Nature & Science
November 2025, Vol. 7, Issue 11, pp. 37–43
DOI: https://doi.org/10.36719/2707-1146/62/37-43

The Impact of Modern Agrotechnical Practices Based on Intelligent Agriculture Systems on Plant Quality Indicators

Ali Muradli

Abstract. *Within the framework of agronomic approaches, digital tools such as GPS, drones, and high-resolution satellite imagery play a crucial role in the zonation of plantations and in the management of fields according to their microeconomic characteristics. Modern IoT-based smart gateway systems facilitate the collection of environmental data including solar radiation, temperature, relative humidity, and other factors through integrated ecological sensors and monitoring devices. By leveraging "EDGE Computing" technologies, these systems enable on-site preliminary processing of collected data, ensuring its rapid transmission via wireless communication and accelerating decision-making processes. Consequently, agricultural enterprises gain the capacity for more precise and flexible control over production processes. For the storage and processing of collected data, cloud-based storage solutions and virtual server infrastructures are employed. This technological framework allows for the analysis of large datasets, thereby supporting the comparative study of the growth environments of various crops, including grapevine varieties.*

Keywords: *ıntelligent agriculture, agronomic practices, GPS and drone technologies, fertigation, artificial intelligence, morphometric, photosynthetic*

Introduction

In the contemporary period, enhancing product quality in the agricultural sector and ensuring the sustainability of production emerge as key indicators of competitiveness (FAO, 2022; World Bank, 2021). To this end, alongside traditional agrotechnical measures, the application of intelligent agricultural systems has gained particular relevance (Wolfert et al., 2017). Approaches based on digital technologies, automated monitoring mechanisms, and analytical processing of data enable more precise regulation of plant growth and development stages. The quality attributes of plant-derived products are directly dependent on the effective planning of agrotechnical measures, accurate assessment of soil and climatic conditions, appropriate selection of crop varieties, and the implementation of vegetation and harvesting stages at optimal times (Liakos et al., 2018). In this context, modern intelligent systems and agrotechnical practices play a crucial role in the process of crop cultivation. However, despite the growing application of intelligent agricultural technologies, their integrated impact on the quality indicators of perennial crops under specific agro-ecological conditions has not been sufficiently investigated. Therefore, the present study aims to evaluate the effect of intelligent agricultural systems combined with modern agrotechnical measures on selected quality parameters of perennial plants. The findings of this research are expected to contribute to the optimization of sustainable agricultural practices and the improvement of product quality (FAO, 2022).

Azerbaijan Cooperation University, Master student, Baku, Azerbaijan
E-mail: muradli.eli53@gmail.com
Received: 25 August 2025; Accepted: 22 October 2025; Published online: 25 November 2025

Materials and Methods

Within the framework of agrotechnical approaches, digital tools such as GPS technologies, unmanned aerial vehicles (drones), and high-resolution satellite imagery play a significant role in the zoning of plantations and the management of agricultural fields according to their micro-environmental characteristics. Modern IoT-based smart gateway systems enable the collection of data on solar radiation, temperature, relative humidity, and other environmental parameters through the use of ecological sensors and monitoring equipment (Fig. 1) (Adamu, 2024).

Through the implementation of edge computing technologies, these systems perform preliminary on-site data processing, thereby facilitating the rapid wireless transmission of information and accelerating decision-making processes. As a result, more flexible and precise control over production processes is achieved in farming operations.

For the storage and processing of the collected data, cloud-based data storage solutions and virtual server infrastructures are employed (Fig. 2). This infrastructure enables large-scale data analysis, allowing for comparative assessment of the growth environments of various crops, including different grapevine varieties. Topographic and agro-ecological mapping of vineyards is conducted, enabling detailed analyses of key parameters such as soil structure, moisture levels, temperature variations, and the spatial distribution of solar radiation (GIGABYTE, 2019).

Figure 1.

Figure 2.

Within the framework of the development of modern agricultural technologies, the "GIGABYTE Smart Farming System – IoT Gateway", and particularly its component "IoT Eco Box", plays a significant role in ensuring optimal growth conditions for plants (Fig. 3). This system is equipped with integrated sensors and actuators that enable real-time monitoring and control of environmental factors. Through artificial intelligence–based sensors embedded in the "IoT Eco Box" system, key ecological parameters such as light intensity, humidity, and temperature are continuously measured (GIGABYTE, 2019).

