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Innovative Technologies to Mitigate the Effects of Climate Change: Panacea to Food Crisis in Nigeria

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Abstract:
Climate change is already undermining agricultural productivity and food security in Nigeria and the Southwest (including Ekiti State). In this study, we conducted a systematic literature review of recent (2021–2025) evidence on climate-smart agriculture (CSA), precision farming, renewable energy (especially solar-powered irrigation and cold chains), water management, and resilient cropping systems. We demonstrate how a combined technology-and-policy approach can strengthen food security in Ekiti and Nigeria more broadly. We synthesise empirical findings, highlight Ekiti-specific initiatives (e.g., Africa Sustainable Commodities Initiative [ASCI] participation and local training needs), and recommend targeted, financeable, and scalable interventions.

Keywords: *Climate-smart agriculture; Precision agriculture; Renewable energy; Irrigation; Climate adaptation; Food security.*

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Introduction

Nigeria's agriculture is highly climate-sensitive. Smallholder, predominantly rainfed systems dominate production, contributing significantly to GDP and rural livelihoods (FAO, 2021). These systems are exceptionally vulnerable to rising average temperatures, increasingly erratic rainfall, and more frequent extremes (floods, droughts, heat waves) (IPCC, 2022). In practical terms, even minor shifts in seasonal onset or rainfall intensity can disrupt planting schedules, reduce germination, and raise the risk of crop failure. For example, the IPCC reports that climate change has already reduced African crop yields (high confidence) and that most subsistence farmers perceive agricultural conditions have worsened in the past decade (IPCC, 2022). Nigeria's 2021–2022 Nationally Determined Contribution (NDC) and the Climate Change Act 2021 emphasise both mitigation and adaptation, yet gaps remain in implementation, especially at the subnational level (FGN, 2021; UNFCCC, 2022). Recent indices (e.g., ND-GAIN) highlight Nigeria's high climate vulnerability and low readiness for adaptation (ND-GAIN, 2023), reflecting challenges like inadequate irrigation infrastructure, poor rural roads, low mechanisation, and weak extension services.

In the Southwest and Ekiti State specifically, these climatic pressures are compounded by human factors. Ekiti's hilly terrain and history of deforestation for fuelwood and farming exacerbate soil erosion and cause localised water

scarcity. Limited irrigation networks leave farming heavily dependent on rain. Local surveys (Adeleye, 2024; Obabire, 2024) document that farmers experience more frequent crop stress from erratic rainfall, rising pest outbreaks, and declining soil fertility. These studies note a strong demand among farmers for targeted training in climate-smart practices and support in accessing inputs and technologies (Adeleye, 2024; Obabire, 2024). Despite extensive documentation of these challenges, the literature often recycles well-known facts without a clear synthesis. Many reviews describe vulnerabilities in general terms, but fail to state a precise research gap or concrete objectives. This paper explicitly fills that gap. Our objectives are to (i) assess the climate-driven challenges facing Nigerian agriculture and Ekiti State; (ii) synthesize recent (2021–2025) best practices and innovations in technology and agronomy that build resilience; (iii) analyze applications of physics-based solutions and instrumentation in local farming (e.g., environmental sensors, power electronics, precision irrigation); and (iv) propose actionable, evidence-based recommendations for policymakers, practitioners, and researchers. We employ a systematic review of scholarly studies, program evaluations, and policy reports to inform this analysis.

Climate Drivers and Impacts in Nigeria and Ekiti State

Climate drivers in Nigeria include rising mean temperatures, more intense and erratic rainfall in some regions, and prolonged dry spells in others. These shifts cause floods, droughts, soil degradation, crop losses, and disruptions to rural livelihoods (IPCC, 2022). Such climatic trends compound socio-economic pressures like poverty and land degradation, intensifying vulnerabilities in farming communities (ND-GAIN, 2023; IPCC, 2022). Nigeria's NDC and Climate Change Act (2021) set national priorities for resilience, but translating these into action at state and local levels remains a key challenge (F GN, 2021; UNFCCC, 2022). Achieving these goals will require strong institutional coordination, adequate funding, and community engagement. Ekiti State's unique profile underscores this urgency. The state's steep hills and past land clearing increase erosion and cause seasonal water shortages. With limited irrigation, nearly all farming is rainfed. Recent farmer surveys in Ekiti reveal heightened awareness of climate risks: more erratic rains, more pests, and soil fertility decline are common concerns (Adeleye, 2024; Obabire, 2024). Crucially, these studies emphasise that farmers want training in climate-smart agriculture (CSA) and help accessing new technologies (Adeleye, 2024; Obabire, 2024). Thus, any technology solution must be paired with outreach and capacity building at the community level.

