with characteristics similar to those of France or Spain.

The 2020 grape harvest in Romania's northeast region was up to 15.70% lower than the previous year, but the quality of the wine that year was above average. The extremely warm June and variable conditions in August contributed to the gradual growth and ripening of the grapes. Even the rains in August and September did not cause major damage and the grapes were in very good condition.

The prediction of the area planted in vines was made using the Holt exponential smoothing model, responding to European and national subsidies for the sector. The prediction model with parameters alpha = 0.7, gamma = 0.8 and phi = 0.6 provided the lowest MAPE values of 0.587%, thus indicating good accuracy in predicting the planted area. In recent years, domestic wine production in the northeast region of Romania has fluctuated. In 2013, production was around 878,000 hectolitres, which is 100,000 hectolitres less than the 2015 production of around 970,000 hectolitres. In 2016, domestic production increased significantly to 1,085,000 hectolitres, representing about one-third of Romania's annual wine consumption. In 2021, wine production in the northeast region of Romania was estimated to be similar to that of 2020, when it exceeded 1,000,000 hectolitres, representing the total production.

Wine consumption in the northeast region of Romania has developed interestingly over the decades, as the purchasing power of the population and economic growth have contributed to the growth of the wine market over the last 10 years. However, despite this growth, wine consumption per capita in the northeast of Romania remains below the European average (on average, wine consumption per capita in Europe is around 20–25 litres per year).

This phenomenon is leading the wine-growing regions in northeast Romania, especially the Cotnari wine-growing region, to gradually switch from vine varieties that are mainly adapted to the production of white wines to those suitable for red wines. Global warming is undoubtedly having an impact on Romania, as in the last 50 years, the average temperature in the northeast region of Romania has risen by about 2.3ºC. However, it is important to stress that climate change is not only changing average temperatures but also climate variability and weather extremes. Thus, despite the general trend towards higher temperatures, areas in Romania may still be affected by extremely low temperatures during winter, which could endanger cold-sensitive vine varieties. Therefore, winegrowers need to be aware of these risks and take appropriate measures to protect their crops from climatic extremes, including the use of frost protection technologies and the choice of more cold-resistant varieties for areas with harsher climatic conditions.

Drought is a frequently discussed and predicted problem, especially for farmers. Although vines are relatively more drought resistant than other crops, drought still has an impact on vineyards, and a significant increase in temperatures can negatively influence the taste of grapes (Germanier and Moricciani, 2023). This is an important issue, as

grape-growing regions are confronted with a constant increase in temperature during the growing season, as well as restrictions on the use of water for irrigation to compensate for water shortages.

Regarding the prediction of the wine-growing area within the northeast region of Romania, statistical data show that a slight increase in the wine-growing area is expected between 2024 and 2030, from 27,587 to 32,500 hectares, representing an increase of 17.80%, which indicates the sustainable development of viticulture in the coming years and suggests that there will be no significant loss of vine area during this period. Thus, despite climate changes, the wine industry in the northeast region of Romania seems to be adapting its practices to face the new conditions and to ensure the sustainable development of this sector in the future.

Table 1 analyses the relationship between vine area and grape production, highlighting the different statistical aspects and giving a comprehensive picture of the relationship between vine area and grape production, including the variability of the data and their average value. The expansion of the area planted with vines in the northeast region between 2013 and 2022 is a sign of the growth and development of the wine industry in the country. From 776 hectares in 2013, the total area planted with vines has increased significantly, reaching 1018 hectares in 2022.

This growth trend is reflected in the efforts of vine growers and the wine industry to expand production and meet the growing demand for quality wines. This growth may also be influenced by investments in modern viticulture and winemaking technologies as well as improvements in infrastructure. Additionally, the increase in planted area may be seen as a sign of adaptation to climate change or market requirements.

The production achieved increased slightly to 23 tonnes in 2022, but although the increase in grape production was modest, this may indicate good stability in grape production in this region, despite the increase in planted area.

