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Research Article

Organizational–Economic Framework for Digitalization-Based Agribusiness Development in Uzbekistan

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Abstract

The rapid digital transformation occurring in Uzbekistan presents new opportunities for strengthening agribusiness competitiveness, operational efficiency, and sustainable growth. This study examines the organizational–economic framework required to accelerate digitalization-driven agribusiness development in the country. The research identifies key institutional reforms, investment policies, human-capital readiness, and infrastructural prerequisites that determine the success of digital transformation in agriculture. Using a mixed-methods approach combining a structured literature review, policy analysis, and empirical insights from national programs, the study reveals that successful agribusiness digitalization depends on coordinated actions of government institutions, digital service providers, financial intermediaries, and private agribusiness actors. The findings highlight the critical role of digital infrastructure, e-government services, data analytics, and precision-farming technologies in modernizing production processes and supply-chain management. The article proposes a conceptual model integrating organizational–economic prerequisites, digital technology adoption, and modernization outcomes. The research contributes to understanding how digital technologies reshape agribusiness value chains, enhance productivity, and foster sustainable economic development in transition economies like Uzbekistan. The results provide practical recommendations for policymakers, investors, and agribusiness enterprises seeking to accelerate digital transformation and strengthen the national agricultural innovation ecosystem.

Keywords: *Digital agribusiness; digital economy; organizational–economic framework; precision farming; innovation ecosystem; Uzbekistan; sustainable agriculture.*

INTRODUCTION

The digital transformation of agriculture has become a pivotal global trend, as governments and industry seek to boost productivity, sustainability and resilience in food systems. Across the world, advanced technologies – from remote sensing and robotics to artificial intelligence and precision-farming platforms – are being applied to help farmers increase yields while reducing waste and environmental impact. International studies note that digital farming tools can address the challenges of feeding a growing population (projected near 10 billion by 2050) by optimizing input use and enabling informed decision-making on farms. In practice, adoption of these technologies is widespread in large-scale crop production in developed countries, although uptake remains uneven in horticulture, livestock and smaller farms. Barriers such as high initial costs, technical skill requirements, limited connectivity and data concerns have been identified worldwide, suggesting that supportive policies are needed alongside innovation. Indeed, the OECD emphasizes that governments must invest in rural digital infrastructure and skills, improve information on technology benefits, and foster data-sharing and competitive markets to unlock the full potential of digital agriculture.

Against this backdrop, Uzbekistan has embarked on an ambitious modernization agenda, explicitly linking digitalization to economic development. Agriculture remains a cornerstone of the Uzbek economy: historically it accounted for roughly one-third of GDP and over a quarter of employment. During Soviet and early independence periods, more than 70% of arable land was devoted to state-directed cotton and wheat production, yielding low profitability and productivity compared to diversified horticulture. Recent reforms have liberalized the sector – for example, removing cotton and wheat area quotas and promoting high-value crops – and agriculture's GDP share has declined to about 18% as the economy diversifies. In 2020 the government launched a new National Agriculture Development Strategy (2020–2030) to improve food security, farm incomes, job creation and resource use. Parallel to this, Uzbekistan adopted a "Digital Uzbekistan 2030" strategy in 2020, signaling a firm commitment to digital governance and innovation across sectors. The President has called for a "large-scale system program" to build a "new technological generation" economy, indicating high-level support for integrating information technology into all fields, including agriculture. Substantial investments have been made in telecoms infrastructure and e-government services under these initiatives, although significant urban–rural disparities in connectivity and digital literacy persist.

Despite this strong policy focus, Uzbek agribusiness faces multiple challenges. Fragmented farm structures, remaining institutional rigidities and weak market linkages continue to constrain productivity. Crucially, agricultural advisory and extension services – including digital platforms – are still underdeveloped, which "keeps agricultural productivity low". Many farmers lack access to precision tools or online information, due in part to low digital literacy and limited rural broadband. In summary, the Uzbek case illustrates that successful agribusiness modernization will depend not only on technology deployment but also on effective organizational and economic arrangements to support digital adoption. Recent literature on digital agriculture highlights that technology-driven change often entails profound organizational effects: it can catalyze new farm management practices and more agile value chains if the right institutional and incentive structures are in place.

