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THE ROLE OF DIGITAL TECHNOLOGIES IN UZBEKISTAN'S AGRICULTURAL DEVELOPMENT

Abstract

Agriculture remains a cornerstone of Uzbekistan's economy, accounting for a significant share of employment and export earnings. Yet the sector faces mounting pressures from climate variability, water scarcity, fragmented land tenure, and the need to meet rising domestic and international food demand. Digital technologies—encompassing precision agriculture, mobile advisory platforms, remote sensing, digital finance, and e-commerce—offer a promising avenue for addressing these structural challenges and accelerating the modernization of Uzbekistan's agricultural sector. This article presents a narrative literature review examining the role of digital technologies in Uzbekistan's agricultural development, drawing on international studies, Central Asian research, and available Uzbekistan-specific sources. The review finds that while global evidence strongly supports the productivity and income benefits of digital technology adoption in agriculture, realization of these benefits in Uzbekistan is constrained by limited rural connectivity, low digital literacy among farmers, insufficient access to agricultural finance, and gaps in the regulatory framework governing agricultural data. International experiences—particularly those of the Netherlands, Israel, China, Turkey, and Kazakhstan—offer transferable lessons, though adaptation to Uzbekistan's smallholder-dominated, water-stressed context is essential. The article concludes with targeted policy recommendations for government, extension services, educational institutions, and researchers, and identifies priorities for a contextually grounded research agenda on digital agriculture in Uzbekistan and Central Asia.

Keywords: digital agriculture; precision farming; Uzbekistan; agricultural economics; rural digitalization; smallholder farmers; Central Asia

1. Introduction

Agriculture occupies a distinctive position in Uzbekistan's economic and social landscape. Despite decades of structural transformation and a progressive shift toward services and industry, the agricultural sector continues to employ a substantial share of the country's workforce. It contributes meaningfully to export earnings, particularly through fruits, vegetables, cotton, and grain. For rural households, which represent a significant proportion of Uzbekistan's total population, farming remains the primary livelihood. The performance of agriculture is therefore not merely a sectoral concern; it is a matter of broad economic welfare and food security.

The pressures bearing on Uzbekistan's agriculture are considerable. The country's arable land base is limited—roughly 4.2 million hectares under cultivation against a total territory of 44.7 million hectares—and is subject to ongoing degradation from soil salinity, erosion, and the consequences of decades of input-intensive cotton monoculture (FAO, 2021). Water scarcity is perhaps the most acute long-run constraint: Uzbekistan is the most water-dependent country in Central Asia in absolute terms, yet it sits at the downstream end of river systems whose flows are increasingly contested and climate-affected. Average farm sizes remain small by international standards, and most agricultural households operate plots that limit the viability of conventional capital-intensive mechanisation.

Against this backdrop, digital technologies represent not simply a productivity enhancement but a potential restructuring of the information architecture through which Uzbekistan's farmers make decisions, access markets, and obtain finance. Globally, the literature documents substantial gains from precision agriculture, IoT-enabled irrigation management, mobile advisory services, and digital supply chain platforms. These tools reduce information asymmetries, lower transaction costs, and support more efficient resource allocation—each of which addresses specific inefficiencies that characterise Uzbek agriculture today.

The government of Uzbekistan has recognised the strategic importance of digitalisation. National strategies for digital economy development, promulgated in the early 2020s, encompass the agricultural sector and outline objectives to modernise cadastral systems, expand rural connectivity, and develop digital platforms for agricultural finance and marketing (World Bank, 2022). However, translating high-level strategic ambitions into tangible improvements at the farm level requires a clear understanding of what works, under what conditions, and for whom—a question that existing literature on Uzbekistan specifically has not yet answered comprehensively.

This article seeks to address that gap. It aims to synthesise available international and regional evidence on the role of digital technologies in agricultural development and to assess critically how this evidence applies to Uzbekistan's specific context. The objectives are: (i) to review major international and Central Asian findings on digital agriculture; (ii) to characterise the current state of Uzbekistan's agricultural sector and its constraints; (iii) to examine relevant international experiences and their transferability; (iv) to provide an analytical discussion comparing international evidence with Uzbekistan's realities; and (v) to derive practical, context-sensitive recommendations for policy and research. The remainder of the article proceeds as follows: Section 2 reviews the literature; Section 3 describes the current agricultural situation in Uzbekistan; Section 4 presents international experiences; Section 5 discusses the findings analytically; Section 6 sets out policy recommendations; and Section 7 concludes.

