Precision Viticulture in Central Europe: A Comparative Analysis of Technological Adoption in the Czech Republic and Austria

Olga REGNEROVÁ*, Jitka ŠIŠKOVÁ, Daniela PFEIFEROVÁ and Ivana KUCHAŘOVÁ

University of Life Sciences Prague, Prague, Czech Republic; oregnerova@pef.czu.cz; siskova@pef.czu.cz; pfeiferova@pef.czu.cz; kucharovai@pef.czu.cz

* Corresponding author: oregnerova@pef.czu.cz

Abstract: Precision viticulture (PV), a subfield of precision agriculture, has become increasingly relevant in Central Europe as wine producers face mounting environmental, economic, and technological challenges. This article presents a comparative analysis of PV technology adoption in the Czech Republic and Austria, drawing upon secondary data and a qualitative, multi-dimensional framework. The study evaluates adoption across seven key areas—including satellite imaging, drone use, soil and microclimate sensors, and variable rate applications—while integrating economic indicators such as investment costs, operational savings, return on investment (ROI), and subsidy intensity. Findings indicate that Austria leads in PV adoption due to coherent institutional support, stronger financial incentives, and effective integration of research and practice. The Czech Republic, while showing accelerating uptake, continues to face structural barriers related to farm fragmentation, limited advisory capacity, and less targeted funding instruments. This indicates that structural scale alone is insufficient without institutional and advisory coordination. The article also considers tax implications, including VAT and excise duties, highlighting their influence on the economic attractiveness of PV technologies. A 5–10-year prognosis suggests that sustained investment, improved training systems, and climate-driven pressures could substantially increase PV adoption in Czech vineyards.

Keywords: precision viticulture; technological challenges; agricultural policy; Czech Republic; Austria

JEL Classification: Q12; Q18; H25

1. Introduction

Precision agriculture (PA) has emerged over the past decades as a core paradigm for improving the economic and environmental performance of farming systems through targeted input use, spatially differentiated management, and data-driven decision-making (Zhang et al., 2002; Gebbers & Adamchuk, 2010). Within this framework, precision viticulture (PV) represents a specialised application to vineyard systems, addressing inherent spatial and temporal variability (Matese & Di Gennaro, 2015).

The relevance of PV has intensified as European wine regions experience increasing climate variability, droughts, and disease pressure. Technologies such as satellite remote sensing, UAVs, soil and microclimate sensors, and decision support systems enable vineyard managers to respond effectively to these challenges (Reynolds, 2021; Tardaguila et al., 2021; Santesteban, 2018).

The Czech Republic and Austria provide a comparative context. Both countries share similar agro-climatic conditions and viticultural traditions yet differ markedly in the pace and depth of digital technology adoption. Austria has positioned itself as a frontrunner in sustainable and digitally supported viticulture, supported by stable rural development programmes and close cooperation between research institutions and practitioners (Smart Rural 21, 2023).

Viticulture contributes significantly to rural employment, regional branding, and tourism (Anderson and Pinilla, 2018; Santini et al., 2013). Wine is often perceived by many consumers as a natural and sustainable product. However, there are several environmental and socio-economic challenges which the wine industry has to overcome in order to do justice to this assessment. The ongoing global warming with its negative effects on cultivation emphasize the need for a rapid transformation towards more sustainability (Wagner et al., 2023). In addressing the trade-offs between the various pillars of sustainability, wine producers should be able to prioritize investments that bolster environmental sustainability without compromising their economic viability. Ideally, such investments should generate synergies that enhance economic sustainability by providing additional revenue streams for producers (Padilla et al., 2022). Although precise national statistics on precision viticulture (PV) adoption are not systematically collected, available sectoral analyses and expert reports indicate a clear difference between the two countries. In Austria, an estimated 35–45% of vineyards use at least one PV-related technology (e.g., remote sensing, UAV monitoring, or decision support systems), whereas in the Czech Republic adoption is lower, approximately 15–25%. This disparity reflects differences in advisory systems, institutional continuity, and historical pathways of technological innovation in viticulture.