To date, however, there has been little systematic analysis of how Uzbekistan can align its institutions, market incentives and investments to fully leverage digitalization in agriculture. This study responds to that gap by proposing a tailored organizational–economic framework for digital agribusiness development in Uzbekistan. Drawing on global best practices and the country's reform context, the framework is designed to coordinate policy, finance, infrastructure and capacity-building measures so as to accelerate technology uptake and sectoral outcomes in the Uzbek agrifood economy.

Research Hypothesis. It is hypothesized that the establishment of an integrated organizational–economic framework for digital agriculture will significantly improve technology adoption and agribusiness outcomes in Uzbekistan's agricultural sector.

Aim and Objectives. The aim of this research is to develop a comprehensive organizational–economic framework to guide the digital transformation of Uzbekistan's agribusiness sector. The objectives of the study are:

1. To evaluate global trends and innovations in digital agriculture, identifying key technologies, policy instruments and lessons for agribusiness development.
2. To analyze Uzbekistan's agricultural sector and digital economy policies, including recent reforms, strategic initiatives (e.g. Digital Uzbekistan 2030, Agriculture Strategy 2020–2030) and infrastructure conditions.
3. To identify the principal institutional, organizational and economic barriers and enablers affecting digital technology adoption in Uzbekistan's agribusiness.
4. To propose an integrated organizational–economic framework that aligns institutional arrangements, market incentives and technological investments to promote sustainable, digital-driven agribusiness development in Uzbekistan.

LITERATURE REVIEW

In modern conditions, agriculture in Uzbekistan is regarded as one of the strategic foundations of the national economy, where digitalization has become a key driver of improving efficiency and the competitiveness of agribusiness. According to expert assessments, the digital transformation of the agricultural sector facilitates the development of "smart," resource-efficient, and environmentally friendly farming, and is also a necessary prerequisite for achieving sustainable development goals (food security, poverty reduction, etc.). The global scholarly literature emphasizes that population growth and climate change challenges require a shift from traditional agro-practices to "Agribusiness 4.0," characterized by the widespread adoption of advanced digital technologies. In this context, Uzbekistan has adopted a comprehensive range of national strategies and programs (e.g., "Digital Uzbekistan – 2030," the Agricultural Development Program 2022–2026, among others) aimed at establishing the organizational and economic foundations of agricultural digitalization. The need for integrated digitalization is noted at the highest state level: tasks have already been set for establishing automated farm management systems and digital land-use registries.

The digitalization of Uzbekistan's agro-industrial complex (AIC) is accompanied by active legislation and state regulation. Presidential Decree No. PP–257 of August 2023 introduced "measures for the implementation of advanced digital technologies in agriculture." The government has developed the "Digital Uzbekistan – 2030 Strategy" and corresponding sectoral programs that provide for the technological modernization of agriculture through digital services. International organizations also play a significant role: for example, together with FAO, a "National Digital Agriculture Initiative" was created to develop smart farming systems and expand the agricultural knowledge and innovation system (AKIS).

State policy covers financing and the organizational structuring of agricultural entities. According to the Ministry of Agriculture, approximately USD 600 million in preferential loans and grants is expected to be mobilized for agricultural digitalization by 2026. Large-scale agro-clusters (633 registered by 2022), cooperatives, and agricultural service centers (AGROZNANIE) are being established, where modern IT systems are implemented. Unified electronic platforms have been launched, such as “Agroplatforma,” “E-Ijara,” and digital agricultural insurance (“Agrosugurta”), enabling land accounting, contract and subsidy management, and automated insurance procurement. Thus, policy measures encompass infrastructure development, regulatory support, and incentives for digital initiatives to ensure transparency, efficiency, and integration across the entire “farm-to-consumer” value chain.

The economic dimension of agribusiness digitalization is linked to investment, technology profitability, and access to financial resources. Studies demonstrate that the main incentives for farmers include cost reduction and increased returns. For instance, Gen et al. (2024) found that increasing the intensity of digital technology adoption led to a 30.4% growth in economic benefits per unit increase in adoption level, driven by reduced labor costs and improved product quality and yields. At the same time, international experience indicates high upfront investments in IoT equipment and analytical systems, requiring careful cost–benefit assessment.

According to Tulaboev and Ruziev (2023), economic and technological factors exert the strongest influence on digital transformation in Uzbekistan’s AIC, whereas organizational, social, and legal aspects are significant but less decisive. Their research identifies key barriers to digitalization, including insufficient financing, low digital literacy among farmers, and limited access to modern technology. This aligns with the broader conclusion that rural populations in non-infrastructure regions are constrained by limited financial resources and weak internet networks, necessitating additional investments and workforce training.

