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BUILDING 21ST CENTURY AGRICULTURAL RESEARCH AND EXTENSION SYSTEMS IN AFRICA

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AUTHORS

T. S. Jayne
University Foundation Professor Emeritus,
Michigan State University,
United States

Shamie Zingore
Director, Research and Development,
Africa Plant Nutrition Institute,
Morocco

Amadou Ibra Niang
CEO, Afrik Innovations,
Senegal

Cheryl Palm
Professor, University of Florida,
United States

Saloni Shah
Former Senior Food and
Agriculture Analyst,
Breakthrough Institute,
United States

Emma Kovak
Senior Food and Agriculture Analyst,
Breakthrough Institute,
United States

Pedro Sanchez
Professor Emeritus, University of Florida,
United States

This report elaborates on research previously published by the authors in the European Review of Agricultural Economics (Jayne et al., 2023).

EXECUTIVE SUMMARY

This study 1) explains why improved performance of national agricultural research and extension systems (NARES) is required to achieve many widely shared development objectives of African governments and international partners, 2) examines the effectiveness of international efforts to build the capacities of African NARES, and 3) proposes actions to improve the performance of these systems.

Research on this topic has been impeded by the lack of data on the behaviors of, and interactions between, organizations operating in the agricultural research, development, and extension (R&D&E) space in developing countries. Most available quantitative data lack the depth or nuanced context specificity to shed light on complex institutional behavior. Hence, this study primarily derives its findings from in-depth interviews of individuals with longstanding direct experience working in African NARES and international organizations with a mandate to strengthen the capacities of African NARES. In addition to these, key informant (KI) interviews of 26 senior representatives of African and international agricultural R&D&E institutions and three international donor organizations, the study also draws upon available secondary data on national R&D expenditures and scientific capacity.

The study identifies seven recurrent themes emerging from the KI interviews: (i) building strong NARES will initially require a regional approach for many countries; (ii) sustained commitment and funding from African governments is a precondition for building strong NARES and regional and continental agricultural R&D&E systems; (iii) organizations within the international agricultural research system (IARS) often profess to be strengthening the capacities of the NARES, but their overall contribution has been limited; (iv) the effectiveness of donor funding to the IARS depends on strengthening the NARES; (v) donors should confront the issue of creating organizations that duplicate activities of the NARES; (vi) it is important to integrate nutritional objectives into NARES priorities; (vii) there is a need to recognize and strengthen the performance of tertiary education systems.

The study emphasizes the need to differentiate between individual and institutional capacity development. Most key informants concluded that donors and international partners have increased the number of professional African agricultural scientists while contributing relatively little to the institutional capacities of African NARES. Many of these scientists have joined the ranks of international research centers and universities rather than African NARES. Without institutional capacity development of the African NARES, international research centers will continue to draw talent away from the NARES.

Based on the weight of KI perspectives, the study concludes by proposing that African governments and African development organizations build a 21st-century NARES in which research is defined, prioritized, and implemented by NARES with the IARS being in service to the NARES. Achieving this vision will require action by actors including African development agencies and governments, leadership within the NARES, the CGIAR and other international research organizations, donors, and the private sector.

There is a wide consensus, both among the KIs interviewed for this study as well as in the existing literature, that the most crucial step to improving the performance of NARES is for national governments to increase their funding and commitment to supporting their own NARES, to monitor performance, and to demand greater accountability for results. The African Union and the African Development Bank must play the catalytic role in continental leadership and coordination, including seeking greater accountability and commitment from African governments themselves to build their NARES, and allocating sustained funding required to do so.

The African Development Bank can play a catalytic role to create a new regional architecture for agricultural research, organized by agro-ecological zones, to serve the immediate needs of African farmers while simultaneously building the capacities of NARES in countries where they are particularly weak. The African Union and African Development Bank must also work with international funding partners to ensure a reallocation of donor funding to prioritize institutional capacity development of African continental, regional, and national R&D&E organizations.

Public extension systems should enable bi-directional learning between research units and farmers to encourage adaptation in ways that fit farmers resources, and break down the divisions between R&D and extension systems to ensure that the advisory services received by farmers are founded on established research evidence.

International partners, including the CGIAR (formerly the Consultative Group for International Agricultural Research) and international universities, must develop a greater appreciation of how their own effectiveness (e.g., impact generated per dollar of donor funds allocated) is dependent on the performance of local partners working on the ground, and prioritize efforts to collaborate with and build the capacities of these partners.

Finally, donors must ensure that grants related to African agricultural technical innovation (i) include organizations in the NARES at the design stage, (ii) support nationally led priority-setting agendas, and (iii) ensure that the priorities of national governments are reflected in proposal and budget development. Mandating that grants have co-directors from NARES organizations would encourage greater ownership and commitment of African organizations to achieving the objectives of the grant.

BUILDING 21ST CENTURY AGRICULTURAL RESEARCH AND EXTENSION SYSTEMS IN AFRICA

"We cannot in the third world simply borrow or buy science from those ahead of us. Pure science we can take as it comes, but much of applied science we have to make for ourselves."

