ACADEMIC INN INTERNATIONAL

ISSN NO : 2523-1189

Journal of AGRICULTURAL AND RURAL RESEARCH

open access

ADOPTION AND PROSPECTS OF DRONE-ASSISTED PRECISION AGRICULTURE IN BANGLADESH

Md. Jahidul Amin[1*]

To cite the article: *Md. Jahidul Amin (2025). ADOPTION AND PROSPECTS OF DRONE-ASSISTED PRECISION AGRICULTURE IN BANGLADESH, Journal of Agricultural and Rural Research, 9(1): 1-19.*

Link to this article:
https://aiipub.com/journals/jarr-251211-10093/

Article QR

Journal QR

ADOPTION AND PROSPECTS OF DRONE-ASSISTED PRECISION AGRICULTURE IN BANGLADESH

Md. Jahidul Amin[1, *]

[1]Faculty member, Department of Agriculture, Rabindra Maitree University, Kushtia, Bangladesh.

*Corresponding author: jahidulamin1963@gmail.com

ARTICLE INFO

Article Type: Research

Received: 25 Sep 2025.

Accepted: 19 Oct 2025.

Published: 15 Dec 2025.

Keywords:
Organic farming, sustainable agriculture, Bangladesh, policy, certification, market access, challenges.

ABSTRACT

Bangladesh's agricultural sector, contributing 12% to GDP and employing 40% of the population, faces mounting challenges from climate change, declining arable land, and resource constraints. Drone-assisted precision agriculture presents a transformative solution for enhancing productivity and sustainability. This literature-based study examines the adoption status, technological applications, challenges, and prospects of unmanned aerial vehicles (UAVs) in Bangladesh's agricultural landscape. Through a comprehensive analysis of secondary data from 2018-2024, this research explores drone applications in crop monitoring, precision spraying, soil analysis, and disaster management. Key findings indicate that institutional initiatives, including the Department of Agricultural Extension's partnership with the Asian Development Bank and the World Bank's $578 million Climate-Smart Agriculture Investment Plan, have enabled 127,500 farmers to adopt smart technologies, achieving yield improvements of 15-60%. However, significant barriers persist, including high acquisition costs (Tk 300,000-500,000), regulatory complexities, limited technical expertise, and infrastructural gaps. The study reveals promising prospects through cooperative ownership models, policy development, and capacity-building programs, positioning Bangladesh as a potential leader in climate-resilient, technology-enabled agriculture among developing nations.

1. INTRODUCTION

Agriculture remains the socioeconomic backbone of Bangladesh, supporting the livelihoods of approximately 170 million people in one of the world's most densely populated nations (Khan et al., 2023). With 72.35% of land designated as agricultural and rice covering 80% of cultivable areas, the sector's significance extends beyond its 12% GDP contribution to encompass food security, rural employment, and national economic stability (Hassan and Rahman, 2022; World Bank, 2023). Bangladesh ranks third globally in rice production, achieving 39.1 million tonnes in 2023, demonstrating remarkable agricultural productivity despite limited land resources (BBS, 2024). However, this achievement faces unprecedented challenges as climate change, declining arable land at 0.3% annually, and resource scarcity threaten long-term sustainability (Rahman et al., 2023). The agricultural landscape is characterized by smallholder dominance, with 83% of farmers cultivating less than 1.5 acres and 56% of rural households classified as landless (IFPRI, 2022). Traditional farming methods, relying heavily on draft animals, manual labor, and empirical knowledge, struggle to meet the demands of a population projected to reach 200 million by 2050 (Ahmed and Islam, 2023). Climate-induced disasters, including frequent floods, cyclones, and salinity intrusion, have devastated crops sufficient to feed 10 million people for a month in 2022 alone (Das et al., 2023). These challenges necessitate urgent technological interventions to enhance productivity while minimizing environmental degradation. Precision agriculture, leveraging drone technology, offers a paradigm shift from conventional farming practices to data-driven, resource-efficient cultivation (Alam et al., 2022). Unmanned Aerial Vehicles equipped with multispectral sensors, thermal cameras, and precision spraying systems enable farmers to monitor crop health in real-time, optimize input application, and respond proactively to emerging threats (Singh and Kumar, 2022). Global adoption patterns demonstrate significant benefits, with Japanese farmers reducing pesticide usage by 25% and Indian farmers achieving 10% reduction in crop losses through drone-based monitoring (Tanaka et al., 2023; Patel and Sharma, 2022). Bangladesh's journey toward drone-assisted agriculture, though nascent, shows promising momentum through institutional support, private sector initiatives, and farmer cooperatives. The Department of Agricultural Extension, in partnership with the Asian Development Bank, implemented pilot programs in 2024 training over 300 agricultural extension officers in remote sensing technologies for drought stress assessment, pest pattern identification, and flood damage evaluation (Hossain et al., 2024). The World Bank's Climate-Smart Agriculture Investment Plan facilitated technology adoption among 127,500 farmers, reporting yield improvements ranging from 15% to 60% depending on crop type and regional conditions (World Bank, 2023; Khatun et al., 2025). Private sector engagement, exemplified by ACI Motors introducing agricultural spraying drones with 30-liter tanks covering 40 acres hourly, signals growing commercial viability (ACI, 2024). Despite these advances, adoption remains constrained by regulatory ambiguities, financial barriers, and technical capacity limitations requiring comprehensive policy frameworks and sustained institutional support for widespread implementation (Mandal, 2024).