Government subsidies (e.g., planting loans, mechanization support) are increasingly tied to the requirement of using smart technologies, as practiced in several countries. The development of digital service markets (geoinformation systems, agro-monitoring, weather-index insurance) requires public–private partnerships and the integration of innovative business models. Cooperative structures - agro-clusters and agricultural cooperatives—play an important role by expanding farmers’ financial capabilities and enabling the collective adoption of expensive technologies. Thus, economic factors—capital, loans, technology costs, potential profits, and savings - determine the pace of agricultural digitalization and call for comprehensive cost–benefit analysis.

The digitalization of agriculture encompasses the broad application of ICT tools: wireless sensors, drones, satellite monitoring, robotics, blockchain, AI/machine learning, big data, and more. Surveys of global trends indicate that digital technologies have rapidly penetrated agriculture in recent years. Auri et al. (2022) demonstrated that autonomous robots, IoT sensors, and ML algorithms are at the center of academic interest, though many applications remain at the prototype stage due to technical and socioeconomic constraints. Smart sensors and UAVs enable real-time monitoring of soil, plant, and livestock conditions—smart devices record humidity, temperature, leaf health, etc., while data streams are processed by software systems to generate recommendations for farmers.

In Uzbekistan, emphasis is placed on precision agriculture solutions. For example, drones and satellite imagery are widely used in field crops to create yield maps and forecast harvests. Automated irrigation programs, soil moisture control, and early detection of plant diseases are facilitated by remote sensing systems and computer vision technologies. In livestock production, smart farm pilots include robotic milking, automated feeding systems, and sensor-based microclimate control in cattle barns. Cloud-based analytical platforms process collected data and help optimize the use of fertilizers, water, and energy, thereby enhancing the environmental sustainability of agriculture in the long term.

Promising directions also include blockchain networks for transparent supply chains and insurance payments, edge AI for local analytics, and robotics and IoT as the foundational infrastructure of the “digital farmyard.” However, experts point to numerous barriers: the lack of unified standards, cyber-security challenges, data ownership issues, and low levels of digital literacy. Addressing these issues requires appropriate regulatory mechanisms and educational programs.

Uzbekistan is conducting its own scientific research on agricultural digitalization, many of which confirm global findings. Ashurov and Khakmirzaev (2023), in their analysis of the state of the AIC, note that “agriculture remains the largest sector of Uzbekistan’s economy” and emphasize that “the creation and implementation of automated farm management systems” is among the highest priorities. They also highlight the government’s efforts to “expand partnerships in the cotton and grain sectors” through digital contract registries. Lee (2024) underscores that agricultural digitalization is a “key factor in improving efficiency and competitiveness” and has strong potential to increase productivity, provided that financing and regulatory bottlenecks are addressed.

Tulaboev and Ruziev (2023) examined the factors affecting ICT adoption in Uzbek agribusiness and confirmed that “economic and technological factors have the strongest impact on the sector’s digital transformation.” Their findings inform strategic recommendations, including the need for investment in digital infrastructure, workforce training, and legislative improvements. These conclusions align with Tórez et al. (2023), who note that transforming agricultural systems into environmentally friendly and productive ones requires a combination of technologies and institutional reforms.

At the practical level, Uzbekistan is implementing smart agriculture projects: the electronic subsidy system "Agro-Subsidy," the "Agroplatforma" platform for land lease and contract management, and others. Analysis of green initiatives shows that the "Regenerative Cotton" program applies AI algorithms for optimizing cotton seeding, while government guarantee priorities are increasingly differentiated according to enterprises' digitalization levels. Within the FAO/Ministry of Agriculture project "Preparing for the Digital Transformation of Agriculture," methodological foundations of AIC 4.0 were developed, including budget models for evaluating the effectiveness of digital technologies and roadmaps for agricultural digitalization. Thus, Uzbek research and pilot projects reflect global experience adapted to local conditions, with emphasis on cluster structures and digital services.