— Arthur Lewis, Nobel Banquet address, 1979

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INTRODUCTION

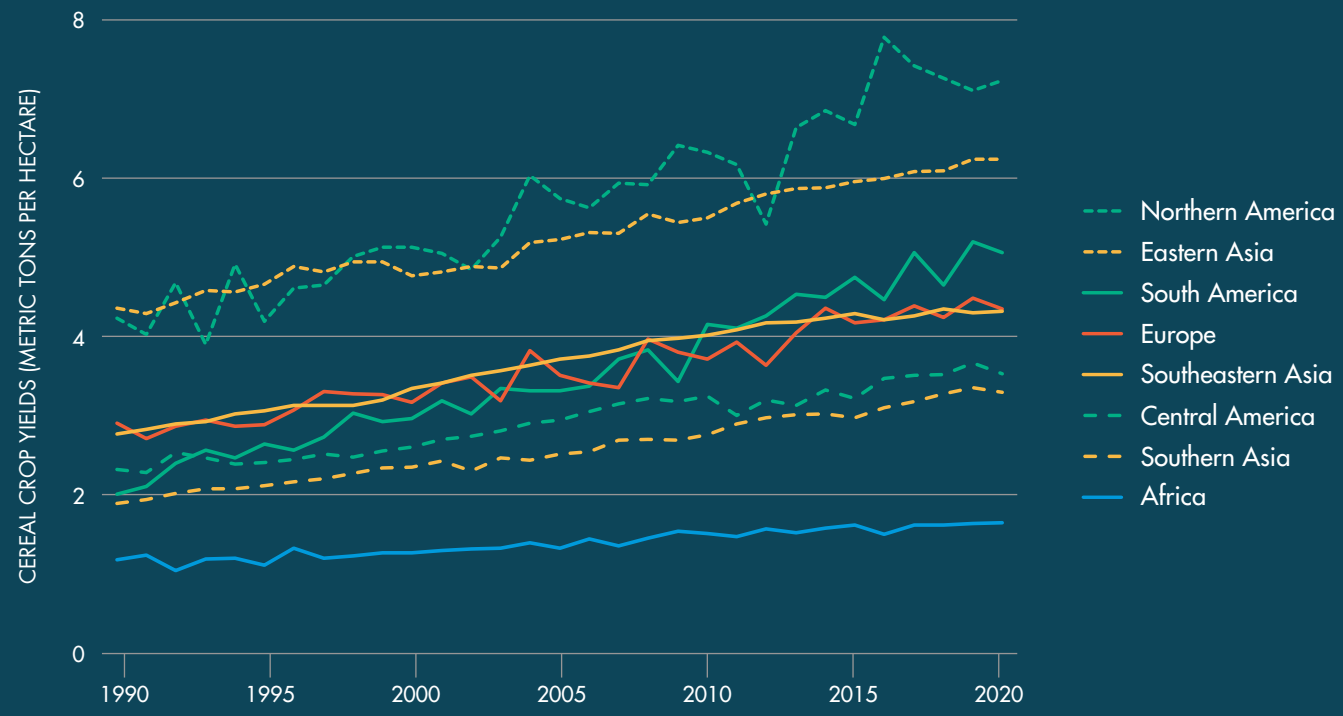
Seventy-four percent of Africa's crop production growth since 2000 came from the expansion of area under cultivation and only 26% from improvements in crop yields (Jayne and Sanchez, 2021). Continued reliance on area expansion to feed Africa's population is not sustainable. While roughly 60% of the world's remaining potentially arable land is in Sub-Saharan Africa (SSA), most of this land is concentrated in just eight countries; the potential for area expansion in most of the region's remaining 41 countries is very limited (Chamberlin et al., 2014; Lambin et al., 2013). Therefore, a relatively large proportion of rural Africans are unable to expand their area under cultivation and must rely on yield improvement to improve their livelihoods.

Continued reliance on area expansion as the main source of agricultural growth is also unsustainable on environmental grounds. Agricultural land expansion has accounted for most of Africa's loss of forests, grasslands, and biodiversity. The goals of feeding Africa's growing population and conserving the planet's natural resources, diverse ecosystems, and the services they provide will be more effectively achieved through productivity improvements on existing farmland instead of area expansion (van Ittersum et al., 2016; Alliance for a Green Revolution, 2022).

For these reasons, sustainable agricultural intensification in Africa increasingly depends on raising yields. Cereal crop yields in Africa overall are the lowest of all regions of the world and the yield gap continues to widen against other developing areas, including Central America and Southern Asia (Figure 1). The slow rate of crop yield growth in SSA over the past four decades attests to the urgent need to understand how to improve the systems responsible for raising crop yields in the region.

Well-functioning agricultural research, development and extension (R&D&E) systems are obviously not sufficient for achieving these varied objectives, but they are indeed necessary because they are the organizations that generate new technologies and management practices required for technical innovation (Fuglie et al., 2020; von Braun et al., 2021). Farm technical innovation is enabled by favorable sectoral and macroeconomic policies, investments in transport and communications infrastructure, and private investments in agrifood systems; all these encourage farmers to invest in their farms (Barrett et al., 2022). But sustainably raising the level of farm output per hectare (yield growth) requires the continuous generation of improved farm technologies and their adaptation to local biophysical and socioeconomic conditions — this cannot occur without functioning agricultural R&D&E systems.

