

Smart Agriculture in Northern Nigeria: Prospects and Challenges for Graduate Farmers

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Abstract

Northern Nigeria's agricultural sector occupies a pivotal but precarious position, in which long-standing subsistence practices are beginning to intersect with emerging digital and climate-smart technologies. This narrative review examines the prospects and challenges of smart agriculture adoption among graduate farmers in the region, drawing on programme reports, policy documents, and peer-reviewed studies published mainly between 2023 and 2026. Three converging opportunity structures are identified: donor- and government-funded schemes such as the Youth Agribusiness Land Trust Fund, the AYuTe Africa Challenge, and the Propcom+ programme; precision and digital technologies, including Internet of Things sensors, drones, satellite remote sensing, and artificial intelligence-based advisory platforms; and market-systems interventions that link smallholder and graduate farmers to inputs, finance, and buyers. Set against these prospects are structural constraints that limit adoption, including persistent insecurity linked to banditry and farmer-herder conflict, high upfront technology costs combined with limited access to credit, deficits in rural electricity, roads and internet connectivity, a widening gap between the theoretical training graduate farmers receive and the practical skills that technology adoption requires, and land tenure arrangements that restrict youth access to farmland. The review argues that the yield gains reported for smart agriculture elsewhere - in the order of 15 to 100 percent - are unlikely to materialise in Northern Nigeria without coordinated action across security, financing, infrastructure, and training systems, and it concludes with differentiated recommendations for graduate farmers, policymakers, financial institutions, and educational institutions.

Keywords: smart agriculture, graduate farmers, Northern Nigeria, digital farming, climate-smart agriculture, agricultural technology, youth agribusiness

Introduction

Agriculture remains central to Northern Nigeria's economy and to Nigeria's food system more broadly. The sector contributes roughly one-quarter of national gross domestic product and employs an estimated 70-80% of the rural workforce, with smallholder farmers accounting for more than 80% of the farming population and over 90% of domestically consumed food (Propcom+, 2024). Within the Sudano-Sahelian zone, spanning Kano, Kaduna, Katsina, Jigawa, Sokoto, Zamfara and Borno States, farming systems built around millet, sorghum, maize, rice, cowpea and livestock production support the livelihoods of millions of rural households.

This agricultural base is under mounting strain. Climate variability, land degradation and a deepening security crisis have combined to push food insecurity to levels rarely seen in the country's recent history: Nigeria recorded an estimated 33.1 million food-insecure people in 2025, the highest total in West Africa (Ndhlovu & Meyer, 2025). Dependence on rain-fed cultivation, weak irrigation infrastructure, and limited access to early warning and climate information services leave farming households in the region especially exposed to these shocks.

Nigeria's youth population offers one possible route out of this vulnerability. With more than 70% of the population under the age of 30, the country has a demographic base that, if channelled into agriculture, could support the sector's modernisation (Bachewe et al 2025). Graduates of agricultural and related tertiary programmes - the “graduate farmers” this review is concerned with - are often positioned as a bridge between formal agricultural training and field-level innovation, since their education and relative familiarity with technology give them an entry point that less formally trained farmers may lack. In practice, however, graduate participation in farming remains constrained by land access difficulties, weak financing, cultural perceptions of farming as a fallback occupation, and a persistent knowledge-practice gap: agricultural curricula tend to emphasise theory over the applied, technology-specific skills that commercial farming increasingly demands.

Smart agriculture - the application of information and communication technologies, Internet of Things (IoT) sensing, drones, satellite remote sensing and artificial intelligence to farm management - has been proposed as one way to narrow this gap, since it can substitute technology-enabled precision for some of the experiential knowledge that graduate farmers lack. Evidence from outside Nigeria suggests these technologies can raise yields by 15 to 100 percent while reducing input costs (Belton et al., 2025), and Nigeria's policy environment has begun to reflect this potential: the Nigeria Digital Agriculture Strategy (NDAS) 2020-2030 sets out a framework for digital transformation in the sector, while programmes such as Propcom+ and the AYuTe Africa Challenge are creating pathways for adoption among smallholder and graduate farmers.

