

DIGITAL TRANSFORMATION IN AGRICULTURE: A COMPARATIVE ANALYSIS OF HUNGARY, ROMANIA AND GREECE AND THE ROLE OF COMPETENCE PROFILING IN THE AGRITECH MANAGER FRAMEWORK

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Abstract

This paper examines the digital transformation of agriculture in Hungary, Romania, and Greece, focusing on national policies, adoption of precision agriculture, and institutional roles. The paper is based on the EU data which have been processed using the following methods: structured desk research, comparative policy analysis, and qualitative triangulation through stakeholder surveys and sector analysis tools, ensuring that findings are both evidence-based and contextually validated. Drawing on data from EU and national sources, there are highlighted significant disparities in technology uptake - Hungary leading with 23% adoption, Romania at 10%, and Greece at 5%. The analysis informed the design of the AGRITECH project, initiated by Austria-based PAMEA, which introduced the AgriTech Manager (ATM) profile. This role integrates green and digital skills aligned with EQF and EU frameworks. The paper outlines how comparative policy research shaped AGRITECH's learning ecosystem and supports competence-based education to drive digital and sustainable innovation in agriculture.

Key words: precision agriculture, digital transformation, AgriTech manager, deep tech, competence-based education

INTRODUCTION

Even agriculture started few years ago its transformation towards Agriculture 4.0, compelling to respond to converging crises such as the demand for increased productivity, the impact of climate change, and/or the imperative for sustainable practices, in the European context, this transformation is increasingly defined by digitalisation and deep tech integration - core elements of the EU's **Green Deal** (European Commission, 2019) [3], **Digital Europe Programme** (European Commission, 2021) [5], and **European Skills Agenda** (European Commission, 2020) [4], as well as by the growing policy focus on smart

farming and technology-driven sustainability [7].

However, the capacity to achieve real digital competitiveness in agriculture is different across EU Member States, especially in Central and South-Eastern Europe, where countries like Hungary, Romania, and Greece - despite significant agri-food potential [6], [13] - are still facing structural gaps, namely insufficient digital skills in rural areas, fragmented innovation ecosystems, and poor alignment between education, training, and labour market demands in the Agri-tech sectors (1.2 Needs analysis and specific objectives - AGRITECH Application Form, 2024).

To address these challenges, the **AGRITECH project** (*Alliance for Innovative Learning*

Environment in Advanced Agriculture through Technology and Management) appeared as a strategic educational innovation initiative. Its vision: to foster a new generation of professionals equipped to lead digital transformation in agriculture through deep-tech tools like AI, blockchain, and sensor-based systems, all while anchoring learning in sustainability and entrepreneurship.

The initial concept was developed by **PAMEA**, an Austrian organization with a strong track record in interdisciplinary education projects and agricultural innovation. Building on its prior collaborations with the other consortium institutions, PAMEA conducted a needs analysis revealing critical gaps in **digital literacy, interdisciplinary training, and competence validation** [12]. This analysis catalysed the formation of a transnational consortium and culminated in the AGRITECH project proposal under the ERASMUS+ “Partnerships for Innovation” call.

The project’s flagship innovation is the creation of the **AgriTech Manager (ATM)** competence profile - an advanced, EQF-aligned role that blends green and digital skills with innovation capacity, project leadership, and high capacity for entrepreneurship. Designed to go beyond traditional agricultural training, the ATM profile responds to future-oriented roles involving data-driven decision-making, sustainability transitions, and smart farming integration. This paper provides a comparative analysis of national support frameworks and digital transformation programmes in **Hungary, Romania, and Greece**, exploring how national strategies and institutional actors - such as **MATE, DDTG and Gazda Kontrollin** in Hungary, **USAMV and AgriCloud** in Romania, and **ELGO, AUTH and SACT** in Greece - built the context for digital innovation in agriculture, and explaining how the comparative policy insights shaped the **design of the ATM profile** and its related curricula, certification model, and learning environments.

