

Enhancing sustainability in viticulture through digital technologies: A case study from Smyrnakis winery

Ioannis Smirnakis¹, Konstantinos Belivanis¹

¹ University of Piraeus, Geotechnical Chamber of Greece, Unives

*Corresponding author: smirnakisg@gmail.com

Abstract. The integration of digital technologies in vineyard management offers substantial opportunities for enhancing sustainability, efficiency, and grape quality. This study presents the results of digitalization initiatives implemented at Smyrnakis Winery in Greece, utilizing precision irrigation, IoT-based environmental monitoring, smart insect traps (Attalos system), and AI-powered decision support systems (OptiSol.io). Results demonstrated a 37% reduction in irrigation water usage with simultaneous improvement in grape quality. The Attalos traps—eco-friendly smart traps—provided real-time monitoring of pest populations with automatic photo classification, allowing for timely alerts. In parallel, the OptiSol.io DSS integrated vineyard-specific climate forecasts with pest development models to generate highly targeted and localized spraying recommendations. These led to a 30% reduction in pesticide use and a 28% decrease in labor costs. As reported by McKinsey (2025), while 98% of European farmers have adopted at least one sustainable practice, only a minority—especially among small producers—invest in digital yield-enhancing solutions due to perceived cost and risk. This underscores the strategic importance of clear ROI demonstration and support programs to accelerate adoption. Beyond technological achievements, this study also analyzes strategic frameworks for overcoming barriers to adoption and emphasizes the continued importance of human expertise in decision-making.

1. Introduction

The wine industry is increasingly embracing digital technologies to address challenges associated with resource management, climate variability, and sustainable production. Internet of Things (IoT) devices, AI-driven decision support systems, and smart monitoring solutions are transforming viticulture into a more data-driven, efficient practice. However, the successful transition towards digital viticulture requires not only technological investments but also strategic planning to overcome operational frictions and foster organizational readiness. This paper presents a case study from Smyrnakis Winery, showcasing the tangible benefits achieved through strategic digitalization. According to McKinsey & Company (2025), although 98% of surveyed farmers in France, Germany, and the Netherlands reported using at least one sustainable practice, only 31% of them planned to invest in productivity-enhancing digital tools, compared to 57% of their U.S. counterparts. This discrepancy highlights a caution among European producers—particularly smaller wineries—regarding up-front

technology costs, uncertain returns, and operational complexity. Such findings reinforce the importance of providing tailored, evidence-based support for adoption to secure long-term sustainability and competitiveness in the sector. The global viticulture sector is increasingly shaped by concerns over climate change, environmental sustainability, and market competitiveness. As pressures mount from consumers, regulators, and supply chains, wineries are compelled to adopt advanced tools that reduce resource consumption and improve production efficiency. Digital technologies—such as sensor-based monitoring, artificial intelligence, and decision support systems—are central to this transformation. However, adoption remains uneven. As McKinsey (2025) highlights, smaller producers often face more intense barriers, including lack of technical expertise, uncertainty about return on investment, and limited access to financing. This case study offers a granular look at how one midsize winery overcame these barriers through strategic partnerships, stepwise implementation, and a commitment to workforce engagement.

2. Methodology

- Precision irrigation using IoT soil moisture sensors and flow meters ;
- Smart insect monitoring using Attalos traps equipped with AI image recognition and GSM communication ;
- Integration with localized weather forecasting and pest phenology models via OptiSol.io ;
- Decision Support System (DSS) from OptiSol.io offering dynamic, plot-specific guidance for irrigation and spraying operations based on real-time and predictive analytics.

Baseline data from the 2023 season were compared with the 2024 season after the implementation of these technologies. The deployment of digital tools at Smyrnakis Winery followed a phased strategy designed to minimize risk and build internal capabilities. The precision irrigation system relied on a network of soil moisture sensors distributed across heterogeneous zones in the vineyard, complemented by automated flow meters that adjusted application rates in real time. The Attalos smart traps, developed in Greece, featured solar-powered imaging systems and wireless modules that transmitted photos of trapped insects to a central AI classifier hosted on the cloud. Identification of target species was automated using convolutional neural networks trained on regional pest datasets. Alerts were sent to vineyard managers when thresholds were exceeded. Meanwhile, OptiSol.io's DSS utilized not only pest phenology models but also integrated evapotranspiration data and hyperlocal weather forecasts to recommend ideal spraying and irrigation windows. The system was configured for daily updates and was accessible via mobile app to agronomists and field teams. Training was provided to ensure user familiarity and confidence. The baseline data was drawn from the 2023 growing season, during which traditional methods were used. The post-intervention assessment reflects performance during the 2024 season.

