Digital transformation in Agriculture: Navigating challenges and opportunities for sustainable development⋆

Gavriela Asiminari**,†*, Dimitrios Kateris*†* and Dionysis Bochtis*†*

¹ Institute for Bio-Economy and Agri-Technology (IBO), Centre for Research and Technology-Hellas (CERTH), 6ᵗʰ km Charilaou-Thermi Rd., 57001 Thessaloniki, Greece

Abstract

The agricultural sector is under increasing pressure from resource depletion, climate change, and the demand for sustainable practices, necessitating innovative solutions to ensure food security and economic viability. Digital agriculture, aligned with the Sustainable Development Goals (SDGs), offers significant opportunities for enhancing productivity, market access, social inclusion, and environmental management. This study examines the implementation of high-tech services in Greek agriculture through the DigiAgriFood project. Utilizing tools like the Digital Maturity Assessment Tool (DMAT), the project aims to guide stakeholders toward comprehensive digital transformation across the agri-food value chain. Results indicate that technology adoption varies by demographic, educational, and organizational factors, with younger, more educated farmers and those with larger, urban-adjacent farms more likely to embrace innovation.

Keywords

Digital Agriculture, sustainability, Digital Maturity Assessment Tool, Information and Communication Technology

1. Introduction

Amidst the evolving landscape of agriculture, there exists an urgent imperative to address the multifaceted challenges confronting the sector while striving for efficient and sustainable practices. The agricultural industry, vital for sustaining regional economies and ensuring food security, faces mounting pressures ranging from the depletion of natural resources to the impacts of climate change. In this context, the optimization of agricultural practices and the entrance of new technologies assume paramount importance, necessitating a simultaneous reduction in environmental burdens. Aligned with the Sustainable Development Goals (SDGs), digital agriculture presents a transformative opportunity to unlock economic, social, and environmental benefits. From enhancing agricultural productivity and market opportunities to fostering social inclusivity and environmental management, the potential impact of digitalization on the agri-food sector is profound. However, the realization of this potential is contingent upon overcoming various challenges, particularly in rural areas, where access to technology and infrastructure may be limited. The introduction of Information and Communication Technology (ICT) in agriculture, though supported by policymakers globally, necessitates a comprehensive and systematic approach to ensure equitable access and meaningful adoption.

This work presents the results of the application of high-tech services in the Greek agriculture ecosystem. In more detail, high-tech services are provided by the partners of the DigiAgriFood

project to Greek beneficiaries in five regions of Greece. This action aims to empower the digital and green transformation of the entire spectrum of the agri-food value chain with immediate benefits for citizens, small and medium-sized enterprises (SMEs) and public sector in the Regions of Eastern Macedonia and Thrace, Central Macedonia, Western Macedonia, Epirus and Thessaly. It also presents the application of a Digital Maturity Assessment Tool (DMAT) enabling stakeholders to identify strengths and weaknesses, prioritize resources effectively, and chart a clear path towards comprehensive digital transformation [1].
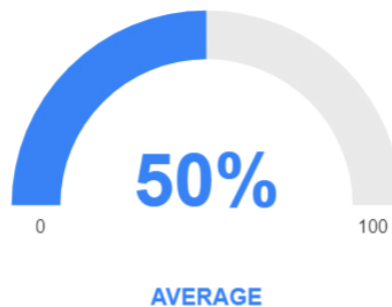
2. Digital maturity assessment

This section presents the application of the digital maturity assessment in a use case, providing valuable insights gleaned from the application of the digital maturity evaluation framework. This use case concerns a micro-enterprise, comprising 1-9 employees, situated in north-eastern Greece. Specializing in agricultural biotechnology and food biotechnology, the enterprise's staff engaged in rigorous testing of cutting-edge digital solutions and technologies. The enterprise explored a variety of services, including: a) CO_2 monitoring tool; b) Insect traps; c) Conductivity mapping using EM38; d) UAV field monitoring; e) Weather forecast; and f) Variable rate application. Through this testing phase, the enterprise gained valuable insights into the practical applications and potential benefits of these advanced agricultural technologies.