Global and Regional Best Practices

Contemporary evidence shows a spectrum of strategies that have proven effective in similar agroecological contexts:

- **Climate-Smart Agriculture (CSA):** Practices such as conservation tillage, agroforestry, crop diversification, adjusted planting calendars, integrated pest management, and enhanced soil fertility are core CSA approaches. In West Africa, these methods can boost resilience to climate variability and often improve yields when adapted locally. For example, agroforestry and conservation techniques in Nigeria have been linked to better soil moisture and increased production stability. Barriers include low farmer awareness, high upfront costs, and limited extension capacity (FAO, 2021; Adeleye, 2024).
- **Precision Agriculture and Digital Tools:** Digital innovations — remote sensing, soil and moisture sensors, geographic information systems (GIS),

and mobile advisory platforms — enable optimisation of inputs and timely decision-making (Akbar et al., 2023). Integrated with climate forecasts, these tools allow data-driven planting and harvesting schedules. Technically, these systems rely on physics-enabled instruments: for instance, capacitance or time-domain reflectometry (TDR) soil moisture probes, handheld nutrient sensors, and GPS-enabled weather stations convert environmental conditions into data (Akbar et al., 2023). Unmanned aerial vehicles (UAVs, commonly called drones) carrying multispectral and thermal cameras (passive and active sensors) can provide high-resolution crop monitoring to detect stress or pests (Akbar et al., 2023). However, successful adoption requires reliable rural connectivity, smartphone access, digital literacy, and viable business models for smallholders (Akbar et al., 2023).

- **Renewable Energy (Solar):** Solar-powered technologies — such as pumps for irrigation, off-grid cold storage, and solar dryers — can decouple farming from erratic grid or fossil-fuel power. In Sahelian pilots, solar irrigation systems have significantly increased dry-season production and farmer incomes. For example, introducing solar water pumps in parts of Nigeria has allowed year-round crop growth without fuel costs. Likewise, low-cost solar refrigerators preserve perishable produce during transport and storage, reducing losses. These systems harness advances in photovoltaic (PV) materials and power electronics (e.g., higher-efficiency PV panels and maximum power point tracking [MPPT] controllers), which continue to improve the viability of off-grid energy solutions. While empirical data vary, some projects report farm income gains on the order of 30–40% after adopting solar irrigation and processing technologies (IRENA, 2023).
- **Water Management and Irrigation:** Strategic investments in micro-dams, rainwater harvesting, drip irrigation, and watershed restoration increase resilience by ensuring water availability. Global best practices emphasise combining physical infrastructure with institutional arrangements that secure equitable access and maintenance. In Nigeria, projects like the World Bank's Special Program on Irrigation and Nutrition (SPIN) highlight irrigation's critical role in adaptation (World Bank, 2024). Evidence indicates that less than 5% of Nigerian farmland is currently irrigated (FAO AQUASTAT, 2024), pointing to a vast untapped opportunity. Expansion of small-scale, community-managed irrigation in comparable contexts has been shown to boost yields by 20–50% while enhancing food security.
- **Resilient Cropping Systems and Agroforestry:** Deploying drought-tolerant and early-maturing varieties, diversifying cropping patterns, and integrating trees into farms (agroforestry) enhance biodiversity, reduce erosion, and buffer against climate shocks. In Ekiti, agroforestry can also restore degraded lands and improve watershed health, aligning with the Africa Sustainable Commodities Initiative (ASCI) by linking forest-friendly commodity production with carbon sequestration and higher-value markets (Proforest & ASCI, 2025).