Figure 1. Cereal crop yields in Africa are the lowest in the world



Source: FAOSTAT (last accessed May 2022).

The international agricultural research system (IARS) — including the CGIAR, international universities, United Nations organizations, and others — has by most accounts successfully generated new agricultural technologies, practices and other international public goods that have improved livelihoods around the world (von Braun et al., 2021; Alston et al., 2022). However, the impacts of the IARS have been limited in areas lacking well-functioning national R&D&E systems. It is widely recognized that international research organizations are not well suited to scale-out technical innovations across highly varied agroecological conditions in Africa, nor do they have the resources to do so. Hence strong national and regional partners on the ground are necessary. The fact that much improved genetic materials developed by international research fail to be commercially distributed and adopted by African farmers attests to the need to strengthen African National Agricultural Research and Extension Systems (NARES) to achieve greater impact from funds allocated to international research. Likewise, the widespread adoption of management practices validated by international research to improve soil health and address plant disease and pest control has been in many instances constrained by the absence of well-functioning local adaptive R&D&E units interacting with smallholder farmers (Cassman and Grassini, 2020).

For precisely these reasons, the IARS has attempted to build the capacity of national research systems in developing countries and directly collaborate with them to transfer and adapt internationally generated technologies to farmers. Many organizations within the IARS state that capacity development of African-led agricultural research organizations is among their primary mandates (e.g., CGIAR-IEA (2017) and they have received substantial international funding for at least four decades to achieve this goal. More and more international donor organizations are explicitly prioritizing "locally led development." However, even after decades of capacity development efforts, most African NARES remain weak and dependent on the IARS (Stads, 2021).

This study examines the effectiveness of international efforts to build the capacities of agricultural R&D&E systems in Africa and identifies actions for strengthening the capacities and performance of both African NARES and international research and donor partners. Research on this topic has been impeded by the lack of data on the behaviors of, and interactions between, organizations operating in the agricultural R&D&E space in developing countries. Most available quantitative data lack the depth or nuance to shed light on complex institutional behavior. Hence, in addition to using secondary data on national R&D expenditures, this study derives its findings from key informant (KI) interviews of 26 senior representatives of African and international agricultural R&D&E institutions and three international donor organizations.

Respondents from both groups highlighted aspects of donor funding and IARS behavior that have delayed the transition to more effective NARES led and owned by African states and society. Based on the weight of KI perspectives, the study concludes by proposing that African governments and African development organizations proceed to build what we call a 21st-century NARES in which research is defined, prioritized and implemented by NARES with the IARS being in service to the NARES. The IARS still has a crucial role to play, but that role would be shaped by and in service to the NARES, African governments, and African development organizations themselves. Achieving this vision will require that international donors and the IARS show greater commitment to building a truly African-led system, with associated changes in the allocation of agricultural research funding for Africa. The study concludes with proposals for consideration by African governments, African R&D&E organizations, international research organizations, donors, and the private sector.

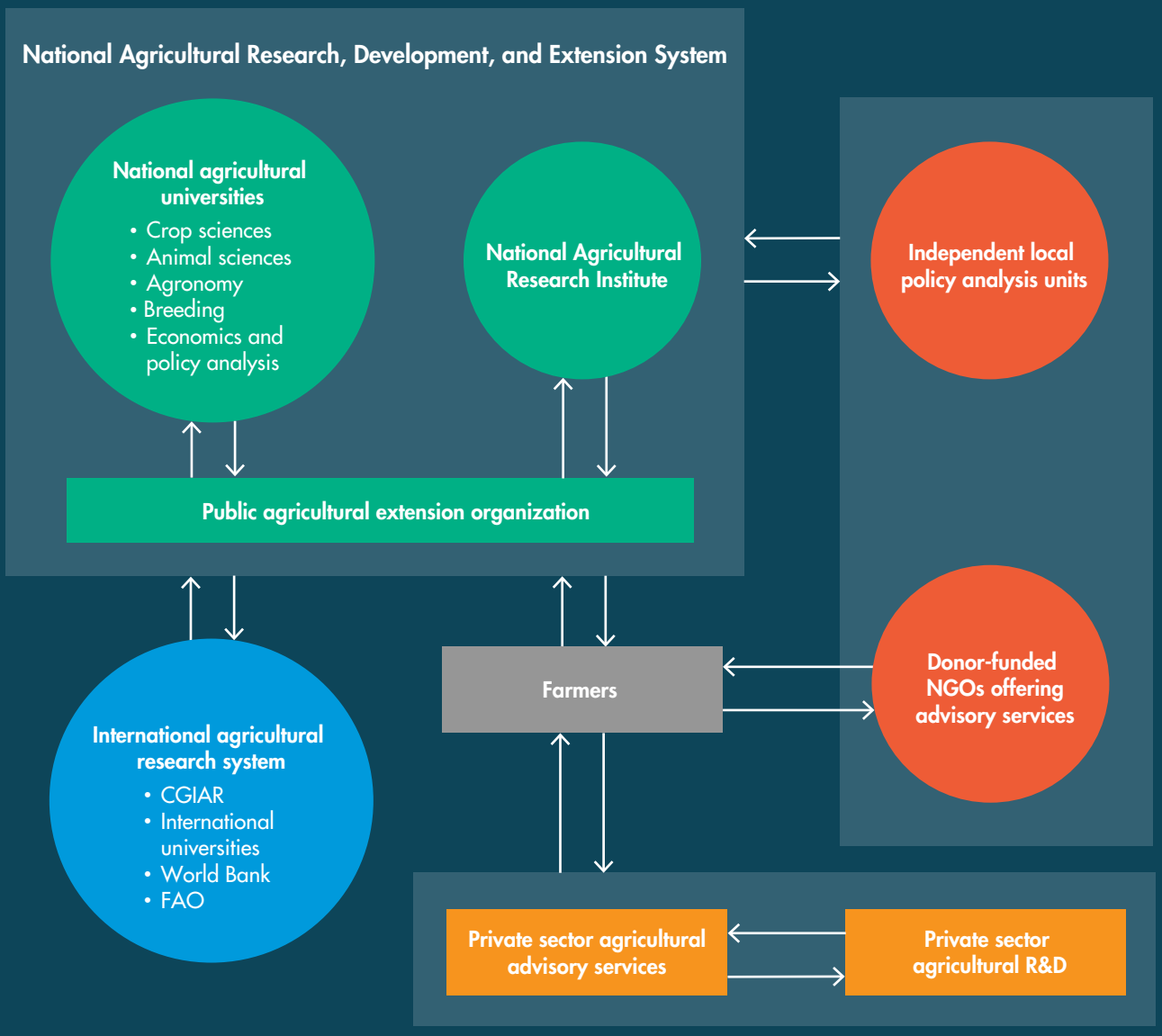
WHAT ARE NATIONAL AGRICULTURAL RESEARCH AND EXTENSION SYSTEMS?