Through this lens, the paper aims to showcase how **cross-border collaboration, policy alignment, and competence-based innovation** can catalyse inclusive and resilient

digital transformation in the European agricultural landscape.

MATERIALS AND METHODS

This study applied a **comparative qualitative approach** to analyse the national readiness and support mechanisms for digital transformation in agriculture across Hungary, Romania, and Greece, methodology designed to identify key gaps, drivers, and institutional roles that inform the AGRITECH project’s design and educational innovation strategy.

Primary data were collected through **desk research**, focusing on official **EU-level policy documents** (e.g. the European Green Deal, Digital Europe Programme, European Skills Agenda) [3],[4],[5], and **national digital agriculture strategies**, including Hungary’s Digital Agricultural Strategy [10], Romania’s CAP digitalisation initiatives [13], and Greece’s Digital Transformation Bible [9]. Further insights were derived from the **AGRITECH project application**, consortium reports, and published research on digital and sustainable agriculture.

Additionally, the study examined **institutional practices and pilot initiatives** through public reports, academic sources, and project documentation (e.g. Erasmus+ project applications and progress reports). Verified statistical indicators on the adoption of precision agriculture and digital tools were retrieved from **Eurostat**, national ministries of agriculture, and recent studies conducted by EU agencies and academic institutions [1], [8], [6], [7].

The methodology adopted a **comparative framework**, evaluating the three countries based on four thematic dimensions:

- (1) national policy readiness for digital agriculture,
- (2) adoption levels of precision agriculture and deep tech,
- (3) the role and capacity of educational institutions, and
- (4) alignment among key stakeholders, including public authorities, universities, and agribusiness actors. This structure enabled contextual benchmarking and helped surface

both structural strengths and capacity gaps within each country (Fig. 1).

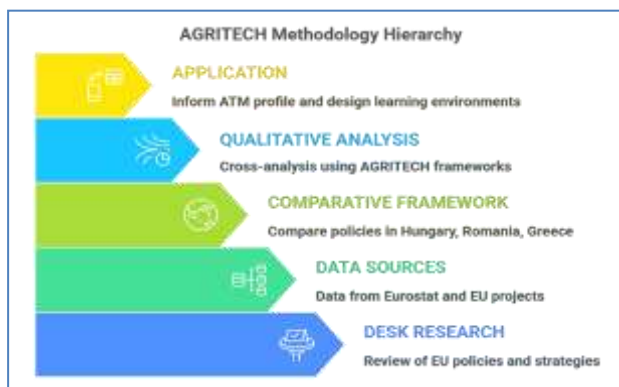


Fig. 1. AGRITECH Methodology Hierarchy
Source: [8] PAMEA, 2023, AGRITECH Preliminary Needs Assessment Report. Berg: Project Advisory and Management Expert Association.

The framework also systematically linked macro-level policy with institutional practices and labour market needs - serving as the analytical foundation for the design of the **AgriTech Manager competence profile**.

The findings were interpreted using a **qualitative analysis model**, combining descriptive synthesis and comparative policy mapping. This was reinforced through triangulation with the AGRITECH project's internal needs analysis and competence framework development, ensuring alignment with EU standards such as EQF, ESCO, and DigComp.

RESULTS AND DISCUSSIONS

National policy landscape and support programmes

The following section provides a concise overview of the national policy landscapes and support programmes in the three countries analysed. Each subsection highlights the key strategic frameworks, institutional actors, and implementation challenges relevant to the digital transformation of agriculture, offering a comparative lens for understanding the context in which the AGRITECH project was developed.

Hungary-Advancing Digital Agriculture through Strategic Academia-Government Synergy

Hungary has demonstrated a strong commitment for digitalising its agricultural sector, primarily through the **Digital Agricultural Strategy (DAS)** [10], adopted in 2019 under the country's **Digital Success Programme 2.0**. This strategy defines a vision for a modern, data-driven agri-food system, emphasizing precision farming, smart farm management, and the digital upskilling of rural stakeholders. Key objectives include enhancing digital infrastructure in rural areas, promoting innovation in agritech, and supporting the uptake of technologies such as IoT, AI, and remote sensing among farmers.