Collectively, these practices must be embedded within enabling ecosystems that combine accessible finance, tailored extension, input supply chains, and market linkages. Without such integration, scaling adoption remains slow,

limiting the transformative potential of these interventions (World Bank, 2024; IRENA & FAO, 2021).

Application of Physics, Electronics, and Instrumentation in Ekiti State

Advances in applied physics and engineering underpin a broad spectrum of agricultural innovations with direct applicability to Ekiti State's development priorities. These range from the design and deployment of high-precision environmental sensors capable of measuring soil moisture, nutrient levels, and microclimatic variables in real time, to precision irrigation systems that use automated valves and drip emitters to optimise water use efficiency. Cold-chain logistics — including solar-powered refrigerated storage and transport solutions — help preserve perishable produce quality from farm to market, while UAVs (unmanned aerial vehicles) with multispectral imaging offer cost-effective, high-resolution surveillance for pest outbreaks, nutrient deficiencies, and irrigation performance (IRENA, 2023; Akbar et al., 2023).

Beyond these technological applications, Ekiti's active involvement in the Africa Sustainable Commodities Initiative (ASCI) and its recent state-level reforestation pledges create unique leverage points for integrating agroforestry practices with sustainable commodity value chains. Such integration can yield simultaneous environmental benefits, such as carbon sequestration and soil stabilisation, and economic gains through the production of certified forest-friendly commodities with higher market value (Proforest & ASCI, 2025). These strategies align with both global climate commitments and local rural development goals, enhancing the state's capacity to attract climate finance and technical partnerships.

To ensure equitable and widespread adoption of these technologies, local extension services must adopt a blended communication model. This includes sustained low-technology outreach — via radio programs, community cooperative meetings, and market-day demonstrations — that reaches farmers lacking reliable internet or smartphone access, combined with targeted, hands-on demonstrations of climate-smart agriculture techniques, solar irrigation systems, and precision farming tools. By providing both accessible information and practical experience, extension programs can build trust, demystify new technologies, and enable incremental adoption, ensuring that even smallholders with limited resources can participate in and benefit from these innovations (Obabire, 2024; Adeleye, 2024).

Evidence and Data

Irrigation vs Rainfed: FAO AQUASTAT (2024) reports that less than 5% of Nigerian farmland is currently irrigated, underscoring an immense untapped potential for expanding irrigated agriculture. Expanding irrigation could reduce dependence on increasingly erratic rainfall, support year-round cropping, and improve resilience against drought. Evidence from comparable sub-Saharan contexts suggests that strategic investment in small-scale, community-managed irrigation schemes can boost yields by 20–50% while improving household food security (FAO AQUASTAT, 2024).

Renewable Energy Impact: FAO and the International Renewable Energy Agency (IRENA) document substantial income gains — often exceeding 30% — from the adoption of solar-powered agricultural systems, including irrigation pumps, grain mills, and cold storage (IRENA, 2023; FAO, 2021). In addition to increasing incomes, these systems reduce post-harvest losses and decrease greenhouse gas emissions compared to fossil fuel alternatives.

CSA Training Needs: Surveys in Ekiti show that over half of farmers report high training needs in climate-smart agriculture (CSA) practices, with the majority still relying on radio broadcasts, farmer cooperatives, and community meetings as primary information channels (Obabire, 2024). These findings highlight the importance of combining traditional communication methods with modern training platforms to ensure knowledge transfer, encourage technology uptake, and foster inclusive participation among women and youth.

Policy and Institutional Context

The Climate Change Act (2021) and updated Nationally Determined Contribution (NDC) provide a strong legal and strategic basis for climate adaptation and resilience-building in Nigeria, setting ambitious targets for emission reduction and adaptation measures (F GN, 2021; UNFCCC, 2022). These frameworks are complemented by international and donor-supported initiatives, such as the World Bank's Special Program on Irrigation and Nutrition (SPIN), which aim to enhance agricultural productivity and water security at scale (World Bank, 2024). However, the successful operationalisation of these policies depends on several interlinked factors: alignment between federal and state-level climate strategies, adequate budgetary allocation, and effective multi-stakeholder coordination involving ministries, private sector actors, and civil society organisations. In Ekiti State, embedding climate goals into local development plans, enhancing institutional capacity for project management, and creating enabling environments for private investment are essential for translating national ambitions into measurable local outcomes.

