A systematic review of the drivers of agriculture 4.0 technologies in the agri-food system

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Abstract

The integration of Agriculture 4.0 technologies—such as AI, robotics, IoT, machine learning, and drones—into agri-food systems is increasingly essential for addressing global challenges related to food security, sustainability, and productivity. However, the process of adoption faces several challenges, including the rapid pace of technological advancements and the need for specialized skills to effectively integrate these innovations. Identifying the key factors that drive the adoption of these technologies is essential for developing the necessary infrastructure and capabilities for their successful implementation. This study addresses this need by identifying the primary drivers behind the adoption of Agriculture 4.0 technologies in the agri-food system. A Systematic Literature Review (SLR) was conducted, analyzing 70 articles from reputable sources such as Science Direct and Web of Science, based on strict inclusion and exclusion criteria. The identified drivers were grouped into five categories: social, technological, political, economic, and environmental. These drivers encompass various factors—ranging from human behavior to environmental considerations—that influence the decision-making process regarding technology adoption. The insights derived from this analysis offer valuable guidance for both public and private sector stakeholders, enabling them to create targeted policies, investment strategies, and collaborative initiatives to accelerate the adoption of Agriculture 4.0 technologies. By focusing on these drivers, this study contributes to the ongoing efforts to transform the global agri-food system through the integration of advanced technologies, ensuring greater sustainability, efficiency, and food security.

Keywords: Digital Transformation; Innovation; Enablers; Agri-food ecosystem.

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1. Introduction

Agri-food systems play a pivotal role in ensuring food security, promoting sustainability, and supporting human nutrition, but they increasingly face complex and interrelated challenges, including climate change, social inequalities, and post-pandemic effects (Walls et al., 2019). These combined threats raise concerns about a potential global food crisis. Agriculture 4.0—marked by the use of AI, robotics, and digital tools—has emerged in this sector as a promising response to increase productivity, sustainability, and resilience (Trendov et al., 2019; Eastwood et al., 2021). However, adoption remains fragmented and varies by region and context. Most existing studies focus on barriers, while few explore the enablers that foster the uptake of these technologies (Silveira et al., 2021). This review addresses that gap by identifying and organizing the main drivers behind the adoption of Agriculture 4.0 technologies. The findings offer actionable insights that can support strategic planning and policy development, ultimately contributing to more inclusive, scalable, and effective digital transformations in agri-food systems.

2. Methods

This study conducted a Systematic Literature Review (SLR) to explore the drivers influencing the adoption of Agriculture 4.0 technologies in the agri-food system, adhering to the PRISMA protocol to ensure methodological rigor, transparency, and replicability (Denyer; Tranfield, 2009; Moher et al., 2010). The search strategy was based on three groups of carefully selected keywords—related to Agriculture 4.0 concepts, implementation drivers, and adoption processes—applied across two comprehensive and reliable scientific databases: Science Direct and Web of Science. After an initial retrieval of 1.336 records, duplicates were removed, and strict inclusion and exclusion criteria were applied regarding publication date (2020–2024), language (English), document type (peer-reviewed articles), and relevance to the agricultural sciences and engineering. Screening and content analysis were carried out by two independent reviewers using structured evaluation protocols, reducing the dataset to a final sample of 70 articles. The entire process followed a transparent and reproducible workflow, contributing to a robust understanding of the academic landscape surrounding Agriculture 4.0 in the agri-food sector.

3. Results and Discussion

No prior research has comprehensively mapped or classified the key elements that enable the adoption of Agriculture 4.0 technologies within agri-food systems. This SLR identified 20 core drivers, organized into five clusters: technological, economic, political, social, and environmental. Among these, social drivers were the most frequently cited, followed by technological and political ones. The most recurrent drivers included D1 – Connectivity and Digital Integration, D14 – Continuing Education and Training, D15 – Cooperation and Collaboration Networks, and D3 – Usability and Functionality. Figures 1 through 5 below illustrate how these drivers are distributed across the clusters identified in this review.