This review asks how these prospects and constraints interact for graduate farmers specifically. It draws on programme reports, government and donor policy documents, and recent peer-reviewed studies to (i) map the main categories of smart agriculture technology and the funding and training ecosystem available to graduate farmers, (ii) identify the principal barriers to adoption in the Northern Nigerian context, and (iii) derive recommendations for graduate farmers, policymakers, financial institutions and educational institutions.

Approach to the Review

This is a narrative rather than a systematic review. Sources were identified through targeted searches of institutional and donor publications (including Propcom+, the International Institute of Tropical Agriculture, Heifer International, and the Food and Agriculture Organisation), Nigerian government policy documents (the NDAS 2020-2030, National Agricultural Development Fund materials, and the National Artificial Intelligence Strategy), and peer-reviewed journal articles addressing smart agriculture, drone and IoT adoption, and conflict-related agricultural disruption in Nigeria, published mainly between 2023 and 2026.

Because several of the funding and training initiatives discussed are recent and have not yet been independently evaluated in peer-reviewed literature, the review draws on programme and organisational reporting for descriptive detail - funding amounts, beneficiary numbers, and programme design - while relying on peer-reviewed sources for evidence of technology performance, adoption behaviour, and conflict impacts. This mixed sourcing is a limitation inherent to reviewing an emerging, practitioner-led field, and the discussion notes where a claim rests on programme reporting rather than independently verified research.

Prospects of Smart Agriculture in Northern Nigeria.

Precision Agriculture and Digital Technologies

Precision agriculture technologies - IoT sensors, drones, and automated irrigation systems - allow farmers to base input decisions on measured field conditions rather than routine or guesswork. IoT systems that monitor soil moisture, nutrient levels, temperature and humidity can trigger irrigation automatically once predefined thresholds are reached, conserving water in a zone where scarcity and irregular rainfall are recurring constraints.

Agricultural drones extend this logic to crop monitoring, pest and disease detection, and precision input application. A 2026 study of smallholder farmers in Ondo State found generally positive perceptions of drone technology, with respondents agreeing that drones improve productivity, save time, and support early pest detection (Olalekan et al., 2026); while that sample was drawn from Southwest rather than Northern Nigeria, the underlying mechanisms - reduced scouting time and earlier intervention - are not specific to one region. Beyond crop scouting, drones can perform mechanical tasks such as seeding, fertiliser spreading and pesticide application, extending to graduate farmers in the Global South a level of capability historically confined to mechanised farms in wealthier countries (Belton et al., 2025).

Solar-powered irrigation is a particularly relevant fit for Northern Nigeria, where abundant solar radiation can substitute for the diesel and grid power that rural areas often lack, enabling dry-season cultivation without adding to fossil-fuel dependence. Pairing solar pumping with soil-moisture sensors further improves water-use efficiency in the water-stressed Sudano-Sahelian zone. At a broader scale, satellite remote sensing - supported by Nigeria's NigeriaSat-1, NigeriaSat-2 and NigeriaSat-X programmes, managed by the National Space Research and Development Agency - provides land-use mapping and crop-monitoring capability that can inform both farm-level and policy-level decisions. Artificial intelligence applications, meanwhile, are being positioned for crop-disease diagnosis, yield prediction and market-price forecasting; Nigeria's National Artificial Intelligence Strategy frames locally developed AI tools as better suited to local growing conditions than externally imposed models (NCAIR, 2025). Digital extension platforms that deliver advisory content through mobile devices are a further avenue for addressing Nigeria's extension-worker shortage, and where they are linked to IoT sensor data they can generate advisory feedback loops that improve in accuracy over time.