2. Methodology

This study uses a qualitative comparative research design based on secondary data analysis from peer-reviewed journals, EU and national policy documents, agricultural chambers, funding agencies, and platforms such as Smart Rural 21.

Research Question:

How do institutional support, policy frameworks, advisory services, and fiscal mechanisms influence the adoption and economic feasibility of precision viticulture technologies in Austria compared to the Czech Republic?

To address this question, the study employs a qualitative comparative approach based on secondary data analysis. Data sources include peer-reviewed journal articles, government and EU reports, white papers from agricultural technology providers, and online repositories such as Smart Rural 21. The analysis focuses on seven dimensions of PV technology adoption:

- Satellite imagery and remote sensing,
- Use of drones (UAVs),
- Soil and microclimate sensors,
- Variable rate application (VRA),
- Meteorological data systems,
- Policy support and funding mechanisms,
- Training and extension services.

A SWOT framework and trend extrapolation are used to interpret the findings and provide a 5–10-year outlook for PV adoption, integrating economic and fiscal considerations. This approach allows for a comprehensive, context-sensitive comparison of technology adoption patterns without relying on formal statistical testing, while linking insights to policy and economic implications.

Analytical methods combine descriptive comparison, SWOT-based interpretation, trend extrapolation, and integration of economic indicators including investment costs, operational savings, subsidy intensity, and ROI (Pierpaoli et al., 2013; Landwirtschaftskammer Österreich, 2024; SZIF, 2024). Adoption dynamics are interpreted using diffusion theory (Lowenberg-DeBoer & Erickson, 2019). The analysis also draws upon recent research on drivers and barriers of precision agriculture adoption in Central European farming systems, particularly studies examining structural and behavioural determinants of technology uptake in the Czech context. (Žáková Kroupová et al., 2026).

Methodological note on economic and adoption indicators

The economic figures presented in the cost–benefit and ROI table are based on a scenario model developed for a hypothetical 10-hectare vineyard. These values are not farm-survey averages but model-based estimations combining (i) investment cost ranges reported in precision viticulture literature and industry sources, (ii) subsidy intensity levels from national and EU rural development frameworks, and (iii) performance effect intervals (yield gains, input savings, quality improvements) commonly reported in PV impact studies. The purpose of these figures is illustrative and comparative, showing the order of magnitude and structural differences between national contexts rather than statistically representative outcomes.

Structural characteristics of vineyard ownership and management

A crucial factor influencing precision viticulture adoption lies in the distinction between land ownership fragmentation and operational farm structure. These two dimensions are often conflated but have different implications for technological uptake.

In the Czech Republic, although vineyard ownership is fragmented, operational management is highly concentrated. According to national vineyard register statistics, agricultural enterprises cultivating vineyard areas exceeding 30 hectares manage more than half of the total national vineyard area (Central Institute for Supervising and Testing in Agriculture, 2024).

This results in a relatively consolidated operational structure, enabling economies of scale, higher capital availability, and better access to mechanization and digital technologies. Such structural conditions create a potentially favourable environment for investment in PV technologies. While vineyard ownership is fragmented in both countries, the Czech Republic exhibits higher operational concentration. However, this indicates that structural scale alone is insufficient without institutional and advisory coordination. Austria displays greater alignment between ownership and management at smaller scales.

Austria, in contrast, is characterized by a predominance of small and medium-sized family-operated vineyards, where ownership and management are closely linked. Although this structure supports strong local knowledge networks and cooperative systems, individual producers often operate on a smaller scale, which may limit investment capacity and increase dependence on collective advisory services and subsidy mechanisms.

Therefore, while Austria currently demonstrates higher PV adoption, the Czech structural model contains latent potential for rapid technological diffusion through large operational units, provided institutional and advisory barriers are addressed.

3. Results

Austrian vineyards—particularly in Wachau and Burgenland—widely employ satellite imagery, UAV monitoring, and soil sensors to manage variability and optimise inputs (Smart Rural 21, 2023). These technologies are embedded within integrated decision support systems developed in collaboration with universities and advisory bodies. In the Czech Republic, PV adoption is more fragmented, with UAVs and remote sensing in experimental settings or larger producers. Smaller vineyards face financial constraints, limited technical support, and lower awareness of PV benefits.

