

Dynamics of the Global Wine Sector in the 2015–2024 Period: Comparative Analysis of Vineyard Area, Table Grape Production and Wine Production

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Abstract. The global wine sector represents one of the most dynamic segments of global agriculture, characterized by a complex interdependence between natural resources, agroclimatic conditions, economic structures and international demand. In the last decade, developments in this sector have been significantly influenced by climate variability, changes in consumer preferences, and reorganization processes in agri-food chains. According to the International Organization of Vine and Wine (OIV), global grape and wine production has experienced significant fluctuations in recent times, while the table grape segment has experienced sustained expansion, especially in Asia. This study comparatively analyzed the dynamics of the global wine sector during the period 2015–2024, using three fundamental indicators: vine area (VA), table grape production (TGP) and wine production (WP). The analysis was conducted for the main producing countries, including the aggregates "Other Countries" and "World", based on a harmonized statistical database. The objectives of the research were: highlighting the evolution over time of the three indicators, identifying changes in the hierarchy of countries, determining growth rates and analyzing statistical relationships between the components of the wine system. The methodology used combined time series analysis (fixed-base and chain-linked dynamic indices, average annual growth rates), comparative and hierarchical analysis, as well as statistical methods for investigating relationships between variables, including Pearson and Spearman correlation coefficients. The results were supported by graphical representations and correlation matrices, which allowed highlighting structural trends and the degree of interdependence between the vineyard area and the level of production. The results of the study highlighted the existence of significant differences between the dynamics of vineyard area and production, suggesting an intensification of resource use in certain regions, as well as a functional specialization between countries oriented towards wine production and those oriented towards table grapes. The correlation analysis indicated different relationships between variables, reflecting the diversity of development models of the global wine sector. The study contributes to the understanding of recent transformations in global viticulture and provides an analytical basis for agricultural policies and development strategies in the field.

Keywords: indicators, table grapes, trend dynamics, vineyards, wine, wine industry

INTRODUCTION

The wine sector represents one of the most complex and globalized subsystems of agriculture, characterized by multiple interactions between natural resources, technological processes and market mechanisms. Grapevines are cultivated on all continents, and the resulting products – especially wine and grapes for fresh consumption – are of major importance from both an economic and cultural perspective. According to data provided by the International Organization of Vine and Wine, the world's wine-growing area is around seven million hectares, while global production reflects significant variability depending on climatic conditions and production structure (OIV, 2024; OIV, 2025a; OIV, 2025b).

The analysis of the wine sector requires an integrated approach, which simultaneously includes the resource dimension (vineyard area), the primary production dimension (grapes) and the processing dimension (wine). The specialized literature emphasizes that the relationship between these components is not linear, being influenced by economic, technological and agroecological factors (Anderson and Nelgen, 2020; Pomarici and Sardone, 2020). In this context, the evolution of the wine sector reflects both global trends and regional particularities related to specialization and competitiveness.

One of the most studied factors influencing the wine sector is climate change. Research shows that variations in temperature, precipitation and solar radiation directly affect grapevine phenology, yields and production quality (Jones et al., 2005; Fraga et al., 2017; Santos et al., 2020). Increasing average temperatures accelerate grape ripening and alter the sugar-acidity balance, impacting the wine's characteristics (van Leeuwen and Darriet, 2016). At the same time, the intensification of extreme phenomena – such as droughts or late frosts – leads to increased production volatility, affecting the economic stability of the sector (Mozell & Thach, 2014; Schultz, 2016). Viticultural technologies have been studied and sequentially adjusted in order to adapt to new climatic conditions, soil conditions and genotypes, for the sustainability of vineyards and winegrowers (Dobrei et al., 2009, 2015).

In the long term, climate change may lead to a geographical redistribution of viticulture. Studies

conducted globally highlight that traditional production areas, especially those in the Mediterranean regions, may become less favorable, while regions located at higher latitudes or higher altitudes may become more suitable for vine cultivation (Hannah et al., 2013; Santillán et al., 2019; Webb et al., 2007). These transformations have direct implications on the hierarchy of producing countries and the structure of the world wine market.

In parallel with the influence of climatic factors, the wine sector is shaped by economic and commercial transformations. The globalization of markets has led to an intensification of international exchanges and an increase in competition between producers (Anderson and Nelgen, 2020). At the same time, agricultural policies, especially in the European Union, have influenced the structure of production and the allocation of resources, contributing to the modernization of the sector and increasing efficiency (Pomarici and Sardone, 2020).

An important phenomenon in recent decades is the growth of the table grape segment. Unlike wine, which is a processed product, fresh grapes are integrated into fast logistics chains and dependent on urban demand. The FAO–OIV report highlights that this segment has experienced significant expansion, particularly in emerging economies, where rising incomes and urbanization have boosted fresh fruit consumption (FAO–OIV, 2016; FAO, 2024).

At the same time, the wine sector is facing structural challenges, including declining consumption in some traditional markets and increasing production variability. Studies show that this variability is driven by both climatic factors and changes in consumer preferences and market structure (Ashenfelter and Storchmann, 2016). These developments highlight the need for a comparative analysis between the different uses of wine production.

Another relevant factor is technological progress. The development of precision agriculture, the use of sensors, remote sensing and artificial intelligence contribute to optimizing the use of resources and increasing production efficiency (Matese and Di Gennaro, 2015; Sidorkiewicz et al., 2025). These technologies allow for real-time monitoring of environmental conditions and adaptation of agricultural practices to climate variability, contributing to increasing the resilience of the sector.

The concept of "terroir" remains central to the analysis of viticulture, reflecting the complex interaction between natural conditions and agricultural practices. Climatic classifications of wine-growing regions highlight the fact that world production is concentrated in certain geographical areas, characterized by specific agroclimatic conditions (Tonietto and Carbonneau, 2004; Mariani et al., 2012). Changes in these conditions can affect both the quantity and quality of production, generating changes in the market positioning of different regions.

There are numerous studies in the literature dedicated to the impact of climate change on viticulture, technological adaptation and wine market evolution. However, there is relatively little research that simultaneously analyzes, on a global scale and over a recent period, the relationship between vineyard area, table grape production and wine production. Most studies focus on one of these dimensions or on specific regions, without integrating these variables into a global comparative framework (Resco et al., 2016; Balogh, 2025).

Therefore, a gap in the literature regarding the integrated analysis of these three fundamental components of the wine sector was identified. The present study aimed to contribute to covering this gap by using a harmonized database for the period 2015–2024 and by applying comparative and correlational statistical methods. The main objective of the research is to analyze the dynamics of the world wine sector through the lens of the three fundamental indicators: vineyard area, table grape production and wine production. The specific objectives include: (i) assessing the evolution over time of these indicators at global and national levels; (ii) identifying changes in the hierarchy of producing countries; (iii) determining the degree of concentration and stability of leaders; and (iv) analyzing the statistical relationships between the variables studied.