Each sensor is linked to specific operational processes; for instance, the light sensor regulates the lighting system, while the temperature sensor controls the activation of ventilation units. Communication between the sensors and the "GIGABYTE IoT Gateway" is established via the ZigBee protocol, and the collected data are transmitted to a cloud-based database through the internet. The system can be remotely managed via a mobile application or a computer interface. Users are able to monitor environmental parameters in real time, access live camera feeds, and perform relevant operational tasks. These functionalities enable farmers to supervise plant growth processes from any location and at any time. Consequently, the "GIGABYTE Smart Farming System – IoT Eco Box" technology contributes not only to the improvement of product quality but also to the promotion of environmentally friendly and safe food production that supports a healthy lifestyle (Fig. 4).

Equipped with artificial intelligence capabilities, the system represents not only a technological innovation but also a key driver of sustainable development in the agricultural sector (Consumer Technology Association 2020 CES.)

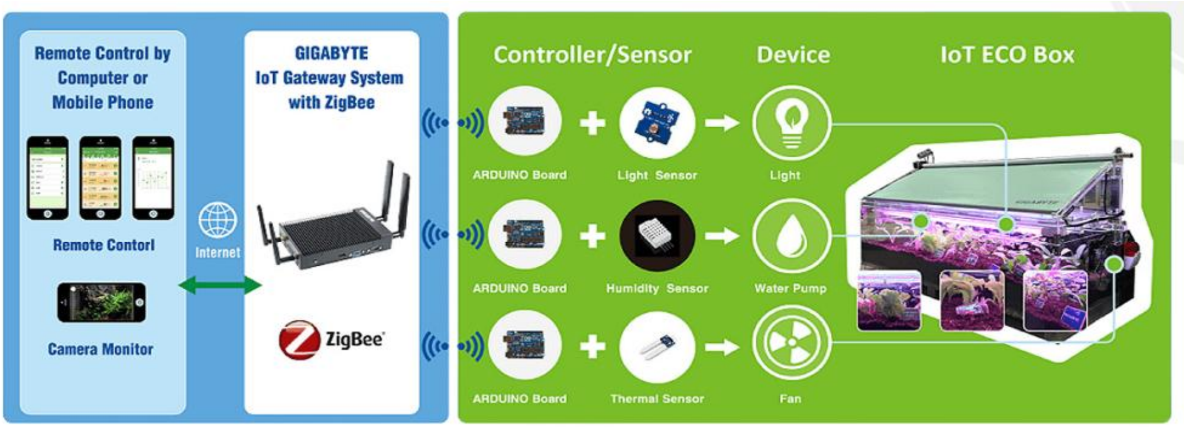

Figure 3.

Figure 4. CES 2020 Exhibition of Artificial Intelligence, Cloud Solutions, and Smart Applications

Results

The results of the conducted studies indicate that the agrotechnical care measures applied during 2024–2025 had a positive impact on both the morphometric and technological parameters of the "Madrasa" and "Khindoghni" grape varieties. In particular, an increase in berry and cluster weight was observed for both varieties in 2025. In this regard, the "Khindoghni" variety demonstrated superior performance, with an average cluster weight of 159 g and a berry weight of 1.8 g, surpassing the "Madrasa" variety. Analysis of technological parameters revealed that the "Khindoghni" variety maintained a stable sugar content of 16.4% compared to the previous year, while titratable acidity showed a slight decrease. This trend can be attributed to the relatively earlier achievement of technological ripeness under the regional warming conditions. For the "Madrasa" variety, although an increase in berry and cluster size was noted in 2025, the sugar content remained stable at 19.9%, while acidity exhibited a declining tendency. These observations indicate that the variety possesses relative biochemical stability and exhibits moderate sensitivity to climatic factors (Table 1).

Overall, the results demonstrate that agrotechnical approaches integrated with sensor technologies, digital monitoring, and drip and fertigation irrigation systems have a tangible and positive effect on enhancing both the production and quality potential of agriculture.

Table 1.

