EMPOWER CLIMATE-RESILIENT SMALLHOLDER AGRICULTURE by INVESTING in AFRICAN RESEARCH and INNOVATION

Three recommendations by African researchers and innovators

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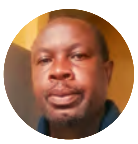

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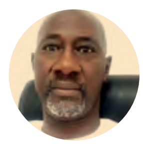

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SUMMARY

IN THE FACE OF CLIMATE EXTREMES AND ECONOMIC SHOCKS, RESILIENCE-ORIENTED INNOVATION IS ESSENTIAL to sustain and increase productivity and to ensure food security in small-scale agrifood systems. With investments in agricultural research and adaptation well below estimated needs, Africa is at a disadvantage in the fight against climate challenges

Drawing on the collective insights of fifteen African researchers and innovators, this brief recommends three strategies for more effectively investing in smallholder-centered research and innovation that advance climate-resilient and sustainable agriculture.

1. CAPACITY FIRST – Without robust, local capacity for context-specific research, climate-resilient production, and commercialization, African agrifood systems will not be able to take advantage of new technologies generated by international scientific programs. Substantive contributions by in-region researchers, producers, extension advisors, agri-entrepreneurs, public officials, and local financial institutions are critical to adaptation on farms and in agricultural value chains.

2. COLLABORATE IN CONTEXT – Resilience materializes when in-region institutions and local agrifood system stakeholders have access to relevant knowledge, technologies, and resources. Better connectivity across upstream and downstream research, between public and private sectors, and among research and policy communities can encourage context-specific co-investments that align with national priorities and foster regional-level coordination on a shared agricultural resilience agenda.

3. CONTINUITY ACROSS INVESTMENTS – Coping with climate change requires continuous support for a diverse R&D portfolio and smoother transitions across different stages of innovation and funding sources. With de-risking by donors and better collaboration across the public-private divide, existing financial flows and new forms of patient capital can be steered toward climate-resilient innovation in Africa's smallholder agricultural systems.

When they are empowered by context-specific research and complementary support, smallholders, rural communities, and value chain actors can innovate and adapt to climate change. By cultivating co-investment in durable research capabilities, Africa's innovation ecosystems can shift away from crisis management and toward global leadership in building sustainable agricultural resilience.

Individually and collectively, global donors, research centers, governments, producer associations, private companies, financial institutions, NGOs, and other agri-food system stakeholders can more effectively invest in African-led research and resilience-oriented innovation in smallholder farming systems. If Africa's R&D deficits were to be filled, innovation epicenters could flourish across the continent.

Climate-resilient smallholder agriculture in Africa is critical to long-term, global prosperity, equity, and environmental sustainability. Inclusive, transformative change in small-scale agrifood systems can boost the food security of farm-based families and growing populations and stabilize rural communities, while enhancing agrobiodiversity, resource conservation, and ecological health.

INTRODUCTION

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THE WORLD DEPENDS HEAVILY ON SMALL-SCALE FARMERS IN LOW- AND MIDDLE-INCOME COUNTRIES, who produce one-third of our food supply [1-3] while operating within fragmented value chains and facing a broad set of chronic risks [4]. Smallholders, rural communities, and value chain actors can build resilience against climate extremes and economic shocks if robust research and development (R&D) empowers them to undertake context-specific innovation.

Coping with climate change requires continuous investment in a diverse global R&D portfolio that enables every country to pursue its own pathway to climate-resilient agriculture. However, only 6% of the money governments spend on agriculture today goes to R&D and this is declining in many countries [5]. Existing research-generated knowledge and technologies are at risk of obsolescence as public funding levels stagnate and climatic conditions shift [6].

Not only is the total level of research investment insufficient, but there is also significant under-investment in R&D focused on small-scale agriculture. Only 2% of published agricultural research is relevant for small-scale producers [7] and this imbalance could worsen as urgent humanitarian crises squeeze public research budgets.

Small farms produce most of sub-Saharan Africa's food, yet many of these farming households are poor, food-insecure, and vulnerable to volatile weather and market conditions [4,8]. In many African farming contexts, under-funded agricultural innovation capacity impedes climate adaptation [6,8], yet only 1% of all adaptation finance commitments for Africa goes to agricultural research.[i] Representing less than 1% of global gross domestic R&D expenditures (40% of this spent by South Africa), African countries are at risk of becoming 'scientific have-nots,' unable to adequately protect their agrifood systems and their populations [10].

“A key challenge for science and innovation in agri-food systems is the strategic importance of responding to the needs of a diversity of local contexts, including the needs of the large number of small-scale producers and family farmers. In addition, there is under-investment in national agri-food innovation systems, which are crucial to adapting innovations to local contexts.”