Through its integrated approach, the study offers a comprehensive perspective on the recent transformations of the global wine sector and contributes to understanding the mechanisms underlying its evolution in the context of multiple pressures - climatic, economic and technological.

MATERIAL AND METHODS

Database and information resources

The analysis was based on a statistical database (OIV, 2025), built on the basis of annual series for the period 2015–2024, structured into three main components of the global wine sector: vineyard area – VA (kha: thousands of hectares), table grape production – TGP (mt: millions of tonnes), wine production – WP (mhl: millions of hectolitres).

Data processing and cleaning

In the preprocessing stage, the following operations were performed: checking the consistency of the time series; standardizing the units of measurement; treating missing values (if applicable). The data were structured separately for each of the three categories, allowing for both individual and comparative analyses.

Dynamics analysis indicators

Various statistical indices were used to evaluate the evolution of the indicators over time.

Absolute change (ΔX), Equation (1)

$$\Delta X = X_{2024} - X_{2015} \quad (1)$$

where: ΔX – absolute change; X – considered component (VA, TGP, WP)

This formula is used in time series analysis to evaluate absolute variation (Gujarati and Porter, 2009).

Relative change (%), Equation (2)

$$R = \frac{X_{2024} - X_{2015}}{X_{2015}} \times 100 \quad (2)$$

where: R – relative change; X – considered component (VA, TGP, WP)

Indicator is used to measure relative variation in economic analysis (Bluman, 2018)

Fixed base index (I_t), Equation (3)

$$I_t = \frac{X_t}{X_{2015}} \times 100 \quad (3)$$

where: I_t – fixed-base index; t – reference time (year; 2015 = 100); X – considered component (VA, TGP, WP)

Fixed-base indices are standard in analyzing the dynamics of economic phenomena (Maddala & Lahiri, 2009).

Chain index ($I_{t/t-1}$), Equation (4)

$$I_{t/t-1} = \frac{X_t}{X_{t-1}} \times 100 \quad (4)$$

where: $I_{t/t-1}$ – Chain index; t – reference time (year); X – considered component (VA, TGP, WP)

Chain indices are used to analyze successive variations in time series (Stock and Watson, 2020).

Average annual growth rate (r), Equation (5)

$$r = \left(\frac{X_{2024}}{X_{2015}} \right)^{\frac{1}{n}} - 1 \quad (5)$$

where: r – average growth rate; X – considered component (VA, TGP, WP); $n = 9$ years

This formula is known as the geometric mean growth rate (Wooldridge, 2016).

Variation and stability indicators

To analyze the stability of areas and production, the standard deviation and the coefficient of variation were used as statistical indicators.

Standard deviation (σ), Equation (6)

$$\sigma = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n}} \quad (6)$$

where: X – considered component (VA, TGP, WP)

Standard deviation is a fundamental indicator of dispersion (Montgomery and Runger, 2014).

Coefficient of variation (CV), Equation (7)

The coefficient of variation allows comparison of relative variability (Everitt and Skrondal, 2010).

$$CV = \frac{\sigma}{\bar{X}} \times 100 \quad (7)$$

where: X – considered component (VA, TGP, WP)

This indicator allows for the comparison of the degree of volatility between countries and between the three components of the wine sector.

Hierarchical analysis of countries

To highlight the relative position of the states, the following were carried out: (a) annual rankings (2015 and 2024); (b) average rankings for the entire period; analysis of the change in position in the hierarchy; (c) identification of: stable leaders, emerging countries, declining countries.

A separate analysis was conducted for the "Other Countries" and "World" aggregates, which were used as a global reference.

Correlation analysis

To investigate the relationships between variables, two types of coefficients were used (Pearson, and Spearman).

The Pearson correlation coefficient, Equation (8), measures the intensity and direction of the linear relationship between variables. The Pearson coefficient measures the linear relationship between variables (Rodgers and Nicewander, 1988).

$$r = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2 \sum (Y_i - \bar{Y})^2}} \quad (8)$$

The Spearman correlation coefficient, Equation (9), is useful for monotonic relationships, data with non-normal distributions, validating the robustness of the results. Spearman's coefficient is used for monotonic relationships and ordinal data (Conover, 1999).

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \quad (9)$$

Comparative analysis between the three components

In order to highlight the structural differences between vineyard area (VA), table grape production (TGP), wine production (WP), the following were carried out: comparisons of growth rates; analysis of disproportions between resources and production; identification of the functional specialization of countries.

Graphic and visual representations

To interpret the results, the following were used: line graphs (temporal trends); bar graphs (hierarchies); heatmaps (variations and correlations); scatter plots (relationships between variables); correlation matrices; ranking/slope chart graphs.

Analysis tools

Data processing was performed using: Microsoft Excel (primary processing); statistical tools (Python/R – optional for correlations and advanced visualization), PAST software v.4.14 (Hammer et al., 2001).

RESULTS AND DISCUSSIONS

Global dynamics of the wine sector (2015–2024)

The comparative analysis of the main indicators of the global wine sector highlighted a divergent evolution in the period 2015–2024, characterized by different dynamics of the vineyard area (VA), table grape production (TGP) and wine production (WP).

The evolution of the global vineyard area is illustrated in Figure 1, where a moderate downward trend was observed, from approximately 7446 thousand ha in 2015 to 7066 thousand ha in 2024, corresponding to a reduction of approximately 5.1%.

Figure 1 highlighted a moderate but persistent downward trend in the world's vineyard area. The decline was not abrupt, indicating that it was not the result of a singular shock, but of a cumulative process, distributed over time, over the study period. This evolution suggested: processes of structural restructuring of the sector, conversion of land to other agricultural or non-agricultural uses, policies of area reduction in certain regions (especially in the EU). The reduced amplitude of annual variations confirmed that the vineyard area is a rigid variable, with high inertia.