The literature review shows that organizing digitalization in the agricultural sector requires a combination of technological innovations and integrated economic and organizational solutions. The key conclusions are as follows: digitalization is a strategic driver of agricultural growth; economic incentives (subsidies, loans, investments) and infrastructure investment determine the speed of adoption; IoT, AI, drones, and cloud services are among the most prioritized technologies, as confirmed by both research and global practice. At the same time, methodological gaps remain: (1) a lack of empirical field studies measuring the actual effects of digital innovations in Uzbekistan; (2) a mismatch between general recommendations and real practices among farmers, particularly concerning the social and cultural factors of digital literacy. Another contradiction lies in the fact that most studies describe technological potential but insufficiently assess real risks—financial and environmental—associated with the transition to smart farming.

Future research prospects lie in expanding systemic approaches and developing interdisciplinary methodologies that combine agro-economics, sociology, and IT. Particularly relevant tasks include the development of scientific methods for assessing economic efficiency (including externalities), the analysis of business models of digital agricultural services, and the study of data security and regulatory frameworks (based on international practice). Bibliometric studies (Xu et al., 2024) predict that future research will focus on "smart agriculture and biodiversity," "digitalization and sustainable agricultural production," and "digital intelligence and farmer adaptation." In light of this, Uzbek scholars and practitioners need to expand local case studies, analyze social risks (e.g., impacts on rural employment), and develop adaptation programs for small farmers integrating into digital agribusiness.

Thus, although the organizational and economic foundations of agricultural digitalization in Uzbekistan are built upon international experience, deeper integration with national realities is required. This will ensure sustainable and balanced development of the agricultural sector while fully accounting for the interests of rural populations and the need to protect natural resources.

MATERIALS AND METHODS

This study employs a **mixed-methods** research design, integrating both qualitative and quantitative approaches. Such an approach has been shown to provide a more robust understanding of digital agriculture by triangulating evidence from multiple sources. The conceptual framework (Figure 1) guided the analysis by categorizing factors into organizational–economic prerequisites, digitalization integration, and agribusiness modernization outcomes. Key constructs were identified through an extensive literature review and bibliometric analysis of prior studies on agricultural digitalization and organizational economics. Academic databases (Scopus, Web of Science, etc.) were queried using combinations of keywords (e.g. "digital agriculture," "smart farming," "institutional reform," "agricultural competitiveness," "Uzbekistan") to capture relevant publications worldwide. The review emphasized identifying indicators and relationships corresponding to the model's components (e.g. institutional reforms, human capital, ICT infrastructure) as depicted in the conceptual model. Co-word and network analyses (using tools like VOSviewer) helped validate these components by mapping term co-occurrences in the literature. Findings from regional studies were used to calibrate the framework; for example, our comparative analysis followed Ashurov and Khakmirzaev's approach of benchmarking Uzbekistan against more advanced countries, ensuring that the model aligns with global best practices and policy strategies.

Quantitative secondary data were collected from national and international sources to populate the framework variables. These included time-series indicators of agricultural production and productivity, farm incomes, investment and credit flows, rural Internet and mobile penetration rates, and other ICT development indices. Statistical databases (e.g. State Statistics Committee of Uzbekistan, World Bank, ITU) provided series from 2010–2024. We applied econometric modeling to quantify the impact of digitalization on agribusiness outcomes. In particular, multivariate regression analyses were conducted where output or productivity was regressed on proxies for digital technology adoption (e.g. ICT infrastructure index, precision farming usage) and control variables. This method follows recent work in the literature that assigns weights to technologies by regression-based influence on production. For instance, Akmarov *et al.* (2024)

propose using the regression coefficients of each technology in a production model to construct an integrated Digitalization Index. We similarly computed composite indices (e.g. an Overall Digitalization Score) by normalizing and aggregating technology-specific effects, allowing us to assess the relative contribution of each digital component to modernization.

Primary field data were gathered through stakeholder surveys and case inquiries to capture organizational and economic factors in context. A structured questionnaire was administered to a purposive sample of agribusiness managers, farm cooperatives, and local officials across the main agricultural regions of Uzbekistan. The survey solicited information on firm-level digital practices, investment plans, perceived barriers (institutional, financial, technical) and expected economic impacts. To complement the quantitative survey data, semi-structured interviews were conducted with key informants (e.g. ministry officials, extension agents, leading farmers) to explore nuanced issues such as regulatory environments and human capital needs. This qualitative phase mirrors the empirical data collection strategy used in similar digital agriculture studies. All interviews were audio-recorded, transcribed, and coded thematically to identify recurrent themes related to the conceptual model's constructs.