3. Results and Discussion

3.1. Irrigation Optimization

Metric	Standard practice	After Digitalization	Improvement (%)
Annual Water Consumption (m ³ /ha)	5,400	3,400	-37%
Grape Sugar Content (Brix)	21.5	23.0	+7%

3.2. Pest Management Efficiency

Metric	Standard practice	After Digitalization	Improvement (%)
Pesticide Application Frequency	10 sprays/plot	7 sprays/plot	-30%
Pesticide Cost in total	1357€/ha	918€/ha	-33.4%
Labor Hours for Monitoring and sprays (h/ha)	130	93.6	-28%

3.3. Overall Sustainability Gains

The combined effect of optimized irrigation and pest management practices led to improved resource efficiency, lower production costs, and enhanced crop quality, aligning with sustainable viticulture goals. In addition to quantitative improvements in resource use, the winery observed qualitative benefits that were not easily measurable. Grape quality assessments conducted by oenologists indicated more consistent sugar content, reduced incidence of fungal disease, and a narrower maturity window, allowing for more efficient harvesting. Field staff also reported improved clarity in daily decision-making, with fewer last-minute interventions. From a broader sustainability perspective, the digital system minimized tractor use (and therefore CO₂ emissions) by optimizing treatment timing. Wastewater generation declined due to better irrigation management, and community stakeholders recognized the reduced pesticide drift as a positive outcome. These gains collectively support the winery's commitment to ISO 14001 certification and position it for future ESG-related marketing advantages.

3.4. Strategic Imperatives for Digital Adoption

Despite the evident benefits, the adoption of digital technologies in viticulture faces multiple frictions, including financial constraints, lack of technical expertise, and resistance to change. To overcome these barriers and create strategic advantage, wineries must:

- Develop a Clear Digital Vision
- Invest in Training and Capacity Building
- Implement Incremental Integration
- Foster Organizational Flexibility
- Leverage Collaborative Networks

A proactive and well-articulated digital strategy enables wineries not only to improve operational efficiency but also to enhance their market competitiveness and resilience against climate and economic uncertainties. Creating a successful digital transition pathway involves more than acquiring technology—it requires aligning people, processes, and culture. Smyrnakis Winery emphasized internal communication and training as central pillars of the change process. Teams were consulted prior to tool deployment, and early adopters were tasked with

mentoring others. Regular feedback loops were established to refine usage protocols. Financially, the winery sought EU co-funding to subsidize capital expenditures, while opting for cloud-based solutions to avoid costly infrastructure investments. Long-term success was tied to leadership's willingness to reframe digitalization not as a risk but as a resilience strategy. For small and medium enterprises (SMEs), external advisory support—whether from universities, tech firms, or government extension services—can be crucial. McKinsey (2025) notes that large producers are three times more likely to invest in advanced precision tools than smaller peers. Addressing this imbalance through shared infrastructure models and co-ops could enhance digital inclusion across the sector.

4. The Role of the Human Factor

While digital technologies significantly augment vineyard management, it is ultimately the human factor that determines their effective application. Viticulturists, agronomists, and winery managers are responsible for interpreting data, making informed decisions, and adjusting practices to specific environmental and operational contexts. Human expertise remains irreplaceable in strategic judgment, ethical considerations, and quality assurance. Thus, digital tools should be seen as enablers that support, rather than substitute, human intelligence and experience in viticulture. Ultimately, technology is only as effective as the people who use it. While machine learning and automation offer new capabilities, they must be tempered by human context, judgment, and creativity. Agronomists interpret the output of predictive models by considering local soil variability, historic trends, and personal field experience. In the Smyrnakis case, weekly meetings among viticulturalists helped reconcile DSS recommendations with real-world anomalies, such as unexpected microclimatic shifts. Moreover, technology adoption has motivational implications. Staff felt more engaged and responsible when empowered with new tools and decision autonomy. This supports recent research in agricultural innovation, which emphasizes that socio-technical integration—rather than mere digitization—is key to enduring change. In this light, the role of continuous training and participatory system design cannot be overstated.

5. Conclusions

The experience of Smyrnakis Winery demonstrates that targeted digitalization can deliver measurable benefits in vineyard management. Implementing IoT-based monitoring, smart pest control, and AI-supported decision systems achieved significant reductions in water and pesticide usage while improving grape quality and operational efficiency. However, for broader adoption, wineries must strategically plan to overcome adoption barriers and build internal capabilities. Moreover, sustaining competitive advantage in digital viticulture fundamentally depends on empowering human actors,

whose critical thinking and experience guide the meaningful use of technology.

6. References

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