Indicators	2024 Madrasa	2025 Madrasa	2025 Khindoghni
Cluster weight, g	256	271	355
Cluster width, cm	13.5	14	11
Cluster length, cm	19	18	16
Number of berries per cluster, pcs	201	152	223
Berry weight, g	2.31	2.2	2.7
Berry width, mm	11	14.3	15.9
Berry length, mm	11	14.6	16.6
Weight of 100 berries, g	134	189	175
Volume of 100 berries, ml/cm³	195	275	270
Juice yield per cluster, ml	110	147	153
Juice yield per 100 g of berries, ml	47–59	60–105	45–81
Seed weight, g	12	15	13
Residual pulp and seed weight, g	98	81	143
Weight of 100 seeds, g	5	6	4
Sugar content, %	20.4	19.9	16.4
Titratable acidity, g/dm³	6.9	11.2	9.09

The application of soil and climate sensors enables the collection and processing of data in real time. Based on this information, irrigation and fertilization activities can be carried out on a demand-driven basis and at optimal dosages, thereby ensuring both the efficient use of resources and stress-free plant growth. According to records obtained using the PIX4Dfields software, areas within vineyards exhibiting lower photosynthetic activity (marked in blue) have been identified (Fig. 5) (Guebsi et al., 2024). Additionally, the DJI Mavic 3 Multispectral drone represents a modern unmanned aerial technology utilized for capturing high-resolution imagery of vineyards (Fig. 6) (Pix4D 2020 July 22)

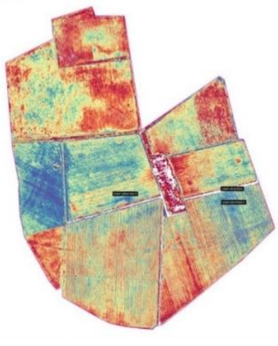

Figure 5.

Figure 6.

Among agrotechnical practices, canopy management holds particular importance. Through leaf thinning and proper formation of shoots, the exposure of grape clusters to sunlight and the level of ventilation are enhanced (Van Leeuwen & Seguin, 2006). This, in turn, promotes increased photosynthetic activity in the berries, consequently facilitating the accumulation of sugars and the intensified synthesis of anthocyanins (Reynolds, 2010). High concentrations of anthocyanins serve as one of the key quality indicators of grape-derived products, influencing both color intensity and phenolic content (Bably & Rana, 2025).

Regulation of the irrigation regime is also a critical factor in maintaining and improving fruit quality in vineyards. Irrigation should be conducted according to the phenological stages of the plants: typically once every 7–10 days during early developmental stages, and 4–5 times throughout the vegetative period during fruit set and ripening stages. In this context, drip irrigation ensures the efficient use of water resources, maintains soil moisture balance, and supports optimal root system development.

Fertilization practices directly affect the biochemical composition of plants. Periodic soil loosening, weed removal, and structural improvement throughout the vegetative period expand the nutrient availability to the root system. Applying nitrogen-based fertilizers in early spring and phosphorus- and potassium-based fertilizers in autumn helps maintain an optimal balance between vegetative growth and the formation of generative organs. Moreover, pruning is an essential agrotechnical practice for the proper formation of grapevine shoots and regulation of yield. The application of both short and long pruning methods facilitates optimization of shoot load, enhances the quality attributes of berries, and ensures uniformity of the harvest.

The application of subsurface (injection) irrigation and fertigation technologies in the Ganja-Dashkasan economic region, as well as in other areas with high viticultural potential, has demonstrated significant results. Fertigation, which involves the direct delivery of fertilizers to the plant root zone through irrigation water, ensures substantial savings in both water and agrochemical resources. For comparison, traditional irrigation methods consume 2–3 times more water and require approximately 60% more fertilizers than subsurface irrigation systems (Mirsalahova, 2024).

The automation of irrigation and fertilization processes is carried out through modern sensors and transmitters, allowing for more precise and sustainable management of agrotechnical practices. Observations conducted in experimental plots indicate that the application of these technologies has positively influenced yield. For instance, grape varieties “Madrasa” and “Khindoghni” exhibited yields of 183–195 centners per hectare, reflecting an approximate 20–25% increase in productivity. In addition, economic efficiency has significantly improved. The implementation of fertigation and injection irrigation technologies enabled a net income of 245.7 thousand AZN per hectare. Furthermore, these technologies help prevent soil erosion, minimize water losses, and reduce the environmental impact of viticultural practices (Mirsalahova, 2024).

Discussion

The findings of this study demonstrate that the integration of intelligent agriculture systems with modern agrotechnical practices has a significant and measurable impact on plant quality and productivity, particularly in perennial crops such as grapevine. Improvements in morphometric, biochemical, and yield parameters confirm that digital monitoring and sensor-based decision-making enhance the precision and efficiency of crop management. A key outcome of the research is the 20–25% increase in yield and improved berry quality observed in the “Madrasa” and “Khindoghni” grape varieties. These results are consistent with previous studies indicating that sensor-driven irrigation and fertigation optimize water and nutrient use, reduce abiotic stress, and support balanced vegetative and generative growth. The higher productivity recorded in experimental plots is primarily attributed to demand-based irrigation scheduling and precise nutrient delivery enabled by real-time soil and climate monitoring. Increases in cluster and berry weight indicate that optimized canopy management, irrigation regulation, and nutrient availability collectively enhanced photosynthetic efficiency and assimilate distribution.