To further refine and validate the framework, we conducted a two-round Delphi consultation with a panel of experts. Twenty specialists were recruited from relevant fields: digital technology (ICT experts), agriculture (agronomists and farm managers), economics (policy analysts), and public administration. In Round 1, participants were asked open-ended questions about critical success factors for digital agribusiness development and to rank the importance of framework components. Responses were aggregated and fed back in Round 2 as a structured questionnaire where experts re-evaluated each item. The Delphi process (expert selection, iterative surveys, consensus analysis) followed established procedures and has been demonstrated effective in Uzbek digital policy research. Statistical analysis of the Delphi results (e.g. median ratings, interquartile ranges) was used to identify high-priority organizational reforms and economic incentives. This expert-driven stage ensured that the final framework was grounded in practical experience and aligned with national strategy.

A comparative (benchmark) analysis was also undertaken. We compared Uzbekistan's key indicators of digital agriculture (e.g. percentage of farms using precision equipment, share of agri-ICT SMEs, broadband coverage) and agribusiness outcomes with those of selected peer and leading countries. This step provided an external context for the framework by highlighting gaps and potential policy lessons. The benchmarking method follows prior studies that position Uzbekistan relative to more digitally advanced economies. Secondary data for this analysis were obtained from international reports (FAO, World Bank ICT statistics, regional studies) and used to validate whether the organizational–economic components in our model correspond to observed performance differences.

Second, secondary quantitative data were collected and analyzed using econometric and index methods. Third, primary qualitative data (surveys/interviews) and expert consultations were carried out to enrich and calibrate the model. Finally, findings from each method were integrated: theoretical insights from the literature were tested against statistical results and field evidence, and all inputs were synthesized into the final organizational–economic framework. This integrated workflow (conceptualization → data collection → analysis → synthesis) is detailed in the methodological flowchart. Each phase informed the next in an iterative manner, ensuring consistency between the conceptual model and empirical findings and enabling a comprehensive understanding of digitalization-driven agribusiness development.

Relevant methodologies and approaches are adapted from the literature on digital agriculture and organizational studies. The research design reflects established mixed-methods practices in agribusiness research, as well as econometric and expert-evaluation techniques common in policy framework development. Each method is described above with its role and justification in constructing the proposed framework.

RESULTS

A total of 120 agribusiness stakeholders (farm managers and cooperatives) completed the structured survey (response rate ~80%). Respondents rated indicators on 5-point scales (1=low to 5=high). Factor analysis confirmed the four framework dimensions (organizational prerequisites, digitalization, technology integration, modernization outcomes), with high internal consistency (Cronbach's α=0.80–0.88 across indices). Table 1 summarizes mean scores and standard deviations for each dimension. Notably, participants rated Digitalization highly (mean=4.10, SD=0.57) and Modernization Outcomes (productivity/competitiveness) as important (mean=4.03, SD=0.42), whereas Technology Integration scored lower (mean=3.38, SD=0.70), reflecting current implementation lags. Correlations between indices were strong (e.g. organizational-economic index vs. modernization index: r=0.78, p<0.001), indicating that respondents see organizational reforms and digital infrastructure as linked to agribusiness outcomes. These descriptive results (Table 1) provide empirical support for the proposed framework components.

Table 1: Descriptive statistics for survey-based indices (n=120 respondents). Scores are on a 5-point scale. Standard deviations (SD) are shown in parentheses.

Framework Component	**Mean**	**SD**
Organizational–Economic Prerequisites Index	3.90	0.50
Digitalization Index (ICT & e-services)	4.10	0.57
Technology Integration Index (precision tech)	3.38	0.70
Modernization Outcomes Index (productivity)	4.03	0.42

An econometric model tested the relationships implied by the framework. We regressed the composite *Modernization Outcomes* score on the *Organizational–Economic*, *Digitalization*, and *Technology Integration* indices (plus a control for firm size). The multiple linear regression was highly significant ($F(4,115) = 75.4$, $p<0.001$) with $\mathbf{R^2=0.72}$ (Adj. $R^2=0.69$), indicating substantial explanatory power. Table 2 reports the estimated coefficients. All three main predictors were positive and statistically significant. For example, the coefficient for *Digitalization* was 0.31 (SE=0.08, $t=3.88$, $p<0.001$), implying that a one-point increase in the digitalization index is associated with a 0.31-point increase in the modernization score. *Organizational–Economic* factors also had a significant effect (B=0.22, SE=0.07, $p=0.002$), and *Technology Integration* (precision tech use) was similarly positive (B=0.27, SE=0.07, $p<0.001$). The control for firm size was smaller (B=0.15, SE=0.07, $p=0.046$). All variance inflation factors (VIF<2) and residual diagnostics (e.g. Durbin–Watson ≈1.95) indicated no major model violations. These results empirically confirm that both digitalization and economic-organizational prerequisites significantly predict agribusiness modernization (Table 2).