In 2013, the standard deviation of the surface was 533.16 ha, and in 2022, the standard deviation increased to 703.57 ha. This increase in standard deviation indicates a greater variation in vineyard area in 2022, meaning a greater dispersion of plantings.

In 2013, the minimum area was 22 ha, and the maximum was 776 ha. In 2022, the minimum area was 23 ha, and the maximum was 1018 ha.

These values show the range of variation in planted area in the period under analysis and indicate that there were both small and large areas of vines in 2022. The increase in the range of variation suggests a larger variation between the areas planted to vines in the region in 2022. The coefficient of variation shows the percentage of variability in the data; it increased slightly in 2022, indicating more variation in the data for the area planted to vines.

The standard deviation of area and production increased in all three categories over the period analysed, indicating more variation in the area and production data.

Table 1 – The interaction between vine area and grape production

Indicator	Vines of 2 years after planting, in production - total		Vine of 2 years after planting in production - grapes for PDO wines		Vines of 2 years after planting in production - grapes for PGI wines		Vines of 2 years after planting in production - grapes for wines without PDO or PGI	
Period	2013	2022	2013	2022	2013	2022	2013	2022
Vine area (ha)	776	1018	726	872	48	132	1	14
Grape production (tons)	22	23	22	10	14	4	3	9
n	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Standard deviation	533.16	703.57	498.51	609.53	24.04	90.51	1.41	3.54
Mean standard deviation	377.00	497.50	352.50	431.00	17.00	64.00	1.00	2.50
Arithmetic mean	399.00	520.50	374.50	441.00	31.00	68.00	2.00	11.50
Min	22.00	23.00	22.00	10.00	14.00	4.00	1.00	9.00
Max	776.00	1018.00	727.00	872.00	48.00	132.00	3.00	14.00
The amplitude of the variation	754.00	995.00	705.00	862.00	34.00	128.00	2.00	5.00
V % = standard deviation*100/ arithmetic mean	133.62	135.17	133.11	138.21	77.55	133.10	70.71	30.74

Source: own calculations in SPSS software based on data provided by ONVPV (2023)

The mean standard deviation showed a significant increase in all three categories, indicating an increase in the variation in the data from the arithmetic mean.

The coefficient of variation (V%) increased, indicating an increase in variability in the data over time, with the largest increases observed in the PGI and non-PDO or non-PGI categories, suggesting greater variation in area and production data compared to the arithmetic mean. *Table 2* shows the influence of row spacing and plant spacing per row on wine production.

Statistical data on wine consumption in the northeast region of Romania revealed a number of significant aspects related to the evolution of this sector in recent years. Wine consumption in the region was relatively stable over the monitored period, fluctuating between 5.57 million hectolitres in 2019/2020 and 6.13 million hectolitres in 2021/2022. The difference between these two extremes was 560 thousand hectolitres, representing a relatively small change of only 10.15% compared to consumption in 2019/2020.

This relative stability of consumption indicates a sustainable development of wine production in the northeast region of Romania. It is important to stress that this stability does not mean stagnation but rather indicates a consolidation of the market and a balanced approach to wine supply and demand.

In terms of consumer preferences, the survey revealed a significant popularity of white wines in the northeast region of Romania.

Table 2 – Influence of row spacing × plant spacing per row

Indicator	Vine not yet in production - grapes for PDO wines		Vines not yet in production - grapes for PGI wines		Vines not yet in production - grapes for wines without PDO or PGI	
Distance between rows x distance between plants per row (cm)	2013	2022	2013	2022	2013	2022
140 x 70	63.2 (ha)	67.6 (ha)	65 (ha)	75.3 (ha)	77.5 (ha)	80.4 (ha)
160 x 30	73.8 (ha)	74 (ha)	81 (ha)	90.9 (ha)	88.6 (ha)	97.6 (ha)
135 x 25	63.4 (ha)	73.7 (ha)	68 (ha)	77.5 (ha)	83.3 (ha)	98.7 (ha)
n	**3.00**	**3.00**	**3.00**	**3.00**	**3.00**	**3.00**
Standard deviation	6.06	3.61	8.50	8.44	5.55	10.26
Mean standard deviation	3.50	2.09	4.91	4.87	3.21	5.93
Arithmetic mean	66.80	71.77	71.33	81.23	83.13	92.23
Min	63.20	67.60	65.00	75.30	77.50	80.40
Max	73.80	74.00	81.00	90.90	88.60	98.70
The amplitude of the variation	10.60	6.40	16.00	15.60	11.10	18.30
V % = standard deviation*100/ arithmetic mean	9.08	5.03	11.92	10.39	6.68	11.13