National agricultural research and extension systems (NARES) are defined in this study as encompassing all public institutions devoting their activities to agricultural research and advisory services to farmers and committed to a nationally defined research agenda. NARES include at least three types of organizations: (i) national agricultural research institutes; (ii) national agricultural universities and their affiliated institutes that generate agricultural research on crop science, seed breeding, veterinary sciences, agronomy, economics, policy analysis, and advisory services to farmers, inter alia; and build the capacities of the national workforce involved in farming and agrifood systems; and (iii) technical departments of public sector ministries involved in agricultural research, advisory services to farmers, and testing and adapting new technologies and practices in consultation with farmers.

This study distinguishes between NARES and NARS: national agricultural research systems (NARS) include the organizations within the NARES responsible for research and development and exclude extension organizations, whereas NARES refers to the full set of public agricultural research, development, and extension organizations.

The international agricultural research centers of the CGIAR are not part of NARES; they have a global mandate and their activities are not defined by national governments. However, their activities are in principle coordinated with the NARES. The historical division of labor between the CGIAR and NARES has been that the CGIAR is responsible for managing the international gene bank, generating improved technologies, and transferring them over to NARES, who are in turn responsible for adapting the technologies to local conditions and ensuring farm adoption (Byerlee and Lynam, 2020). Figure 2 shows the various types of public and private sector organizations operating in agricultural R&D&E systems in most African countries.

Figure 2. System of national and international agricultural research, development and extension systems operating in African countries



The national entities in green are public sector organizations. In some countries there is more than one national agricultural research institute and more than one public extension system.

WHY ARE WELL-PERFORMING NARES SO IMPORTANT?

While agricultural research, development, and extension (R&D&E) is widely accepted as contributing to agricultural productivity growth, the degree to which agricultural R&D&E systems influence the achievement of most major development goals of African governments and development partners is often underappreciated.

For example, the pace of growth in off-farm employment depends on the pace of agricultural productivity growth and the multiplier effects generated from it (Mellor, 1976; Jayne et al., 2018), meaning that agricultural productivity growth could contribute to increasing off-farm employment for the 300 million young Africans who will enter the labor force over the next decade (ILO 2022; Stads et al., 2021). Raising farm productivity growth is also crucial for improving the livelihoods of women and youth in rural Africa, most of whom are engaged in farming or activities tied to farming. National priorities related to agrifood system transformation likewise require farm productivity growth; new investment and employment in most stages of agricultural value chains tend to atrophy unless domestic farm production grows (Yeboah and Jayne, 2018). Slow farm productivity growth over the past five decades in sub-Saharan Africa (SSA) is partly responsible for the region's massive increase in food imports, which rose from USD7 billion in 2000 to over USD45 billion in 2020 (Fox and Jayne, 2020); reducing import dependence will require major increases in farm productivity. Moreover, widespread technical innovation on tens of millions of African farms is required to avoid major environmental destruction, including the loss of the region's forests, grasslands, biodiversity, and associated ecosystems services, which itself may threaten the region's ability to achieve sustainable, resilient, or more productive food systems (Garnett al., 2013; van Ittersum et al., 2016).