A central academic driver of this transformation is the **Hungarian University of Agriculture and Life Sciences (MATE)**. As the largest agricultural higher education institution in Hungary, MATE plays a very important role in implementing DAS objectives through education, applied research, and professional training. It hosts specialized departments such as the **Department of Precision Agriculture and Digital Farming**, and leads national and EU-funded research and development initiatives in fields like data-driven crop monitoring, decision support systems, and smart irrigation.

MATE is also a **partner in the AGRITECH project**, reflecting its strategic alignment with EU-level objectives for green and digital transition in agriculture. Within AGRITECH, MATE contributes to the definition and piloting of the **AgriTech Manager (ATM) competence framework**, and leads on the integration of practical digital tools and sustainability skills into the curriculum. Its expertise helps bridge policy with practice by ensuring that deep tech competencies - such as AI implementation, geospatial analytics, and blockchain applications - are embedded in formal education and lifelong learning pathways.

In terms of policy support, the **Hungarian Ministry of Agriculture** acts as an associated partner of AGRITECH, providing regulatory insight and facilitating the alignment of project outcomes with Hungary's **Common Agricultural Policy Strategic Plan 2023–2027**, plan which includes measures for the digitalisation of farm management and

advisory systems, further reinforcing the enabling environment for innovations piloted by AGRITECH.

However, barriers remain. According to recent studies, only **23% of Hungarian crop farms currently use precision agriculture technologies** [1], with usage concentrated in large-scale farms (Bai et al., 2022). Major obstacles include high investment costs, fragmented knowledge transfer systems, and a persistent gap in digital skills among older farmers and smallholders.

Hungary's integrated approach - linking government strategies, academic leadership through MATE, and EU-level innovation ecosystems - provides a strong foundation for addressing these gaps. AGRITECH builds on this momentum by contributing to **curricular modernization, competence validation, and cross-sectoral cooperation**, thus enhancing the long-term digital competitiveness of Hungary's agri-food sector through the definition of **AgriTech Manager profile**.

Romania: Bridging Structural Gaps through Emerging Ecosystems and Educational Innovation

The **National Strategic Plan 2023–2027 of Romania** under the **Common Agricultural Policy (CAP)** serves as the foundation for digital transformation in agriculture by supporting **smart farming solutions** and **data-driven advisory systems** and **agricultural training modernization**. The CAP plan of Romania serves as the main framework for digital agriculture development because it does not have a separate national digital agriculture strategy. The **EU-level SmartAgriHubs** project has Romania as one of its participating members to support digital innovation hubs throughout Member States [6].

Still, the widespread adoption of precision agriculture faces significant obstacles in Romania because of its structural challenges despite having strong policy intentions. The adoption of precision agriculture technology during 2020 reached only **10% of farms which mostly involved large commercial operations**. European Commission (2020) and Romanian Ministry of Agriculture (2023) identify equipment costs as a major barrier together with restricted financing options and

insufficient digital competencies especially among small farmers and older farmers [4], [13].

Nonetheless, the digitalisation landscape is evolving through the efforts of both educational and private sector actors. A leading academic institution in this space is the **University of Agronomic Sciences and Veterinary Medicine of Bucharest (USAMV)**, another project partner in AGRITECH. USAMV integrates digital and environmental innovation into its curricula and contributes directly to the **design of the AgriTech Manager profile**, particularly in areas like digital competence mapping, sustainability assessment, and curricular validation.

The emergence of **AgriCloud**, a company listed in the top five deep tech Romanian companies which focuses on cloud-based solutions for agriculture and AGRITECH partner, represents a concrete step forward in linking data science, AI, and blockchain with practical farm management [16], [14]. AgriCloud supports knowledge transfer and facilitates cooperation between tech providers and agri-enterprises, aligning directly with AGRITECH's goals to build smart learning ecosystems and cross-sectoral incubators.