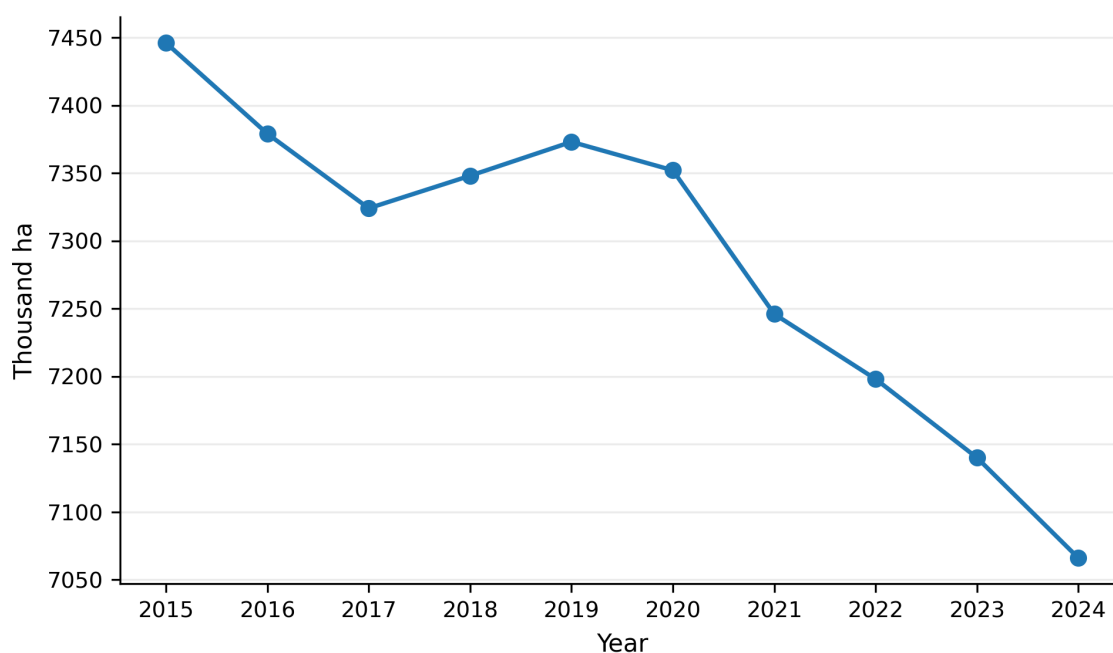


Figure 1. Global vineyard area trend (2015–2024)

In contrast, world table grape production showed a clear upward trend (Figure 2), increasing from approximately 28.1 million tonnes to 33.3 million tonnes (+18.5%).

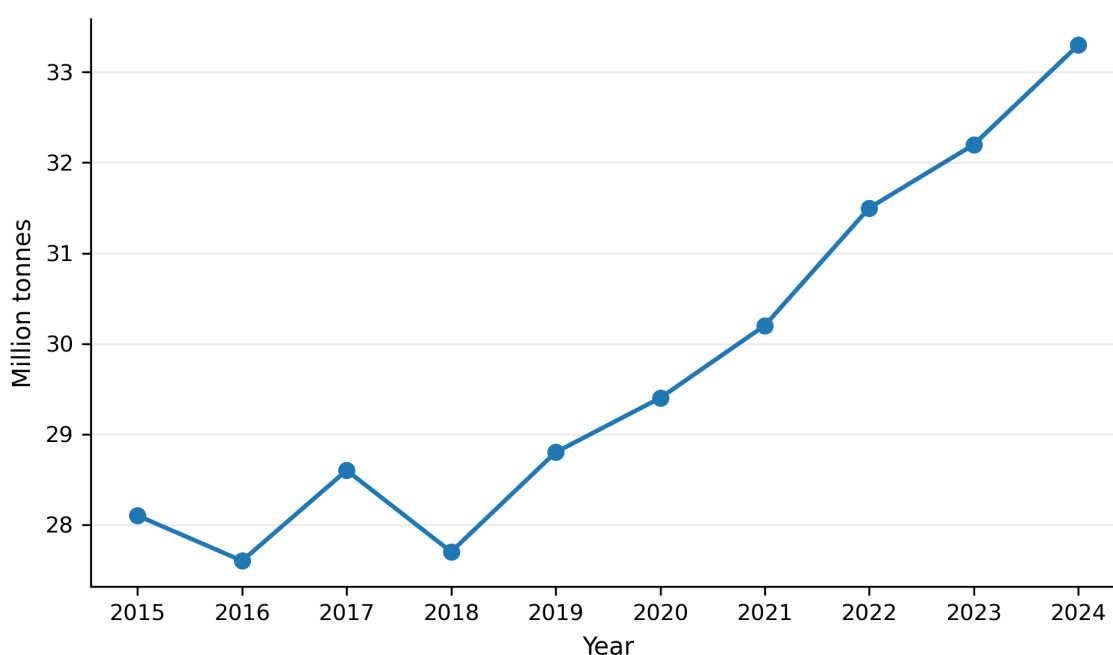


Figure 2. Global table grape production trend (2015–2024)

Figure 2 showed a clear and sustained growth in table grape production, without major episodes of contraction. This trend indicated: increasing global demand for fresh produce, expansion of emerging markets, intensification of production (not necessarily increase in area). The table grape production segment is expansive and market-oriented, unlike wine.

At the same time, wine production recorded a significant decrease (Figure 3), from approximately 278.3

million hl to 225.6 million hl (-18.9%).

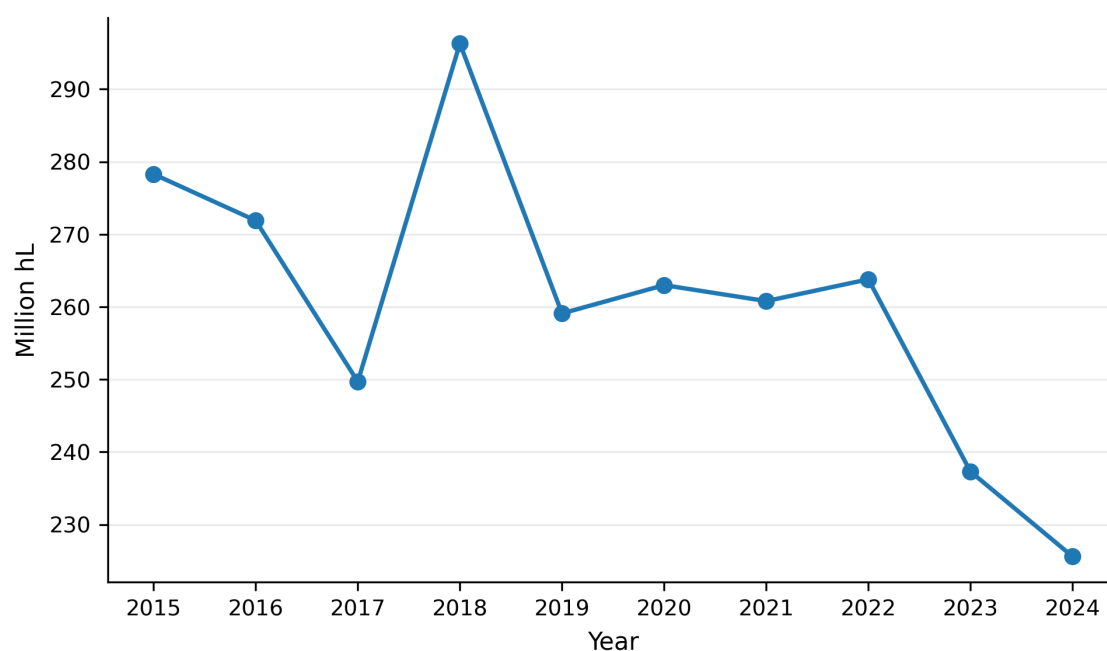


Figure 3. Global wine production trend (2015–2024)

Figure 3 highlighted a downward trend combined with high volatility. This reflected the impact of climate variability (drought, frost, extreme temperatures), changes in consumption (decrease in some mature markets), structural adjustments in production. Unlike surface area, wine is a variable strongly dependent on annual conditions.

