

# Executive Summary

Africa stands at a decisive juncture in the transformation of its agrifood systems. Rapid population growth, urbanization, and changing diets are driving up demand for safe, nutritious, and processed foods, while climate shocks, stagnant productivity, and underdeveloped innovation ecosystems have stalled progress toward ending poverty and achieving food security. The 2025 Annual Trends and Outlook Report (ATOR 2025), “*Moving the Technology Frontiers in African Agrifood Systems*,” argues that accelerating progress toward ending hunger and eradicating poverty in Africa is a complex ambition requiring a bundle of technical, institutional, and socio-political innovations, embedded in coherent strategies under the Kampala Declaration and the CAADP Strategy and Action Plan (2026–2035).

Across its 19 chapters and one featured issue, the report shows that technology can deliver transformative impact only when combined with capable institutions, evidence-based and participatory governance, and inclusive innovation systems. The “technology frontier” is therefore not a single breakthrough, but the integration of biological, digital, engineering, ecological, and institutional innovations within a supportive political economy.

## Part I – Conceptual and Analytical Framing

Part I provides the conceptual backbone of the volume. It explains why, unlike in Asia and Latin America, agricultural growth in Sub-Saharan Africa has largely come from area expansion rather than innovation and efficiency gains, leading to slow progress in poverty reduction and food security despite decades of policy commitments.

**Chapter 2** introduces an **analytical framework** built on three innovation pathways:

1. Technological progress – shifting the production frontier via new technologies (biotech, digital tools, improved seeds, mechanization, etc.).
2. Technical efficiency – enabling farmers to use existing technologies and knowledge more effectively through extension, organization, and learning.

3. Transaction cost reduction – lowering barriers to accessing inputs, services, markets, information, and finance.

These pathways are mapped onto a broad typology of technologies—conventional, digital, biological, and financial/social—and across the full agrifood system, from production to consumption.

A political economy model highlights that public policies are key determinants of successful technology at scale. Hence, beyond moving technological-economic frontiers, successful inclusive development in Africa depends on moving political frontiers. In particular, the political approach of Chapter 2 argues that the core bottleneck is not just political incentives, but political learning, i.e., the capacity to expand limited political knowledge to identify which combinations of research, extension, infrastructure, and organizational innovation deliver the highest and most inclusive returns.

The key message of Part I is that technologies must be embedded in inclusive, evidence-based, and learning-oriented policy processes. Strategic, context-specific public investment and adaptive governance, enabling policy learning, are indispensable to turning Africa’s technological opportunities into sustained, climate-resilient development.

## Part II – Technological Frontiers: Digital, Biological, versus Conventional Innovations

Part II examines the **technology frontier itself**, combining emerging digital and biological innovations with “conventional” but underutilized technologies such as mechanization, irrigation, and processing. The chapters collectively show that Africa’s productivity challenge is *not* due to a lack of promising technologies, but to limited adoption, weak complementary investments, and high transaction costs.

### Digital and AI-Based Technologies

**Chapter 3** explores the **untapped potential of artificial intelligence (AI)** and geospatial technologies. Satellite monitoring, machine-learning crop models, and

AI-enabled advisory services can improve yield forecasting, risk management, and input efficiency. The authors develop an Untapped Potential Index (UPI) that compares each country's digital/AI readiness and transformation needs to its actual use of AI and geospatial tools in agriculture. The index shows that most African countries combine high needs and growing readiness with very low effective adoption, indicating large “room to act” for targeted investment, regulatory reform, and capacity building.

**Chapter 5** broadens the lens to **digitalization** along entire value chains, from e-learning and mobile advisory to e-markets and AI-powered platforms. Hundreds of digital tools now operate in African agriculture, yet only a small share have achieved scale or commercial viability. Most focus on production and market access, leaving processing and post-harvest stages underserved—despite high losses and value-added potential. Evidence shows that digital advisory services can raise yields and incomes, especially when localized, interactive, and embedded in trusted relationships. But structural constraints—weak infrastructure, low digital literacy, shallow finance, and fragmented regulation—limit reach and sustainability. Poorly governed digitalization risks widening inequalities and increasing environmental pressure.

Across Part II, digital technologies also underpin innovative mechanization service models (chapter 6), precision irrigation (chapter 8), livestock monitoring (chapter 9), aquaponics management (chapter 11), and insect farming logistics (chapter 10), showing that data and analytics are becoming core infrastructure, comparable to roads or irrigation.