– FAO Science and Innovation Strategy, 2022

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AFRICAN PERSPECTIVES on INNOVATION

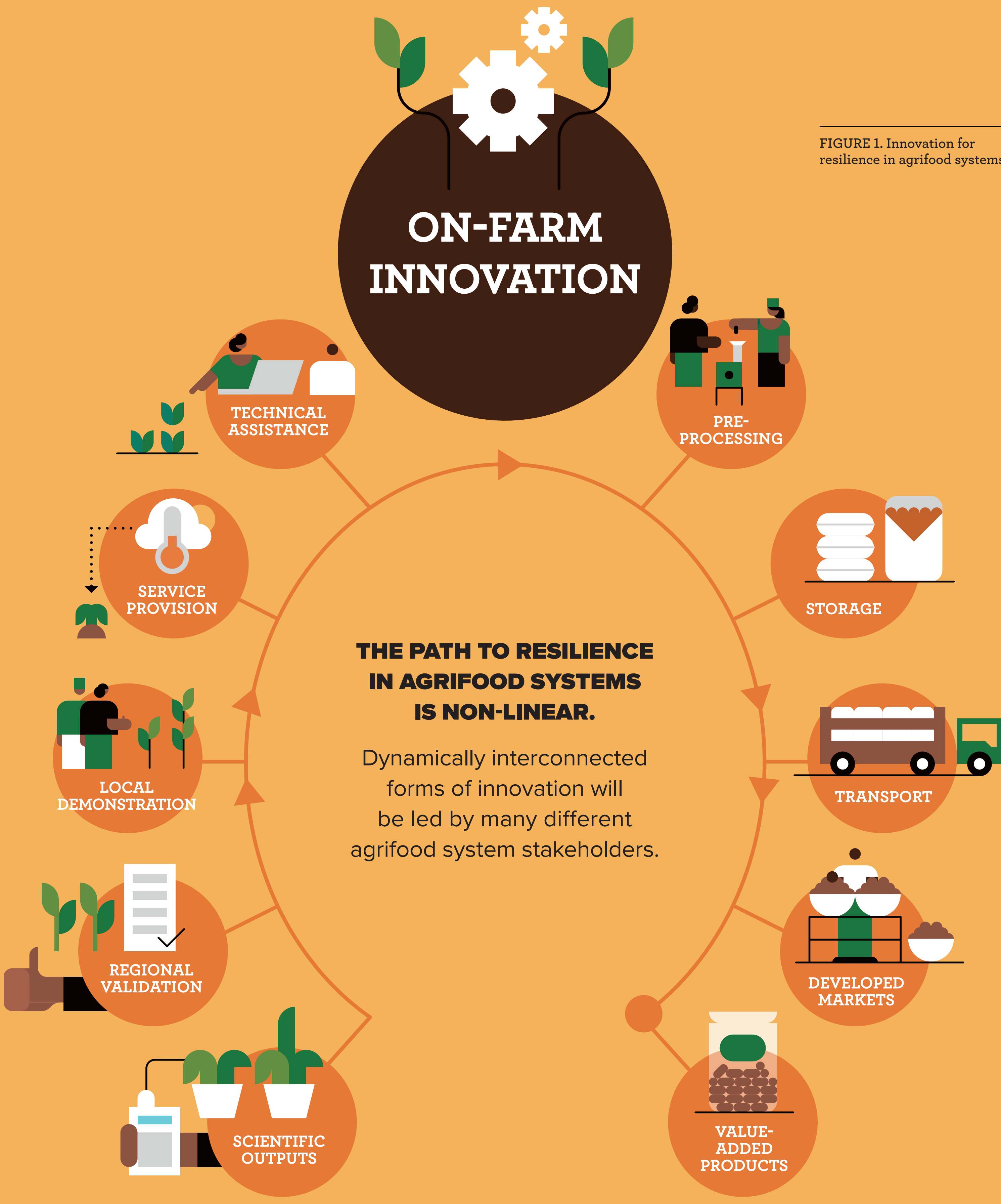
IN THE LEAD UP TO THE AGRICULTURE INNOVATION MISSION FOR CLIMATE (AIM for Climate) Summit in May 2023, two virtual roundtables considered strategies for increasing investment in research and innovation for resilient smallholder agriculture in Africa. Hosted by the United Nations Foundation, these sessions brought together representatives from national agricultural research systems (NARS), universities, CGIAR programs, regional networks, and producers' associations, as well as agri-entrepreneurs and other innovators in African agricultural value chains.[ii]

These experts surveyed major R&D investment barriers and proposed actions that can be taken, individually and collectively, by global donors, research centers, governments, producer associations, private companies, financial institutions, NGOs, and other agri-food system stakeholders to facilitate resilience-oriented innovation in smallholder farming systems.