Comparing these developments through indices (2015 = 100) clearly highlighted the structural divergence of the sector (Figure 4). The results indicated that the global wine sector has undergone a process of structural reconfiguration, in which the reduction of the vineyard area coexists with the expansion of the table grape segment and the contraction of the wine segment.

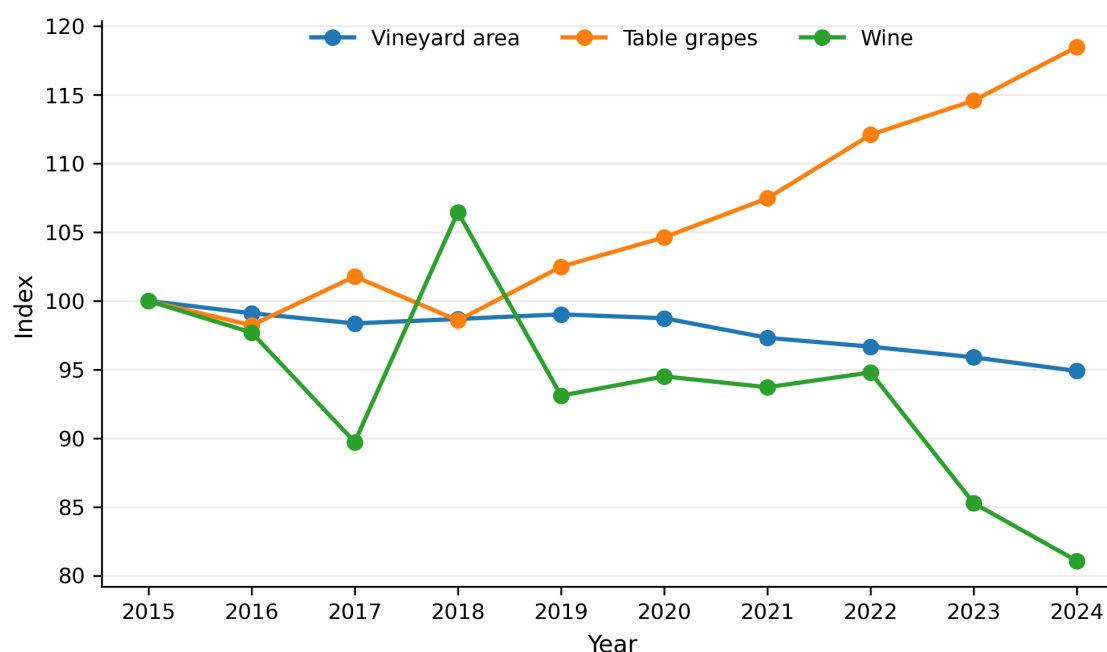


Figure 4. Global index comparison (2015 = 100)

Figure 4 represents the “key figure” of the article. The figure clearly highlighted the systemic divergence: decreasing vineyard area (VA, ↓), increasing table grape production (TGP, ↑), decreasing wine production (WP, ↓). These results showed that the wine sector is not evolving unitarily, but is reorienting itself functionally. It is evidence of a decoupling between the resource and its use.

Vineyard area: structure and stability

The distribution of the world's wine-growing area showed a relatively stable hierarchy of the main producing countries (Figure 5).

Countries such as Spain, France, China and Italy maintained their dominant positions, reflecting a high structural inertia of the sector. However, the dynamic analysis revealed significant differences between countries, with some recording increases (e.g. Italy, India) and others experiencing sharp decreases (e.g. Türkiye, USA).

The relative stability of these developments was confirmed by the volatility analysis (coefficient of variation, CV), which indicated low values for traditional countries, and higher values for emerging economies. Thus, the vineyard area can be considered the most rigid component of the analyzed system.

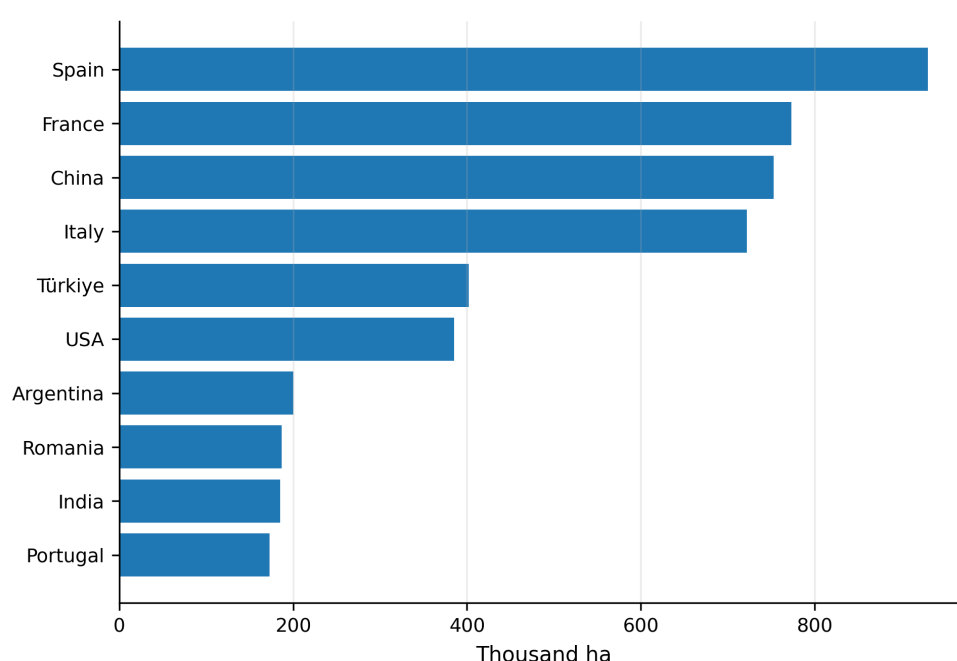


Figure 5. Top countries by vineyard area (2024)

Figure 5 confirmed a concentrated and stable structure of the global vineyard area. The characteristics derived from the graphical analysis indicated European dominance (Spain, France, Italy) and the entry of China as a major player.

It can also be interpreted that the spatial distribution is the result of an accumulated historical capital, and changes are slow, with a possible high barrier to entry.

Table grape production: expansion and concentration

The table grape segment was characterized by strong upward dynamics and a high degree of geographical concentration (Figure 6). China dominated this segment, holding approximately 43% of world production, followed by India, Egypt and Türkiye.

The sharp increase in production in these countries highlighted the growing importance of the direct consumption segment. At the same time, the high volatility of this segment, further highlighted in the visual analysis, suggested an increased sensitivity to market and climatic factors.

Figure 6 showed extreme concentration of production. China dominates the system and has a systemic role. Inferred implications indicate global dependence on a few players, and vulnerability to regional shocks. The segment is less traditional, more economically oriented than historically.