3.1. Comparative Adoption of Precision Viticulture Technologies

The following Table 1 provides a comparative overview of the adoption of key precision viticulture technologies and institutional support mechanisms in Austria and the Czech Republic. It highlights substantial differences in the extent of technological implementation, access to advisory and training services, and the strength of policy and funding frameworks. Overall, the comparison illustrates Austria’s more advanced and integrated precision viticulture ecosystem, while the Czech Republic remains at an earlier and more fragmented stage of adoption. Adoption levels are expressed as qualitative intensity categories derived from structured synthesis of secondary sources rather than measured adoption rates. Classification reflects convergence across policy documents, sector reports, and academic studies.

Training and knowledge transfer also differ. Austria has well-established vocational and extension systems; Czech advisory services are still developing.

Table 1. Comparative adoption of precision viticulture technologies

Technology / Practice	Austria	Czech Republic
Satellite Imagery & Remote Sensing	Widely adopted in larger vineyards; commonly used for canopy mapping, zoning, and vigour assessment.	Limited use; primarily within research projects or by large-scale producers.
Drones (UAVs)	Regularly used for aerial monitoring, stress detection, and disease assessment.	Growing interest: adoption remains largely experimental.
Soil & Microclimate Sensors	Commonly integrated into vineyard management systems; applied to optimize irrigation and fertilization.	Used selectively, mainly in pilot projects or academic research settings.
Variable Rate Application (VRA)	Applied in combination with soil mapping and decision support tools; supported by EU and national subsidies.	Rare; limited adoption due to high costs and insufficient technical support.
Yield Monitoring Systems	Present in some mechanized vineyards; frequently linked to GPS-based harvesting systems.	Limited availability: yield estimation is predominantly manual.
Decision Support Systems (DSS)	Widely available and increasingly used; often integrated with mobile applications.	Few commercial solutions available; adoption constrained by digital infrastructure.
GIS-based Vineyard Zoning	Advanced implementation in premium wine regions (e.g., Wachau); widely used for spatial management.	Emerging interest: GIS tools used mainly for academic or experimental purposes.
Training & Extension Services	Well-established; provided by viticultural schools, cooperatives, and advisory bodies.	Fragmented and limited; advisory services remain under development.
Government Policy & Funding	Strong support through rural development programs and innovation-oriented grants.	Moderate support: funding is available but not specifically targeted at PV technologies.
Collaboration with Research Institutions	Close cooperation with universities (e.g., BOKU Vienna); field-testing and applied research encouraged.	Active academic research; weaker transfer to commercial vineyard practice.

3.2. Economic Assessment and Adoption Dynamics

Table 2 presents a comparative analysis of the estimated return on investment (ROI) for a medium-sized (10 ha) vineyard implementing precision viticulture (PV) technologies in the Czech Republic and Austria.

Table 2. Comparative ROI analysis (10 ha vineyard)

Indicator	Austria	Czech Republic
Initial Investment	€ 90,000	€ 85,000
Annual operational savings	€ 14,000	€ 12,000
Increase in average yield	+ 10%	+8%
Increase in premium grape share	+18%	+15%
Estimated ROI period	5.8 years	6.5 years
Average subsidy intensity	~ 50%	~ 40%

Note: Values represent model-based scenario estimations for a medium-sized vineyard and serve illustrative comparative purposes. They are not empirical sample averages.

The indicators summarize capital expenditures, operational savings, yield improvements, and subsidy intensity, providing a clear overview of the economic feasibility of PV adoption in both contexts. This comparison highlights the influence of national policy support and market conditions on the financial attractiveness of precision technologies.

Differences shown in Table 2 are shaped by three interacting factors: (1) structural farm characteristics, (2) institutional and advisory systems, and (3) financial support mechanisms. Austria's higher intensity of PV adoption reflects stable advisory networks, integration between research institutions and practice, and targeted rural development schemes. Conversely, the Czech Republic combines favourable operational farm size with weaker institutional coordination and less specialized support for digital technologies. This configuration explains why structural capacity alone does not automatically translate into higher adoption rates.