2. METHODOLOGY

2.1 Research Design and Approach

This study employs a comprehensive literature-based research methodology to examine the adoption and prospects of drone-assisted precision agriculture in Bangladesh. The research design follows a systematic review approach, integrating secondary data from multiple authoritative sources to provide holistic insights into technological adoption patterns, implementation challenges, and future prospects (Snyder, 2019). The methodological framework encompasses data collection from peer-reviewed journals, government statistical reports, international development organization publications, industry reports, and policy documents spanning 2018-2024, ensuring contemporary relevance and empirical validity (Booth et al., 2022). The study adopts a mixed-method approach combining quantitative data analysis of agricultural statistics, adoption rates, and economic indicators with qualitative assessment of policy frameworks, institutional initiatives, and farmer experiences reported in literature (Creswell and Plano Clark, 2018). This triangulation strategy enhances research credibility by cross-validating findings across multiple data sources, methodologies, and theoretical perspectives (Denzin, 2017). The temporal scope focuses on recent developments post-2018, capturing Bangladesh's accelerated digitalization efforts, climate-smart agriculture initiatives, and emerging drone technology applications in the agricultural sector (Kabir et al., 2023).

2.2 Data Sources and Collection Strategy

Secondary data collection followed a structured protocol targeting five primary source categories. First, academic databases including ScienceDirect, Google Scholar, ResearchGate, PubMed Central, and IEEE Xplore were systematically searched using keywords: "drone agriculture Bangladesh," "precision farming South Asia," "UAV crop monitoring," "agricultural technology adoption developing countries," and "smart agriculture Bangladesh" (Rahman and Ahmed, 2023). Search filters limited results to publications between 2018-2024, prioritizing peer-reviewed articles, conference proceedings, and systematic reviews in agricultural technology, precision farming, and rural development domains (Moher et al., 2021). Second, official government sources provided essential statistical data and policy information. Bangladesh Bureau of Statistics (BBS) agricultural yearbooks, quarterly crop statistics, and agricultural labor wage reports furnished comprehensive production data, land utilization statistics, and farmer demographic information (BBS, 2024). Ministry of Agriculture policy documents, Department of Agricultural Extension program reports, and Civil Aviation Authority of Bangladesh regulatory frameworks illuminated institutional perspectives on drone technology adoption and implementation strategies (DAE, 2024). Third, international development organizations contributed valuable insights through project reports, technical assessments, and policy recommendations. World Bank, Asian Development Bank, and International Food Policy Research Institute publications provided adoption statistics, impact assessments, and comparative analyses of precision agriculture initiatives across South Asian contexts (World Bank, 2023; ADB, 2024). Fourth, industry reports from agricultural technology companies, drone manufacturers, and precision farming service providers offered practical perspectives on technological capabilities, market trends, and implementation challenges. Publications from ACI Motors, Sky Biz Limited, Bangladesh Drone Company, and international manufacturers like DJI Agriculture illuminated commercial developments, product specifications, and service delivery models (ACI, 2024). Fifth, reputable news media outlets including The Financial Express, The Business Standard, The Business Post, and Observer Bangladesh provided timely coverage of recent developments, policy announcements, and stakeholder perspectives (Financial Express, 2024).

2.3 Inclusion and Exclusion Criteria

Rigorous inclusion criteria ensured data quality and relevance to research objectives. Studies were included if they: (1) focused specifically on drone technology applications in agriculture or precision farming practices; (2) addressed Bangladesh or comparable South Asian agricultural contexts with smallholder farmer dominance; (3) were published in English between 2018-2024; (4) provided empirical data, case studies, or systematic analysis rather than purely theoretical discussions; and (5) originated from credible sources including peer-reviewed journals, government agencies, or established international organizations (Page et al., 2021). Exclusion criteria eliminated irrelevant or low-quality sources. Studies were excluded if they: (1) focused exclusively on military drone applications or non-agricultural sectors; (2) lacked specific data on technological adoption, implementation outcomes, or farmer experiences; (3) predated 2018 except for seminal works establishing foundational concepts; (4) originated from questionable sources lacking editorial oversight or peer review; and (5) discussed drone technology only peripherally without substantive analysis of agricultural applications (Higgins et al., 2019). This systematic screening process initially identified 187 potentially relevant sources, which were reduced to 89 publications meeting all inclusion criteria through title-abstract screening, followed by full-text review yielding 35 core references integrated into the final analysis.

2.4 Data Extraction and Analysis Framework

Data extraction employed a standardized template capturing key information across multiple dimensions. For each source, researchers documented: (1) bibliographic information including authors, publication year, journal/publisher, and citation details; (2) study characteristics encompassing research design, sample size, geographical scope, and temporal coverage; (3) technological specifications detailing drone types, sensor configurations, application methods, and operational parameters; (4) adoption metrics including farmer participation rates, coverage areas, implementation timelines, and institutional involvement; (5) performance outcomes reporting yield improvements, cost reductions, resource efficiency gains, and environmental impacts; (6) implementation challenges identifying financial barriers, technical constraints, regulatory issues, and capacity limitations; and (7) policy recommendations proposing interventions for enhanced adoption and sustainability (Munn et al., 2018). Quantitative data underwent descriptive statistical analysis, calculating means, ranges, and percentages to characterize adoption patterns, technological performance, and economic impacts. Agricultural production statistics from BBS were tabulated, showing temporal trends in rice, wheat, and maize cultivation across different regions. Adoption rates calculated from World Bank and ADB reports illustrated the scale of farmer participation in precision agriculture programs. Cost-benefit analyses synthesized from multiple sources compared traditional versus drone-assisted farming economics (Liberati et al., 2009). Qualitative data analysis followed thematic coding procedures, identifying recurring patterns across sources. Initial open coding generated preliminary categories related to technology adoption drivers, implementation barriers, institutional responses, and farmer perceptions. Axial coding established relationships between categories, revealing how financial constraints interact with technical capacity limitations and regulatory frameworks to shape adoption patterns. Selective coding integrated themes into coherent narratives explaining Bangladesh's drone agriculture trajectory, challenges, and prospects (Braun and Clarke, 2022).

2.5 Quality Assessment and Validation

Research quality assurance incorporated multiple validation strategies. Source credibility assessment evaluated publication venues, author qualifications, institutional affiliations, and citation indices to ensure data reliability (Shamseer et al., 2015). Cross-validation compared findings across multiple independent sources, with convergent evidence strengthening conclusions while divergent data prompted additional investigation. Temporal consistency analysis examined whether reported trends aligned with broader agricultural and technological development patterns in Bangladesh. Geographical contextualization verified that international comparisons appropriately considered Bangladesh's unique agricultural characteristics including farm sizes, crop types, climate patterns, and socioeconomic conditions (Gough et al., 2017).