2. Literature Review

2.1 International Foundations

The academic literature on digital agriculture has expanded substantially over the past decade, mirroring the rapid proliferation of relevant technologies in both high-income and developing country farming systems. Wolfert et al. (2017) provided an early landmark synthesis, identifying big data as a transformative force capable of improving farm-level decision-making across production, marketing, and supply chain domains. Their review found that integrated data-driven systems could raise agricultural productivity by up to 20 per cent in optimised settings. This finding has since been corroborated across multiple crops and regions. Klerkx et al. (2019), in a comprehensive bibliometric review of the smart farming literature, confirmed exponential growth in publications while identifying a relative neglect of governance, equity, and political economy dimensions. This gap remains pertinent when assessing the prospects of digital agriculture in developing-country contexts.

Precision agriculture, the most extensively studied component of digital farming, encompasses GPS guidance, variable-rate input application, remote sensing, and yield monitoring. Schimmelpfennig (2016) documented positive economic returns from the adoption of precision agriculture in large-scale farming in North America, reporting input savings of 10–25 per cent and yield gains of 5–15 per cent under optimised conditions. However, Pivoto et al. (2018) caution that these results may not translate directly to smallholder settings, where the minimum viable scale for precision technologies often exceeds the average farm size. This scale constraint is highly relevant to Uzbekistan, where the average size of farms worked by dehqon (smallholder) households is measured in fractions of a hectare.

Mobile and digital advisory services have consistently had positive effects on smallholders in developing economies. Barrett et al. (2020), in a randomised controlled trial in Sub-Saharan Africa, found that mobile market information services increased smallholder incomes by 8–15 per cent, primarily through improved price information and greater negotiating leverage with traders. The mechanisms—better information, reduced dependence on exploitative intermediaries, improved timing of sales—are equally applicable to Uzbekistan's fragmented agricultural marketing system.

Digital financial services represent another domain with strong evidence. The World Bank (2022) has specifically identified digital finance, including mobile payments, index-based insurance, and digital warehouse receipt systems, as high-priority instruments for agricultural development in Central Asia. Index-based crop insurance—where payouts are triggered by satellite-derived vegetation indices or weather station data rather than costly farm-level assessments—is particularly relevant in contexts where formal insurance penetration is low, and smallholder risk exposure is high.

2.2 Central Asian and Regional Studies

Research specifically addressing digital agriculture in Central Asia remains sparse compared with the global literature. The World Bank (2022) report on digital solutions for agriculture in Central Asia provides the most comprehensive regional assessment available, documenting significant variation in digital readiness across Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. Kazakhstan emerges as the regional leader, having invested substantially in national digital agriculture platforms and rural connectivity infrastructure. Uzbekistan is identified as having a rapidly digitising economy overall, with the agricultural sector lagging the financial and services sectors in digital transformation.

Water management—central to agricultural viability across the region—has been identified as a particularly high-value application domain for digital technologies in Central Asia. Remote sensing-based monitoring of irrigation canals and soil moisture, combined with digital water allocation systems, could substantially improve the efficiency of the Amu Darya and Syr Darya river basin systems that underpin agricultural production across the region. However, the transboundary political economy of water allocation in Central Asia complicates national-level digital interventions, as data sharing and coordinated management require multilateral cooperation that has historically been difficult to achieve (FAO, 2021).

2.3 Uzbekistan-Specific Research

Peer-reviewed literature focused specifically on digital agriculture in Uzbekistan is limited, reflecting the country's relatively recent emergence as a subject of international development research following the post-2016 reform period. The available evidence base draws primarily on international organisation assessments, government policy documents, and general studies of Uzbekistan's agricultural sector that address digitalisation as one of many components.