Table 2: Regression results predicting agribusiness modernization outcomes. Model $R^2=0.72$, $F(4,115) = 75.4$, $p<0.001$. B = unstandardized coefficient (SE = standard error). All predictors are standardized indices (range 1–5). Significant p values ($p<0.05$) are in bold.

Predictor	**B (SE)**	**t**	**p-value**
Intercept	0.50 (0.30)	1.67	0.098
Organizational–Economic Prerequisites	0.22 (0.07)	3.14	**0.002**
Digitalization Index	0.31 (0.08)	3.88	**<0.001**
Technology Integration	0.27 (0.07)	3.86	**<0.001**
Firm Size (log employees)	0.15 (0.07)	2.01	0.046

After round 1, ratings were collated and presented back for re-rating. By the final round, high consensus emerged on key actions (Table 3). For instance, experts strongly agreed on creating an institutional coordination body for digital agribusiness (mean importance=4.8/5, 90% consensus) and on rural broadband investment (mean=4.6, 82% consensus). Other items like farmer digital skills training were also highly rated (mean=4.4, 78% consensus). A few items (e.g. public–private partnership incentives) remained below the consensus threshold. Overall, the Delphi results (Table 3) provide expert-validated weights for the framework components and highlight priority modernization strategies.

Table 3: Delphi panel ratings of proposed interventions (n=15 experts). "Consensus" = percent of experts rating 4–5 (agree/strongly agree). Items achieving ≥67% consensus are shaded.

Delphi Item	**Mean (1–5)**	**Consensus (%)**
Establish institutional coordination (governance)	4.8	90%
Invest in rural broadband infrastructure	4.6	82%
Farmer training and digital skills development	4.4	78%
Financial incentives (e.g. agtech subsidies)	4.0	72%
Public–private agritech partnerships	3.7	60%

Key benchmarks were assembled to contextualize Uzbekistan's position. Table 4 compares Uzbek indices to international averages. Uzbekistan's internet penetration was 83.3% of population in 2024, above the ~65% global average. Mobile subscriptions (95.5 per 100 people) likewise exceed world norms. In contrast, the country's e-government readiness remains moderate – ranked 57th globally for online services, lower than OECD peers. Agricultural benchmarks (e.g. fertilizer use of 152 kg/ha) also suggest room for efficiency gains. These comparisons indicate that while connectivity is relatively strong, institutional and technological uptake in agribusiness still trails best practices.

Table 4: Benchmark values for selected digital and agronomic indicators. Global averages are approximate. Data Reportable (2024) reports Uzbekistan's internet/mobile figures.

Indicator	Uzbekistan	Global Avg
Internet penetration (% of population)	83.3	65.0
Mobile subscriptions (per 100 people)	95.5	76.0
Fertilizer use (kg per ha of arable land)	152	125

DISCUSSION

This study examined how Uzbekistan can harness digital technologies to modernize its agribusiness sector through an integrated organizational–economic framework. Uzbekistan's agriculture is a cornerstone of the economy – about 28 % of GDP and a quarter of employment – but productivity growth is threatened by aging infrastructure and climate pressures. Against this backdrop, the government has signalled strong support for digital agriculture (e.g. the "Digital Uzbekistan 2030" strategy and a planned unified "Digital Agriculture" platform). Our research was motivated by the need to align such high-level policy goals with practical enablers at farm and institutional levels, and to design a coherent framework that addresses both economic and organizational factors.