This brief presents the collective insights and recommendations of a diverse group of African innovators to inform public, private, and philanthropic funders about effective investment strategies for smallholder-centered research and innovation.

Photo © Extension Africa

FIGURE 1. Innovation for resilience in agrifood systems



RECOMMENDATION 1

CAPACITY FIRST

- Capacity for context-specific research
- Capacity for climate-resilient production
- Capacity for commercialization

THE CURRENT GLOBAL PORTFOLIO OF AGRICULTURAL RESEARCH is heavily weighted toward upstream research and technology development.[iii] In pursuit of enhanced productivity, profitability, and environmental performance, many R&D investments seek to generate novel technologies and practices. Scientific and technological advances of the last half-century have anchored significant food security gains, including through technology transfer from the USA and Western Europe to developing countries.[iv] However, research investments focused on technology breakthroughs commonly have unclear pathways to directly benefitting smallholders[v] and low adoption rates reveal the limitations of 'supply-driven' technology dissemination [11-12].

Scientific outputs are unlikely to translate into adoption of new technologies or practices unless they align with smallholders' capacities and incentives.[vi] For example, small-scale producers may adopt new technologies when they can benefit from price-stabilizing contracts and higher value crops, although positive effects may be out of reach for asset-poor producers and those located far from transportation routes and market infrastructure [13].[vii] The weak track record for smallholder adoption and benefit from technology 'push' approaches is due, in part, to inadequate assessment of local demand, financial risks, and absorption capacity for technologies and technical assistance.[viii]

What does smallholder-centered innovation look like?

Agricultural innovation has been defined as a multi-scale "process of creating and putting into use agricultural practices, new to a particular environment [14]." Efforts to stimulate innovation in small-scale agricultural systems and value chains should:

- Account for significant variation arising from numerous biophysical and socio-economic factors that influence farm size, household income, food security, and capacity for adaptation.[ix]
- Recognize the different needs of women, youth, and other commonly marginalized groups.
- Empower small-scale producers and entrepreneurs to innovate on-farm and in value chains by engaging them in local demonstrations, by communicating actionable information through established channels, and by facilitating their access to finance.
- Simultaneously enhance capacities of individuals (e.g. skill-building), their communities (e.g. collaborative leadership), and their larger institutional contexts.

Agricultural innovation encompasses more than technology development (see Table 1). Downstream innovation in markets, infrastructure, and policies can strongly influence smallholders' access to inputs, farm credit, and buyers and thus their profitability and capacity to implement adaptation measures [13]. Leaders in low- and middle-income countries have been vocal about the need for balance across upstream and downstream R&D investments.[x]

Adopting a 'capacity first' approach to investing in agricultural innovation opens the door to more empowered contributions by in-region researchers, producers, agri-entrepreneurs, public officials, and local financial institutions in achieving climate resilience. The disconnect between scientific outputs and agricultural practices can be bridged when these essential stakeholders have the resources to undertake *in situ* innovation on farms and in agricultural value chains.

To bolster smallholder-centered resilience, recommended capacity investments fall into three categories:

CAPACITY for CONTEXT-SPECIFIC RESEARCH

Many African countries have a large percentage of the population working in agriculture yet have very limited research facilities and extension capabilities, contributing to large yield gaps and high environmental vulnerability. An infusion of new funding toward human resources, including training young scientists, would enable local research systems to better support national resilience and food security priorities.

CAPACITY FOR CLIMATE-RESILIENT PRODUCTION

Despite its abundant agroecological diversity and year-round production potential, there are significant untapped opportunities for diversification in African agrifood systems.[xi] When paired with complementary support, multi-objective R&D investments that develop locally relevant knowledge and technologies can empower producers to incorporate a broader range of crop types and production strategies. Centers of excellence can accelerate this process by facilitating cooperation within regional networks based on comparative R&D advantage in different crop and livestock categories.[xii]

CAPACITY FOR COMMERCIALIZATION

Poor transport and storage systems, under-developed markets, low value addition, and other challenges reduce profitability and disincentivize innovation in many African agrifood systems. In addition to development of climate-resilient technologies, investment is needed in infrastructure, information systems, and new business models that can enable small-scale producers and agri-entrepreneurs to identify or create commercially viable commercially viable, profitable, and inclusive pathways to resilience.