2.1. Results regarding each direction

2.1.1. Digital Business Strategy

Figure 1 illustrates the score of the use case regarding the digital business strategy dimension, which was 50%.
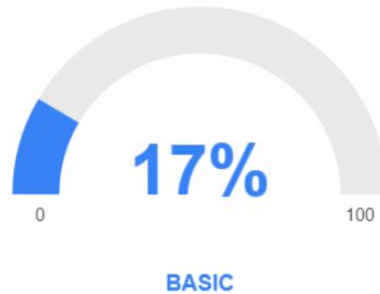

Figure 1: The score of use case regarding the digital business strategy dimension of digital maturity assessment tool.

Companies at this maturity level are in the early stages of integrating business strategy and investments for digitalization, presenting significant opportunities for growth. While the SME has an initial plan, resources, and receptive management, there is a need to increase commitment and effort to accelerate digital transformation. Some investments in digital technologies have been made to modernize operations, such as product/service design and project planning and management. However, the SME could further benefit from automating key aspects of its operations, including production and customer services, and by adopting advanced digital technologies in areas like logistics, marketing, sales, purchasing, procurement, and advanced security. The SME has a foundational IT infrastructure to support basic digitalization efforts and some IT-skilled personnel, although their expertise is somewhat limited. Expanding this capability and focusing on advanced digital tools could unlock significant efficiency and growth potential.

2.1.2. Digital Readiness

Figure 2 shows the score of use case regarding the digital readiness dimension, which was 17%. Companies at this maturity level are in the early stages of digital readiness, having adopted a small number of mainstream digital technologies with minimal business applications. There remains significant untapped potential for the SME to enhance internal productivity and improve customer service by leveraging both mainstream and advanced digital technologies.
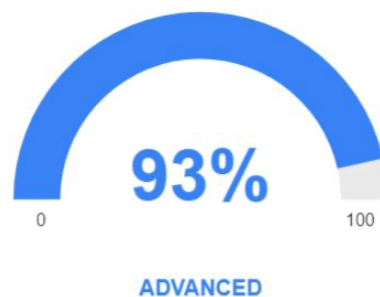

Figure 2: The score of use case regarding the digital readiness dimension of digital maturity assessment tool.

This SME would benefit a lot if it considers implementing a number of digital technologies that could boost its sales (i.e., e-commerce, e-marketing, etc.), improve business efficiency (Information Management Systems), improve customer satisfaction (web based tools to communicate with customers), upgrade personnel skills/increase personnel satisfaction and retention (remote business collaboration (teleworking, virtual learning, etc.)).

2.1.3. Human-Centric Digitalization

Figure 3 displays the score of use case regarding the human-centric digitalization dimension, which was 93%.

Figure 3: The score of use case regarding the human-centric digitalization dimension of digital maturity assessment tool.

Companies at this maturity level are highly advanced in fostering human-centric digitalization, particularly in developing digital skills. A robust training plan is in place to reskill and upskill staff, actively monitored and implemented. Employees regularly receive comprehensive training in advanced technologies and digital skills, tailored to their specific roles and needs. This training is often complemented by opportunities for experimentation and the autonomy to make decisions or innovate.

The company provides career development pathways for digitally skilled employees and ensures their active involvement in shaping the company's strategy. Job roles have been redesigned to align with the demands of the digital era, supported by innovative, digitally enhanced working

environments and a dedicated digital support service. Overall, staff possess advanced digital skills, ensuring they are well-prepared for the challenges of the digital age.

2.1.4. Data Governance

Figure 4 presents the score of use case regarding the data governance dimension, which was 45%. Companies at this maturity level tend to be in an early stage with regard to data management (storage, organization, access, exploitation, and security of data). The owners of this SME should adopt and closely monitor a well-defined data management policy or plan. While some data is stored in a structured digital format, primarily for administrative and financial processes, the integration and exchange of data across different applications remain limited. As a result, data is not fully utilized to enhance business operations or inform decision-making to its full potential. Additionally, while the SME employs mainstream cybersecurity tools, it lacks a comprehensive and concrete cybersecurity policy to ensure robust data protection.
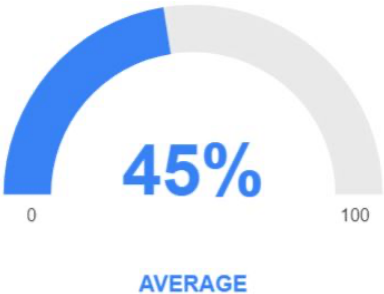
Figure 4: The score of use case regarding the data governance dimension of digital maturity assessment tool.