The use of multispectral drone imagery and NDVI-based analysis enabled early identification of zones with reduced photosynthetic activity, allowing targeted interventions that represent a clear advantage over uniform management practices.

The relative stability of sugar content and titratable acidity further demonstrates the effectiveness of intelligent agrotechnical management. Differences observed between varieties confirm that crop response to digitalized management systems is genotype-dependent. Fertigation and subsurface irrigation significantly improved resource-use efficiency, reducing water and fertilizer consumption while maintaining or enhancing product quality, in line with sustainability objectives.

From an economic perspective, the reported net income of 245.7 thousand AZN per hectare highlights the practical feasibility of intelligent agriculture technologies. Reduced input costs, lower water losses, and improved yield stability contribute to overall economic sustainability. Nevertheless, the study underscores the need for long-term monitoring and multi-year datasets to evaluate the stability of quality indicators under changing climatic conditions. Overall, the results confirm that intelligent agriculture systems integrated with scientifically grounded agrotechnical practices provide an effective and scalable approach for improving crop quality, resource efficiency, and economic performance in modern agriculture.

Conclusion

The conducted study demonstrates that the application of modern agrotechnical practices based on intelligent agriculture systems is highly effective in improving productivity and quality indicators across agricultural crops. The integration of IoT sensors, digital monitoring, drone technologies, and data-driven management enables irrigation, fertilization, and cultivation practices to be implemented in accordance with the actual needs of plants. The results indicate that this approach ensures efficient resource utilization, reduces plant stress factors, and enhances morphometric and biochemical quality parameters. Moreover, the adoption of intelligent agricultural systems contributes to lower production costs, increased economic efficiency, and reduced environmental impact. Overall, intelligent agriculture technologies represent a promising and sustainable approach for ensuring resilient agricultural production systems and improving product quality in modern agriculture.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Adamu, I. A. (2024). Study based artificial intelligence (A.I.) agriculture: A review. *Asian Journal of Advanced Research and Reports, 18*(8), 203–210. https://doi.org/10.9734/ajarr/2024/v18i8722
2. Bably, K., & Rana, C. (2025). Artificial intelligence in agriculture: A comprehensive review of applications, challenges, and future prospects. *International Journal of Science and Innovation*. https://doi.org/10.70849/IJSCI
3. FAO. (2022). *The future of food and agriculture – Drivers and triggers for transformation*. Food and Agriculture Organization of the United Nations. https://www.fao.org

4. GIGABYTE. (2019, December 13). A smarter solution to fight agriculture industry change. GIGABYTE Global. https://www.gigabyte.com/Article/a-smarter-solution-to-fight-agriculture-industry-change
5. Guebsi, R., Mami, S., & Chokmani, K. (2024). Drones in precision agriculture: A comprehensive review of applications, technologies, and challenges. *Drones, 8*(11), 686. https://doi.org/10.3390/drones8110686
6. Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors, 18*(8), 2674. https://doi.org/10.3390/s18082674
7. Mirsalahova, L. M. (2024). Üzüm plantasiyalarının becərilməsində tətbiq olunan fertirriqasiya texnologiyasının təkmilləşdirilməsi [Improvement of fertigation technology applied in the cultivation of grape plantations] (PhD dissertation abstract). https://aak.gov.az/upload/dissertasion/aqrar_elml_r/2024_AVTOREFERAT_AZ%C6%8FRBAYCAN_RESPUBL%C4%B0KASI_-A5.pdf
8. Reynolds, A. G. (Ed.). (2010). *Managing Wine Quality: Viticulture and Wine Quality*. Woodhead Publishing. https://www.researchgate.net/publication/295747582_Managing_Wine_Quality_Viticulture_and_Wine_Quality
9. Van Leeuwen, C., & Seguin, G. (2006). The concept of terroir in viticulture. *Journal of Wine Research, 17*(1).
10. Vineyard monitoring with multispectral imagery. (2020, July 22). Pix4D. https://www.pix4d.com/blog/vineyard-monitoring-multispectral-imagery
11. Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming – A review. *Agricultural Systems, 153*, 69–80. https://doi.org/10.1016/j.agsy.2017.01.023
12. World Bank. (2021). *Smart agriculture for sustainable food systems*. https://www.worldbank.org