Data triangulation integrated statistical evidence from government sources, qualitative insights from academic studies, and practical perspectives from industry reports to construct comprehensive understanding. Methodological transparency maintained detailed documentation of search strategies, selection criteria, data extraction procedures, and analytical approaches to enable replication and verification (Uman, 2011). Limitations acknowledgment recognized potential biases including publication bias favoring positive outcomes, geographical bias toward regions with active research programs, and temporal lag between technological innovations and published evaluations. These quality measures enhance confidence that findings accurately represent current knowledge regarding drone-assisted precision agriculture adoption and prospects in Bangladesh (Petticrew and Roberts, 2008).

2.6 Ethical Considerations

Although this literature-based study did not involve primary data collection from human subjects, ethical research practices were maintained throughout. All secondary sources were properly attributed with complete citations acknowledging original authors' intellectual contributions. Data reporting maintained accuracy and objectivity, presenting both favorable and unfavorable findings without selective emphasis. Interpretation avoided overgeneralization beyond available evidence, clearly distinguishing empirical observations from speculative projections. Critical analysis balanced technological enthusiasm with a realistic assessment of implementation challenges and limitations (Israel and Hay, 2006). Stakeholder perspectives received equitable consideration, incorporating viewpoints from government agencies, international development organizations, private sector entities, research institutions, and farmer communities as represented in the literature. Policy recommendations prioritized farmer welfare, environmental sustainability, and equitable access to technological benefits rather than privileging commercial interests or institutional agendas. Acknowledging knowledge gaps and uncertainties prevented misleading claims about drone technology's agricultural potential, supporting informed decision-making by policymakers, practitioners, and farming communities (Smith, 2003). This comprehensive methodological approach ensures rigorous, credible, and ethically sound analysis of drone-assisted precision agriculture adoption and prospects in Bangladesh's agricultural transformation journey.

3. RESULTS

3.1 Current Status of Drone Technology Adoption in Bangladesh Agriculture

Bangladesh's drone-assisted precision agriculture adoption exhibits promising momentum despite nascent developmental stages. The Department of Agricultural Extension, collaborating with the Asian Development Bank, initiated comprehensive pilot programs in 2024 integrating drones and satellite imaging into routine field assessments (Hossain et al., 2024). This initiative trained over 300 agricultural extension officers across multiple upazilas in remote sensing technologies, enabling the interpretation of aerial imagery for drought stress identification, pest pattern mapping, and flood-induced crop loss evaluation. The World Bank's $578 million Climate-Smart Agriculture Investment Plan, launched in 2023, catalyzed technology adoption among 127,500 Bangladeshi farmers, demonstrating tangible yield improvements ranging from 15% to 60% per hectare depending on crop type and regional conditions (World Bank, 2023). Private sector engagement significantly advanced commercial drone availability and service provision. ACI Motors pioneered agricultural spraying drone introduction in Bangladesh, featuring 30-liter tank capacity, 9-meter spraying width, and coverage rates up to 40 acres per hour (ACI, 2024). Field testing across maize, rice, and fruit orchards demonstrated operational viability under Bangladeshi agricultural conditions. Sky Biz Limited announced plans for domestic drone manufacturing with $4.6 million investment, targeting production of 10 UAV models including agricultural sprayers for both domestic use and export markets, signaling growing industry confidence (Rahman, 2024). Bangladesh Drone Company established precision agriculture services offering crop quality assessments and image-based problem area identification for agro-customers, expanding technological accessibility beyond large commercial farms (BDC, 2024). Table 1 summarizes the institutional initiatives and their implementation scales-

Table 1: Major Institutional Initiatives in Drone-Assisted Agriculture (2023-2024)

Institution/Program	Implementation Scale	Key Features	Reported Outcomes
DAE-ADB Pilot Program (2024)	300+ extension officers trained across multiple upazilas	Remote sensing technology training, aerial imagery interpretation for drought, pest, and flood assessment	Enhanced field assessment capacity, improved disaster response
World Bank Climate-Smart Agriculture Investment Plan (2023)	127,500 farmers	Integration of UAVs, satellite imaging, precision input application	Yield improvements 15-60% per hectare depending on crop and region
ACI Motors Agricultural Drone Initiative (2024)	Commercial introduction	30L tank capacity, 9m spraying width, 40 acres/hour coverage	Demonstrated operational viability in maize, rice, fruit orchards
Sky Biz Limited Manufacturing Project	$4.6M investment, 10 UAV models planned	Domestic production for agriculture spraying and export	Production expected January 2025
Post-Disaster Drone Deployment (Cyclone Sitrang 2022, Sylhet Floods 2023)	District-level assessments	Rapid cropland damage assessment by NGOs and district administrations	Expedited compensation disbursement under government relief programs

The crop portfolio includes vegetables (tomato, brinjal, cabbage), fruits (mango, pineapple), spices (turmeric, ginger), and niche crops like tea. The export of organic products is increasing but still limited (Mahedi et al., 2025); for example, organic tea exports reached 450 metric tons valued at USD 1.2 million in 2021 (BEPB, 2022; Prodhan et al., 2023).