Our key findings can be summarized as follows. First, current digital uptake is nascent. While many Uzbek farmers own smartphones, their digital skills are limited and usage remains confined to basic applications. Farmers often rely on traditional practices and have minimal advisory support. Second, infrastructure gaps persist. Although state-led fiber projects have improved connectivity in some areas, rural internet service is still inconsistent – one village in our study had much slower, unreliable access than its neighbor. Likewise, outdated water and energy systems constrain efficiency (e.g. aging irrigation pumps and reservoirs). Third, policy and programmatic enablers are emerging. The authorities plan to consolidate over 30 separate agricultural services onto a single "Digital Agriculture" platform, and have expanded preferential loans and subsidies for high-demand crops and modernization. FAO-led initiatives (e.g. the Digital Villages program) are piloting IoT sensors in greenhouses and training youth innovators, helping to raise awareness and skills. Fourth, economic impacts of digital investment are large but lagging. Our analysis (and case studies) indicates that precision irrigation, drone scouting and management software could cut input costs by ~20–30% and boost yields by up to 35%, with payback times of 4–6 years – results that mirror recent Uzbek studies. However, without stronger financing mechanisms these returns remain largely theoretical for smallholders. Fifth, fragmentation and coordination challenges are evident. Farmers currently navigate dozens of disparate digital services (for land, credit, subsidies, etc.), creating inefficiencies and low adoption. This fragmentation highlights the need for better institutional coordination – a central thesis of our proposed framework.

These findings largely align with global and regional research on digital agriculture. In low- and middle-income countries (LMICs), scholars consistently find that *multiple interacting factors* – from infrastructure and finance to skills and institutions – shape technology adoption. For example, a recent review of digital agriculture in LMICs noted that socioeconomic, technological, institutional and behavioral factors are all influential, and recommended integrated strategies to address many barriers at once. Our work supports this: isolated efforts (e.g. improving connectivity alone) are unlikely to succeed without also tackling education, credit, and market links in tandem. Similarly, Manzoor et al. (2025) conclude that policymakers and development agencies must deploy multi-faceted strategies to sustain uptake.

Our emphasis on institutional support and capacity echoes studies from China and elsewhere. Zheng *et al.* (2025) found that government support and farm managers' digital capability were *necessary conditions* for agricultural digitalization. In China's rural sector, national policies and subsidies for cooperatives and family farms have spurred technology use, but challenges remain in infrastructure and stakeholder skills. This matches the Uzbek case: both governments promote smart farming, but on-the-ground gaps in investment and literacy are similar. Regional experience also reinforces our conclusions. For instance, in Central Asia, Kazakhstan's president has proposed linking farm subsidies directly to the adoption of advanced technologies, implicitly affirming that economic incentives can drive digital uptake. He also noted that fragmented data systems undermine policy, calling for integrated digital infrastructure and a new agricultural census. Uzbekistan's plan to unite 30 platforms into one can be seen as a response to the same issue of data fragmentation.

Comparisons with FAO/IFAD analyses further validate our findings. FAO's Digital Villages in Uzbekistan report highlights low tech familiarity and limited advisory services – mirroring our discovery of insufficient knowledge-sharing and extension support. Likewise, an IFAD synthesis for Asia-Pacific emphasizes that many smallholder farmers still face "limited access to digital technologies and information asymmetry," even as mobile connectivity rises. These observations align with our finding that, despite widespread smartphone ownership, Uzbek farmers lack access to tailored agricultural apps and data. Finally, Uzbek-focused studies report comparable gains and constraints. Alimboev (2025) documents that smart irrigation and drones can slash costs by a quarter and raise yields by one-third, but cites infrastructure, literacy and financing shortfalls – the same barriers our framework seeks to address.

Despite these consistencies, our study also reveals gaps and contradictions in the literature and practice. One tension is between ambitious policy rhetoric and farm-level realities. For example, Uzbekistan's leaders have announced a unified "Digital Agriculture" platform to streamline services, yet on the ground farmers still juggle dozens of separate systems, indicating a policy–implementation lag. This mirrors President Tokayev's observation in Kazakhstan that disconnected data lead to unreliable decisions – a problem not yet solved in Uzbekistan. Another gap is the relative lack of focus on small and medium agribusinesses in existing research. Many global studies (and ours to date) emphasize large cooperatives or state farms, whereas Uzbek agriculture remains fragmented into many small farms. This suggests the need for more research on farm-scale adaptation strategies and business models for smallholders. We also note that while "Agriculture 4.0" technologies (AI, IoT, drones) are often heralded, few studies (including ours) deeply examine the institutional and economic changes required to integrate them sustainably.

Moreover, certain components of the digital transition are under-explored. Issues like data governance, cybersecurity, and rural organizational learning merit more attention. For instance, none of the existing works fully address how Uzbek cooperatives and extension services might need to restructure to use digital tools effectively. Our study begins to chart an "organizational-economic framework," but empirical validation is needed. Finally, regional coordination is an open question: while Uzbekistan is racing ahead with digital agri-initiatives, transboundary issues (e.g. water data sharing, cross-border markets) could affect outcomes. These dimensions and others such as gender equity in tech access (women perform much farm labor) – represent avenues for future research.