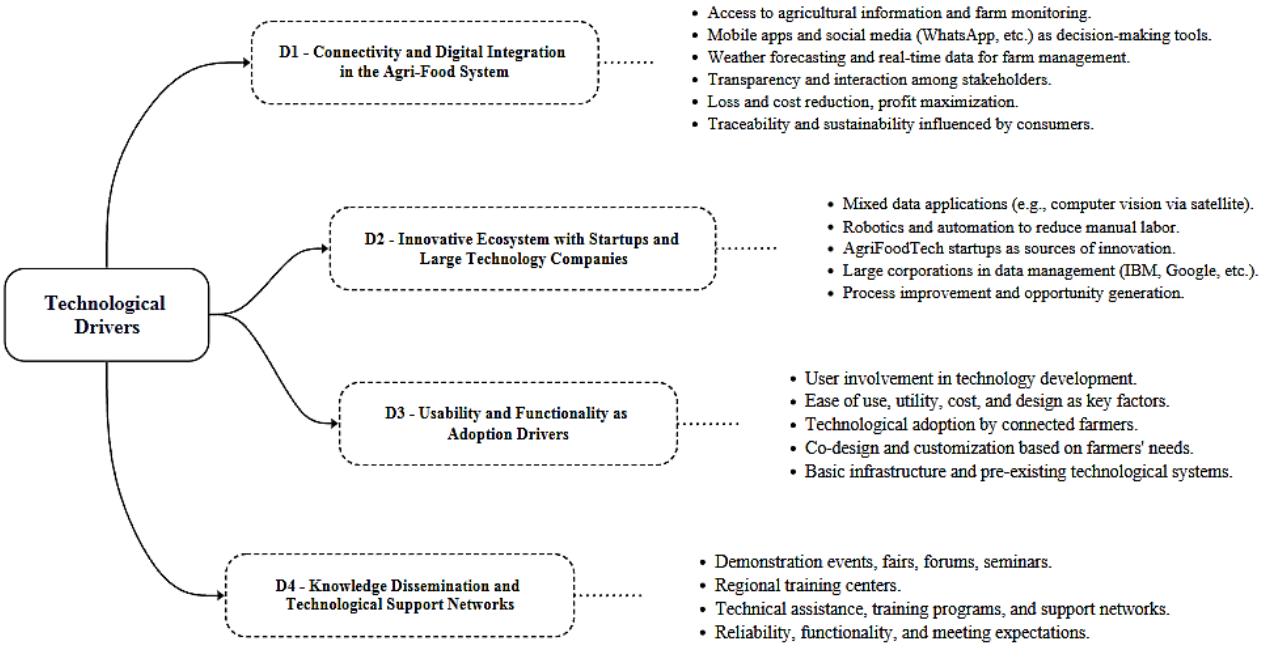

Figure 1. Technological drivers of agriculture 4.0.

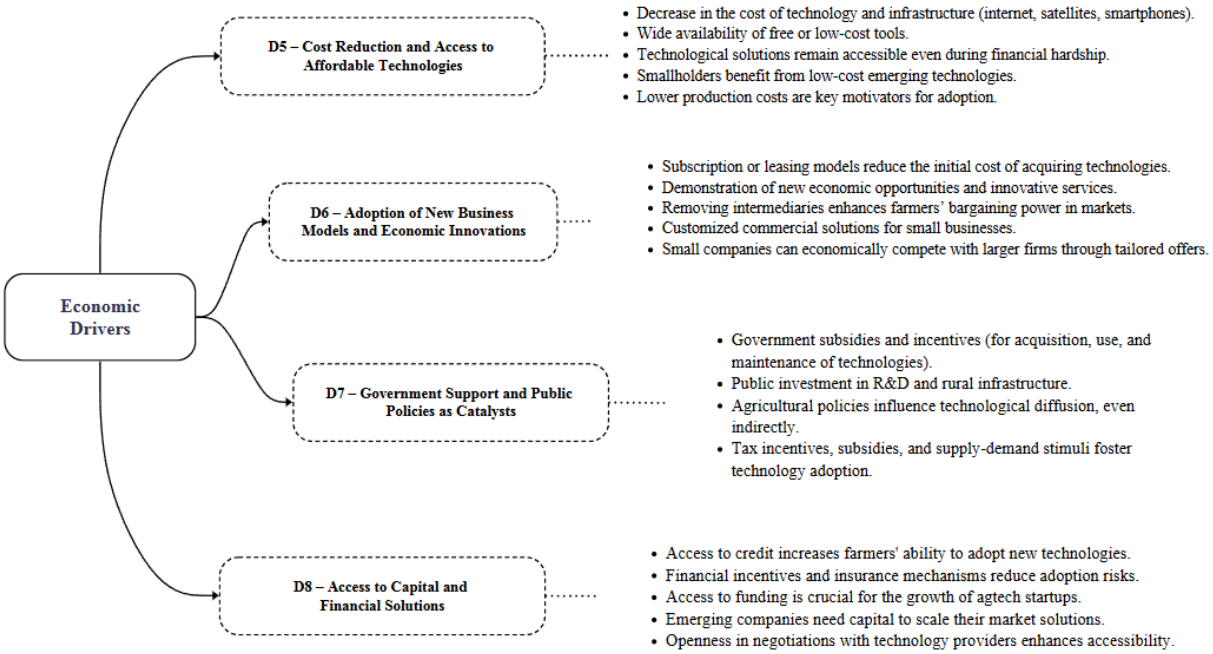

Figure 2. Economic drivers of agriculture 4.0.