Romania's AGRITECH partners collectively act as catalysts in transforming national strategy into operational models for digital learning and innovation. By co-developing the competence-based profile of the **AgriTech Manager** and piloting modular learning programs, they address existing gaps in skills development and stakeholder coordination. This aligns with broader EU calls for reinforcing the role of **vocational education and training (VET)** and **higher education** in driving the green and digital transition.

Romania's ongoing transformation is therefore marked by both opportunity and urgency. AGRITECH reinforces this trajectory by promoting structured collaboration between universities, private tech actors, and policymakers - contributing not only to educational reform but also to long-term agricultural competitiveness and rural resilience.

Greece: Policy Commitment and Pilot Innovation Towards Smart Agriculture

Greece has started progressively to incorporate the digital transformation into its national development agenda, agriculture being recognized as a priority sector in several policy instruments. The most important strategic plan is the **Digital Transformation Bible 2020–2025** [9], issued by the Greek Ministry of Digital Governance, which explicitly highlights **smart farming** and **digital rural development** as areas of national focus, complemented by Greece's **National Strategic Plan under the Common Agricultural Policy 2023–2027**, which includes provisions for modernising agricultural practices through precision technologies, training, and digital advisory systems.

Despite the strategic alignment, Greece's adoption of precision agriculture remains limited. In 2021, only around **5% of Greek farms** were implementing precision farming tools, mainly used for high-value sectors such as olive groves, vineyards, and greenhouse production (Hellenic Ministry of Rural Development and Food, 2021) [9]. The identified key barriers include **fragmented land holdings, financial constraints, and low digital readiness** in the rural communities.

However, Greece is also host for promising educational and institutional initiatives that are accelerating digital innovation in the agri-food sector. The coordinator of AGRITECH project is **ELGO-DIMITRA**, the National Agricultural Organization responsible for professional training, innovation dissemination, and agricultural research. ELGO's involvement ensures the practical integration of AGRITECH outputs into national extension systems and lifelong learning pathways. It also serves as a testing ground for piloting the AgriTech Manager training model in real farming contexts.

In parallel, **Aristotle University of Thessaloniki (AUTH)** have led several pilot projects in smart farming, remote sensing, and geospatial analysis, often funded through Horizon Europe and national R&D programmes, projects which have put the groundwork for deploying IoT systems,

precision irrigation platforms, and AI-enabled crop monitoring tools, helping to build an innovation-ready ecosystem aligned with AGRITECH's goals.

Through AGRITECH, Greek partners contribute to developing and validating the **AgriTech Manager competence framework**, particularly in areas of smart farming, green transition, and entrepreneurial education. Their experience with modular and digital learning also supports the design of **micro-credential-based learning pathways**, which are crucial for addressing upskilling needs among adult learners and professionals in rural areas.

While Greece still faces structural limitations in scaling digital agriculture, its integration of pilot programmes, academic expertise, and national digital strategy offers a strong foundation. AGRITECH amplifies this trajectory by fostering cross-sectoral collaboration and embedding competence-based learning into the broader policy and innovation ecosystem.

Comparative analysis

The policy and institutional review of Hungary, Romania, and Greece revealed **converging strategic intentions** but **diverging capacities** to implement digital transformation in agriculture (Fig. 2). All three countries have aligned themselves with EU-level priorities under the Green Deal and Digital Europe Programme, yet they differ significantly in adoption levels, stakeholder coordination, and educational integration.

Hungary stands out as the most advanced in both policy execution and institutional engagement. The **Digital Agricultural Strategy (DAS)** provides a clear national framework, supported by the strong involvement of academic institutions like **MATE**, which link research, training, and policy implementation. Hungary also records the **highest adoption rate of precision agriculture at 23%**, with widespread use of GPS systems and line guidance technologies - primarily in large-scale farms [1].

In contrast, **Romania's policy framework**, while formally integrated into its CAP 2023 - 2027 Plan, is less centralized and relies heavily on emerging actors such as **AgriCloud** and **USAMV** to bridge policy with practice.