TABLE 1. Examples of investment needs for smallholder-centered innovation

INNOVATION OBJECTIVES	EXAMPLES
R&D SYSTEMS that effectively integrate in-region and international research capacities	Capacity development for in-region research institutions. Public-private R&D partnerships *(e.g. high-functioning seed systems).* Integration of research, extension, and development programs *(e.g. participatory research and testing; tailoring scientific outputs into actionable recommendations).*[xiii] Research to support policy development.
INFORMATION SYSTEMS that increase access and utility of data resources	Data development and data-sharing mechanisms *(e.g. for risk analysis; performance assessment; policy adjustment; product traceability).* Development and calibration of region-specific models. Demand-driven digital services *(e.g. tailored agro-climate advisories in local languages).*
PRODUCTIVITY GAINS that sustainably increase, stabilize, and diversify yields	Improved seeds[xiv] and fertilizers. Validated management practices *(e.g. organic matter utilization; erosion control; disease prevention).* Right-sized infrastructure *(e.g. irrigation powered by renewable energy)* and mechanization *(e.g. small-scale equipment).* Rotation crops *(e.g. to improve soil improvement and enhance nutrition).*
MARKET DEVELOPMENT that expands income opportunities for producers and value chain actors	Farmer aggregation and co-ownership models. Offtake guarantees / competitive farmgate pricing. Storage and transport infrastructure to reduce post-harvest loss.[xv] Local food processing and value addition. Market intelligence (e.g. price alerts).
FINANCE strategies that steer capital toward sustainable technologies and practices	Risk-based lending and insurance. Blended finance facilities. Financial inclusion *(e.g. youth agri-entrepreneurs).*
POLICY integration of resilience and equity objectives within regulations, institutions, programs, and economic incentives	Public subsidies *(e.g. to achieve social equity for marginalized groups, activities, or crops).* Streamlined regulatory processes *(e.g. seed registration).* Transparent, predictable market pricing and export policies. Legal reforms *(e.g. land tenure; public domain and proprietary IP; data policies).* Land use planning *(e.g. protect productive lands from encroachment).*

RECOMMENDATION 2

COLLABORATE in CONTEXT

- Upstream and downstream R&D
- Public and private sectors
- Research and policy communities

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EVERY COUNTRY HAS A UNIQUE SET OF KNOWLEDGE AND TECHNOLOGY needs to support its trajectory toward climate resilience [15-16]. A strong in-region value proposition for climate-resilient agricultural technologies and practices is unlikely to emerge without complementary investment in testing and adaptation in local production systems [17-18] and integration within regional institutions.[xvi]

National policies are essential for enabling smallholders to employ resilience strategies, however, this is constrained by short planning horizons for the agricultural sector in many African countries. Coherent policy development is challenging when effective evaluation of synergies and tradeoffs is inhibited by a complex, fragmented evidence base [19]. 'Top down' sustainability roadmaps often receive a lukewarm reception from national and sectoral decision makers, who may have been sparingly engaged in their development and who understand the real-world obstacles to implementing their recommendations.

Right-sized investments can empower local innovators

Most small-scale agricultural systems would benefit from increased access to labor-saving and value-adding technologies and improved infrastructure, but when seeds, equipment, storage, and other assets are too costly, smallholders are unlikely to gain access or achieve profitability. Right-sized investments are more likely to be:

- Complementary bundles that enable producers to profit from yield gains *(e.g. preventing post-harvest loss through accessible storage, transport, and marketing options).*
- Effective at removing value chain bottlenecks *(e.g. machinery that significantly reduces pre-processing time or achieves a more marketable product).*
- Decentralized to accommodate transportation challenges *(e.g. satellite storage facilities; mobile equipment).*
- Co-owned by cooperatives, village residents, or other social groups that can establish and maintain mechanisms for shared governance *(e.g. timing and duration of use).*
- Service-based business models with low capital requirements that create income-earning opportunities for women and youth.

Underlying assumptions about how innovation occurs steer the R&D investments made by research and funding institutions [20]. When key constituencies are not included in priority-setting, funding portfolios may not deliver anticipated benefits or reach intended beneficiaries. In international dialogues, many voices have called for a more demand-driven approach to agricultural R&D that recognizes the need for an inclusive innovation ecosystem.[xvii] Philanthropic funders are increasingly signaling their embrace of locally-led, smallholder-centered R&D investment that aligns with national priorities and expands access to planning, policy, extension, and market systems [21].

The profound diversity across smallholder production systems necessitates context-specific approaches that make effective use of all available resources and innovation capabilities [22]. Better integrating governments, producers, agri-entrepreneurs, and other local agrifood system stakeholders into R&D priority-setting can more effectively steer national and international investments toward resilience-building opportunities in specific smallholder production systems, increasing adoption and impact.