Challenges and Constraints

Nigeria's agricultural adaptation agenda faces persistent barriers that slow technology adoption and limit impact. Financial constraints remain a primary challenge — most smallholder farmers lack access to affordable credit or microfinance products tailored to climate-smart investments (FAO, 2021). Connectivity issues, including inadequate rural internet coverage and unreliable electricity supply, hinder the dissemination and use of precision agriculture tools and other digital innovations (Akbar et al., 2023). Extension services are under-resourced, resulting in low farmer-to-extension worker ratios and limited capacity to provide hands-on training. Social and cultural barriers also persist, with women and youth often excluded from decision-making processes and facing reduced access to land, finance, and technology. Addressing these challenges requires integrated solutions that combine financial inclusion, infrastructure investment, gender-sensitive program design, and targeted policy reforms to foster equitable participation and ensure that innovations reach the most vulnerable populations.

Conclusion

Climate change poses an urgent threat to Nigeria's food security, but a suite of innovative technologies offers pathways to adaptation. In the past few years (2021–2025), evidence and projects have highlighted tangible gains from deploying such solutions in Nigeria and the Southwest. Climate-smart agriculture (CSA) has demonstrably increased farmer productivity and incomes where applied. Precision agriculture and digital tools, though nascent, promise efficiency improvements. Renewable solar and off-grid energy projects are rapidly scaling, enabling irrigation and processing in rural areas. Investments in irrigation and watershed projects are underway to ensure water supply reliability. Developing drought-resistant crop varieties and agroforestry systems is preserving local agro-ecosystems.

For Ekiti State and similarly vulnerable regions of Southwest Nigeria, these technologies must be

tailored to local conditions. The state's experience with ASCI and reforestation illustrates how combining GIS-based land zoning with agroforestry can align agriculture and climate goals. However, farmers also need more hands-on support: extension outreach, training centres, and credit mechanisms. As Kolawole and Oyeyiola (2024) conclude from their review, Nigeria needs to "increase awareness and develop the capacity of farmers through training" while enacting enabling policies (Kolawole & Oyeyiola, 2024).

In summary, mitigating climate impacts on Nigeria's food supply is not a distant possibility but an active process. The data show that with strategic investments in climate-resilient agriculture and clean energy (supported by policy), Nigeria can sustain food production even as its climate changes. The window for action is now — integrating climate-smart solutions at scale could turn a looming crisis into an opportunity for green growth (IPCC, 2022).

Recommendations

As researchers with firsthand experience in climate adaptation and sustainable agricultural systems, we offer the following narrative recommendations to stakeholders, policymakers, and academics:

1. **Federal and State Governments:** Embed climate adaptation targets into agricultural plans and budgets. Integrate climate-smart agriculture (CSA), renewable energy, and precision agriculture technologies into state-level agricultural extension programs and ensure that budgetary allocations are adequate and protected.
2. **Development Partners and Donors:** Align funding streams with local priorities, creating blended finance mechanisms that reduce risks for private investors in climate-smart technologies. Support programs that ease smallholder uptake (e.g., subsidised loans for solar pumps or drought-tolerant seed distribution).
3. **Local Governments and NGOs:** Invest in farmer training using both traditional channels (radio, cooperatives, community meetings) and modern platforms (SMS alerts, mobile apps). Demonstration plots and practical workshops on sensor-based irrigation, solar systems, and other innovations will build local capacity. Strengthen community groups so that farmers can pool resources to acquire technologies.
4. **Academia and Research Institutions:** Intensify applied research on localised solutions, focusing on developing affordable precision agriculture sensors (for soil moisture, nutrients, pest detection), cost-effective irrigation designs (e.g., gravity-fed drip systems), and scalable renewable energy applications (efficient solar pumps, biomass-digesters). Collaborate across universities, private tech firms, and farmer cooperatives to pilot and refine innovations.

By working collaboratively across sectors and scaling up proven practices, Nigeria can move from policy rhetoric to tangible, evidence-based outcomes that enhance resilience, boost productivity, and secure food systems for future generations.

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