What is established is that Uzbekistan's agricultural sector is undergoing significant structural change. The progressive diversification away from cotton monoculture toward horticulture and grain has altered the skill and information requirements of farming households. The government's explicit export promotion agenda for fruits and vegetables creates demand for digital traceability and food safety documentation systems compatible with importing countries' requirements. At the same time, the financial sector's rapid digitalisation—driven by government mandates for electronic payments and the growth of mobile banking—is creating an expanding infrastructure that could be leveraged for agricultural finance applications.

Research gaps identified by this review include: the absence of farm-level impact evaluations of digital agriculture interventions in Uzbekistan; limited analysis of the gender dimensions of digital access in Uzbek agriculture; insufficient attention to the specific constraints facing smallholders in irrigated versus dryland farming systems; and a lack of independent analysis of the implementation progress and outcomes of government digital agriculture initiatives.

Table 1. Summary of Selected Key Studies on Digital Agriculture

Author(s) & Year	Region	Technology	Method	Key Finding
Wolfert et al. (2017)	Global	Big data, IoT	Review	Data-driven farming can raise productivity by up to 20%
FAO (2021)	Global / Dev. countries	ICT tools	Policy analysis	Digital tools essential for food-system resilience
Klerkx et al. (2019)	Europe, Americas	Smart farming	Bibliometric review	Governance and equity dimensions remain understudied
Barrett et al.	Sub-Saharan	Mobile	RCT	Mobile services

Author(s) & Year	Region	Technology	Method	Key Finding
(2020)	Africa	advisory		raise smallholder income by 8–15%
World Bank (2022)	Central Asia	Digital finance	Mixed methods	Mobile payments improve smallholder market access
Huang et al. (2022)	China	E-commerce	Econometric	Digital marketing generates price premiums for small farms
Pivoto et al. (2018)	Brazil / BRICS	Precision agr.	Survey, meta-analysis	Adoption constrained by infrastructure and human capital
Kamilaris & Prenafeta-Boldú (2018)	Global	AI / deep learning	Systematic review	Computer vision achieves >95% accuracy in disease detection

3. Current Situation in Uzbekistan

3.1 Agricultural Structure and Economic Role

Uzbekistan's agricultural sector is characterised by a dual structure: a layer of medium and large commercial farms (farmer households) operating under long-term lease arrangements on state land, alongside a substantially larger number of smallholders dehqon households farming private plots. This duality creates differentiated needs and capacities for digital technology adoption. Farming households with more land and capital are better positioned to adopt precision equipment and digital management platforms. In contrast, dehqon households—who collectively account for a large share of fruit, vegetable, and livestock production—face greater barriers related to cost, literacy, and connectivity.

Agriculture contributes approximately 25–28 per cent of GDP in Uzbekistan, a share significantly higher than the average for upper-middle-income countries, reflecting the sector's continued centrality to the national economy (World Bank, 2022). Employment in agriculture accounts for a substantial proportion of total employment, concentrated in rural oblasts such as Fergana, Andijan, Namangan, and Kashkadarya, where irrigated horticulture dominates. Export earnings from agricultural products—primarily fruits, vegetables, and cotton—represent an important source of foreign exchange.

3.2 Key Challenges

Several structural challenges constrain the productivity and competitiveness of Uzbekistan's agricultural sector. Water scarcity and irrigation inefficiency are paramount: the dominance of flood and furrow irrigation systems, inherited from the Soviet period, results in significant water losses and contributes to soil salinity—an estimated 50 per cent of irrigated land in Uzbekistan shows some degree of salinisation (FAO, 2021). Climate projections for Central Asia indicate declining river flows and increasing temperature variability in the coming decades, intensifying the urgency of irrigation modernisation.

Post-harvest losses are a second major economic challenge. In the absence of adequate cold-chain infrastructure, losses of fruits and vegetables are estimated at 25–30 per cent between the farm gate and the final consumer, representing a substantial loss of agricultural value (World Bank, 2022). The limited availability of rural finance is a third constraint: formal credit penetration among smallholders is low, and the absence of functioning crop insurance products leaves farm households highly exposed to weather-

related income shocks. Market fragmentation and reliance on trading intermediaries further limit the share of final consumer prices that producers capture.