Collaboration and co-investment can emerge from enhanced engagement across the following divides:

UPSTREAM and DOWNSTREAM R&D

Climate-resilient innovation is more likely to occur when R&D funding is balanced across farmer engagement, basic and applied research, local technology validation and adaptation, market assessment and development, and tailored dissemination, advisory, and finance mechanisms. For example, demand-led, participatory R&D models inject information about producers' real-world needs throughout the scientific discovery process.

PUBLIC AND PRIVATE SECTORS

Significant volumes of public and private capital flow into and out of smallholder production systems through many different channels. With clear policy signals and whole-of-government coordination, these capital flows can contribute to a resilience agenda. Effective co-investment in smallholder-centered innovation could occur through differentiated strategies that leverage the capabilities and aligned interests of public and private agrifood system stakeholders.

RESEARCH AND POLICY COMMUNITIES

Closer engagement between researchers and government officials can reduce policy barriers (e.g. outdated institutional mandates) and encourage coordinated, context-specific investments in smallholder resilience (e.g. streamlined mechanisms for knowledge transfer). When scientific activities are aligned with national priorities, research outputs are more likely to be supported by policy directives and to be disseminated through government agencies. Similarly, research networks that extend across disciplines and across borders can inspire more effective regional-level policy alignment (e.g. common standards facilitating transnational trade and improving smallholders' access to inputs and markets).

Public or private investment?

It's well understood that both are needed to stimulate innovation on farms, in value chains, and across the realms of technology, policy, and finance. Alignment between concessionary and commercial funding streams can be mutually reinforcing:

PUBLIC SECTOR – Donor governments invest in smallholder-focused R&D, bilaterally and through multilateral funds, to meet mandates ranging from enhancing scientific capacity and research infrastructure to scaling climate-resilient technologies and practices to de-risking local agri-entrepreneurship. African governments provide institutional support to NARS and other domestic research and extension organizations and, through various channels, use public funds to directly and indirectly support agricultural production and value chain activities.

PRIVATE SECTOR – Large companies can finance major scientific projects to develop novel, proprietary technologies if substantial commercial returns are anticipated in the medium- or even long-term. Smaller companies can also get a return on R&D investments when these are focused, for example, on validating and adapting technologies to regional supply chains or developing new data streams to improve service delivery. Financial institutions can steer capital toward entities that seek to deliver new agricultural services or technologies, to build transport or processing infrastructure, or to insure against transition risks.

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RECOMMENDATION 3

CONTINUITY ACROSS INVESTMENTS

- **Enduring support**
- **Patient capital**

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IN THE POST-WORLD WAR II PERIOD, HIGH-INCOME COUNTRIES SUPPORTED ESTABLISHMENT of NARS in low-income countries and funded the CGIAR and other international agricultural research centers,[xviii] which have delivered high returns on investment (ROI).[xix] Despite spill-over benefits to their own agricultural systems,[xx] over the last decade, donor nations have slowed their support for R&D in low-income countries.[xxi] Prominent international initiatives are advocating for an investment surge in agricultural R&D, even as urgent humanitarian crises are straining public budgets.[xxii]

Historically, donor-funded agricultural R&D has operated on short project cycles, emphasizing dissemination of technologies without a complementary focus on adaptive management within dynamic and complex environmental, socio-economic, and policy contexts.[xxiii] Limited duration funding, driven by shifting donor government priorities, does not typically correspond with the time-to-maturity of novel technologies. Short-term projects do not readily accommodate participatory approaches to technology validation and adaptation and other key components of smallholder-centered innovation. Explicit 'handoffs' of information and roles across essential phases of research and innovation are atypical.

Data are essential for navigation

Innovation is an inherently unpredictable process that is best served by a continually adaptive approach informed by multiple data streams. Rather than R&D budgets guided by centralized, timebound decision processes, investments can achieve better returns and avoid lock-ins if they are allocated in a more iterative way, benefitting from insight gained during initial project stages [3]. Investment in localized, smallholder-relevant data systems is essential for:

- Ensuring that monitoring and learning translate into ongoing improvement in smallholder-centered solutions and service delivery.[xxiv]
- Communication among research centers, government agencies, companies, and financial institutions about emerging needs and opportunities.
- Devolved priority-setting and decision making based on evidence provided by diverse stakeholders about outcomes on farms (e.g. performance of new technologies) and in value chains (e.g. market volumes and prices for rotation crops).
- Foresight and risk analysis to inform actions and investments by producers, companies, governments, financiers, and philanthropies.