The data suggest that while both countries demonstrate positive economic outcomes from PV adoption, Austrian vineyards benefit from slightly higher operational savings, larger increases in yield and premium grape share, and shorter ROI periods, reflecting stronger subsidy coverage and more established technological ecosystems. In the Czech context, ROI remains favourable, but adoption may be constrained by lower subsidy intensity and limited access to advisory support. These results underscore the importance of tailored financial instruments and institutional support to accelerate the adoption of precision viticulture in regions with smaller or fragmented vineyard holdings.

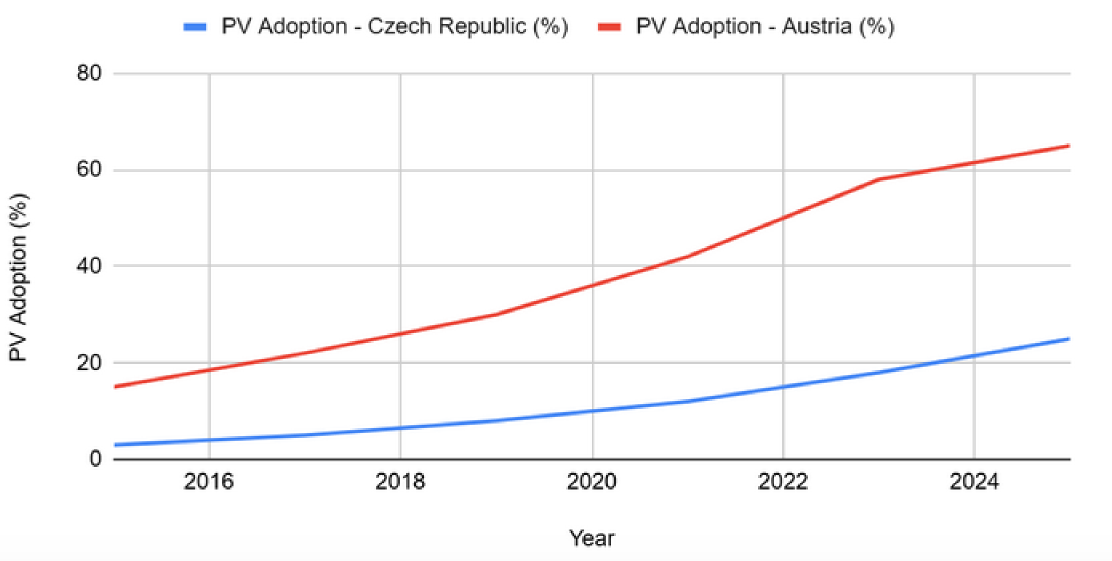

Figure 1. Conceptual illustration of relative precision viticulture adoption trends in Austria and the Czech Republic (2015–2025).

Figure 1 provides a conceptual illustration of the relative adoption trajectories of precision viticulture (PV) technologies in Austria and the Czech Republic between 2015 and 2025. Adoption rates represent vineyards using at least two core PV technologies, data are synthesized from Smart Rural 21 (2023) and recent literature. The figure does not represent a statistical time series. Instead, it visualizes the direction and relative dynamics of adoption derived from qualitative synthesis of sector reports, policy documents, and academic literature. The graphical representation is intended to support the comparative interpretation presented in the text by illustrating Austria's earlier and steeper adoption pathway in contrast to the Czech Republic's later but gradually accelerating uptake. It reflects differences in institutional support, advisory systems, and policy continuity discussed in Sections 2 and 3.

The figure serves an explanatory and heuristic purpose rather than providing measured quantitative adoption rates. Graphical trend illustrations are used in a conceptual manner to visualise comparative adoption dynamics and should not be interpreted as statistically measured time-series data.

3.3. Taxation and Fiscal Considerations

The adoption of precision viticulture (PV) technologies is closely linked to taxation and fiscal policy, as changes in vineyard productivity, grape quality, and wine output directly affect taxable income and overall profitability. Understanding these interactions is essential for assessing the true economic feasibility of PV investments.