3.3 Government Reforms and Digital Initiatives

Since 2016, the government of Uzbekistan has embarked on a broad programme of economic reform that places significant emphasis on the agricultural sector. Reforms have aimed to diversify crop production, liberalise input and output markets, improve land tenure security, and expand agricultural export capacity. The Digital Uzbekistan strategy and associated sectoral programmes reflect a commitment to leveraging technology across the economy, including in agriculture.

In the agricultural domain, government initiatives have included the development of a digital land cadastre, pilots of electronic agricultural market platforms, programmes to expand rural internet coverage, and steps toward the digitalisation of agricultural subsidy disbursement. The State Committee for Land Resources has advanced satellite-based land monitoring, and several regions have piloted remote sensing applications for crop area estimation and yield forecasting. While these initiatives represent meaningful progress, independent assessment of the depth of their implementation, farmer uptake, and economic outcomes remains limited in the published literature.

Table 2. Uzbekistan's Agricultural Challenges and Corresponding Digital Solutions

Challenge Area	Current Situation in Uzbekistan	Potential Digital Solution
Water management	Over-reliance on flood irrigation, significant water losses in distribution, and the Aral Sea basin constraints	IoT soil-moisture sensors; satellite-based irrigation scheduling; smart canal management systems
Market access	Fragmented smallholder markets; strong dependence on intermediaries; limited price transparency	Digital trading platforms, mobile price-alert services, and e-commerce channels for direct sales
Agricultural finance	Limited formal credit access for smallholders; lack of collateral; underdeveloped insurance market	AgriFintech credit scoring using alternative data; index-based mobile insurance; digital warehouse receipts
Extension services	Insufficient extension officer-to-farmer ratios; uneven geographic coverage; slow knowledge transfer	Mobile advisory apps; AI-driven crop recommendation systems; digital video extension content
Post-harvest losses	An estimated 25–30% losses in fruits and vegetables due to storage and logistics gaps	IoT cold-chain monitoring; digital logistics platforms; quality-tracking traceability systems
Land management	Incomplete cadastral records; fragmented plot structure; limited soil data availability	Digital land registry; remote sensing-based soil mapping; GIS-enabled farm planning

4. International Experience

4.1 Lessons from Advanced Economies

The Netherlands represents the most instructive global example of technology-driven agricultural intensification in a land-constrained setting. Through sustained public and private investment in greenhouse technology, precision sensing, and integrated crop management systems, the Netherlands has achieved world-leading horticultural productivity per hectare—producing and exporting at scale from a land base smaller than Uzbekistan's cultivated area. The Wageningen University and Research network has

been instrumental in translating scientific advances into practical farm applications, and the Dutch cooperative model for processing and marketing agricultural produce provides a complementary institutional framework. In Uzbekistan's Fergana Valley, where intensive horticulture on small plots dominates, the Dutch model—suitably adapted to local climate and resource conditions—offers a compelling reference point, particularly for greenhouse vegetable production and post-harvest cold-chain management.

Israel's experience with drip irrigation and sensor-integrated water management is directly relevant to Uzbekistan. Faced with extreme water scarcity, Israel developed and commercialised precision drip irrigation systems that deliver water and nutrients directly to root zones with dramatically reduced losses. Studies document water savings of 40–50 per cent compared with flood irrigation under comparable crop and soil conditions (FAO, 2021). Given that water is Uzbekistan's most binding agricultural constraint, Israeli experience—including its approach to public-private partnership in irrigation technology development—merits close examination.

4.2 Experiences from Emerging Economies

China's Digital Village Programme, launched in 2019, demonstrates the potential for government-led digital infrastructure investment to create rural economic transformation at scale. By combining investment in rural broadband, logistics networks, and digital payment infrastructure with the rapid growth of e-commerce platforms, China has enabled smallholder farmers in remote areas to access premium urban consumer markets directly. While the Chinese context—in terms of market size, state capacity, and platform ecosystem—is not directly replicable in Uzbekistan, the underlying mechanisms of rural e-commerce development offer lessons for Uzbekistan's ongoing efforts to expand agricultural export channels and improve domestic market access for smallholders.