As the private sector has taken on a larger share of global R&D investment in recent decades,[xxv] the possibility of harnessing private capital to the climate resilience and agricultural development agendas has been enthusiastically pursued. In the 2010s, private investment in agricultural innovation focused on the Global South was more than double investment by global donors, with the majority allocated to mechanization, pesticides, seed development, and biotechnology [23]. The private sector has an essential role to play in building agricultural resilience, although the objectives and modalities of private investment are not necessarily aligned with public sector approaches and smallholder R&D needs.[xxvi]

Greater continuity across investments can generate better resilience returns on R&D expenditures. Escalating climate risks cannot be mitigated with short-term and narrowly scoped funding for agricultural research and innovation, especially in low-asset, small-scale production systems that require multiple forms of capacity building and technical support. Smoother transitions are needed across different stages of innovation (e.g. technology validation; novel service delivery models; local value addition) and funding sources (e.g. national governments; impact investors; regional agri-companies) (see Figure 2).

More continuous and better functioning investment in African resilience encompasses two dimensions:

ENDURING SUPPORT

To build and sustain vibrant regional agricultural research and innovation ecosystems, some functions require ongoing sources of public or other concessionary support. In addition to rural advisory services, long-term institutional and network-based mechanisms are needed for foresight that anticipates new risks and opportunities. Investment in ‘career pipelines’ is key to the retention of scientific capacity within national research centers.

PATIENT CAPITAL

Producers and agri-entrepreneurs require access to working capital in forms that align with their capacity and timelines for implementing and profiting from innovative practices. If equitable, diversified commercial value chains are to be the engine of agricultural resilience, patient capital is the fuel for that engine. Context-specific risk analysis helps investors assess opportunities and develop funding mechanisms that unlock appropriate forms of capital.

Investment in smallholder-centered R&D faces headwinds including tight public budgets, unclear private sector roles, and a pattern of short-term funding.

Photo © Neil Palmer | CIAT

FROM 'SCIENTIFIC HAVE-NOTS' to INNOVATION EPICENTERS

REBALANCE INVESTMENT

Agricultural productivity and resilience depend on R&D investment, yet there is wide variation among countries in their capacity to fund and conduct agricultural research. With a disproportionate share of 'scientific have-not' nations, sub-Sarahan Africa is disadvantaged in the fight against climate challenges that threaten its agrifood systems.[xxvii]

Lagging agricultural research capacity in low-income African countries impedes climate adaptation in specific farming contexts [6,9]. International public finance for adaptation in Africa is well below estimated costs,[xxviii] unevenly distributed, and affected by significant disbursement gaps.[xxix] The efficacy of R&D investments is hampered by institutional constraints in low-income countries as well as by increasingly complex project funding structures [24-26].

Historically, high-income countries have achieved significant productivity increases by channeling large R&D investments through robust research institutions with strong cross-sectoral linkages, resulting in improved technologies adopted by producers with access to commercial and concessionary finance [25]. Continuous innovation in industrialized agricultural systems is funded by a mix of public and private sources, including producer associations (e.g. commodity checkoff funds for research and market development[xxx]). To overcome major gaps in scientific knowledge and in regionally validated solutions [22,27], African agriculture needs a counterpart system to support iterative, ongoing progress toward resilient farms and value chains.

Dynamic trends in global R&D investment

Across all types of global R&D expenditures, the contribution of major economies dropped from over 70% in 1980 to under 50% in 2013 [10]. During this same period, expenditures by nations with low R&D capacity declined further and private sector expenditures increased, although unevenly across regions [10]. Spending by middle-income countries is now a dominant share of global public agrifood R&D funding, outspending and significantly out-producing high-income countries [6]. Of the USD 35-45B spent annually on agricultural innovation by Global South governments during 2010-2019, 48% was spent by China, 7% by India, and 5% by Brazil [23].

Long-term structural and ideological factors, low decision making power by smallholder constituencies [4], and international stakeholders advocating for divergent or competing priorities have all contributed to imbalanced funding across countries and research areas. Greater coordination, organized around robust evidence and informed by those with direct resilience-building experience in smallholder production systems, is needed to address significant unmet research and innovation needs in Africa.

TABLE 2. Examples of co-investment in smallholder-centered innovation and resilience

African agrifood systems lack adequate, consistent flows of R&D investment. At the same time, they are already experiencing major climate change impacts and have, of necessity, become decentralized incubators of innovative responses. If Africa's R&D deficits were to be filled, innovation epicenters could flourish across the continent.