3.2 Technological Applications and Operational Capabilities

Drone technology demonstrates diverse agricultural applications addressing Bangladesh's specific challenges. Crop monitoring applications utilize multispectral and hyperspectral sensors capturing high-resolution imagery for vegetation health assessment through Normalized Difference Vegetation Index (NDVI) analysis (Alam et al., 2022). These sensors detect subtle variations in crop chlorophyll content, identifying nutrient deficiencies, water stress, and disease symptoms before visible manifestation, enabling proactive interventions minimizing yield losses (Singh and Kumar, 2022). Thermal imaging capabilities monitor crop canopy temperature variations indicating irrigation requirements, optimizing water resource utilization in water-stressed regions (Das et al., 2023). Precision spraying represents the most commercially advanced drone application in Bangladesh. Typical agricultural spraying drones carry 10-30 liter liquid pesticide tanks with discharge rates of approximately 1 liter per minute, covering one hectare in 10 minutes compared to half-day manual labor requirements (Mandal, 2024). The downward airflow generated by drone rotors enhances penetration of pesticide droplets into crop canopy, improving coverage uniformity and efficacy while reducing chemical usage by 20-30% compared to traditional methods (Khan et al., 2023). Variable-rate application synchronized with precision imaging enables targeted treatment of affected areas only, further minimizing chemical inputs and environmental impacts (Kabir et al., 2025). Soil analysis applications employ drones for comprehensive assessment of soil conditions, nutrient status, moisture content, and topographical variations informing cultivation planning (Rahman and Ahmed, 2023). Three-dimensional terrain mapping identifies micro-variations affecting water flow and nutrient distribution, supporting precision land preparation and drainage management. Disaster risk reduction applications proved invaluable during Cyclone Sitrang (2022) and Sylhet floods (2023), with drones providing rapid damage assessments facilitating timely compensation disbursement under government relief programs (Hossain et al., 2024). Table 2 details the comparative performance metrics of drone-assisted versus traditional agricultural practices:

Table 2: Comparative Performance Metrics of Drone-Assisted vs. Traditional Agricultural Practices

Parameter	Traditional Method	Drone-Assisted Method	Improvement (%)	Reference
Pesticide Spraying Time (per hectare)	4-6 hours (manual labor)	10-12 minutes	95% time reduction	Mandal (2024)
Pesticide Usage Efficiency	Baseline application rate	20-30% reduction	20-30% chemical savings	Khan et al. (2023)
Crop Monitoring Coverage	Limited visual inspection	100-500 acres per flight	Comprehensive field coverage	Ahmed and Islam (2023)
Labor Cost (spraying operations)	Baseline labor costs	30-40% reduction	30-40% cost savings	World Bank (2023)
Early Disease Detection Accuracy	Visible symptom identification only	87-93% pre-symptomatic detection	Proactive intervention capability	Alam et al. (2022)
Water Use Efficiency (irrigation optimization)	Traditional scheduling	30-50% water savings	Enhanced resource conservation	Das et al. (2023)
Field Assessment Speed (disaster	Days to weeks	Hours to 1-2 days	90% time reduction	Hossain et al. (2024)

evaluation)				

3.3 Economic Analysis and Cost-Benefit Assessment

Economic viability constitutes a critical determinant of drone technology adoption among Bangladesh's predominantly smallholder farmers. High-end agricultural drones capable of autonomous operations, precision spraying, and large field coverage cost Tk 300,000-500,000 (approximately \$2,700-\$4,500), representing prohibitive investments for individual smallholders cultivating less than 1.5 acres (IFPRI, 2022). However, cooperative ownership models and service-based deployment demonstrate promising economic feasibility. Farmer producer groups (FPGs) pooling resources for shared drone ownership distribute acquisition costs across multiple members while maximizing utilization through coordinated scheduling (Rahman et al., 2023). Service provision models, where specialized operators offer drone spraying, monitoring, or mapping services for per-hectare fees, eliminate capital investment requirements for individual farmers. Typical drone spraying services charge Tk 800-1,200 per acre (\$7-11 per acre), competitive with traditional labor costs while delivering superior application efficiency and time savings (ACI, 2024). Cost-benefit analyses conducted across World Bank pilot projects demonstrated positive returns within 2-3 growing seasons through combined yield improvements (15-60%), input cost reductions (20-30% pesticide savings), and labor cost decreases (30-40%) (World Bank, 2023). Long-term economic benefits extend beyond direct farm profitability to encompass environmental cost reductions and market value enhancement. Reduced chemical runoff minimizes water contamination costs, while precise application decreases human pesticide exposure health impacts (Khan et al., 2023). Enhanced crop quality through optimized nutrient and water management improves market value and export potential, particularly for high-value crops including fruits, vegetables, and specialty rice varieties (Ahmed and Islam, 2023). However, economic viability depends critically on supportive policies including subsidized acquisition programs, favorable financing terms, tax incentives, and sustained technical support infrastructure ensuring operational effectiveness. Table 3 presents detailed economic analysis of drone adoption under different operational models:

Table 3: Economic Analysis of Drone-Assisted Agriculture: Operational Models and Cost-Benefit Assessment

Cost/Benefit Category	Individual Ownership (Large Farm >10 acres)	Cooperative Model (FPG 5-10 members)	Service Model (Per-Hectare Fee)	Traditional Method (Baseline)
Initial Capital Investment	Tk 300,000-500,000	Tk 50,000-80,000 per member	Nil	Minimal equipment
Annual Operating Costs	Tk 30,000-50,000	Tk 8,000-12,000 per member	Included in service fee	Variable labor costs
Per-Hectare Service Cost	Self-operated	Tk 600-900 (shared)	Tk 800-1,200	Tk 1,000-1,500 (labor)
Yield Improvement	15-60% increase	15-60%	15-60%	Baseline

		increase	increase	
Input Cost Savings (pesticides)	20-30% reduction	20-30% reduction	20-30% reduction	Baseline
Labor Cost Reduction	30-40% decrease	30-40% decrease	30-40% decrease	Baseline
Break-Even Period	3-4 growing seasons	2-3 growing seasons	Immediate	N/A
Net Annual Benefit (10-acre farm)	Tk 80,000-150,000	Tk 70,000-130,000	Tk 60,000-110,000	Baseline
Scalability	Limited to large farms	Medium scalability	High scalability	Universal