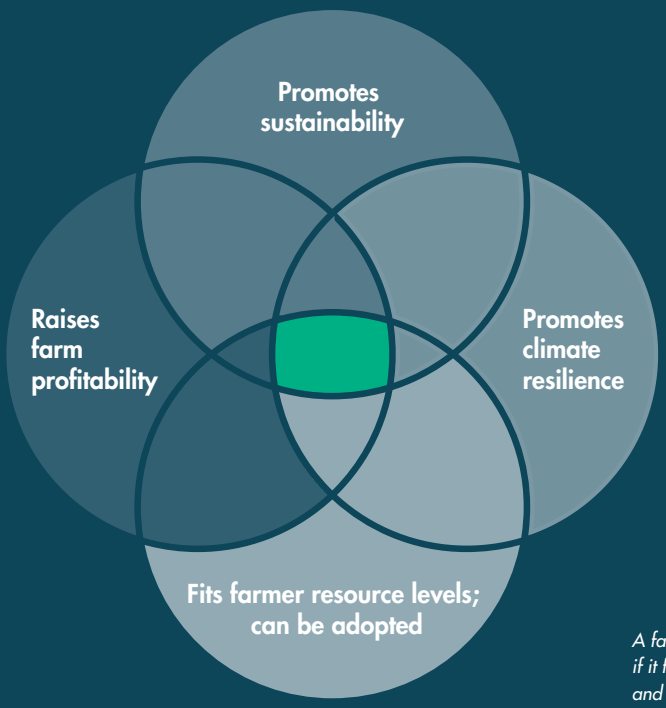
Furthermore, SSA is arguably the region of the world most vulnerable to the effects of climate change; farm technical innovation is necessary for adapting to and mitigating the effects of more extreme weather in SSA. Sustainable land management practices that promote the resilience of food systems also require continuous adaptation of farming practices to changing environmental, climate, demographic, and economic conditions. Technical innovation hence becomes crucial to maintain sustainable and resilient food systems.

For all these reasons, farm technical innovation and the institutions and organizations responsible for promoting it remain fundamental to achieving many of SSA's most crucial development goals. Well-functioning R&D&E systems are obviously insufficient for achieving these varied objectives, but they are necessary because they are the organizations that generate new technologies and management practices required for technical innovation that anticipates and adapts to changing climatic,

environmental, economic, social, and demographic conditions (Fuglie et al., 2020; von Braun et al., 2021). Empirical investigations of the impacts of investments in agricultural R&D&E indicate that they are among the most effective public investments driving agricultural productivity globally (Alston et al., 2022), even in Sub-Saharan Africa (e.g., Thirtle et al., 2003; Fuglie and Rada, 2012; Pardey et al., 2014; Fuglie et al., 2020, Bambio et al., 2022), where crop yields have in most countries grown slowly over the past four decades.

The demands on the organizations creating technical innovation for African farmers are daunting because they need innovation that satisfies multiple conditions (Figure 3). A precondition for viability is that technical innovation must be adoptable and adaptable by resource-constrained smallholder farmers and fit with cultural and dietary preferences. In addition, viable farm technical innovation must contribute to profitability, reduce yield variability in the face of extreme weather, contribute to soil health and environmental sustainability, and/or minimize the impacts of farming on the environment and biodiversity. Satisfying all these conditions is crucial for human welfare and planetary sustainability and hence there is much at stake for ensuring that the organizations and system responsible for co-creating technical innovation with Africa farmers succeeds.

Figure 3. Multiple criteria associated with viable farm technical innovation



A farm technical innovation may be adopted if it fits farmers' resource levels and preferences, and satisfies one or more of the other criteria.

TRENDS IN AGRICULTURAL R&D FUNDING IN AFRICA

African governments have historically spent relatively little on agricultural R&D compared to other regions of the world. Table 1 reports R&D expenditures in relation to agricultural gross domestic product (GDP), hectares of cropland, and the number of agricultural laborers in the country. By most of these measures, funding for NARES has been lower in SSA than in other regions for decades. According to other sources, at least 20 African governments spend so little on their national agricultural research and extension systems (NARES) that they are effectively defunct (African Union, 2021). National systems in such countries as Kenya, Ethiopia, Nigeria, Ghana, and Rwanda have made important strides, but their capacities are still in great need of improvement.

Table 1. Sub-Saharan Africa falls behind many world regions in public agricultural R&D spending

	% increase in public agricultural R&D expenditures (1980 to 2016)	Public agricultural R&D intensity in 2016		
		R&D/GDP (%)	R&D/hectare cropland ($)	R&D/farmer ($)
Australia – NZ – S Africa	-21.7	1.94	22.59	742.03
Canada – USA	32.4	2.27	27.78	2,034.01
Central Europe	35.6	0.97	23.18	157.78
Central America	44.9	0.75	25.22	62.86
Western Europe	61.0	3.03	84.89	1,398.30
Sub-Saharan Africa	64.6	0.30	8.31	10.55
South America	88.7	1.40	33.04	174.61
Japan-Korea-Taiwan	130.2	0.93	30.45	55.23
North Africa	164.2	0.40	32.09	79.85
West & Central Asia	174.0	0.70	23.40	69.27
Southeast Asia	229.8	0.35	22.54	27.68
South Asia	441.4	0.28	22.30	18.63
China	1,018.2	0.64	75.20	51.67

Source: Fuglie (2018), updated with 2016 data with acknowledgment to K. Fuglie.

Figures for Sub-Saharan Africa exclude South Africa. The table uses R&D spending in millions constant 2011 PPP$ for international comparison purposes.