Table 3. Comparative overview of taxation and fiscal implications for precision viticulture adoption in Austria and the Czech Republic

	Austria	Czech Republic
Value Added Tax (VAT)	Austria applies a standard 20% VAT on wine sales, although certain local initiatives and small-scale producers may benefit from reduced rates for specific products or regional programs.	The standard VAT rate is 21%, with a reduced rate of 15% applied to selected food products. Wine generally falls under the standard rate, though small-scale producers may access exemptions or simplified VAT schemes.
Excise / Alcohol Tax	Wine is generally exempt from excise duties, with taxes applied primarily to fortified wines or products exceeding standard alcohol content thresholds.	Wine with alcohol content below 15% ABV is exempt from excise duties, whereas fortified or higher-alcohol wines are taxed according to national regulations.
Implications for PV adoption	The use of PV technologies often results in higher yields and improved grape quality, which can increase taxable turnover. However, Austria's well-structured subsidy schemes and investment incentives, particularly under rural development programs, mitigate these fiscal effects. In practice, subsidies can offset a substantial portion of VAT liabilities and initial investment costs, improving net profitability for vineyards adopting PV technologies. Additionally, precision monitoring allows producers to target quality-enhancing interventions selectively, optimizing both tax efficiency and economic returns.	Implementation of PV technologies can lead to higher yields and an increase in premium-quality wine production, directly affecting VAT obligations. While eligible subsidies from the European Union and national programs partially offset these fiscal burdens, the Czech system currently provides less targeted support than Austria. Consequently, vineyards must carefully plan for potential VAT increases associated with productivity gains. PV-driven yield optimization can help align production with tax planning, for example by enabling strategic allocation of grapes to premium products with favorable market pricing, which can improve after-tax returns.

3.4. Comparative Insights

- Both countries demonstrate that PV adoption has a dual effect: while it increases revenue potential through higher yields and improved wine quality, it simultaneously raises taxable turnover and potential fiscal liabilities.
- Austria's system of targeted subsidies, in combination with stable rural development incentives, provides more predictable mitigation of fiscal impacts, effectively lowering financial risk for adopters.
- In the Czech Republic, fiscal planning is more critical, as subsidies are less directly linked to PV investment, requiring careful assessment of potential VAT liabilities when scaling production or introducing premium product lines.

3.5. Strategic Recommendations for Vineyards

- Incorporate PV-driven yield forecasts into tax planning and cash flow projections.
- Align PV interventions with subsidy eligibility criteria to maximize fiscal offsets.
- Consider product segmentation (standard vs. premium wine) to optimize VAT exposure.
- Maintain detailed records of PV-enabled improvements to support claims for investment grants and future tax deductions.

Taxation and fiscal policies play a critical role in determining the net economic benefit of PV technologies. While PV adoption enhances operational efficiency and quality outcomes, vineyard managers must account for potential VAT and excise impacts. Austria's stronger fiscal and subsidy framework facilitates smoother adoption, whereas in the Czech Republic, targeted fiscal planning and strategic use of subsidies are essential to ensure that increased production and quality translate into tangible, after-tax profitability.

Data synthesized from Austrian Ministry of Finance (2024); Ministry of Finance of the Czech Rep. (2024); SZIF (2024)

4. Discussion

The comparative analysis highlights several important insights. Austria demonstrates not only higher PV adoption but also a more integrated ecosystem encompassing research institutions, advisory services, and rural development funding. This coherence allows Austrian winegrowers to leverage PV technologies more effectively, achieving both operational efficiency and quality improvements.

In contrast, the Czech Republic, despite recent progress, faces structural challenges that hinder rapid adoption. Fragmented vineyard ownership, limited access to technical support, and lower levels of subsidy intensity reduce the immediate economic feasibility for many small and medium-sized producers. However, pilot projects and academic collaborations indicate growing awareness and interest.