Source: own calculations in SPSS software based on data provided by ONVPV (2023)

This preference was observed among all age groups but was more pronounced among young people aged 18–25. However, it is important to note that young people under 34 also consumed a significant proportion of the total wine consumed in the region.

These findings suggest that the wine sector in the northeast region of Romania enjoys relative stability and a degree of adaptation to consumer preferences. Stable wine consumption, together with the popularity of white wines, indicates a relatively strong market and may provide a favourable outlook for producers and traders in the local wine industry.

The validity of the hypothesis on the sustainable development of viticulture and wine production in the northeast region of Romania was confirmed based on the data analysis and findings presented above. This validation is based on concrete facts and trends, providing a solid basis for future assessment and planning of the wine sector in the region.

The evolution of wine consumption in the northeast region of Romania provides an interesting insight into changes and trends in the wine sector over the last decades. In the 2000s, wine consumption per capita in the region was only 4.8 litres, reflecting a modest level of wine consumption. However, in the subsequent period, this consumption increased significantly, reaching around 6.2 litres per capita. This trend indicates a change in the preferences and

consumption habits of the region's population.

According to data from the 2020/2021 wine year, total wine consumption in the northeast region of Romania was 4.135 thousand hectolitres, which is a significant figure and reveals the importance of the wine industry in this region. Moreover, wine consumption per capita reached 27.2 litres per person per year in 2020, reflecting an impressive increase of 35.71% compared to the 2013 level. This significant increase may be the result of an increase in living standards, changes in consumer preferences, and the promotion of wine as part of culture and lifestyle.

However, despite the increase in wine consumption in the region, there are still considerable opportunities for local wine producers. Many consumers in the region prefer wines produced in the country, indicating an interest in and support for local production. Thus, the wine market in the northeast region of Romania is constantly evolving and presents opportunities for local producers to increase their market share and strengthen their position vis-à-vis international competition.

To better understand consumer preferences and behaviour in the region, a survey was conducted in autumn 2023. It investigated consumer interest in wine and involved 50 respondents aged 18 and over from the northeast region of Romania. The survey, conducted online and focused on direct response questions, shed light on the preferences and consumption habits of the local population in terms of preferred types of wine and their popularity in the region. This information is valuable for local wine producers in developing marketing strategies and meeting the needs and preferences of consumers in the northeast region of Romania. The survey targeted both the age of the respondents and their preferences by age (*Figure 8*).
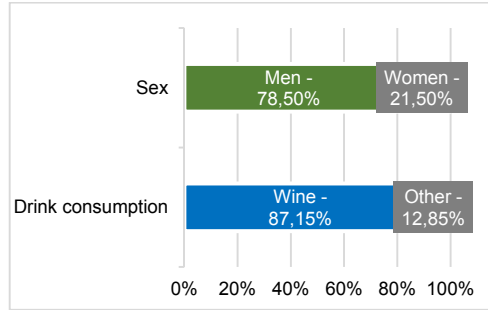
Figure 8 – Survey results on wine consumption and gender of respondents

The results of the survey carried out in the autumn of 2023 in the northeast region of Romania revealed significant aspects related to the preferences and consumption habits of wine consumers in the area. According to these results, the majority of wine consumers were men, representing 78.50% of the total respondents who consumed wine. This reflects the trends and consumption habits among the population, as well as cultural and social influences in terms of alcoholic beverage consumption.