Turkey's TARSİM agricultural insurance system, which digitised claims assessment and subsidy disbursement across a large and diverse smallholder farming population, provides a template for Uzbekistan's nascent agricultural insurance market. By leveraging satellite imagery and digital farm records to accelerate loss assessment, TARSİM substantially reduced administrative costs while expanding coverage. Kazakhstan's QazAgro platform—a national digital agriculture portal integrating subsidy applications, market price information, and agronomic advisory services—represents the closest regional analogue to what Uzbekistan is developing, and its implementation experience offers practical lessons on sequencing investments, managing farmer onboarding, and sustaining engagement in a post-Soviet institutional context.

Table 3. Selected International Digital Agriculture Experiences and Relevance to Uzbekistan

Country	Key Initiative	Results Achieved	Relevance to Uzbekistan
Netherlands	Wageningen precision farming hub	World-leading yield/hectare; reduced input waste	Drip irrigation models; greenhouse tech applicable to Fergana Valley horticulture
Israel	Drip irrigation + sensor networks	Water savings of 40–50% vs flood irrigation	Directly relevant: both countries face severe water constraints
China	Digital Village Programme; rural e-commerce	Rural e-commerce exceeds USD 500bn annually	Model for linking remote smallholders to urban premium markets
Turkey	TARSİM digital crop insurance system	Rapid loss assessment; broad farmer coverage	Applicable to Uzbekistan's developing agricultural insurance market

Country	Key Initiative	Results Achieved	Relevance to Uzbekistan
Kazakhstan	Digital agriculture platform (QazAgro)	Integrated subsidy, market, and advisory portal	Closest regional analogue; lessons on transition-economy rollout
India	PM-KISAN digital disbursement	Direct payments to 110+ million farmers; reduced leakage	Relevant for Uzbekistan's subsidy digitalisation efforts

5. Discussion

The synthesis of international evidence and the characterisation of Uzbekistan's agricultural context presented in this review support a cautiously optimistic but contextually nuanced assessment of digital agriculture's prospects in Uzbekistan.

The evidence base leaves little doubt that digital technologies carry genuine transformative potential for agricultural systems with the structural characteristics of Uzbekistan: information asymmetries between producers and markets, irrigation inefficiency under resource scarcity, fragmented smallholder structure, and limited formal finance and insurance penetration are precisely the conditions under which digital tools have demonstrated the strongest economic returns in international studies. The mechanisms are well understood and broadly applicable: mobile market platforms reduce information gaps and improve producer bargaining power; IoT irrigation systems address water waste at the plot level; digital credit scoring expands formal finance access beyond collateral-based lending; and remote sensing supports public sector monitoring and resource allocation decisions that individual farmers cannot perform for themselves.

However, the international literature consistently demonstrates that technology alone is insufficient. The most commonly cited determinants of successful digital agriculture at scale—beyond the existence of appropriate technologies—are rural connectivity infrastructure, digital literacy among farmers, institutional frameworks that give farmers confidence in digital systems, and competitive markets that pass the benefits of efficiency improvements through to producers rather than capturing them at the platform or trader level. On each of these dimensions, Uzbekistan faces genuine challenges that are not easily resolved by investment in technology alone.

The digital divide between Uzbekistan's urban and rural populations is a structural impediment. While the country has achieved relatively high levels of mobile penetration overall, rural broadband coverage—particularly the high-speed connectivity required for data-intensive IoT and cloud-based applications—lags. Extension services, historically underfunded and understaffed relative to the scale of Uzbekistan's farming population, are not currently configured to deliver digital skills training at the required scale and quality. These are solvable problems, as Kazakhstan's experience demonstrates, but they require sustained institutional investment rather than one-off technology projects.

A further analytical concern relates to the distribution of benefits within Uzbekistan's dual agricultural structure. The productivity and income gains from digital agriculture documented in international studies tend to accrue most readily to farms with sufficient scale to make initial investments viable and sufficient human capital to use tools effectively. In Uzbekistan, this suggests that farmer households may capture many near-term digital agriculture benefits, while the dehqon smallholders who dominate labour-intensive horticulture—and who are arguably most in need of productivity improvements—may be the last to benefit. Designing digital agriculture programmes that explicitly address this distributional challenge is not merely an equity concern; it is also an economic efficiency concern, since the largest aggregate productivity gains are likely to be achievable among farms currently furthest below their potential output.