3.4 Challenges and Barriers to Widespread Adoption

Despite promising pilot outcomes, multiple interconnected challenges constrain widespread drone technology adoption in Bangladesh agriculture. Financial barriers constitute the primary impediment, with high acquisition costs (Tk 300,000-500,000) exceeding annual incomes of most smallholder farmers earning less than $730 annually (IFPRI, 2022). Limited access to agricultural credit specifically designated for technology investments compounds this challenge, as traditional lending mechanisms prioritize conventional inputs like fertilizers and seeds over capital equipment (Rahman et al., 2023). Insurance mechanisms protecting against drone damage or operational failures remain underdeveloped, increasing perceived investment risks. Regulatory complexities significantly impede adoption momentum. The Drone Registration and Flying Act 2020 established four drone categories with varying operational restrictions, but agricultural drones frequently exceed permitted consumer drone weights while requiring commercial-grade capabilities (CAAB, 2020). Licensing processes, airspace management protocols, and operational restrictions designed primarily for security and privacy concerns inadequately accommodate agricultural requirements for routine low-altitude flights over farmland (Mandal, 2024). The Civil Aviation Authority of Bangladesh collaborates with the Ministry of Agriculture developing sector-specific regulatory frameworks, but implementation timelines remain uncertain, deterring potential investors and operators. Technical capacity limitations pose substantial operational challenges. Effective drone utilization requires skills in equipment operation, flight planning, data interpretation, and maintenance—competencies largely absent among current extension officers and farmers (Khan et al., 2023). Training programs, while expanding, reach only small fractions of Bangladesh's extensive agricultural workforce comprising millions of smallholders distributed across diverse geographical regions. Multispectral imagery interpretation, NDVI analysis, and variable-rate application programming demand specialized knowledge rarely available at village level, creating dependency on external expertise and limiting autonomous adoption (Ahmed and Islam, 2023). Infrastructure deficiencies constrain operational effectiveness. Most agricultural drones depend on stable 4G/5G connectivity for real-time data transmission and cloud-based processing, yet rural Bangladesh experiences inconsistent network coverage and frequent service interruptions (Das et al., 2023). Electrical power availability for battery charging remains unreliable in many agricultural regions experiencing regular load-shedding, complicating operational scheduling. Weather dependencies limit operational windows, with monsoon rains, high winds, and extreme temperatures restricting drone flights during critical agricultural periods, reducing overall utilization efficiency and economic returns (Hossain et al., 2024). Socio-cultural factors influence adoption patterns. Skepticism toward unfamiliar technologies, risk-aversion among farmers operating at subsistence margins, and lack of demonstration effects in peer communities slow acceptance (Rahman and Ahmed, 2023). Gender disparities in agricultural technology access disproportionately exclude women farmers from training and adoption opportunities despite their substantial contributions to agricultural labor. Generational divides separate tech-savvy youth increasingly migrating to urban areas from older farmers controlling land but resistant to technological change. Table 4 systematically categorizes and prioritizes adoption barriers based on literature analysis:

Table 4: Challenges and Barriers to Drone Technology Adoption in Bangladesh Agriculture

Challenge Category	Specific Barriers	Impact Severity (1-5)	Affected Stakeholders	Potential Mitigation Strategies
Financial Barriers	High acquisition costs (Tk 300,000-500,000)	5	Smallholder farmers, FPGs	Subsidies, cooperative models, service-based deployment
	Limited agricultural credit access	4	Individual farmers	Specialized technology financing products
	Absence of equipment insurance	3	Drone owners, operators	Development of agricultural equipment insurance schemes
Regulatory Complexities Technical Capacity	Ambiguous legal framework for agricultural drones	4	Private sector, operators	Sector-specific regulatory guidelines
	Restrictive weight limitations	4	Commercial operators	Agricultural exemptions or modified classifications
	Burdensome licensing procedures	3	Service providers	Streamlined agricultural drone licensing
	Insufficient operator training	5	Extension officers, farmers	Comprehensive training programs at upazila level
	Limited data interpretation skills	4	Farmers, extension officers	Digital literacy initiatives, user-friendly interfaces
	Maintenance expertise shortage	4	Drone owners	Authorized service centers, warranty support
Infrastructure	Inconsistent 4G/5G	4	All stakeholders	Telecommunications

Deficiencies	connectivity in rural areas			infrastructure investment
	Unreliable electrical power supply	3	Operators	Solar charging solutions, battery swap systems
	Weather-dependent operational windows	3	Service providers, farmers	Weather forecasting integration, resilient designs
Socio-Cultural Factors	Technology skepticism and risk-aversion	3	Smallholder farmers	Demonstration farms, peer learning networks
	Gender disparities in technology access	4	Women farmers	Targeted programs, inclusive training
	Urban youth migration reducing tech-savvy rural population	3	Agricultural sector	Rural retention incentives, agri-tech career pathways
Knowledge Gaps	Limited awareness of drone capabilities	4	Farmers, policymakers	Awareness campaigns, farmer field days
	Insufficient local research on Bangladesh-specific applications	3	Research institutions	Increased R&D funding, collaborative studies

3.5 Policy Landscape and Institutional Support Framework

Government policy evolution demonstrates increasing recognition of precision agriculture's strategic importance. The Ministry of Agriculture's collaboration with CAAB developing regulatory frameworks for agricultural drone usage represents significant progress, addressing licensing provisions, airspace management, data governance, and user training requirements (DAE, 2024). However, comprehensive national Smart Agriculture Policy unifying standards for drone technology, artificial intelligence systems, data protection, and public-private collaboration remains under formulation, lacking definitive implementation timelines (Khan et al., 2023). Institutional support mechanisms exhibit gradual expansion. The Department of Agricultural Extension's 2024 pilot program training 300+ extension officers established foundational capacity for technology dissemination, though scaling to Bangladesh's 64 districts and 492 upazilas requires sustained resource allocation (Hossain et al., 2024). Financial support programs include the World Bank's $578 million Climate-Smart Agriculture Investment Plan providing technology adoption grants, but beneficiary coverage represents less than 1% of Bangladesh's estimated 18 million farm households, indicating vast unmet demand (World Bank, 2023; BBS, 2024). Research and development initiatives remain limited. Bangladesh Agricultural University, Bangladesh Rice Research Institute, and other agricultural research institutions conduct modest drone application studies, but lack dedicated funding for comprehensive field trials across diverse agro-ecological zones and cropping systems (Ahmed and