Table 2 shows the relative contributions of African governments and international donor organizations to agricultural R&D funding per agricultural laborer over the 2010-2019 period. Some African governments, like Nigeria, Senegal and Kenya, do fund national R&D institutions per agricultural person at levels comparable to many countries in Asia and Latin America. Table 2 also shows that, with a few notable exceptions, African governments spend more on agricultural R&D expenditures than donors do, with only two countries spending less than twice as much as donors (Burkina Faso and Malawi).

Table 2. A few countries in Sub-Saharan Africa stand out in public agricultural R&D spending, and all spend more than donors

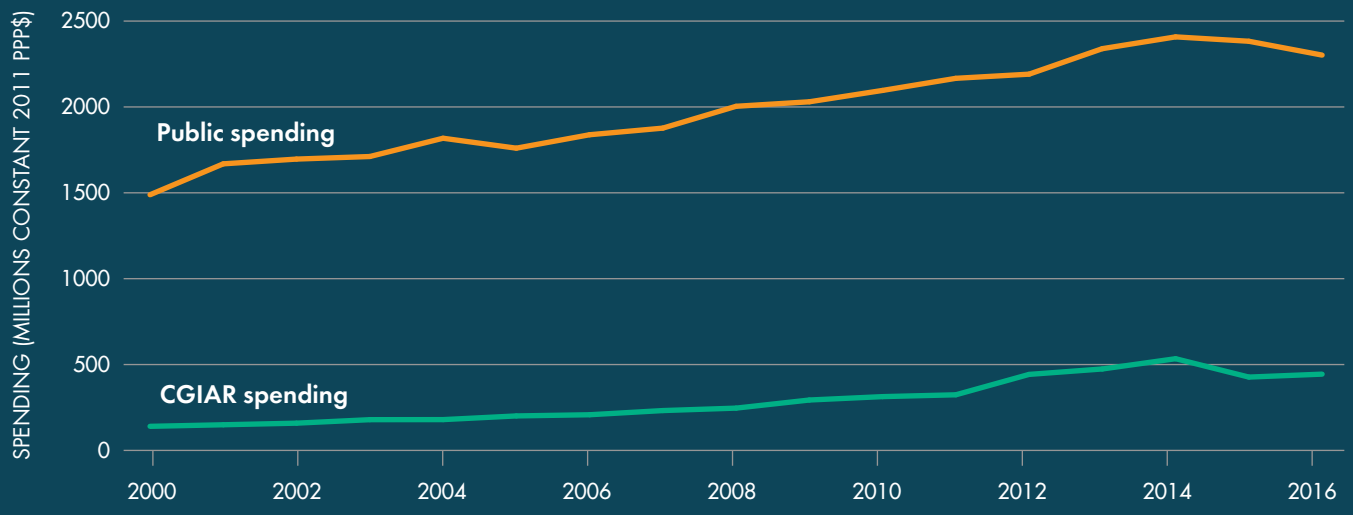
	Average yearly public ag R&D expenditures, in millions constant 2011 PPP$ per agricultural persons			Average yearly donor spending on ag R&D&E, in millions constant 2019 USD$ per agricultural persons		
	1990–1999	2000–2009	2010–2013	1991–1999	2000–2009	2010–2019
Burkina Faso	7.9	7.8	14.2	0.79	1.97	5.45
Côte d'Ivoire	28.3	24.5	23.9	1.55	0.39	2.49
Ethiopia	4.3	3.6	3.6	0.75	0.54	1.11
Ghana	20.4	23.5	32.9	3.56	2.43	2.99
Kenya	60.9	31.4	24.5	6.25	2.69	2.53
Malawi	9.4	6.0	7.4	0.82	1.03	4.85
Mali	16.7	14.7	12.1	4.18	3.86	2.69
Nigeria	8.5	20.4	23.2	0.80	0.20	0.76
Rwanda	3.5	5.0	8.1	0.18	0.46	1.60
Senegal	39.3	24.5	28.7	3.06	8.22	5.16
Tanzania	5.3	5.5	6.9	1.02	1.08	1.13
Brazil	5.5	6.6	9.6	0.48	0.32	0.86
China	165.4	152.4	243.4	0.06	1.15	0.72
India	5.5	12.9	32.8	0.17	8.61	2.80
Pakistan	5.9	9.4	14.8	0.17	0.16	0.15
Vietnam	13.7	14.0	12.2	0.10	0.08	0.65
Bangladesh	1.0	4.2	5.5	0.02	0.45	0.35

Sources: FAOSTAT, Agricultural Science and Technology Indicators (ASTI; last accessed May 2022).

Donor funding includes multilateral, bilateral and private donors including FAO, IFAD, BMGF, etc. Recipients of donor funds are "bilateral recipients" involved in agricultural research; data does not specify which organizations receive the funds or whether they are national or international recipients. For additional details, see https://www.asti.cgiar.org/methodology. Funding sources include core government allocations from the central government budget, like through a ministry or the treasury for salaries or operating expenses; other government allocations, like through competitive funding sources; loans from multilateral or bilateral donors; grants from multilateral or bilateral donors; allocations derived from commodity levies or producer organizations; revenues derived from the sale of goods and services; and any other recorded sources. ASTI's national agricultural research expenditure data is categorized as salary-related expenses, operating and program costs, and capital investments by government, nonprofit, and higher education agencies. R&D spending by private entities is excluded due to lack of available data.