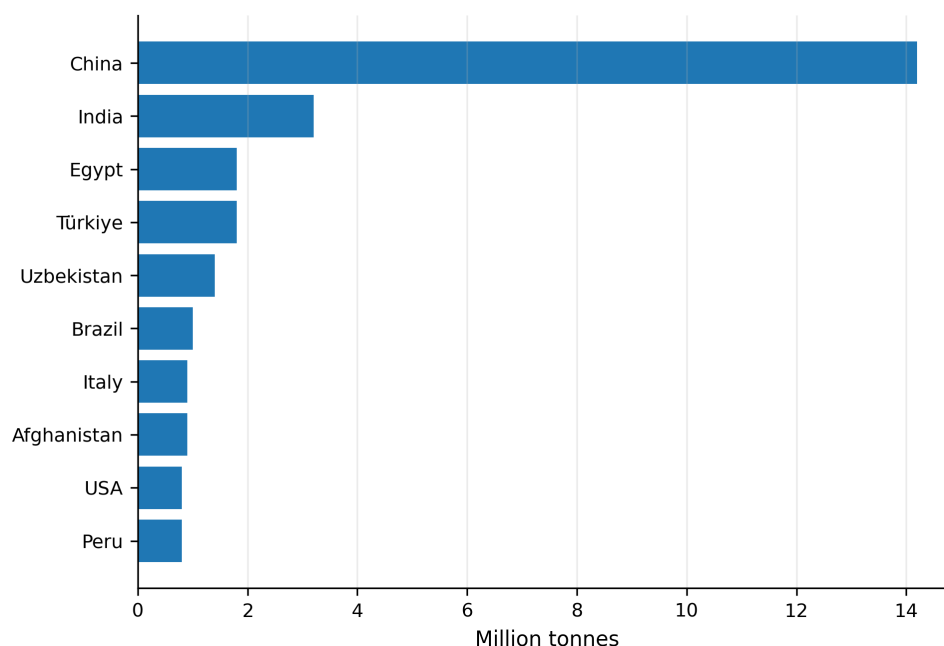


Figure 6. Top Countries by table grape production (2024)

Wine production: contraction and volatility

The distribution of wine production worldwide for the period under review is shown in Figure 7. Italy, France and Spain remain the global leaders, but all of these countries recorded production declines during the period under review. This development suggested a general contraction of the wine segment, in contrast to the positive dynamics of table grapes. In addition, the higher volatility of wine production indicated an increased sensitivity to climatic conditions and demand variations.

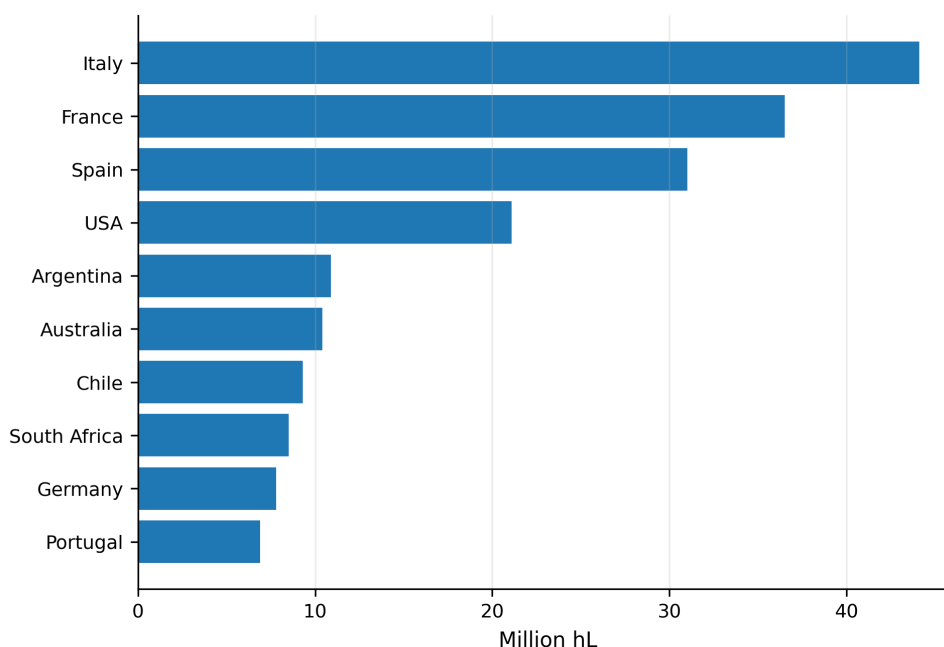


Figure 7. Top countries by wine production (2024)

Figure 7 highlighted a moderate but stable concentration. The inferred characteristics indicate a clear dominance of Europe, and the stability of the leaders. The interpretation of the data and the distribution indicate

that wine is a sector with a strong geographical identity, less mobile than the mass segment.

Analysis of statistical relationships

The correlation analysis revealed significant relationships between the analyzed variables, subsequently confirmed visually (Figure 8). The results indicated: a strong negative correlation between the vineyard area and the production of table grapes; a positive correlation between the area and the production of wine; a negative correlation between table grapes and wine. These relationships suggested the existence of divergent trajectories of the segments of the wine sector, confirming the hypothesis of structural reconfiguration.

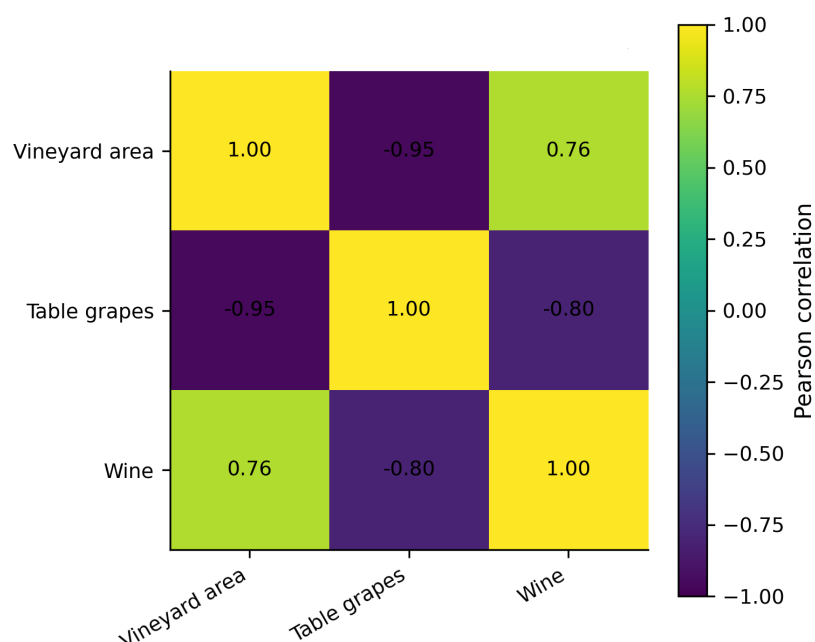


Figure 8. Correlation matrix of global variables

The results confirmed a negative relationship between the vineyard area and the production of table grapes, a positive relationship between the vineyard area and the production of wine, and a negative relationship between the production of table grapes and the production of wine. A deeper interpretation of the results showed that the sector is characterized by structural divergence between segments.