The integration of taxation considerations further nuances the economic analysis. While PV can improve yields and increase premium grape share, it also increases taxable turnover. Effective fiscal planning and targeted subsidies are therefore critical to ensure that PV adoption translates into net economic benefits. In Austria, higher subsidy intensity and institutional support help offset VAT liabilities, while in the Czech Republic, ongoing EU co-financing and national support programs provide partial mitigation but remain less targeted.

The adoption curves suggest that PV uptake in the Czech Republic is accelerating, particularly in South Moravia, but still lags Austrian regions. Policy interventions focused on training, advisory support, and integration with digital platforms can catalyse further adoption. The findings of Žáková Kroupová et al. (2026) underscore the need for targeted policy measures. Additionally, climate change and labour shortages are likely to increase the attractiveness of precision technologies across both countries. Currently, remote, and proximal monitoring technologies and variable-rate machinery are applied on a broad basis, while robotics reported in this review are in an experimental stage. (Matese & Di Gennaro, 2015). Looking ahead, climate change pressures, labour shortages, and market demand for quality and traceability are likely to further strengthen the economic rationale for PV adoption across both countries, consistent with recent international evidence (Martínez-Falcó et al., 2024).

Overall, the findings underscore the need for a multifaceted approach to PV adoption that combines technological investment, fiscal planning, policy support, and human capital development. A 5–10-year outlook indicates that, with sustained EU co-financing and targeted national measures, Czech vineyards could achieve a 30–50% increase in PV adoption, narrowing the gap with Austrian counterparts. These insights have implications not only for economic efficiency but also for long-term sustainability, resilience to climate change, and competitive positioning in European and global wine markets (Martínez-Falcó et al. 2024).

5. Conclusions

This article has examined the adoption of precision viticulture (PV) technologies in Central Europe through a comparative analysis of the Czech Republic and Austria, integrating technological, economic, institutional, and fiscal perspectives. The findings confirm substantial differences in adoption dynamics between the two countries, reflecting broader disparities in policy coherence, institutional support, and economic incentives.

Austria emerges as a mature adopter of PV technologies, supported by a well-integrated ecosystem that combines research institutions, advisory services, and targeted rural development funding. This alignment enables winegrowers to translate technological investments into tangible gains in operational efficiency, grape quality, and long-term competitiveness. The Austrian case illustrates how coordinated policy frameworks can reduce adoption risk, shorten return-on-investment periods, and facilitate diffusion beyond early adopters.

In contrast, the Czech Republic remains at an earlier stage of the adoption curve. Structural factors—such as fragmented vineyard ownership, limited advisory capacity, and lower subsidy intensity—continue to constrain the economic feasibility of PV investments for small and medium-sized producers. Nevertheless, indicators from pilot projects and academic collaborations indicate increasing awareness and a gradual shift toward digital vineyard management, particularly in South Moravia. Adoption trajectories suggest that the Czech viticulture sector is entering an acceleration phase, albeit from a lower baseline.

A key contribution of this study lies in the explicit integration of taxation considerations into the economic assessment of PV adoption. While precision technologies enhance yields and increase the share of premium grapes, they also raise taxable turnover and VAT liabilities. The results highlight the importance of aligning innovation support with fiscal policy to ensure that productivity gains translate into net economic benefits at the farm level. Austria's higher subsidy coverage partially offsets fiscal burdens, whereas Czech support schemes, though improving, remain less targeted and thus less effective in accelerating adoption.

From a technological perspective, the analysis confirms that remote and proximal sensing technologies, decision support systems, and variable-rate applications are currently the most widely implemented PV tools, while advanced robotics remain experimental (Matese & Di Gennaro, 2015).

Overall, the study underscores that precision viticulture adoption is not merely a technological decision, but a multifaceted economic process shaped by policy design, fiscal conditions, institutional capacity, and human capital development. Given the presence of large operational vineyard enterprises, the Czech Republic may experience faster PV diffusion once institutional and advisory barriers are reduced. Structural readiness in terms of farm scale may allow more rapid technological scaling than in systems dominated by very small holdings.

Conflict of interest: none

References

Anderson, K. & Pinilla, V. (2018). *Wine Globalization: A New Comparative History.* Cambridge University Press.