Age was an important factor in determining preferences for the type of wine, with the 26–39 age group showing a preference for quality and premium wines. In terms of the price of wine, the research revealed that this is not a major factor in the purchasing process, with the majority of consumers buying wines in the price range of 25 to 45 lei per litre. This indicates that despite a preference for quality wines, consumers are willing to pay a reasonable price for desired products.

The research carried out shows that consumer preferences for wine are influenced by age, gender and global trends in the wine industry. Romania is experiencing a shift in consumer preferences with an increasing interest in quality and drier wines. This data is valuable for wine producers in the northeast region of Romania, giving them the opportunity to better understand market needs and preferences and to develop and promote their products in line with these trends.

CONCLUSIONS

The results of the analysis suggest that the sustainable development of viticulture and vine-growing in the northeast region of Romania depends both on the preferences of wine consumers and the impact of climate change. Changing consumer preferences, especially towards red vines, have had a significant impact on the development of the sector, and climate change has also played an important role in this equation, influencing the composition of vineyards in favour of red vine varieties.

Despite the forecast that the average temperature will not increase significantly over the next 20 years, changes are evident in the sum of the average and maximum temperatures throughout the year. This evolution indicates a continuous warming trend, reflected in the increase in the value of the Huglin Index in the wine-growing regions of northeast Romania.

The impact of climate change is causing wine-growing regions, especially Cotnari, to switch from varieties adapted to the production of white wines to those suitable for red wines. The increase in average temperatures by about 2.3ºC in the last 50 years highlights the significant changes in the climate. The years 2019 and 2020 brought challenges and notable changes in the harvest and quality of wine, underscoring the need for continuous adaptation by winegrowers. From 2013 to 2022, meteorological fluctuations influenced the production of grapes, and adaptation to climate change remains a priority for ensuring the viability of the wine industry in the northeast region of Romania.

Wine production in the northeast region of Romania has experienced significant variations in recent years, highlighting the dynamics of the industry and consumer preferences. From the level of 878.000 hectolitres in 2013, production increased to over 970,000 hectolitres in 2015, reaching a notable peak of 1,085,000 hectolitres in 2016 and representing approximately one-third of Romania's annual wine consumption. In 2020 and 2021, wine production in the region was estimated at over 1,000,000 hectolitres, indicating the stability of the sector despite fluctuating challenges. This figure includes both locally produced wines and imports.

Although economic growth and purchasing power have contributed to the expansion of the wine market over the past 10 years, per capita wine consumption in the region remains below the European average. However, the data showed a significant increase from 4.8 litres per capita in the 2000s to 27.2 litres in 2020, reflecting development opportunities for local producers given the increased consumer preference for domestic wines.

The 2023 survey highlights a significant share of wine consumers in the northeast region, with a predominance of men (78.50%). The prevalence of white and red wine, especially among women, and the increased interest in quality wines among younger age groups indicate fertile ground for the growth of the local wine industry.

Finally, this research provides a solid basis for decision-making on the future of viticulture in the northeast region of Romania and for the development of sustainable strategies that consider consumer preferences and the impact of climate change on the sector.

The limitations of the research provide a clear perspective on what the study does not cover, highlighting issues that can be explored in the future or add depth to the research. This study focused mainly on the northeast region of Romania and did not make direct comparisons with other wine-growing regions or countries with similar conditions.

Further extension of the research to an inter-national level could provide a more comprehensive picture of the impact of climate change on viticulture; comparisons with other wine-growing countries with similar land and conditions could provide broader and more comprehensive insights into trends and issues.

Although this study focused on consumer preferences in terms of wine types (red, white), a more detailed analysis of consumer preferences could provide a more complete picture of how climate change may influence consumer choices. Although the impact of climate change is mentioned, this study does not provide an in-depth analysis of how climate change has influenced vineyards, wine production or consumer preferences.

The study is largely based on qualitative observations and conclusions based on theoretical analysis, and future studies and statistical analysis could strengthen the research arguments.

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Academic Editor: Dr. Mihaela Rosca