Climate-Smart Agriculture and Resource-Efficient Production

Climate-smart agriculture (CSA) encompasses practices intended to raise productivity, build resilience, and reduce emissions simultaneously - a combination that speaks directly to Northern Nigeria's triple exposure to climate variability, food insecurity, and resource degradation. Seed-based interventions form one strand of this work: Propcom+ is promoting biofortified, drought-tolerant seed varieties and aims, by 2026, to facilitate the off-take of 10,000 metric tonnes of biofortified grain annually through at least 5,000 smallholder farmers (Propcom+, 2024). A second strand, solar-powered irrigation, reduces reliance on diesel pumps while permitting multiple cropping cycles per year when paired with precision irrigation. A third strand, controlled-environment agriculture, is exemplified by Soilless Farm Lab, which has trained more than 10,000 young people in hydroponic production since 2019 (TriplePundit,

2025); hydroponic systems are of particular relevance to areas affected by desertification, since they decouple production from soil quality and seasonal rainfall.

Market-Systems and Institutional Support

Beyond individual technologies, market-systems interventions are working to make smart agriculture commercially viable at scale. Propcom+, a £95 million initiative funded through the UK's International Climate Finance and structured around a Market Systems Development approach, has enabled more than 536,000 people - nearly half of them women - to access improved inputs, climate-smart technologies and digital extension services (Propcom+, 2024). Its stated strategy of piloting business models, scaling proven ones, and shaping enabling policy is intended to generate £132 in net annual farmer income by 2030. Biofortification initiatives associated with HarvestPlus operate on a related logic, building market linkages between seed producers, farmers and processors so that nutritional and productivity gains reinforce one another rather than competing for investment.

Funding, Training and Career Pathways for Graduate Farmers

A cluster of targeted programmes has emerged specifically to support graduate and youth participation in agriculture. The BATN Foundation Graduate Agripreneur Programme provides grants, training and mentorship intended to close the financing gap that discourages educated youth from entering agricultural value chains. The Youth Agribusiness Land Trust Fund, launched by the Federal Ministry of Youth Development with the International Institute of Tropical Agriculture, targets land access specifically - arguably the most binding constraint on youth participation - aiming to train six million young people and support 500,000 agribusiness enterprises over three years by linking land access to inputs, markets and advisory services (IITA, 2025). The AYuTe Africa Challenge Nigeria, run by Heifer International and Wenvovation Hub, offers up to \$40,000 in prizes for youth-led agritech ventures, alongside post-award business advisory support; since 2022 it has drawn more than 2,000

entries, an indication of active interest in agricultural technology among young Nigerians (Heifer International, 2026).

Training and incubation capacity is developing alongside these funding mechanisms. The Nigeria Climate Innovation Centre offers investment-readiness support and mentorship for climate-smart and green enterprises, with cross-learning links to its Kenyan counterpart. Soilless Farm Lab, founded by Samson Ogbale, provides free hydroponics and agribusiness training supported by the Mastercard Foundation. Digital training academies such as Precision Field Academy and Integrated Aerial Precision are building a cadre of practitioners skilled in precision agriculture, drone operation and data analytics. Taken together, these programmes point to several viable career pathways for graduate farmers: agri-tech entrepreneurship (developing and commercialising locally relevant innovations); fee-for-service provision (drone operation, sensor maintenance, data analytics for smallholder clients); and value-chain integration as aggregators, processors or digitally enabled marketers.

Challenges to Adoption

Security Crisis

Insecurity is arguably the most consequential barrier to smart agriculture adoption in Northern Nigeria, because it undermines the basic precondition - a stable farming environment - on which technology investment depends. Banditry has become widespread in states such as Zamfara, Katsina, Sokoto and Niger, with kidnapping, cattle rustling and attacks on rural communities producing displacement described in the literature not as a series of local incidents but as a regional collapse of farming systems (RSIS International, 2025). Research on the economic consequences finds that banditry reduces agricultural output, causes livestock losses, inflates food prices, and drives hunger in affected zones (IJRAMR, 2025; see also Asaju & Kwakwano, 2025). Farmer-herder conflict compounds this picture,

as competition over land and water resources - sharpened by climate change and the southward expansion of the Sahara - continues to produce fatalities, farmland destruction and displacement.

For smart agriculture specifically, the security crisis operates through three linked mechanisms. It discourages investment in technologies that may be damaged, stolen, or abandoned in the event of displacement; it restricts the ability of extension workers, service providers and technology companies to operate in affected areas; and it erodes the community networks that typically support the collective action needed for technology diffusion, such as shared equipment use or coordinated input purchasing.