Austrian Ministry of Finance. (2024). *Taxation of Wine.* BMF

Austrian Wine. (2025). *History of Austrian Wine.* https://www.austrianwine.com

Bacco, M., Barsocchi, P., Ferro, E., Gotta, A., & Ruggeri, M. (2019). The digitization of agriculture: A survey of research activities on smart farming. *Future Generation Computer Systems*, *100*, 1–19. https://doi.org/10.1016/j.array.2019.100009

Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ). (2024). *Vineyard Register – Structure of Vineyard Holdings by Farm Size.* Brno.

Gebbers, R., & Adamchuk, V.I. (2010). Precision agriculture and food security. *Science, 327*(5967), 828–831. https://doi.org/10.1126/science.118389

Landwirtschaftskammer Österreich. (2024). *lkonline*. https://www.lko.at/

Lowenberg-DeBoer, J., & Erickson, B. (2019). Setting the record straight on precision agriculture adoption. *Agronomy Journal, 111*(4), 1552–1569. https://doi.org/10.2134/agronj2018.12.0779

Martínez-Falcó, J., Sánchez-García, E., Marco-Lajara, B., & Georgantzis, N. (2024). The interplay between competitive advantage and sustainability in the wine industry: a bibliometric and systematic review. *Discovery Sustainability, 5*, 13. https://doi.org/10.1007/s43621-024-00196-4

Matese, A., & Salvatore F. Di Gennaro. (2015). Technology in precision viticulture: A state of the art review. *International Journal of Wine Research, 7*, 69–81. https://doi.org/10.2147/IJWR.S69405

Ministry of Finance of the Czech Republic. (2024). *VAT and Excise Tax on Wine.* https://www.mfcr.cz/cs/dane-a-ucetnictvi/dane

Padilla J., Toledo C., & Abad J. (2022). Enovoltaics: Symbiotic integration of photovoltaics in vineyards. *Frontiers Energy Research, 10*. https://doi.org/10.3389/fenrg.2022.1007383

Pierpaoli, E., Carli, G., Pignatti, E., & Canavari, M. (2013). Drivers of precision agriculture technologies adoption. *Procedia Technology, 8*, 61–69. https://doi.org/10.1016/j.protcy.2013.11.010

Reynolds, A. (2021). *Managing Wine Quality: Viticulture and Wine Quality*. Woodhead Publishing.

Santesteban, L.G. (2018). Precision viticulture and advanced analytics: A short review. *Agronomy, 9(*12), 833. https://doi.org/10.1016/j.foodchem.2018.11.140

Santini, F., Guri, F., & Gomez y Paloma, S. (2013). *Labelling of agricultural and food products of mountain farming.* European Commission JRC.

Smart Rural 21. (2023). *Precision Viticulture*. https://www.smartrural21.eu

Státní zemědělský intervenční fond – SZIF. (2024). *Dotace a podpora zemědělců*. https://www.szif.cz

Tardaguila, J., Stoll, M., Gutiérrez, S., Proffitt, T., & Diago, M.P. (2018). Smart and sustainable viticulture. *OENO One, 52*(3), 217–226.

Wagner, M., Stanbury, P., Dietrich, T., Döring, J., Ewert, J., Foerster, C., Freund, M., Friedel, M., Kammann, C., & Koch, M. (2023). Developing a Sustainability Vision for the Global Wine Industry. *Sustainability*, *15*, 10487. https://doi.org/10.3390/su151310487

Zhang, N., Wang, M., & Wang, N. (2002). Precision agriculture—a worldwide overview. *Computers and Electronics in Agriculture, 36*(2–3), 113–132. https://doi.org/10.1016/S0168-1699(02)00096-0

Žáková Kroupová, Z., Rumánková, L., Bajan, B., Čechura, L., Hloušková, Z., Aulová, R., Šimek, P., & Jarolímek, J. (2026). Drivers and barriers to precision agriculture adoption in Czech agriculture. *Precision Agric, 27*, 17. https://doi.org/10.1007/s11119-026-10315-y