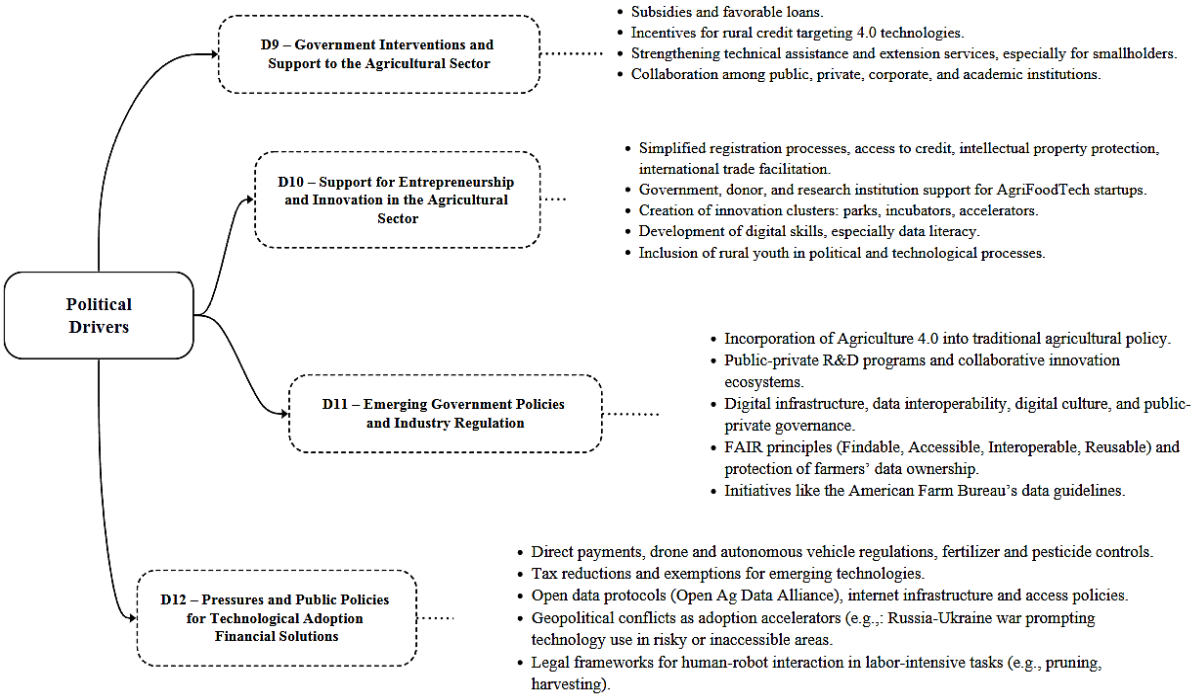

Figure 3. Political drivers of agriculture 4.0.