Cost and Financing Barriers

High upfront cost is the second major constraint. Drones with sensor and imaging packages, IoT sensor networks, automated irrigation, and other precision equipment all represent substantial capital outlays, and research on Nigerian agriculture identifies high initial capital cost as a leading barrier to technology adoption generally (Olalekan et al., 2026). For graduate farmers with limited personal capital and constrained access to credit, this cost barrier can be prohibitive even where the technology's economic case - higher yields, lower input waste - is clear. Underlying this is a broader financing gap: high interest rates, collateral requirements that exclude young farmers without land titles, and a shortage of long-term agricultural credit persist despite efforts such as the National Agricultural Development Fund (NADF) to expand access.

Infrastructure Deficits

Smart agriculture technologies are, almost by definition, infrastructure-dependent, and rural Northern Nigeria's infrastructure gaps limit their functionality accordingly. Electricity supply is erratic or absent in much of the region, constraining automated irrigation, cold storage and processing equipment unless farmers can absorb the added cost of solar alternatives. Poor rural road networks raise transport costs, restrict market access and increase post-harvest losses, which is particularly costly for technology-

intensive operations that depend on the timely delivery of inputs and specialised services. Limited internet connectivity restricts the functionality of IoT systems, digital advisory platforms and AI-based applications that depend on data transmission and cloud analytics, reproducing a digital divide between urban and rural areas.

Knowledge-Practice Gap and Extension Capacity

A recurring theme in this literature is the gap between the theoretical knowledge graduate farmers acquire through university agricultural programmes and the practical, technology-specific skills that farm management now requires. This gap is compounded by a severe shortage of extension workers relative to the farming population, which limits the technical support available to farmers attempting to operate and maintain smart agriculture equipment. Perception studies reinforce this picture: farmers surveyed on drone technology described the equipment as technically complex and requiring specialised knowledge to use effectively (Olalekan et al., 2026), a barrier that is likely to be more acute among farmers with limited prior digital literacy.

Land Access Barriers

Land tenure systems across Northern Nigeria often channel land through inheritance and family ownership, leaving young people dependent on family allocations that may be too small to support commercial-scale farming. The absence of secure tenure also discourages the long-term investment - in irrigation infrastructure, soil improvement, or fixed equipment - that technology adoption typically requires. Land fragmentation driven by population growth and inheritance practices compounds this constraint, since farm sizes below a certain threshold rarely justify the fixed costs of mechanisation or precision equipment.

Environmental Pressures

Advancing desertification across the Sudano-Sahelian zone is reducing arable land, degrading soil quality, and shortening growing seasons, which both increases the urgency of irrigation and climate-smart technologies and reduces the resource base available to invest in them. Rainfall patterns have also become less predictable, with delayed onset, early cessation and greater year-to-year variability increasing the risk of crop failure and undermining the confidence farmers need to commit capital to new inputs or equipment.

Policy Framework and Institutional Support

Nigeria's policy environment provides a partial scaffold for smart agriculture adoption, even where implementation still lags intent. The Nigeria Digital Agriculture Strategy 2020-2030 sets out a framework for scaling ICT solutions, strengthening partnerships, and building institutional capacity for digital agriculture, aligning the sector with the country's broader digital economy policy. The National Agricultural Development Fund addresses financing constraints through programmes such as GRATE (Grant for Resilient Agricultural Transformation and Entrepreneurship) and AgGrow, intended to channel resources toward agricultural investment, including technology adoption.

Public-private partnership models, exemplified by Propcom+, illustrate how government policy, private-sector expertise, and development-partner resources can be combined to build adoption ecosystems rather than relying on any single actor. The Federal Government's broader agricultural renewal plan - anchored on mechanisation, input access, credit expansion and post-harvest management, and reflected in the deployment of more than 2,000 tractors and combine harvesters under the first phase of the Renewed Hope Mechanisation Initiative - provides additional, if still uneven, institutional backing for modernisation efforts of this kind.