An SME in this range possesses significant untapped potential that can be leveraged through the implementation of a robust data management strategy, including cybersecurity measures. By allocating additional resources, the company could unlock the advantages of having its data and processes digitized and integrated via interoperable systems, enabling seamless access from various devices and locations.

2.1.5. Automation & Artificial Intelligence

Figure 5 shows the score of use case regarding the automation and artificial intelligence dimension, which was 20%.
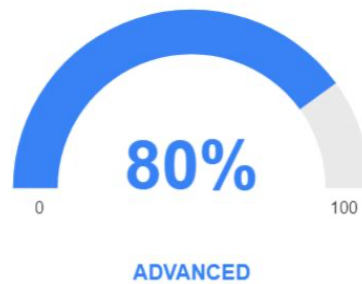

Figure 5: The score of use case regarding the automation and artificial intelligence dimension of digital maturity assessment tool.

Companies at this maturity level are in the very early stages of adopting automation and intelligence through digital integration into business processes. No tasks have been automated at this point, and neither AI nor automation has been utilized to support business, commercial, or operational activities.

2.1.6. Green Digitalization

Figure 6 shows the score of use case regarding the green digitalization dimension, which was 80%. Companies at this stage of maturity are highly advanced in their approach to green digitalization. Environmental considerations are integrated into most digitalization decisions, including those related to procurement, energy consumption, and resource reuse. Digital technologies play a key role in enabling sustainable business practices, such as adopting eco-friendly business models, optimizing product lifecycles, designing sustainable products, streamlining production processes, and enhancing service delivery. These technologies are instrumental in reducing emissions, minimizing pollution, and managing waste. Additionally, they facilitate the efficient use of raw materials and the eco-friendly delivery of products to customers. Overall, digital solutions are extensively leveraged to significantly reduce the organization's environmental footprint, including waste reduction and energy efficiency improvements.


Figure 6: The score of use case regarding the green digitalization dimension of digital maturity assessment tool.

3. Overall results

The results show that the adoption of innovative technologies in agriculture is influenced by factors like farmer age, education, farm characteristics, and external motivations. Older farmers tend to be more conservative due to traditional practices and limited tech familiarity, while younger farmers are more open to new technologies. Higher education levels and participation in agricultural organizations also support technology adoption by providing access to resources and information. Farm size, location, and external factors like financial considerations and social influences further impact adoption rates, suggesting the need for targeted support to encourage wider technology use.

A spider chart illustrating the scores across the six investigated dimensions (a period within six months before the commencement of EDIH support) is provided in

Figure 7a. Subsequently, a final score is calculated as an average from the scores that was obtained over the six dimensions of the submitted digital maturity assessment questionnaire, namely: i) Digital Business Strategy; ii) Digital Readiness; iii) Human-centric digitalization; iv) Data Management; v) Automation and Intelligence; and vi) Green Digitalization. Concerning the present SME, the calculated score was equal to 51%, as can be seen in Figure 7b.

| | (a) | (b) |
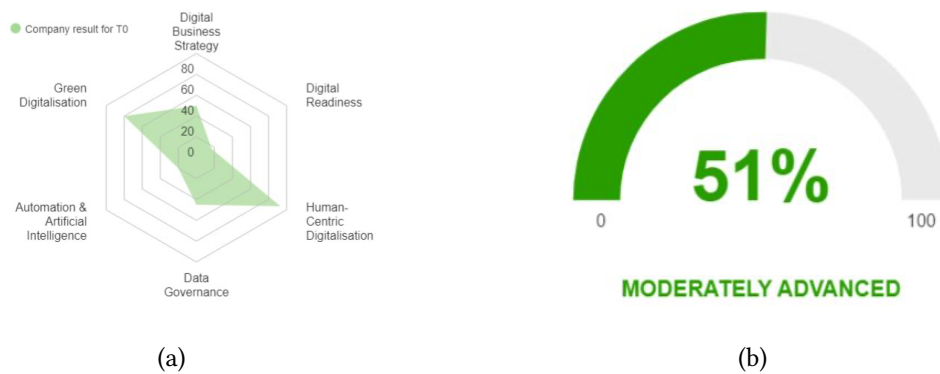
Figure 7: (a) Spider chart summarizing the score of each of the six investigated dimensions (a point of time not longer than 6 months prior to EDIH support start) and (b) The average score representing a moderately advanced stage of the digital transformation process of the present SME.