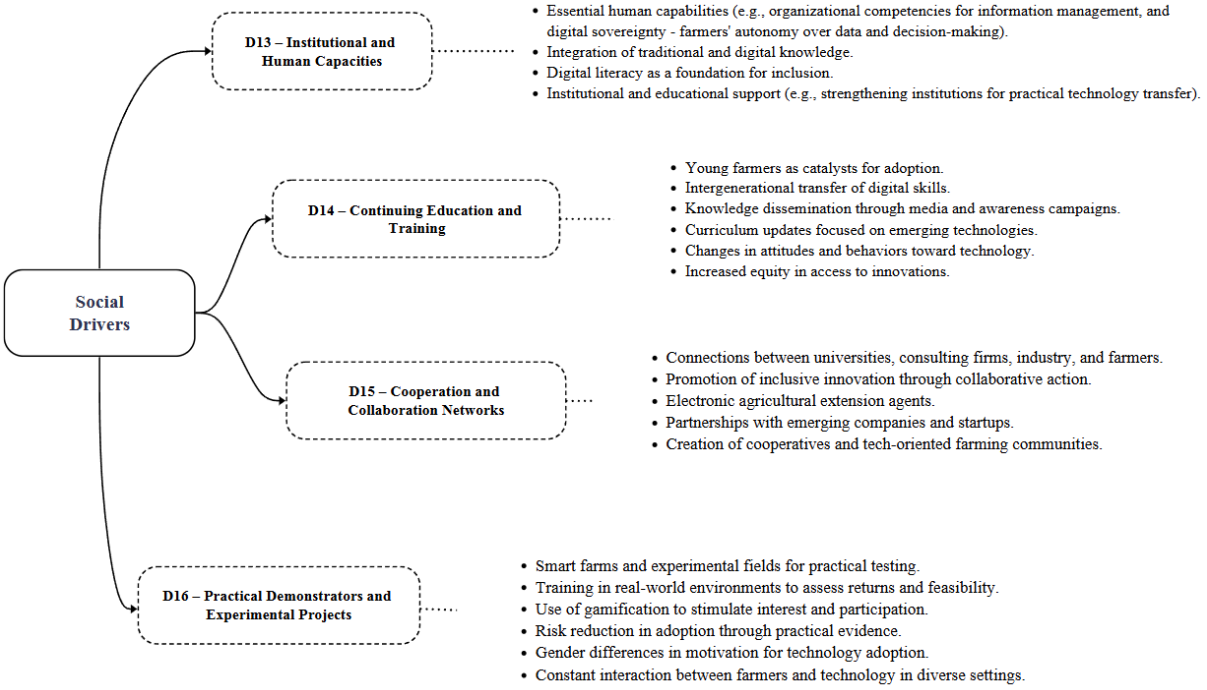

Figure 4. Social drivers of agriculture 4.0.

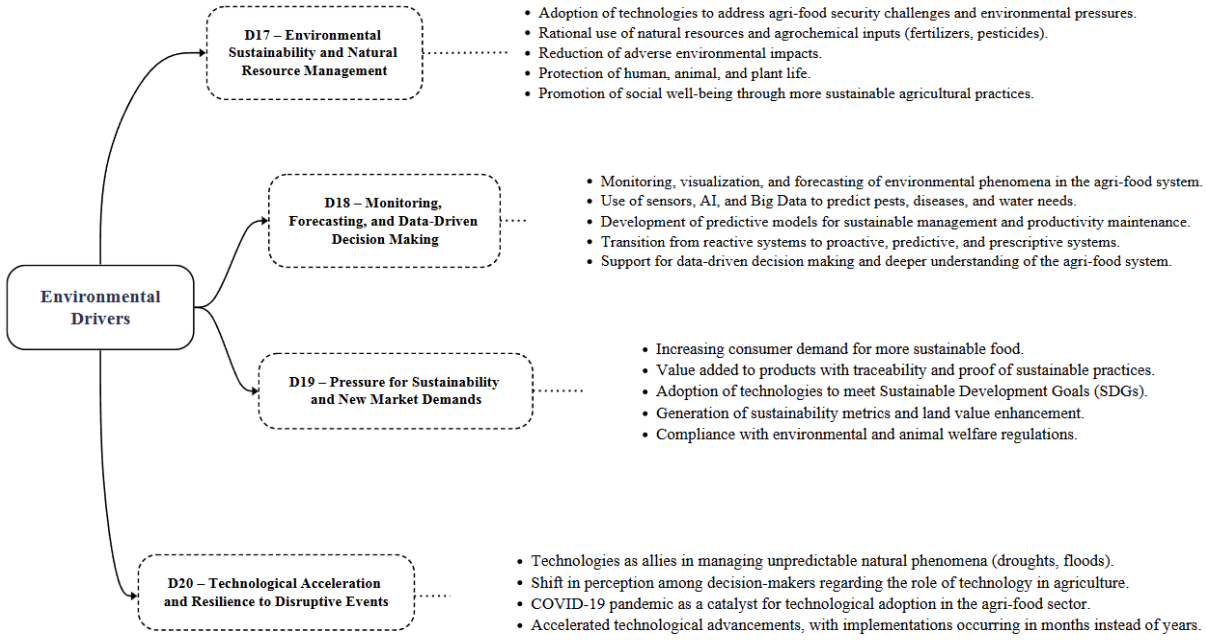

Figure 5. Environmental drivers of agriculture 4.0.

4. Conclusion

The drivers of Agriculture 4.0 technologies in the agri-food system represent a rapidly growing field of academic research. This study, through a Systematic Literature Review (SLR), identified and analyzed the primary factors driving the adoption of these technologies. The results provide a comprehensive understanding of the key drivers, which are categorized into five clusters: technological, economic, social, political, and environmental. Among these, the social cluster emerged as the most significant, followed by technological, political, economic, and environmental factors. This research highlights the importance of these drivers in shaping the adoption of Agriculture 4.0 technologies at global, national, and local levels. It offers valuable insights for policymakers, private investors, and industry stakeholders, helping to inform decisions and strategies aimed at accelerating the widespread adoption of these technologies. The findings contribute to the theoretical understanding of the agri-food system's transformation and its role in the sustainable development of global food systems.

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