The CGIAR is the world's largest publicly funded agricultural research network committed to agricultural innovation for farmers and food systems in the developing world; it currently includes over 9,000 scientists in 15 organizations. The CGIAR plays a crucial role in the global agricultural development landscape, providing evidence to policymakers, innovations to partners, and new tools to harness the power of agriculture to raise living standards in developing areas. Figure 4 compares total expenditures by African governments on the NARS (data is not reported for public extension systems) in SSA and total international donor spending by the CGIAR in support of agricultural development in SSA. Over the past three years for which data is available (2014-2016), the NARS in SSA received an average of USD2.36 billion each year from African governments for agricultural R&D, which was almost five times more than the yearly average from the CGIAR for agricultural programs (including R&D) over the same period (USD468 million). Of the CGIAR's total agricultural expenditures in SSA, agricultural R&D accounts for roughly one-third (Fuglie, 2022), meaning that the CGIAR's agricultural R&D expenditures in SSA are estimated at $150 million per year, less than one-tenth that of funds allocated from African governments to the NARS. In short, the NARES receive the majority of funds expended on agricultural R&D&E in most SSA countries, with the CGIAR playing a vital role but spending only a small proportion of the total funding for agricultural R&D in SSA.

Figure 4. African governments spend more on their NARS than the CGIAR spends on agricultural development for Sub-Saharan Africa



Sources: Agricultural Science and Technology Indicators (ASTI, last accessed May 2022), K. Fuglie (personal communication).

Data on public spending by African governments to African NARS is from ASTI. Data on funding from CGIAR was provided by K. Fuglie, who assembled it from annual financial reports of CGIAR organizations; it reports total expenditures in support of agricultural development in SSA and is not specific to agricultural R&D. Fuglie (personal communication) indicates that CGIAR expenditures on agricultural R&D specifically constitute roughly one-third of the total CGIAR spending on agricultural development generally shown in this figure.

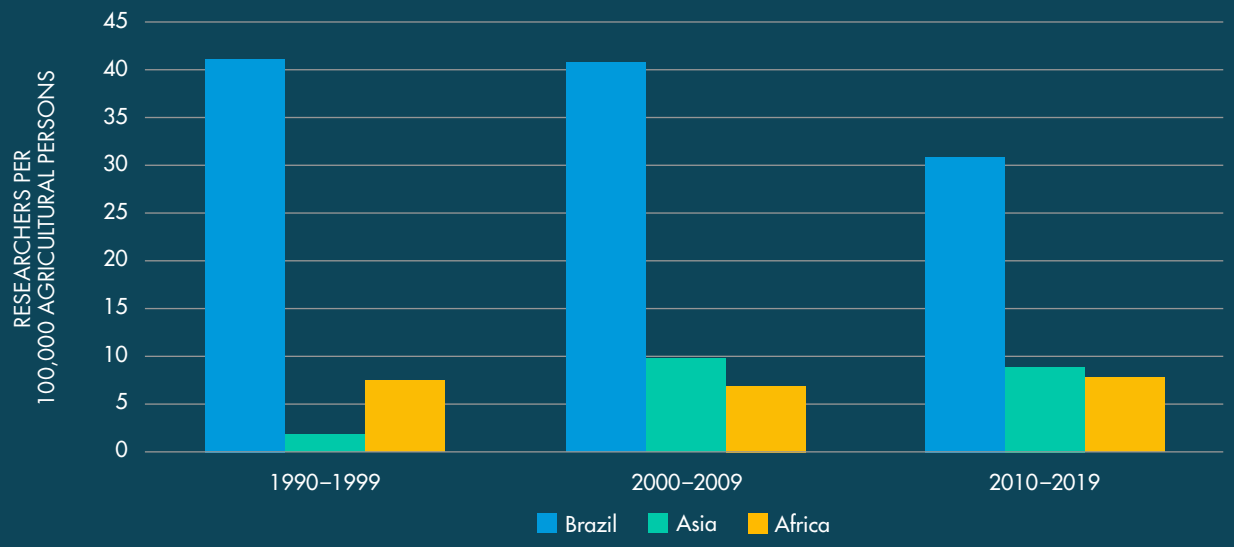
During 2009—2016, 57 percent of the funding to the NARS in SSA (excluding Nigeria, South Africa, and several smaller countries) was provided by national governments, and funding from donors and development banks constituted 28 percent (Stads et al., 2021). Dependency on donor funding is particularly high among francophone West African countries. Many national governments fund little more than the salaries of researchers and staff, leaving budgets for research operations and capital equipment highly dependent on donors and other funding sources. Stads et al. (2021) also found that the amounts disbursed to NARES are routinely lower than — and in some cases only a fraction of — budgeted allocations. These funding discrepancies obviously affect the operations and performance of the NARES; they also make it difficult to analyze relationships between the levels of budget allocations and performance.

We constructed additional indicators of intensity of R&D effort using the number of researchers in the NARS per agricultural person, which is shown in Figure 5 (a metric using the number of researchers in the NARS per hectares under cultivation produces similar results). Figure 5 reports trends in the numbers of researchers in the NARS per 100,000 persons in agriculture over the past three decades. Both Asia and Africa lag far behind Brazil on this indicator, but over the 2010-2019 period the selected Asian and African countries had on average similar numbers of agricultural researchers per agricultural person. This contrasts with the comparison in Table 1, which shows that Sub-Saharan Africa falls behind many world regions in public agricultural R&D spending.