Romania shows **moderate adoption at 10%** [4], constrained by fragmented advisory services, low investment capacity among smallholders, and insufficient digital training. However, its dynamic innovation ecosystem - particularly in tech-agri partnerships - is a promising vector for growth.

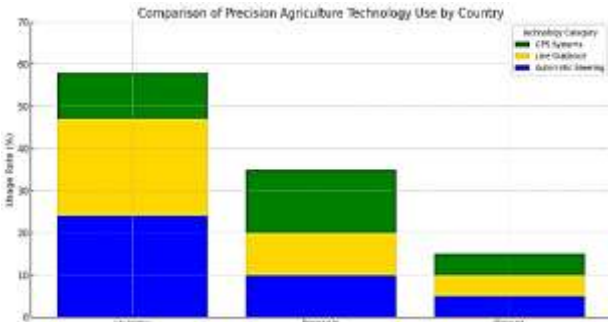


Fig. 2. Comparison of Precision Agriculture Technology Use by Countries
Source: [8] PAMEA, 2023, AGRITECH Preliminary Needs Assessment Report. Berg: Project Advisory and Management Expert Association.

Greece demonstrates strong **strategic alignment** through the **Digital Transformation Bible** and CAP commitments, but **lags in implementation**, with only 5% of farms adopting precision agriculture [9]. Structural constraints - especially fragmented land ownership and rural digital gaps - hamper progress. Nevertheless, Greek institutions like **ELGO-DIMITRA** and **AUTH** are leading notable pilot projects in smart farming, making Greece an important incubator for scalable innovations.

From an **educational and skills development perspective**, all three countries highlight the need to **modernise agri-education, embed digital tools, and support lifelong learning**. However, only Hungary demonstrates a systemic link between national strategy and higher education. Romania and Greece rely more on project-based or pilot approaches, which often lack sustained funding or institutional mainstreaming.

A **shared challenge** across all three is the lack of integrated frameworks for **competence validation, cross-sector collaboration, and micro-credential recognition** - all of which are core pillars of the AGRITECH project. The **AgriTech Manager profile** and related

training pathways are thus conceived as direct responses to these structural gaps, informed by the comparative insights gathered here [12], [6].

Table 1. Summary of Comparative Analysis

Country	Strategy Strength	Adoption Level	Main Gaps
Hungary	Strong	23%	Digital equity, older farmer digital skills
Romania	Emerging	10%	Fragmentation, low VET-business alignment
Greece	Aligned, under-executed	5%	Fragmented holdings, rural digital divide

Source: [8] PAMEA, 2023, AGRITECH Preliminary Needs Assessment Report. Berg: Project Advisory and Management Expert Association.

This comparative overview (Table 1) confirms the need for **transnational collaboration, competence-based curricula, and innovation ecosystems** that link education, technology, and agricultural policy [12] - a mission directly addressed by the AGRITECH project.

AGRITECH PROJECT - bridging gaps through education and innovation

AGRITECH project, conceived as “*Alliance for Innovative Learning Environment in Advanced Agriculture through Technology and Management*”, was launched in response to the clear, cross-cutting gaps identified in national digital agriculture frameworks across initially in Hungary, Romania, and Greece, and later on Italy, Cyprus and Czech Republic. Initiated by **PAMEA**, the concept (Fig. 3) was rooted in comparative needs analysis and structured to directly address the fragmented integration of **digital tools, innovation skills, and sustainability competences** in agricultural education [12].

Co-funded by the ERASMUS+ programme under **Partnerships for Innovation**, AGRITECH brings together higher education institutions, technology providers, research bodies, and public authorities. The project aims to **strengthen the digital and green**

capacities of agricultural training systems through a multi-level approach:

-Competence development through the creation of the **ATM** profile, mapping essential green, digital, and entrepreneurial skills aligned with EQF, ESCO, and EU innovation priorities [3], [4].

