PRECISION AGRICULTURE TECHNOLOGIES AS AN INSTRUMENT OF GREEN ECONOMY IMPLEMENTATION IN UZBEKISTAN'S FARMING SECTOR

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Abstract. *This article investigates how precision agriculture technologies — including remote sensing, Internet of Things sensors, unmanned aerial vehicles, machine learning-based yield forecasting, and blockchain traceability — can serve as practical instruments for implementing green economy principles in Uzbekistan's farming sector. Against a backdrop of rising input costs, water stress, and intensifying export competition, the article analyses the environmental and economic co-benefits of site-specific crop management, real-time field monitoring, and data-driven decision support. Statistical evidence on the current digital penetration of Uzbek farms, government digitisation targets, international co-financing commitments, and documented yield and resource-use outcomes from pilot deployments is presented to demonstrate the transformative potential of precision farming. The article contends that precision agriculture is not merely a technological upgrade but a structural enabler of the green economic transition, capable of decoupling productivity growth from resource depletion.*

Keywords: *precision agriculture, green economy, Internet of Things, remote sensing, UAV, machine learning, digital farming, resource efficiency, Uzbekistan.*

Introduction. Uzbekistan's agricultural sector faces a paradox characteristic of many transitioning economies: the pressure to raise yields and farm incomes is urgent, yet the natural resource base upon which production depends is under severe and accelerating stress. The Aral Sea basin — the hydrological heart of Central

Asian agriculture — has lost approximately 90 percent of its original water volume, and saline groundwater now underlies an estimated 4.9 million hectares of formerly productive farmland [1]. Simultaneously, Uzbekistan's expanding middle class, rapid urbanisation, and growing export ambitions in European and Middle Eastern markets demand higher quality, traceability, and environmental credentials from domestic producers.

Precision agriculture — broadly defined as the application of digital technologies to deliver the right input, at the right place, at the right time, in the right quantity — offers a technologically credible pathway out of this paradox. By enabling site-specific management rather than blanket resource application, precision technologies reduce waste, lower operating costs, and generate the environmental outcomes increasingly demanded by international buyers, regulators, and financiers.

This article situates precision agriculture within the green economy framework, examines the current state of digital technology adoption among Uzbek farms, quantifies the resource and economic impacts of key precision tools, and identifies policy measures needed to accelerate adoption at the national scale.

Literature Review. The green economy is an economic model oriented toward achieving inclusive growth while systematically reducing environmental risks and ecological scarcities. Applied to agriculture, its core operational principles encompass:

- Site-specific and demand-responsive input management to eliminate over-application of water, fertiliser, and crop protection chemicals
- Real-time monitoring and early warning systems to prevent crop losses and disease outbreaks before they require chemical intervention
- Integration of renewable energy into farm operations to reduce fossil-fuel dependency and carbon emissions

- Digital supply chain transparency to verify environmental claims, facilitate premium market access, and deter fraud
- Circular nutrient management — converting crop residues and animal manure into soil amendments — to close agronomic nutrient loops

Researchers including Gebbers and Adamchuk (2010) established the foundational link between precision agriculture and environmental performance, demonstrating that variable-rate application of nitrogen fertiliser can reduce application volumes by 15–35 percent without yield penalty. More recent work by Bannerjee et al. (2022) and Liakos et al. (2018) documents the expanding role of machine learning in yield prediction, pest identification, and irrigation scheduling, reinforcing the environmental and economic case for digital farming. In the Central Asian context, Hamidov et al. (2020) emphasise that technology alone is insufficient without institutional capacity to interpret data and translate recommendations into field decisions — underscoring the importance of farmer training alongside hardware deployment.

Current State of Precision Agriculture Adoption in Uzbekistan. Uzbekistan's precision agriculture landscape is at an early but rapidly evolving stage of development. Based on Ministry of Agriculture data for 2024, the national digital technology penetration among registered farm households is as follows [1, 2]:

Technology Category	Farms Equipped	Coverage (% of total)	Primary Application
Automated drip irrigation with sensors	38,400	9.0	Water scheduling

UAV field surveillance	12,700	3.0	Pest / disease scouting
IoT soil moisture and salinity sensors	24,600	5.8	Irrigation triggering
Satellite crop monitoring (NDVI)	18,300	4.3	Yield estimation
Digital marketplace platforms	87,300	20.4	Sales and logistics
AI-assisted yield forecasting	6,200	1.5	Production planning

Table 2: Precision agriculture technology adoption rates, Uzbekistan, 2024 [1, 2].