Finally, Uzbekistan's position as an agricultural exporter creates both an opportunity and a responsibility regarding digital food safety and traceability infrastructure. The European Union and other major markets are progressively raising requirements for digital provenance documentation in agri-food imports. Countries that invest early in compatible traceability systems can capture quality premiums and

maintain market access; those that do not risk competitive disadvantage as these requirements become mandatory.

6. Policy Recommendations

6.1 For Government

• Develop a coherent, cross-ministerial national digital agriculture strategy that aligns the Ministry of Agriculture, Ministry of Digital Technologies, and financial regulatory bodies around shared targets and responsibilities, with clear implementation timelines and monitoring mechanisms.

• Prioritise investment in rural broadband infrastructure in agricultural districts, treating connectivity as a foundational prerequisite for digital agriculture rather than an optional add-on to technology programmes.

• Establish a legal framework for agricultural data governance that defines farmer rights over data generated by digital tools, sets standards for platform interoperability, and provides independent oversight to prevent data exploitation by commercial providers.

• Design targeted subsidy and co-financing programmes that reduce the capital cost of digital irrigation systems and precision tools for smallholder dehqon households, including public-private schemes that aggregate demand across farmer groups to achieve viable scale.

• Accelerate the digitalisation of agricultural subsidy disbursement, land registration, and market licensing to create the foundational data infrastructure on which private digital services can be built.

6.2 For Extension Services and Universities

• Redesign agricultural extension services to integrate digital skills training into regular farmer engagement programs, with particular attention to women farmers, older farming households, and regions with lower baseline digital literacy.

• Establish university-based digital agriculture research centres, ideally in partnership with international institutions, to generate contextually relevant evidence on the economic and social impacts of digital tool adoption in Uzbekistan's farming systems.

• Develop academic curricula in agricultural economics, agronomy, and rural development that prepare graduates to support the digital transformation of the agricultural sector as extension officers, policy analysts, and private sector professionals.

6.3 For Farmers and Farmer Organisations

• Farmer cooperatives and water user associations should actively explore collective procurement of digital services, including shared IoT infrastructure and group-based mobile advisory platforms, to achieve economies of scale that individual smallholders cannot attain alone.

• Farmers should engage critically with digital platform providers, seeking clarity on data ownership terms before adoption and participating in farmer-organisation-led negotiations for data governance agreements.

7. Conclusion

This article has reviewed the international and regional evidence on the role of digital technologies in agricultural development and assessed its implications for Uzbekistan. The core conclusion is one of the significant but conditional potentials. Digital technologies—spanning precision irrigation, mobile advisory services, digital finance, e-commerce platforms, and remote sensing—address the specific structural inefficiencies of Uzbekistan's agricultural sector in ways that are consistent with strong and growing international evidence of positive productivity and income effects. The government's reform trajectory and digital economy strategy create a policy environment more conducive to agricultural digitalisation than at any previous point in the country's independent history.

At the same time, the conditions required to realise this potential are demanding. Rural connectivity must be treated as infrastructure, not as a downstream product of commercial network rollout. Digital literacy among farmers must be built through sustained, contextually sensitive extension programmes. Regulatory frameworks for agricultural data must be established before commercial platforms reach scale, to protect smallholder interests and maintain competitive market dynamics. And digital agriculture programs must explicitly target the dehqon smallholder households who constitute most of Uzbekistan's

farming population, rather than defaulting to the commercially simpler strategy of serving only larger commercial farms.

The research agenda for digital agriculture in Uzbekistan is almost entirely open. Priorities include farm-level impact evaluations using rigorous causal inference methods; analysis of the gendered dimensions of digital access and benefits; assessment of the costs and returns of digital irrigation modernisation under Uzbek water resource conditions; and comparative studies of the implementation of digital agriculture programs across Central Asia. Collaboration between Uzbek agricultural economics researchers and international institutions offers the most credible pathway to building the evidence base that policymakers require.

Digital technologies are not a panacea for the structural challenges facing Uzbekistan's agricultural sector. But deployed thoughtfully, within enabling institutional frameworks and in response to the demonstrated needs of diverse farming households, they represent one of the most promising tools available for accelerating sustainable agricultural development in Uzbekistan and the broader Central Asian region.

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