-Curriculum innovation, including the co-design of learning modules integrating deep technologies such as **AI, block-chain, remote sensing**, and **IoT**, with a strong emphasis on sustainability, business models, and value chain innovation [2].

-Smart Learning Ecosystems, where formal education, VET providers, and agribusinesses cooperate to pilot immersive, modular learning, supported by digital incubators and peer-based mentorship.

-Policy integration and upscaling, with partners like **MATE, USAMV, AUTH** and **ELGO-DIMITRA** acting as national multipliers to bridge educational outcomes with national digital transformation agendas. What makes AGRITECH unique is its **dual vertical and horizontal integration**. Vertically, it aligns local needs with EU frameworks and funding mechanisms [3], [5], [6], and horizontally, it fosters cooperation between countries at different stages of digital readiness - transforming this diversity into a learning asset.

The project's structure facilitates **peer learning and knowledge transfer**, ensuring that promising practices developed in one region can be adapted and scaled across others. Ultimately, AGRITECH does more than create a new professional profile - it builds a **transnational innovation**.

Through evidence-informed design, iterative piloting, and stakeholder co-creation, the project aims to empower a new generation of professionals who can lead the digital transition of Europe's agri-food systems..

Defining ATM - competence profile development

ecosystem for smart, sustainable agriculture.

At the core of the AGRITECH project is the creation of a new, future-oriented role - the **AgriTech Manager**, a new professional profile designed to meet the evolving demands of the agricultural sector, where environmental

challenges and technological advancement converge. ATM is envisioned as a **hybrid professional** - equipped not only with deep digital and green competences but also with strategic, entrepreneurial, and innovation management skills.

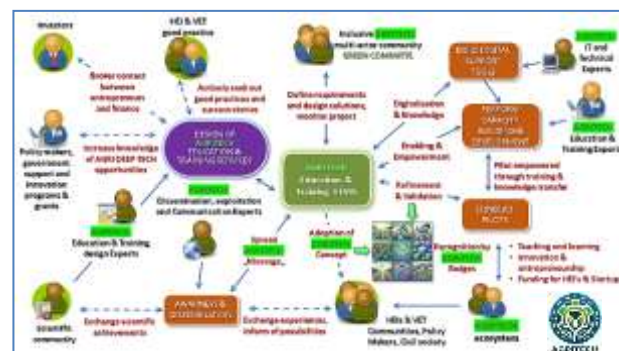


Fig. 3. AGRITECH Concept

Source: PROPOSAL_101187399 - AGRITECH-ERASMUS – EDU - 2024-PI-ALL-INNO.

The competence profile is being developed through a **multi-phase process**, grounded in **EU reference frameworks** such as:

-The European Qualifications Framework (EQF),

-The European Skills, Competences, Qualifications and Occupations (ESCO) taxonomy,

-The DigComp and GreenComp frameworks, and

-Sector-specific inputs from EIP-AGRI and CEDEFOP studies [6].

The development process is **ongoing and evidence-based**, integrating insights from the project's **initial needs analysis**, comparative country review, and practical experience of AGRITECH partners in education, agri-business, and public policy. The competence model covers five core dimensions:

(i)**Smart Agriculture & Deep Tech Integration**

(ii)**Green & Sustainable Value Chain Development**

(iii)**Innovation & Business Model Design**

(iv)**Project and Stakeholder Management**

(v)**Digital Leadership & Lifelong Learning**

To ensure the relevance and adaptability of the profile, AGRITECH has launched a **targeted stakeholder consultation process**, including:

(a) A **Stakeholder Survey** targeting educators, researchers, technology providers, farmers,

and policy experts, aimed at validating competence priorities and identifying potential training formats.

(b) A **Sector Analysis Questionnaire** focusing on business and labor market representatives, to assess digital and green skill gaps, job role forecasts, and learning pathway preferences.

These instruments serve distinct purposes and target groups, but together they support the **triangulation of findings** gathered during the proposal phase. They also reflect the project's commitment to participatory design and policy alignment at both national and EU levels.