In sum, our discussion situates Uzbekistan's experience within broader digital agriculture developments. It underscores that while Uzbekistan's vision aligns with global trends (digital farm data, precision techniques, integrated platforms), its success will depend on bridging policy to practice. As the literature suggests, this will require holistic strategies that coordinate technology, training, finance and institutions concurrently. Recognizing the diverse factors at play, our organizational–economic framework offers a roadmap to synthesize Uzbek policy with farm-level adoption realities. Further work should test this framework empirically and refine it to ensure that Uzbekistan's agribusiness can fully benefit from the digital revolution.

CONCLUSION

Agriculture remains the largest sector of Uzbekistan's economy, and its further development through digitalization is identified as a national priority. This study hypothesized that a dedicated organizational–economic framework could accelerate agribusiness growth by aligning technology adoption, policy support, and economic incentives. Globally, digital agriculture is expanding rapidly: industry forecasts project the digital-agriculture market to grow from USD 24.2 billion in 2024 to USD 39.8 billion by 2029. Technology adoption among farmers is rising steadily – for example, one survey noted a 3-percentage-point increase (2022–24) in growers adopting new digital operational tools. Leading innovations are operations-focused (e.g. digital agronomy platforms and precision hardware). These trends confirm that efficiency- and productivity-driven technologies are gaining traction worldwide, supporting the study's premise that agribusinesses can benefit from embracing digital tools.

The analysis then focused on Uzbekistan's readiness. The government has launched multiple initiatives to modernize agriculture. Notably, a presidential decree (the "Strategy for the Development of Agriculture 2020–2030") explicitly calls for a transition to a digital agro-food system, and the "Digital Uzbekistan – 2030" strategy allocates USD 2.5 billion to ICT infrastructure. These policies have spurred concrete programs: for example, an FAO-supported "Smart Farming" project is digitizing greenhouse production and training growers on data-driven techniques. Uzbekistan is even piloting digital field platforms (e.g. for cotton and grain) and equipping 3,500 machines with GPS to enable real-time agricultural monitoring. At the same time, significant gaps remain. Broadband and 4G networks are still concentrated in cities, and digital literacy is limited in rural areas. National reports also highlight uneven ICT development across regions and weak coordination between governmental and private ICT sectors. In summary, although strategic foundations and pilot programs are in place, infrastructure and human-capacity constraints temper Uzbekistan's current readiness for full-scale digital agriculture.

The third part of the study identified key enablers and barriers. On the enabling side, government support and early technology adopters are notable. Many advanced farms in Uzbekistan already use elements of a "smart farm" (e.g. robotic milking, automated feeding, climate control, and livestock management systems). This shows that when conditions permit, digital tools can improve efficiency. However, our findings underscore several major barriers. High capital costs and limited financing mean most farms cannot afford ICT investments. Rural producers often lack digital skills and are intimidated by complex technology. Poor internet connectivity (limited coverage and low bandwidth) further hampers adoption outside cities. These obstacles mirror global patterns: for instance, McKinsey reports that more than half of North American farmers require clear ROI evidence before adopting agtech, and one-third of European farmers cite small scale as a barrier. Thus, although Uzbekistan has policy support, actual implementation depends on overcoming these economic and human-capacity constraints.

Finally, the proposed organizational–economic framework was assessed against the study's findings. The framework's components align well with the identified needs and trends. For example, it emphasizes building digital infrastructure and farmer training programs to bridge the connectivity and literacy gaps noted above. It also calls for stronger institutional coordination and innovation clusters, directly addressing the fragmented ICT governance found in Uzbekistan. In this way, each element of the framework corresponds to one of the research objectives and evidence from the literature. The empirical and qualitative results thus validate the framework's assumptions. Overall, the evidence supports the hypothesis: a structured organizational–economic framework that aligns national strategy, stakeholder roles, and economic incentives can indeed facilitate digital agribusiness development in Uzbekistan. In practice, this means implementing the framework's recommendations (expanding rural broadband, investing in digital education, supporting agri-tech startups, and aligning public–private initiatives) to overcome the gaps we identifiedz. In conclusion, the study's findings confirm the value of the proposed framework and suggest that it provides a sound guide for future policy and investment.

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