The correlation between vineyard area (VA) and table grape production (TGP) is strongly negative ($r = -0.95$), indicating that, at the global level, increases in table grape production are associated with reductions in total vineyard area.

This reflects a process of intensification, where higher outputs are achieved without expanding land area; it also suggests a functional reallocation of vineyard resources; the expansion of table grapes is not driven by land growth, but by productivity gains and structural shifts. This is one of the strongest findings of the study.

The relationship between vineyard area (VA) and wine production (WP) is positive and relatively strong ($r = 0.76$), indicating that countries (and globally, systems) with larger vineyard areas tend to produce more wine. This can be interpreted as vineyard area remains a structural determinant of wine production; however, the correlation is not perfect, and productivity and climate play a major role; fluctuations in wine production are not fully explained by land availability. This confirms the partial dependence of wine on territorial resources.

A strong negative correlation ($r = -0.80$) was recorded between table grape production (TGP) and wine production (WP). This can be interpreted as the two segments follow divergent structural trajectories; countries and systems tend to specialize in one of the two; growth in table grapes may occur at the expense of wine production (resource allocation effect). This reflects sectoral specialization within global viticulture.

Spearman (robustness check) confirmed the same direction of relationships, slightly weaker. The correlation analysis reveals a strong structural divergence within the global viticulture sector. Vineyard area is negatively associated with table grape production ($r = -0.95$), while maintaining a positive relationship with wine production ($r = 0.76$). Furthermore, table grape production and wine production exhibit a strong negative correlation ($r = -0.80$), suggesting increasing functional specialization of vineyard resources.

Integrated visual analysis

Analiza vizuală avansată a permis aprofundarea relațiilor identificate anterior și evidențierea unor tipare

structurale suplimentare.

Dynamics of the vineyard area

The heatmap highlighted the annual variations in the vineyard area, confirming the relative stability of traditional countries and the higher volatility of emerging ones, Figure 9.

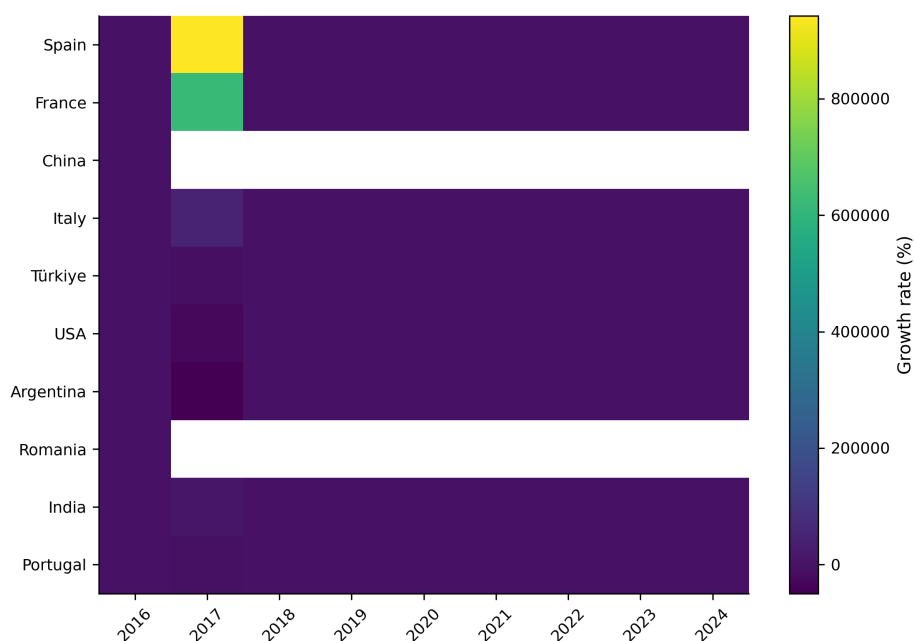


Figure 9. Heatmap of annual growth rates in vineyard area (%)

Figure 9 highlighted the heterogeneity of the dynamics of the vineyard area. General observations indicated stability in traditional countries, volatility in emerging countries. The implication of the dynamics showed that there are two structural regimes: mature systems (stable), and systems in transition (volatile).

Surface area – wine production relationship

Graphical analysis confirmed a positive relationship between area and wine production, but also highlighted differences in efficiency between countries, Figure 10.

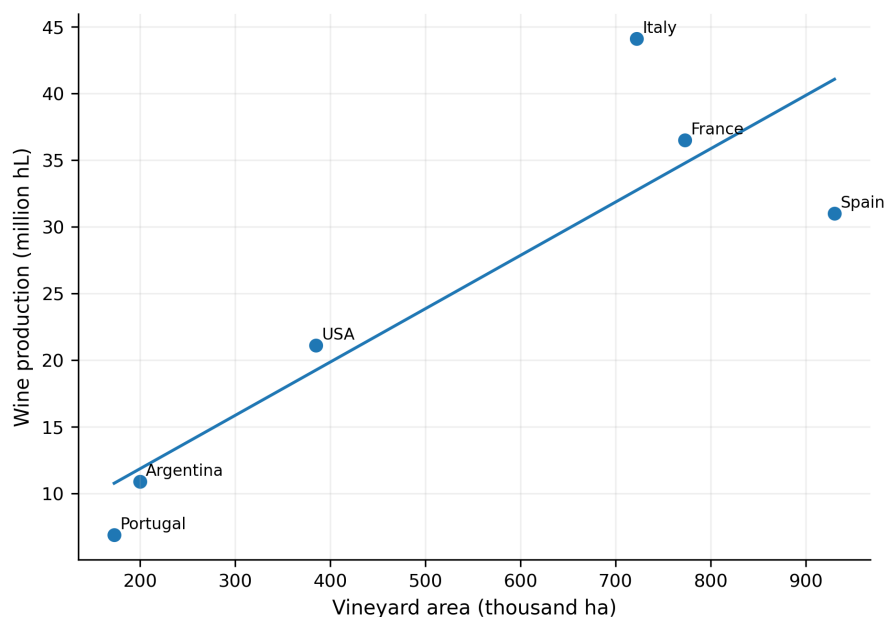


Figure 10. Vineyard area and wine production (2024)

The positive relationship expressed in Figure 9 confirmed the dependence of wine on territorial resources. At the same time, the dispersion of values indicated differences in productivity, and technological differences. Based on the distribution of values, it was assessed that the area is necessary, but not sufficient for performance in wine production.

Hierarchies evolution

The resulting slope chart based on the analysis indicated the stability of the global hierarchies, with limited changes in the top positions, Figure 11.