Islam, 2023). International partnerships with organizations like FAO, IRRI, and bilateral development agencies supplement domestic efforts, yet coordinated national research agenda integrating technological development, adaptation, and impact assessment remains absent (Rahman et al., 2023). Private sector engagement accelerates through companies like ACI Motors, Sky Biz Limited, and Bangladesh Drone Company, but supportive policies including tax incentives for agricultural technology imports, subsidized financing mechanisms, and public procurement programs favoring domestic manufacturers could amplify commercial momentum (ACI, 2024). Farmer organizations and cooperatives increasingly express interest in collective technology adoption, but legal frameworks facilitating cooperative equipment ownership, shared service provision, and risk pooling require strengthening (IFPRI, 2022). Table 5 summarizes the current policy landscape and institutional support mechanisms:

Table 5: Policy Landscape and Institutional Support Framework for Drone-Assisted Agriculture

Policy/Program Area	Current Status	Implementing Agency	Coverage/Scale	Gaps and Recommendations
Regulatory Framework	Under development; Drone Act 2020 provides basic structure	CAAB, Ministry of Agriculture	National	Finalize agricultural-specific guidelines; streamline licensing; establish operational standards
National Smart Agriculture Policy	Draft stage; not yet implemented	Ministry of Agriculture	National	Expedite approval; integrate drone technology standards; ensure multi-stakeholder participation
Extension Officer Training	300+ officers trained (2024 pilot)	DAE-ADB Program	Multiple upazilas	Scale to all 492 upazilas; continuous capacity building; advanced training modules
Financial Support Programs	World Bank Climate-Smart Agriculture Plan ($578M); beneficiaries: 127,500 farmers	World Bank, Ministry of Agriculture	Limited (< 1% farm households)	Expand beneficiary coverage; establish dedicated technology fund; subsidized financing schemes
Research and Development	Limited institutional research;	BAU, BRRI, IRRI, FAO	Fragmented	National research agenda; dedicated R&D funding; field

	international partnerships supplement			trial infrastructure across agro-ecological zones
Private Sector Incentives	Market-driven initiatives; limited policy support	Private companies (ACI, Sky Biz, BDC)	Commercial	Tax incentives for technology imports; subsidized financing; public procurement preferences for domestic manufacturers
Cooperative Support	Growing interest; legal frameworks require strengthening	Farmer cooperatives, FPGs	Community level	Enhanced legal frameworks for cooperative equipment ownership; risk pooling mechanisms; shared service models
Data Infrastructure	Inconsistent 4G/5G coverage; no centralized agricultural data platform	Telecommunications companies, Ministry of Agriculture	Patchy rural coverage	Rural telecommunications investment; agricultural data management system; open data protocols
Insurance Mechanisms	Underdeveloped; no specific agricultural equipment insurance	Insurance sector	Minimal	Agricultural equipment insurance products; risk-sharing facilities; premium subsidies

4. DISCUSSION

4.1 1 Significance of Drone Technology for Bangladesh's Agricultural Transformation

The emergence of drone-assisted precision agriculture represents a potentially transformative intervention addressing Bangladesh's multifaceted agricultural challenges through technology-enabled solutions. With 83% of farmers operating as smallholders on fragmented landholdings averaging less than 1.5 acres and facing escalating climate stresses, conventional agricultural intensification strategies approaching productivity ceilings, drone technology offers pathways toward sustainable intensification, balancing increased output with environmental conservation (IFPRI, 2022; Rahman et al., 2023). The reported yield improvements of 15-60% among World Bank program participants, while variable across crops and regions, demonstrate substantial productivity enhancement potential, particularly significant for food security in a nation where rice consumption dominates dietary patterns and population growth continues (World Bank, 2023). Environmental sustainability dimensions merit particular emphasis. Bangladesh's intensive agricultural systems historically relied on excessive chemical inputs, with pesticide and fertilizer overuse generating environmental degradation, including groundwater contamination, soil health deterioration, and biodiversity loss (Das et al., 2023). Drone-enabled precision application reducing chemical usage by 20-30% while maintaining or improving efficacy represents substantial environmental progress toward sustainable agricultural practices aligned with Sustainable Development Goals and national climate commitments (Khan et al., 2023). Water resource optimization capabilities assume critical importance given groundwater depletion rates of 0.01-0.5 meters annually in intensive rice cultivation regions, threatening long-term agricultural sustainability (Ahmed and Islam, 2023).

Economic implications extend beyond farm-level profitability to encompass rural livelihood resilience and national economic development. Agriculture, contributing 12% to GDP while employing 40% of the population, signals sector productivity improvements translating into broader economic multiplier effects through increased rural incomes, enhanced purchasing power, and expanded demand for goods and services (Hassan and Rahman, 2022). Labor productivity enhancements freeing farmers from labor-intensive operations enable value-addition activities and income diversification strategies, strengthening household economic resilience against agricultural shocks (Alam et al., 2022).

4.2 Comparative Analysis with Regional Drone Agriculture Development

Bangladesh's drone agriculture trajectory exhibits both similarities and distinctions compared to regional neighbors. India's agricultural drone sector, supported by aggressive government subsidies covering 40-75% of drone acquisition costs and streamlined regulatory frameworks exempting nano and micro drones from licensing requirements, achieved rapid commercial scaling with over 1,500 registered agricultural drones by 2023 (Patel and Sharma, 2022). Bangladesh's more cautious regulatory approach and limited financial incentives constrain comparable scaling, though smaller geographical size and higher population density potentially enable faster extension service coverage once regulatory clarity emerges. China's agricultural drone industry represents the global benchmark, with over 140,000 agricultural drones operating by 2023, serving 70% of total farmland through sophisticated service networks (Tanaka et al., 2023). This success derives from coordinated policies integrating technology subsidies, comprehensive operator training programs, supportive regulations, and robust telecommunications infrastructure rarely replicated in developing contexts. Bangladesh faces distinct challenges including fragmented landholdings, limited farmer purchasing power, and infrastructural deficiencies requiring adapted models emphasizing cooperative ownership and service provision over individual acquisition patterns dominant in China.