Ultimately, the AGRITECH Manager is not conceived as a static role, but as a **dynamic competence cluster** that can be embedded into diverse educational settings - ranging from higher education degrees to VET programs, micro-credentials, and lifelong learning formats. This flexible and modular approach enables the profile to **adapt to national contexts**, while supporting **transnational mobility and international professional recognition** across the EU.

Discussions: Policy and Research implications

The comparative analysis and competence-driven approach adopted by the AGRITECH project reveal a number of actionable implications for both **policy-making** and **future research** in the domain of digital and green transformation in agriculture.

From a **policy perspective**, the fragmented nature of digital adoption in the agricultural sector across Member States highlights the need for **stronger coordination between education, innovation, and rural development strategies** [11]. AGRITECH model demonstrates that targeted investment in **competence-based education**, combined with institutional partnerships and incubator ecosystems, can accelerate transformation even in regions with structural disadvantages. Policymakers at national and EU levels are encouraged to:

- Support the integration of hybrid professional profiles like the **AgriTech Manager** into national qualification frameworks;
- Fund the development and recognition of **micro-credentials and modular training**

paths aligned with digital and green competence frameworks;

- Promote the establishment of **agri-innovation hubs** that connect VET providers, HEIs, tech startups, and public bodies in applied learning environments;

- Incentivize **public-private partnerships** to co-design and scale smart agriculture solutions [2], [8], [6], [15].

In terms of **research implications**, AGRITECH offers a replicable methodology for identifying digital skill gaps and validating future job profiles in a sector-sensitive manner. The project's use of **stakeholder surveys**, **sector analysis tools**, and **comparative national assessments** can serve as a reference for other digital transition initiatives within agriculture or adjacent sectors (e.g., forestry, aquaculture, circular bioeconomy). Additionally, the ongoing piloting of the AGRITECH competence profile creates opportunities for longitudinal research on:

- The effectiveness of **deep tech-based learning modules** in agriculture;
- The impact of **cross-sectoral learning ecosystems** on digital uptake and rural employment;
- The feasibility of integrating **AI, blockchain, and IoT** into competence-oriented training frameworks [2].

At the European level, AGRITECH reinforces key dimensions of the **Green Deal, Digital Europe Programme, and Pact for Skills**, showing how transnational cooperation can deliver scalable and context-sensitive educational innovation.

In conclusion, the AGRITECH project contributes not only to solving current educational and skills mismatches in agriculture, but also to **shaping the long-term governance and capacity-building mechanisms** needed for a sustainable digital transition in the sector.

CONCLUSIONS

This paper explored the digital transformation of agriculture in Hungary, Romania, and Greece, expanded before the proposal submission to Italy, Cyprus and Czech Republic too, highlighting both policy-level

commitments and implementation gaps that affect the sector's digital competitiveness. The findings revealed a shared ambition across all three countries to modernize agriculture through smart technologies and sustainability-driven practices, yet with significant variation in adoption rates, institutional engagement, and educational preparedness.

AGRITECH project emerged as a direct response to these disparities, offering a transnational, competence-based framework to equip a new generation of professionals - **AgriTech Managers** - with the competencies and tools to lead sustainable digital change in the agri-food system. By linking national strategies with EU-level goals and integrating stakeholder feedback through structured research instruments, the project bridges systemic gaps in education, innovation, and rural development.

The **comparative policy analysis, competence mapping, and learning ecosystem design** presented here provide a replicable model for future projects aiming to align digital skills development with sector-specific needs. As the green and digital transitions accelerate across Europe [3], [4], [6], the AGRITECH experience reinforces the need for cross-border cooperation, flexible learning pathways, and the strategic involvement of both academic and private sector actors.

Finally, AGRITECH approach offers not just a training solution, but a scalable vision for building **resilient, digitally empowered agricultural systems** that can meet the challenges of tomorrow to real AGRICULTURE 4.0 implementation [6], [17].

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