By cultivating co-investment in durable research capabilities, based on different competencies and aligned interests (see Table 2), and combining foresight and risk analysis with stable funding sources, Africa's innovation ecosystems can shift away from crisis management and toward global leadership in building agricultural resilience. In pursuit of diverse objectives, co-investment can take many forms from loosely coordinated activities to highly structured blended finance instruments that enable collaborators to more effectively 'pass the baton' to one another.

Examples of co-investment in smallholder-centered innovation and resilience

CO-INVESTMENT TYPES	PRODUCER GROUPS	LOCAL VALUE CHAIN ACTORS	AFRICAN GOVERNMENTS	DONOR GOVERNMENTS	PRIVATE SECTOR (companies, banks, funds)
Develop knowledge and resources that enable near-term ROI for producers and agri-SMEs.	In-kind contributions to R&D. Test digital advisory platforms.	Develop and use diagnostic tools and advisory services.	Fund testing / validation of technologies and practices.	Fund in-region R&D and data development.	Invest in technology R&D.
Increase producer access to high-quality, locally-suitable inputs and services.	Coordinate training and cooperative purchasing.	Innovate service delivery models.	Fund smallholder adoption pilots.	Subsidize services. De-risk pre-financing to SMEs.	Provide working capital to producers and SMEs.
Increase producer access to remunerative markets and improve supply chain efficiency.	Coordinate training and cooperative marketing.	Provide efficient offtake and storage.	Fund technical assistance for producers.	Fund improved transport and storage infrastructure.	Provide loans for transport and storage infrastructure.
Expand markets and processing capacity for improved crops, varieties, and breeds.	Co-sponsor field validation studies.	Develop new value chains and processing capacity.	Fund demo projects and technical support.	Fund testing, multiplication, and registration of new varieties.	Provide loans for processing equipment.
Enhance flow of data to improve risk analysis and performance assessment.	Negotiate sharing of producer data	Integrate data to improve service delivery.	Facilitate cross-government data sharing.	Fund data development and training.	Integrate data in purchasing and lending strategies.

Climate-resilient smallholder agriculture requires continuous investment toward many different types of research and innovation that improve productivity, efficiency, diversification, and equity. This brief proposes three major strategic shifts in R&D funding to empower smallholder-centered innovation in African agriculture that will enable the continent to provide global leadership in this critical arena. More effective collaboration among agrifood systems stakeholders and greater continuity across R&D investments can build capacity for the full range of innovation needed for creating climate-resilient, small-scale agriculture.

FIGURE 2. Recommendations for effective investment in smallholder-centered research and innovation

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ENDNOTES

[i] From 2014 to 2018, USD 19.2B in adaptation-related finance were committed by bilateral and multilateral funders to African countries, with 30% directed to the agriculture sector [28].

[ii] The roundtables were co-convened by the United Nations Foundation and its CGIAR partners at the Pan-Africa Bean Research Alliance (PABRA), a regional consortium facilitated by the Alliance of Bioversity International and CIAT, and at the East and Southern African hub of the International Rice Research Institute (IRRI).

[iii] "Technology for sustainable agrifood systems can be defined as the application of science and knowledge to develop techniques to deliver a product and/or service that enhances the sustainability of agrifood systems [29]."

[iv] Transfer channels included foreign direct investment by private companies as well as local entrepreneurial investment [13].

[v] Technological breakthroughs can have higher impact potential as well as higher risk (e.g. no guarantee they will succeed or be compatible with existing governance and value chain arrangements; benefits accrue to larger, wealthier farmers, reinforcing sectoral inequities [15].

[vi] "Many studies that conclude that smallholders are more likely to adopt new approaches — specifically, planting climate-resilient crops — when they are supported by technical advice, input and ideas, collectively known as extension services. Other studies found that these farmers' incomes increase when they belong to cooperatives, self-help groups and other organizations that can connect them to markets, shared transport or shared spaces where produce can be stored. Farmers also prosper when they can sell their produce informally to small- and medium-sized firms [7]."

[vii] "The price messages that farmers depend on are generated from within the food system and they need to be better anticipated, understood and even shaped and this can only happen if we understand better the motives and incentives of stakeholders that farmers depend on [30]."

[viii] "Focus should be on evolving the socio-technological context rather than technology push...Momentum should be built on grass-roots demand and technology pull [26]."

[ix] For example, factors may include prevailing weather, population density, land tenure patterns, number of cropping seasons, yield gaps, and access to commodity markets [8].