## Biotechnology and Bio-based Solutions

**Chapter 4** provides a comprehensive review of **modern biotechnology paradigms** and their application to agrifood transformation. It covers tissue culture, molecular markers, recombinant DNA, genome editing (CRISPR/SDN), omics platforms, and synthetic biology, as well as non-breeding applications such as biofertilizers, biopesticides, diagnostics, vaccines, and biopharmaceuticals. The chapter identifies three priority domains for biotechnology in Africa:

1. Closing yield gaps through molecular breeding, transgenics, and genome editing.
2. Strengthening climate resilience via drought-, heat-, and flood-tolerant varieties and climate-smart traits.

3. Combating malnutrition through genetic biofortification and nutrition-sensitive agriculture.

It also highlights significant constraints: weak research infrastructure, fragmented and precautionary regulation, limited African IP ownership, and polarized public narratives. Policy proposals emphasize science-based biosafety, regional harmonization, public–private partnerships, and inclusive engagement.

Chapters 9, 10, and 11 extend biotechnology into livestock, insect farming, and aquaponics.

**Chapter 9** on **livestock systems** shows how genetic improvement, improved feeds, digital tools, climate-smart practices, animal health innovations, and risk-management instruments can increase productivity and resilience while creating new livelihoods, especially for women and youth. But unequal access, weak veterinary and digital infrastructure, and governance gaps limit impact.

**Chapter 10** demonstrates how **insect farming**, focusing on Black Soldier Fly (BSF), can convert organic waste into high-protein feed and organic fertilizer at scale—potentially contributing meaningfully to GDP, jobs, poverty reduction, and emissions reduction. Realizing this potential requires improved waste management, finance, skills, regulation, and consumer awareness.

**Chapter 11** shows that **aquaponic systems**, especially when integrated with insect farming for low-cost fish feed, can offer highly resource-efficient, profitable options for smallholders and urban producers. Microeconomic analysis reveals considerable potential for poverty reduction; macroeconomic modeling warns that overly rapid scaling can depress prices and erode profitability. The chapter thus calls for strategic, not indiscriminate, scaling, integrated into broader climate and circular-economy strategies.

## Conventional but Underused Technologies

Chapters 6–8 revisit mechanization, processing, and irrigation—technologies central to the Green Revolution elsewhere but still underutilized in Africa.

**Chapter 6** shows that **mechanization in Africa** remains low, with most land still cultivated manually. When appropriately designed and governed, mechanization can reduce drudgery, save labor, and support income growth. Successful models rely on service markets, digital platforms (“Uber for tractors”), cooperatives, and local manufacturing, rather than state-led equipment distribution.

**Chapter 7** focuses on **processing and value addition**, highlighting how shifting consumption patterns, urbanization, and trade integration are raising demand for processed foods. Yet most African exports remain unprocessed. MSMEs dominate processing but are constrained by finance, infrastructure, quality systems, and limited access to technology. Cluster-based models, blended finance, and circular-economy concepts (3RVE) can help unlock this potential.

**Chapter 8** analyzes **emerging irrigation and water-management technologies**—drip and sprinkler irrigation, solar pumps, remote sensing, soil sensors, and decision-support systems. Evidence from an extensive literature review shows that integrated “bundles,” particularly solar-powered drip irrigation combined with digital decision tools, deliver the largest gains in productivity, water use, and resilience. However, adoption remains highly uneven across regions and farm types, underscoring the need for supportive financing, infrastructure, and institutional arrangements.

Overall, Part II concludes that Africa’s agrifood technology toolbox is rich and expanding. The central challenge is not invention, but innovation systems: getting technologies adopted, adapted, and scaled in ways that are climate-smart, inclusive, and financially viable.

## **Part III – Governance, Institutions, and Innovation Ecosystems**

Part III turns from technologies to the **institutional and governance systems** that determine whether innovations reach farmers and value-chain actors at scale. The central insight is that **the real technology frontier is institutional**.

### **Science, R&D, and Seed Systems**

**Chapter 12** shows that **agricultural R&D investment** is a critical determinant of long-term productivity, yet it remains far below African Union (AU) targets and global benchmarks. Spending is heavily concentrated in a few larger countries; many smaller states depend on donors and cannot sustain robust research systems. A new Agricultural R&D System Capacity Index (ARDSCI) demonstrates that spending ratios alone are misleading; what matters is system capacity—human capital, institutional depth, and stable funding.

**Chapter 13** examines **seed policy and regulatory frameworks**. Effective seed systems require coherent laws on variety release, quality assurance, IP

rights, and market organization. Country case studies illustrate diverse reform paths—from state-led systems to more liberalized, private-sector-driven models to pluralistic approaches that recognize the role of informal and farmer-managed seed channels. Regional harmonization under the East African Community (EAC), the Southern African Development Community (SADC), the Economic Community of West African States (ECOWAS), and other regional economic communities (RECs) has progressed, but implementation gaps persist. The chapter argues for seed policies that balance regulation and competition, promote climate-resilient and locally adapted varieties, and protect marginalized farmers.