4.3 Critical Analysis of Implementation Models and Scalability

Service-based deployment models demonstrate greatest near-term scalability potential for Bangladesh's smallholder-dominated landscape. Individual drone ownership economic viability restricted to large commercial farms (>10 acres) excludes 83% of farmers, while cooperative models face coordination challenges and limited institutional capacity despite theoretical advantages (IFPRI, 2022). Specialized service providers offering per-hectare spraying, monitoring, or mapping services eliminate capital investment barriers while concentrating technical expertise and equipment maintenance with professional operators ensuring quality and reliability (Rahman, 2024). However, service model viability depends critically on sufficient demand density within economically serviceable areas. Bangladesh's high population density (1,265 persons per square kilometer) and intensive cultivation patterns creating demand concentration offer favorable conditions compared to geographically dispersed agricultural regions elsewhere (BBS, 2024). Yet seasonal demand fluctuations during planting and spraying periods risk operator idle capacity and economic losses without diversified service portfolios spanning multiple crops and agricultural seasons (Mandal, 2024).

4.4 Technology Adaptation Requirements for Local Context

Imported drone technologies designed for mechanized, large-scale farms in developed countries require substantial adaptation for Bangladesh's specific conditions. Smallholder landholdings averaging 1-1.5 acres demand highly maneuverable drones capable of operating in confined spaces, avoiding obstacles like boundary trees and homesteads, and tolerating frequent takeoffs and landings minimizing operational efficiency losses (Ahmed and Islam, 2023). Tropical monsoon climate imposing extended high-humidity periods, intense rainfall, and extreme temperatures necessitates ruggedized designs withstanding harsh environmental conditions that degrade electronics and mechanical components. Bangladesh's predominant rice-based cropping systems involving flooded paddies present unique operational challenges including restricted takeoff/landing sites, high humidity affecting sensor accuracy, and dense crop canopies impeding pesticide penetration requiring modified spraying configurations (Hassan and Rahman, 2022). Indigenous crop varieties, traditional intercropping patterns, and localized pest complexes differ substantially from regions where drone agriculture technologies primarily developed, requiring extensive field testing and calibration ensuring accuracy and effectiveness under Bangladesh-specific conditions (Hossain et al., 2024).

4.5 Prospects for Future Development and Scaling

Near-term prospects (2025-2027) center on regulatory framework finalization, extension service capacity building, and pilot program expansion consolidating early adoption momentum. The Civil Aviation Authority's collaboration with Ministry of Agriculture developing agricultural drone guidelines expected to resolve licensing ambiguities, enabling commercial operators to establish legal businesses and farmers to access services without regulatory uncertainty (CAAB, 2020). Department of Agricultural Extension scaling training programs to additional upazilas will expand institutional capacity for technology dissemination and farmer support, though budgetary constraints may limit pace (DAE, 2024). Medium-term prospects (2028-2032) envision substantial adoption acceleration driven by decreasing technology costs, expanding telecommunications infrastructure, and demonstrated benefits motivating farmer demand. Global drone manufacturing economies of scale and technological maturation consistently reduce costs, with agricultural drone prices declining 15-20% triennially improving economic accessibility (Singh and Kumar, 2022). Bangladesh's expanding 4G/5G network coverage reaching rural areas by 2028-2030 will alleviate connectivity constraints enabling real-time operations and cloud-based data processing (Das et al., 2023). Long-term prospects (2033-2040) suggest potential integration into mainstream agricultural practices with drone-assisted precision agriculture becoming standard practice rather than novel technology.

Generational transition transferring farm management to younger, technology-comfortable cohorts will accelerate adoption as digital natives replace traditional farmers (Rahman and Ahmed, 2023). Artificial intelligence integration enabling autonomous flight planning, automated crop health assessment, and predictive analytics will enhance operational efficiency and reduce technical skill requirements, expanding accessibility (Alam et al., 2022). However, realizing these prospects requires sustained policy commitment, institutional capacity development, infrastructure investment, and private sector engagement catalyzed by government policies creating enabling environments.

5. SUMMARY

Drone-assisted precision agriculture offers transformative potential for Bangladesh addressing productivity, sustainability, and climate resilience challenges. Despite promising pilot outcomes and institutional momentum, widespread adoption requires regulatory clarity, financial accessibility, technical capacity development, and infrastructure enhancement through coordinated multi-stakeholder efforts.

6. REFERENCES

1. ACI Motors. (2024). Agricultural Spraying Drones: Product Specifications and Field Performance. Dhaka: ACI Limited.
2. Ahmed, R., & Islam, S. (2023). Technological innovations in Bangladesh agriculture: Opportunities and constraints. Journal of Agricultural Technology, 19(3), 567-584.
3. Alam, M. S., Rahman, A., & Bhuiyan, M. K. (2022). Precision agriculture technologies for sustainable crop production in Bangladesh. Agricultural Systems, 201, 103445.
4. Asian Development Bank. (2024). Climate-Smart Agriculture in South Asia: Technology Adoption and Impact Assessment. Manila: ADB.
5. Bangladesh Bureau of Statistics. (2024). Yearbook of Agricultural Statistics 2023. Dhaka: Statistics and Informatics Division, Ministry of Planning.
6. Bangladesh Drone Company. (2024). Precision Agriculture Services: Crop Monitoring and Assessment Solutions. Dhaka: BDC.
7. Booth, A., Sutton, A., & Papaioannou, D. (2022). Systematic Approaches to a Successful Literature Review (3rd ed.). London: SAGE Publications.
8. Braun, V., & Clarke, V. (2022). Thematic Analysis: A Practical Guide. London: SAGE Publications.
9. Civil Aviation Authority of Bangladesh. (2020). Drone Registration and Flying Act 2020: Guidelines and Operational Procedures. Dhaka: CAAB.
10. Creswell, J. W., & Plano Clark, V. L. (2018). Designing and Conducting Mixed Methods Research (3rd ed.). Thousand Oaks: SAGE Publications.
11. Das, P. K., Hossain, A., & Chowdhury, M. R. (2023). Climate change impacts on Bangladesh agriculture: Adaptation strategies and technological interventions. Climate Risk Management, 40, 100498.
12. Denzin, N. K. (2017). The Research Act: A Theoretical Introduction to Sociological Methods. New York: Routledge.
13. Department of Agricultural Extension. (2024). Annual Progress Report 2023-24: Digital Agriculture Initiatives. Dhaka: Ministry of Agriculture.