This average score shows that the organization is at a moderately advanced stage of digital transformation, benefiting from mainstream digital technologies and, to a lesser extent, some advanced tools. While progress has been made, targeted investments in digital technologies and skills could further enhance competitiveness, resilience, and sustainability. Current investments cover a wide range of business operations, but there is room to improve preparedness for more sophisticated solutions. Although most mainstream technologies are in use, there is untapped potential in adopting more advanced and disruptive technologies.

The workforce has strong digital skills, but to advance further, the organization needs a well-planned training program and IT specialists. Encouraging all levels of management and staff to embrace advanced digital solutions will be key to overcoming resistance to change. The organization's data management and security are strong, but it could benefit from digital technologies that enhance business intelligence to stay ahead of competitors. Adopting more ICT technologies could also help reduce the environmental footprint and improve sustainability. Additionally, selecting and using more environmentally friendly digital products (like IT equipment) would further support sustainability goals. Investing in digitalization will elevate the organization's digital maturity, giving it a competitive edge in its region and beyond.

4. Comparison with other enterprises

The bar chart in Figure 8 provides a comparative analysis of the digital maturity level of the SME in question, operating in agricultural biotechnology and food biotechnology, with other enterprises of similar size across the European Union (EU). The scores are represented on a scale from 0% to 100%, where 0% indicates a lack of digital maturity, and 100% signifies leadership in digital transformation within the EU.
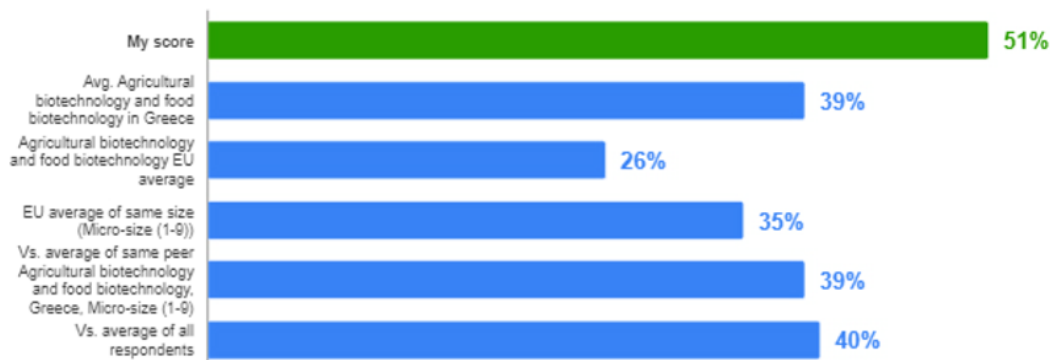
Figure 8: Bar chart depicting the comparison of the average score of the user in question with other enterprises of the same size or country/EU.

The SME's digital maturity score stands at 51%, indicating a moderately advanced stage of digital transformation. This is significantly higher than the average score of 39% for agricultural biotechnology and food biotechnology enterprises in Greece, and far above the EU average of 26%. When compared to similar-sized companies, the SME's score of 51% exceeds the average of 35%.

These results highlight the SME's strong position in terms of digital maturity, both locally and internationally, within the agricultural biotechnology and food biotechnology sectors. However, despite outperforming industry averages, there is still room for further progress. Continued investment in digital capabilities, process optimization, and emerging technologies will enhance its competitiveness and drive further digital transformation within the sector.

Acknowledgements

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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