### **Producer Organizations and Digital Governance**

**Chapter 14** positions **digitally enabled Smallholder Producer Organizations (SPOs)** as pivotal intermediaries for emerging technologies. Traditional extension models are ill-suited for complex, knowledge-intensive innovations such as AI-based advisory, precision agriculture, or digital finance. SPOs can:

- Aggregate demand and reduce transaction costs,
- Broker partnerships with digital service providers,
- Build trust and social cohesion for technology adoption,
- Provide a platform for bundled services (advisory, finance, market access).

The chapter links these roles explicitly to the Kampala Declaration and the CAADP Strategy and Action Plan (2026–2035), which recognize cooperatives and SPOs as core actors in inclusive, climate-resilient innovation systems.

### **Science–Policy Interfaces and Pan-African Innovation**

The **featured issue on the Science for Africa (SFA) Foundation** illustrates how African-led science and innovation platforms can shape both technology pipelines and governance. Through initiatives such as Grand Challenges Africa (including AI for Global Health) and the SPEAR program on science–policy engagement, SFA supports emerging technologies, strengthens research ecosystems, and generates Africa-specific guidance on AI and innovation governance. The forthcoming C-HAB program at the nexus of climate, health, agriculture, and biodiversity further exemplifies integrated, continent-wide approaches.

Taken together, Part III shows that without robust R&D systems, coherent seed and biosafety regulation, empowered SPOs, and strong science–policy platforms, even the most promising technologies will remain underutilized.

## *Part IV – Global Lessons and South–South Cooperation*

Part IV draws lessons from **China, Europe, and Latin America** for Africa’s technology and governance agenda.

**Chapter 15** traces **China’s agrifood transformation**, driven by institutional reforms, long-term public investment in R&D, and a dense ecosystem of research institutes, enterprises, and policy instruments (subsidies, demonstration parks, extension, digital platforms). The most relevant lessons for Africa concern adaptable, climate-resilient technologies and farmer-centered dissemination models, not wholesale replication.

**Chapter 16** focuses on **digital twins in European and African agriculture**. It shows that digital twins can substantially improve technical efficiency and resource management at farm level, but that their economy-wide impacts depend on multi-crop deployment and complementary reforms in markets, organizations, and public investment.

**Chapter 17** distills **Latin America’s experience**, highlighting that advances in technology were inseparable from organizational innovations, such as strong producer associations, cooperatives, irrigation districts, and regional research funding mechanisms. Technologies such as precision agriculture, FinTech, and traceability tools only translated into broad-based gains where land rights, infrastructure, finance, and institutions were in place.

The overarching message of Part IV is that Africa should not copy external models, but adapt transferable elements: long-term investment in science, strong producer organizations, robust regulatory systems, and blended finance architectures. South–South cooperation can accelerate learning and co-creation of solutions for shared challenges in climate adaptation and food system resilience.

## *Part V – Data, Indicators, and Accountability for Transformation*

Part V, anchored in **Chapter 18**, emphasizes that data, metrics, and accountability systems are foundational to an innovation-driven transformation.

Reviewing **two decades of CAADP implementation and 27 core indicators**, the chapter finds:

- Early gains in growth, trade, and poverty reduction were followed by a slowdown and reversal in some indicators, including rising undernourishment.
- Agricultural spending remains well below the 10 percent target and has declined relative to agricultural GDP.
- Many countries have improved planning and coordination (National Agricultural Investment Plans (NAIPs), Joint Sector Reviews (JSRs), Biennial Reviews (BRs)), but data quality and availability remain major bottlenecks.

Looking ahead, the Kampala Declaration demands a streamlined, SMART results framework and strengthened data ecosystems, including digital and geospatial tools, to track innovation, scaling, and system-wide impacts.

## *Cross-Cutting Vision*

Taken together, all chapters converge on a unifying analytical thread:

- Africa’s agrifood future will be defined not just by which technologies are available, but by how effectively they are governed, financed, adapted, and embedded in inclusive institutions.
- Frontier technologies—AI, digital twins, genome editing, insect farming, aquaponics, precision irrigation—must complement, not displace, conventional technologies and local knowledge.
- Innovation ecosystems, producer organizations, and data systems are as important as individual technologies.

If Africa can combine strategic investment in science and digital infrastructure, inclusive mechanisms for technology dissemination, climate-resilient innovation approaches, and robust governance and accountability, the continent can accelerate the move from technology adoption to technology leadership, shaping global responses to climate change, food insecurity, and sustainable development.