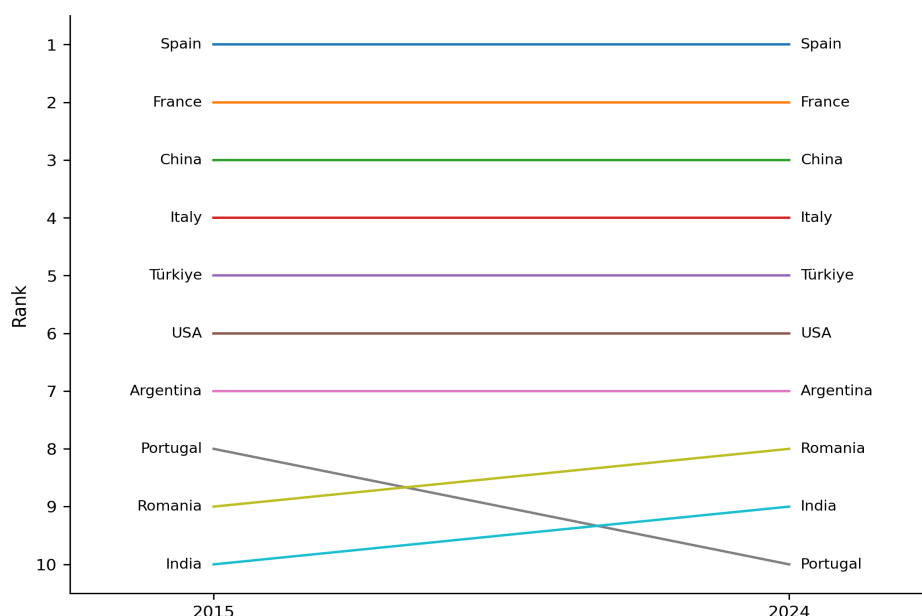


Figure 11. Ranking Changes in Vineyard Area (Top 10 Countries)

Figure 11 showed a high inertia of the global hierarchy. The changes recorded are: slow and limited. As an implication it was appreciated that the sector is structurally stable and the global redistribution is gradual.

Functional specialization of production

The distribution of points highlighted the differences in specialization between countries, confirming the distinct orientation towards wine or table grapes, Figure 12.

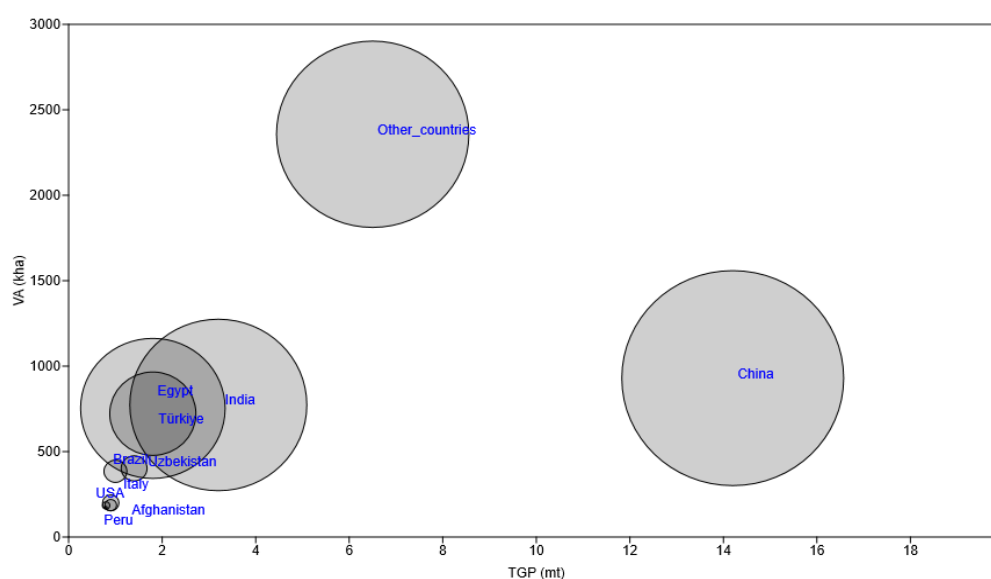


Figure 12. Vineyard area and table grape production (2024)

Figure 12 showed the absence of a linear relationship. Interpretation of the graphical distribution indicated that the area use is functionally different, with the emergence of “wine vs table” specialization, and China positioned itself as an outlier, with high efficiency for table grape production.

Integrated interpretation

The results highlighted the existence of three major trends in the global wine sector: A. Reduction of the global vineyard area, associated with restructuring processes; B. Expansion of the table grape segment, supported by global demand; C. Contraction and volatility of wine production, influenced by climatic and economic factors.

Overall, the global wine sector is not in a uniform process of evolution, but in a complex structural transformation, characterized by specialization, functional differentiation and adaptation to global market conditions.

CONCLUSIONS

The analysis of the evolution of the global wine sector during the period 2015–2024 highlighted the fact that it is not undergoing a uniform development process, but a profound structural reconfiguration, characterized by divergent dynamics between its main components.

A first major result of the study is the moderate reduction of the global vineyard area, which indicated processes of restructuring, optimization and possible conversion of land to other uses. At the same time, this decrease was not abrupt, which confirmed the rigid and inertial character of the territorial vineyard base.

In contrast, table grape production has seen significant and sustained growth, becoming the most dynamic segment of the sector. This development has reflected changes in global consumer preferences, as well as an increasing focus on fresh produce and emerging markets. The high concentration of production in a few countries, especially China, has highlighted the emergence of dominant poles in this segment.

Regarding wine production, the results indicated a downward trend combined with high volatility, suggesting increased sensitivity to climatic and economic factors. Although the hierarchy of the main producing countries remained stable, production levels were affected by the variability of annual conditions and the transformations of the global wine market.

The correlation analysis confirmed the existence of a structural divergence between the segments of the wine sector. The strong negative relationship between the vineyard area and the production of table grapes, as well as the negative correlation between table grapes and wine, highlighted a functional reorientation of the use of wine resources. At the same time, the positive correlation between the area and wine production highlighted the relatively greater dependence of this segment on the territorial base.

Integrated visual analysis reinforced these conclusions, highlighting: the stability of global hierarchies, differences in volatility between countries, structural relationships between variables, and the existence of distinct specialization patterns (wine vs. table grapes).

Overall, the results demonstrate that the global wine sector is undergoing a process of structural transformation characterized by specialization, intensification and functional differentiation. The wine-growing area is no longer a sufficient indicator for explaining the sector's performance, and the relationship between resources and production is becoming increasingly complex and dependent on technological, economic and climatic factors.

STUDY LIMITATIONS

The study has some limitations that need to be considered. First, the analysis is based on aggregated data at the national level of the countries included in the database, which may mask significant regional variations. Second, detailed climatic or economic variables were not included, which could further explain the observed variations. Also, the period analyzed, although relevant, remains relatively short for highlighting very long-term trends.