[x] For example, the 2021 Africa Common Position on Food Systems "proposes climate-smart agricultural practices and significant investments in research, innovation, and technology, together with institutional and physical infrastructure that is responsive to the needs of small-scale producers" and "draws attention to the funding needs for infrastructure development including rural roads; information and communication technologies (ICT) such as mobile technologies and the internet; as well as water and energy generation and distribution [31]." "[W]e also need investment in agriculture-related innovation, infrastructure, information, value-addition, and market access...the funding needed both to respond to humanitarian emergencies and to transform food systems for the future is still not being released and invested where it is most needed [32]."

[xi] Arising during the colonial era and continuing within contemporary globalized markets, monocropping typically reduces soil fertility and nutrition security and marginalizes sorghum, millets, teff, cassava, and other indigenous crop types that can increase agricultural resilience [4].

[xii] For example, given the large diversity of crops grown in African production systems, it is difficult to ensure sufficient R&D capability in every country. Cooperation through regional centers of excellence can facilitate cross-border germplasm transfer and shared market instrastructure.

[xiii] For example, translate research-based knowledge into localized, Extension-ready formats and disseminate through ongoing partnerships with agricultural development organizations

[xiv] Climate-resilient genetic resources can be mobilized through product profiles guided by local, regional, and national markets (e.g. farmer- and market-preferred; early maturing; pest-tolerant; drought-resilient varieties).

[xv] "...The annual value of post-harvest grain loss in sub-Saharan Africa is US$ 4 billion, which exceeds the value of total food aid that the region has received over the past decade. The large majority of this food is lost between harvest and the point of sale. Post-harvest loss occurs owing to inadequate post-harvest management, lack of structured markets, inadequate storage in households and on farms, and limited processing capacity [4]."

[xvi] "Ownership of technology at an institutional level creates a permanent integration into the country's social and economic fabric [26]." "It is very likely that national research institutions help to adapt and disseminate these technologies locally... CGIAR technologies spread more rapidly in African countries with more national agricultural R&D capital [6]."

[xvii] For example, the UN FAO's FAO Science and Innovation Strategy notes that "participation of beneficiaries of research throughout the entire research cycle, including setting research agendas and developing demand-driven participatory research and systemic approaches, will be promoted to ensure effective outcomes that are adapted to the local context and respond to the need of small-scale producers [29]."

[xviii] Over 1962–2011, agricultural R&D spending totaled $1,188 trillion by governments (59% by developed countries) and $330 trillion by the private sector; $12 trillion (principally from funders based in high-income countries) flowed through CGIAR [6].

[xix] Recent estimates indicate an ROI of 10-to-1 [33].

[xx] For example, CGIAR breeding programs have contributed to development of varieties grown on 60% of US wheat area [34].

[xxi] Bilateral funding dropped from USD 4.1B in 2010 to USD 3.2B in 2019 [23].

[xxii] Despite high ROI, agricultural R&D and extension have low visibility and are likely to be sidelined in public budgets, eroding resilience of the sector [35].

[xxiii] For example, crop and soil management alone can require balancing 10-20 different factors in pursuit of yield potentials achieved in controlled trials [15]. "Focus should be on evolving the socio-technological context rather than technology push...Momentum should be built on grass-roots demand and technology pull [26]."

[xxiv] For example, investments in social, demographic and economic data products by the National Institute of Statistics of Rwanda strengthen "the data value chain and promote sustainable development for all [36]."

[xxv] "Worldwide, the private share of GERD [gross domestic expenditure on research and development] has increased over time, from 57.9% in 1980 to 66.0% in 2013 [although] this has occurred unevenly throughout the world...R&D is also an increasingly globalized endeavor...Firms make decisions on where in the world to locate their R&D activities, in part, with an eye to the pattern of R&D investments by other firms and public agencies [10]."

[xxvi] For example, private companies expect to secure intellectual property rights from R&D investments and this diverges from governmental commitments to fund public goods, apply safeguards, and maintain control of national assets [26].

[xxvii] "To the extent living standards are inextricably tied to the pace of productivity growth enabled by investments in R&D, these evolving global patterns of R&D are central to morbidity, mortality and quality-of-life outcomes [10]."

[xxviii] "Africa alone is estimated to need $41.3 billion annually for its adaptation needs, yet sub-Saharan Africa received just $3.6 billion in adaptation finance in 2017-2018 [32]."

[xxix] Disbursement delays are greater in countries with lower GDP and absorptive capacity (e.g. deficient procurement planning; government failure to meet co-funding requirements) and for projects with lower budgets or long durations; rigid rules of multilateral climate funds) [28].

[xxx] Using a similar model, the South African Sugarcane Research Institute funds commodity-specific R&D (e.g. improved varieties and agronomy) and Extension (https://sasri.org.za/about-us/).

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