14. Gough, D., Oliver, S., & Thomas, J. (2017). An Introduction to Systematic Reviews (2nd ed.). London: SAGE Publications.
15. Hassan, M. K., & Rahman, M. S. (2022). Agricultural development and food security in Bangladesh: Progress, challenges and prospects. Bangladesh Development Studies, 45(2), 1-28.
16. Higgins, J. P. T., Thomas, J., & Chandler, J. (2019). Cochrane Handbook for Systematic Reviews of Interventions (2nd ed.). Chichester: John Wiley & Sons.
17. Hossain, M. A., Kabir, M. S., & Alam, M. J. (2024). Remote sensing applications in Bangladesh agriculture: Current status and future directions. Remote Sensing Applications, 33, 101142.
18. International Food Policy Research Institute. (2022). Bangladesh Agricultural Policy Report 2022: Technology Adoption Among Smallholder Farmers. Washington DC: IFPRI.
19. Israel, M., & Hay, I. (2006). Research Ethics for Social Scientists. London: SAGE Publications.
20. Kabir, M. S., Salam, M. U., & Islam, A. K. M. S. (2023). Digital transformation of Bangladesh agriculture: Status, challenges and opportunities. Agricultural Information Worldwide, 14(1), 15-22.
21. Kabir, M. S., Mahedi, M., Pervez, A. K., Alam, M. J., & Shaili, S. J. (2025). Bibliometric analysis of “precision agriculture” in the Scopus database. *World Journal of Advanced Research and Reviews*, *25*(3), 1087-1098.
22. Khatun, M. R., Amin, M. R., Pervez, A. K., Shaili, S. J., Ahmmed, M. B., & Mahedi, M. (2025). A global scientometric analysis of climate-smart agricultural innovations adoption in drought-prone areas. *Asian Research Journal of Agriculture*, *18*(3), 159-176.
23. Khan, M. A. R., Rahman, M. M., & Hossain, M. I. (2023). Drone technology adoption in Bangladesh agriculture: Farmer perceptions and adoption determinants. Technology in Society, 73, 102231.
24. Liberati, A., Altman, D. G., Tetzlaff, J., et al. (2009). The PRISMA statement for reporting systematic reviews. PLoS Medicine, 6(7), e1000097.
25. Mahedi, M., Shaili, S. J., Nurnobi, M., Sakil, A. R., & Rahman, A. (2025). Adoption Of Organic Farming Practices: A Comprehensive Review Of Trends, Determinants, And Challenges. *JOURNAL OF AGRICULTURAL AND RURAL RESEARCH*, *8*(1), 26-45.
26. Mandal, S. K. (2024). Regulatory frameworks for agricultural drones in South Asia: Comparative analysis and policy recommendations. Agricultural Policy Review, 12(2), 134-151.
27. Moher, D., Liberati, A., Tetzlaff, J., et al. (2021). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. International Journal of Surgery, 88, 105906.
28. Munn, Z., Peters, M. D. J., Stern, C., et al. (2018). Systematic review or scoping review? Guidance for authors when choosing between systematic or scoping review approach. BMC Medical Research Methodology, 18, 143.
29. Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71.

30. Patel, R., & Sharma, V. (2022). Agricultural drone adoption in India: Factors influencing technology diffusion among farmers. Agricultural Economics Research Review, 35(1), 89-104.
31. Petticrew, M., & Roberts, H. (2008). Systematic Reviews in the Social Sciences: A Practical Guide. Oxford: Blackwell Publishing.
32. Prodhan, F. A., Afrad, M. S. I., Haque, M. E., Hoque, M. Z., Rokonuzzaman, M., Mohana, H. P., & Pervez, A. K. (2023). Factors driving the adoption of organic tea farming in the northern region of Bangladesh. *Research in Globalization*, *7*, 100145.
33. Rahman, M. A. (2024, March 15). Sky Biz to manufacture drones locally. The Business Standard.
34. Rahman, M. H., Ahmed, R., & Islam, M. S. (2023). Sustainable intensification of Bangladesh agriculture: Challenges and technological solutions. Sustainability, 15(8), 6654.
35. Rahman, M. M., & Ahmed, R. (2023). Precision agriculture technologies for resource-poor farmers: Opportunities and challenges in Bangladesh. Journal of Agricultural Science and Technology, 25(4), 789-806.
36. Shamseer, L., Moher, D., Clarke, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. BMJ, 349, g7647.
37. Singh, R., & Kumar, A. (2022). UAV-based remote sensing for precision agriculture: A review. Computers and Electronics in Agriculture, 198, 107071.
38. Smith, L. T. (2003). Decolonizing Methodologies: Research and Indigenous Peoples. London: Zed Books.
39. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333-339.
40. Tanaka, Y., Nakamura, T., & Sato, K. (2023). Agricultural drone technology adoption in Asia: Comparative analysis of policy frameworks and implementation outcomes. Asian Journal of Agricultural Extension, 41(2), 201-218.
41. Uman, L. S. (2011). Systematic reviews and meta-analyses. Journal of the Canadian Academy of Child and Adolescent Psychiatry, 20(1), 57-59.
42. World Bank. (2023). Climate-Smart Agriculture Investment Plan for Bangladesh: Implementation Progress Report 2023. Washington DC: World Bank Group.