FUTURE RESEARCH DIRECTIONS

Future research could extend the analysis by: integrating climate factors (temperature, precipitation, extreme events); analyzing hectare-level productivity and technological efficiency; detailed regional studies to identify local adaptation patterns; investigating the impact of changes in global consumption on the structure of the wine sector.

The global wine sector is not in a phase of uniform decline or expansion, but in a complex process of structural transformation, in which specialization, efficiency and adaptability become determining factors of its future evolution.

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REFERENCES

1. Anderson K., Nelgen S. Global wine markets, 1961 to 2009: A statistical compendium: List of charts. University of Adelaide Press, 2020, pp. 504.
2. Ashenfelter O., Storchmann K. The economics of wine, weather, and climate change. *Review of Environmental Economics and Policy*, 2016, 10(1), 25-46. <https://doi.org/10.1093/reep/rev018>
3. Balogh J.M. Climate change and global wine production: Economic implications and adaptation strategies. *Agricultural Economics Review*, 2025, 26(1), 45-62. Doi. 10.1162/99608f92.a17caae
4. Bluman A.G. Elementary statistics: A step by step approach (10th ed.). McGraw-Hill, ISBN13: 9780076793952, 2018, 10e.
5. Conover W.J. Practical nonparametric statistics (3rd ed.). Wiley, 1999.
6. Dobrei A., Sala, F., Mălăescu, M., Ghiță, A. Researches concerning the influence of different fertilization systems on the quantity and quality of the production at some table grapes cultivars. *Journal of Horticulture, Forestry and Biotechnology*, 2009, 13, 454-457.
7. Dobrei A., Nistor E., Sala F., Dobrei A. Tillage practices in the context of climate change and a sustainable viticulture. *Notulae Scientia Biologicae*, 2015, 7(4), 500-504.
8. Everitt B.S., Skrondal A. The Cambridge dictionary of statistics (4th ed.). Cambridge University Press, 2010.
9. FAO–OIV. Table and dried grapes: FAO-OIV focus 2016. Food and Agriculture Organization & International Organisation of Vine and Wine, 2016.
10. FAO. FAOSTAT statistical database. Food and Agriculture Organization of the United Nations, 2024, <https://www.fao.org/faostat>
11. Fraga H., Malheiro, A.C., Moutinho-Pereira J., Santos, J.A. Climate factors driving wine production in Europe and implications for climate change. *OENO One*, 2017, 51(2), 147-159. <https://doi.org/10.20870/oeno-one.2017.51.2.1621>
12. Gujarati D.N., Porter D.C. Basic econometrics (5th ed.). McGraw-Hill Inc., 2009, pp. 946.
13. Hammer Ø., Harper D.A.T., Ryan P.D. PAST: Paleontological Statistics software package for education and data analysis. *Palaeontologia Electronica*, 2001, 4(1), 1-9.
14. Hannah L., Roehrdanz P.R., Ikegami M., Shepard A.V., Shaw M.R., Tabor, G., Zhi L., Marquet P.A., Hijmans, R.J. Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences*, 2013, 110(17), 6907-6912. <https://doi.org/10.1073/pnas.1210127110>
15. Jones G.V., White M.A., Cooper O.R., Storchmann K. Climate change and global wine quality. *Climatic Change*, 2005, 73(3), 319-343. <https://doi.org/10.1007/s10584-005-4704-2>
16. Maddala G.S., Lahiri K. Introduction to econometrics (4th ed.). Wiley, 2009, pp. 656.
17. Mariani L., Parisi S.G., Cola G., Failla O. Climate change in Europe and effects on thermal resources for crops. *International Journal of Biometeorology*, (2012, 56(6), 1123-1134. <https://doi.org/10.1007/s00484-012-0528-8>
18. Matese A., Di Gennaro S.F. Technology in precision viticulture: A state of the art review. *International Journal of Wine Research*, 2015, 7, 69-81. <https://doi.org/10.2147/IJWR.S69405>
19. Montgomery D.C., Runger G.C. Applied statistics and probability for engineers (6th ed.). Wiley, 2014.
20. Mozell M., Thach L. The impact of climate change on the global wine industry: Challenges and solutions. *Wine Economics and Policy*, 2014, 3(2), 81-89. <https://doi.org/10.1016/j.wep.2014.08.001>
21. OIV. Statistical report on world vitiviniculture. International Organisation of Vine and Wine, 2024.
22. OIV. State of the world vine and wine sector in 2024. International Organisation of Vine and Wine, 2025a.
23. OIV. OIV Statistical Brief: Wine, Table Grapes & Dried Grapes in 2024. International Organisation of Vine and Wine, 2025, pp 18.
24. Pomarici, E., Sardone R. EU wine policy in the framework of CAP reforms. *Wine Economics and Policy*, 2020, 9, 100146.
25. Resco P., Iglesias A., Bardají I. Exploring adaptation choices for grapevine regions under climate change. *Regional Environmental Change*, 2016, 16(4), 979-993.
26. Rodgers J.L., Nicewander W.A. Thirteen ways to look at the correlation coefficient. *The American Statistician*, 1988, 42(1), 59-66.
27. Santillán D., Iglesias A., La Jeunesse I., Garrote L., Sotes V. Vineyards in transition: A global assessment of adaptation needs. *Science of the Total Environment*, 2019, 657, 839-852. <https://doi.org/10.1016/j.scitotenv.2018.11.317>

28. Santos J.A., Fraga H., Malheiro A.C., Moutinho-Pereira J., Dinis L.-T., Correia C., Moriondo M., Leolini L., Dibari C., Costafreda-Aumedes S., Kartschall T., Menz C., Molitor D., Junk J., Beyer M., Schultz H. R. A Review of the potential climate change impacts and adaptation options for European viticulture. *Applied Sciences*, 2020, 10(9), 3092. <https://doi.org/10.3390/app10093092>
29. Schultz H.R. Global climate change, sustainability, and viticulture. *OENO One*, 2016, 50(3), 141-149.
30. Sidorkiewicz M., Nowak A., Kowalski P. Artificial intelligence applications in viticulture. arXiv preprint, 2025. <https://arxiv.org/abs/2507.21098>
31. Stock J.H., Watson M.W. *Introduction to econometrics* (4th ed.). Pearson, 2020.
32. Tonietto J., Carbonneau A. A multicriteria climatic classification system for viticultural regions. *Agricultural and Forest Meteorology*, 2004, 124(1-2), 81-97. <https://doi.org/10.1016/j.agrformet.2003.06.001>
33. van Leeuwen C., Darriet P. The impact of climate change on viticulture and wine quality. *Journal of Wine Economics*, 2016, 11(1), 150-167. <https://doi.org/10.1017/jwe.2015.21>
34. Webb L.B., Whetton P.H., Barlow E.W.R. Modelled impact of climate change on viticulture. *Australian Journal of Grape and Wine Research*, 2007, 13(3), 165-175.
35. Wooldridge J.M. *Introductory econometrics: A modern approach* (6th ed.). Cengage Learning, 2016.