Conclusion

This review has argued that smart agriculture holds real, if conditional, promise for graduate farmers in Northern Nigeria. The technologies, funding mechanisms and training programmes now available are more extensive than they were even a few years ago, and the region's agro-ecological base and demographic profile give the opportunity genuine substance. Realising it, however, depends on addressing constraints that lie largely outside the technologies themselves: the security crisis that discourages investment and displaces farming communities, the financing gaps that put technology out of reach for most graduates, the infrastructure deficits that limit what deployed technology can actually do, the knowledge-practice gap between academic training and field application, and the land tenure arrangements that restrict youth access to farmland in the first place.

None of these constraints is amenable to resolution by graduate farmers acting alone. Progress is more likely to depend on policymakers addressing security and infrastructure, financial institutions designing products suited to agricultural cycles and youth borrowers, and educational institutions closing the gap between what is taught and what is practised. The policy architecture already in place - the NDAS 2020-2030, the National Agricultural Development Fund, and partnership programmes such as Propcom+ - provides a foundation for this coordinated response, but its impact will depend on the extent to which security and infrastructure constraints are addressed alongside, rather than after, technology-focused interventions.

Implications and Recommendations

The preceding sections suggest that adoption of smart agriculture by graduate farmers in Northern Nigeria is unlikely to be resolved by any single intervention. The recommendations below are grouped by stakeholder, reflecting the different levers each group controls.

For Graduate Farmers

Graduate farmers can improve their own prospects by treating academic qualifications as a starting point rather than a sufficient credential, and pairing them with hands-on training through providers such as Soilless Farm Lab, the Nigeria Climate Innovation Centre, or digital training academies. Given the cost barriers discussed above, an incremental approach - adopting low-cost technologies with demonstrable returns first, then reinvesting profits into more sophisticated equipment - is likely to be more sustainable than attempting wholesale adoption at the outset. Fee-for-service models, in which graduate farmers offer drone operation, sensor installation or data analytics services to smallholder clients, offer a route to income generation that also spreads technology access more widely. Active engagement with funding programmes (YALTF, the AYuTe Africa Challenge, BATN Foundation GAP) and with technology communities and farmer networks can further offset the capital and knowledge constraints individual farmers face.

For Policymakers

Because insecurity is the most consequential barrier identified in this review, security interventions in agricultural zones should be treated as a precondition for, rather than a parallel track to, agricultural technology policy. Alongside this, sustained investment in rural electrification, road networks and telecommunications infrastructure is necessary if smart agriculture technologies are to function as designed rather than as underused capital sitting idle for want of power or connectivity. Extension services warrant particular attention: recruiting and training extension workers specifically in smart agriculture technologies, and pairing them with digital advisory platforms, could meaningfully extend the reach of a chronically understaffed system. Land policy - land banks, lease arrangements, and reform of tenure systems - should be pursued as a distinct priority given how directly land access constrains youth participation in agriculture.

For Financial Institutions

Financial institutions could usefully develop loan products tailored to smart agriculture investment, with repayment schedules aligned to agricultural cycles rather than standard commercial terms. Alternative collateral arrangements - group lending, equipment leasing, guarantee facilities - would help young farmers who lack land titles or other conventional collateral to access credit. Partnership with development programmes such as NADF and Propcom+ offers a mechanism for de-risking agricultural lending, while value-chain financing, in which credit is extended against contractual arrangements with buyers, could allow graduate farmers to access capital on the strength of market relationships rather than collateral alone. Technology subsidies and tax incentives, coordinated with policymakers, would further reduce the effective cost of adoption.

For Educational Institutions

Given the knowledge-practice gap identified throughout this review, agricultural curricula would benefit from the deliberate incorporation of hands-on training in drone operation, sensor technologies and digital platforms, rather than leaving this training to external providers after graduation. University-industry linkages - partnerships with agricultural technology companies, innovation hubs and commercial farms - could give students exposure to real-world applications before they enter the labour market. Incubation centres and startup support programmes would help channel graduate entrepreneurship into viable ventures, and applied research addressing Northern Nigeria's specific adoption barriers would generate the locally relevant evidence base this field currently lacks.

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