These figures confirm that digital marketplace platforms lead adoption, driven by strong private-sector incentives and low capital requirements. Hardware-intensive technologies — UAVs, IoT sensor networks, AI forecasting — lag significantly, reflecting high upfront investment barriers and limited technical literacy in rural areas. Nonetheless, the trajectory is positive: UAV registrations in agriculture doubled between 2022 and 2024, and the government has prioritised precision farming in its 2025–2030 Agriculture Digitisation Strategy [2].

Precision Agriculture as a Green Economy Driver. Precision agriculture technologies enhance green economic performance through several concrete pathways.

In terms of water conservation, automated drip irrigation combined with real-time soil moisture feedback has demonstrated water savings of 38–52 percent compared to furrow irrigation baselines in Uzbek field trials conducted by the Ministry of Water Resources between 2022 and 2024 [2]. At the national scale, if automated drip irrigation were expanded to cover the planned 120,000 additional hectares by 2030, annual water savings would amount to approximately 1.4 billion cubic metres — equivalent to the annual municipal water consumption of Tashkent city.

Regarding crop protection, UAV-based field scouting enables the detection of fungal disease outbreaks seven to ten days earlier than manual inspection, facilitating targeted interventions that reduce fungicide volumes by 40–50 percent [2]. In Uzbekistan's cotton sector — historically one of the heaviest users of pesticides in Central Asia — widespread UAV adoption could generate annual savings of USD 28–35 million in crop protection expenditure while simultaneously reducing soil and groundwater contamination.

Blockchain traceability offers a further competitive dimension. Farms participating in Uzbekistan's pilot digital food traceability programme — which tracked produce from 420 farms across six regions in 2023–2024 — achieved export price premiums averaging 18 percent above untraced equivalents, and reported a 31 percent reduction in product rejection rates at EU border inspections [5].

Government Digitisation Targets and Support Programmes. Uzbekistan has articulated ambitious precision agriculture deployment targets for the 2025–2030 period. The national Agriculture Digitisation Strategy envisages installing precision irrigation control systems across 35 percent of irrigated farmland, establishing satellite-based crop monitoring on 18,000 hectares, and setting up 65 regional agri-digital information centres staffed by trained agronomists [2]. These centres are designed to serve as nodes where farmers can access real-time field data, connect with input suppliers and buyers, and receive subsidised advisory services.

To finance this transition, the government has attracted a USD 180 million International Finance Corporation investment package supporting agri-park and farmer cluster digitisation, including digital infrastructure, agritech startups, and smart irrigation systems [3]. The European Bank for Reconstruction and Development has complementarily committed USD 220 million to a sustainable agriculture and digital transformation project, covering eco-technology adoption, farmer skills development, and market access improvement [4].

Barriers and Policy Recommendations. Despite strong policy momentum, barriers to large-scale precision agriculture adoption persist. High equipment costs, limited rural internet connectivity, shortage of certified agri-digital technicians, and fragmented farm structures that make per-unit technology costs prohibitive for smallholders collectively constrain uptake. Addressing these barriers requires a multi-pronged policy response: (i) establishing a dedicated precision agriculture equipment subsidy scheme modelled on Kazakhstan's AgroTech programme; (ii) accelerating rural broadband deployment under the Digital Uzbekistan 2030 initiative; (iii) creating a national agri-digital technician certification pathway within vocational education institutions; and (iv) promoting farmer cooperative models that enable pooled ownership of expensive hardware such as multi-spectral UAVs and satellite terminal equipment.

Conclusion. Precision agriculture technologies represent a structurally important instrument for translating green economy principles from policy aspiration to farm-level reality in Uzbekistan. The evidence presented demonstrates that IoT sensors, UAVs, satellite monitoring, and digital traceability platforms collectively deliver water savings of 38–52 percent, pesticide reductions of 40–50 percent, and export price premiums of 15–25 percent for participating farms [1, 2, 3, 4, 5].

Realising this potential at scale requires sustained public investment in rural digital infrastructure, targeted equipment subsidy schemes, and institutional support for farmer digital literacy. When these enabling conditions are met, precision agriculture can serve as the technological backbone of Uzbekistan's green agricultural transition — enabling the sector to produce more with less, compete more effectively on quality-differentiated global markets, and contribute to the country's climate commitments under the Paris Agreement.

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