In all three regions, the number of agricultural researchers has increased, almost tripling in Africa (not shown in figure), but the agricultural population in Africa also grew by a similar magnitude over the same period, such that the ratio of agricultural researchers per person in agriculture shown in Figure 5 barely grew from 2000-2009 to 2010-2019.

Figure 6 reports the composition of degree training of agricultural scientists in various countries and shows important disparities between Brazil, Asia, and the 11 African countries for which data is available. The African countries lag somewhat behind Asian comparison countries in terms of the numbers of Bsc-level staff in their NARES, but lag dramatically behind in MSc- and PhD-level staff, highlighting the imperative of capacity building to raise their performance.

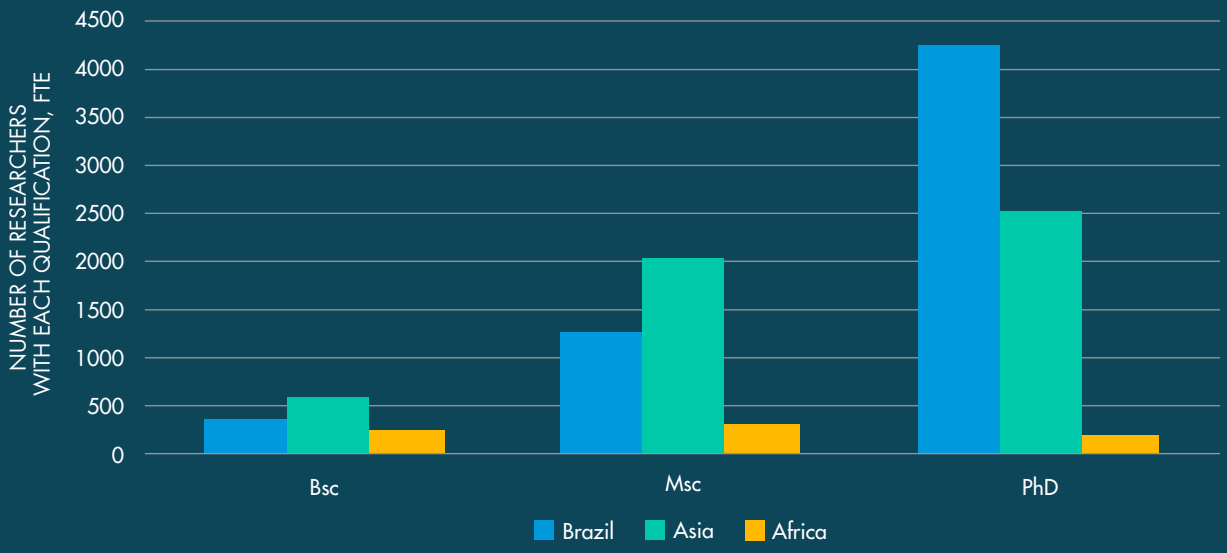
Figure 5. Africa falls behind Brazil and Asian countries in number of NARS researchers per 100,000 farmers



Source: Agricultural Science and Technology Indicators (ASTI), FAOSTAT (last accessed May 2022).

Countries included for Asia are Bangladesh, China, India, Pakistan, and Vietnam; countries included in Africa are Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Rwanda, Senegal, and Tanzania.

Figure 6. Africa falls behind Brazil and Asian countries in number of NARS researchers with advanced degrees



Source: Agricultural Science and Technology Indicators (ASTI, last accessed May 2022).

Countries included for Asia are Bangladesh, India, Pakistan, and Vietnam; countries included in Africa are Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Rwanda, Senegal, and Tanzania.

THEMES FROM KEY INFORMANT INTERVIEWS

To better understand national and international R&D&E organizations' priorities, approaches to collaboration, and opportunities for more strategic interactions, this study included key informant (KI) interviews of senior representatives of national, regional, and international agricultural research institutions, and development and donor organizations. KI selection was necessarily purposive as it was considered infeasible to compile lists of relevant representatives from all national and international organizations involved in agricultural R&D&E in Africa. Details about the KI interview approach, questions posed to KIs, and process of identifying key themes from the interview process are presented in Appendix 1.

This study identifies seven recurrent themes emerging from the KI interviews: (i) building strong NARES will initially require a regional approach for many countries; (ii) sustained commitment and funding from African governments is a precondition for building strong NARES and regional and continental agricultural R&D&E systems; (iii) organizations within the IARS often profess to be strengthening the capacities of the NARES, but their overall contribution has been limited; (iv) the effectiveness of donor funding to the IARS depends on strengthening the NARES; (v) donors should confront the issue of creating organizations that duplicate activities of the NARES; (vi) it is important to integrate nutritional objectives into NARES priorities; (vii) there is a need to recognize and strengthen the performance of tertiary education systems (moderate consensus). All of the seven themes have moderate consensus among the KIs, except for a strong consensus for theme (ii) sustained commitment and funding from African governments is a precondition for building strong NARES and regional and continental agricultural R&D&E systems. These seven themes are elaborated below.

(i) Building strong NARES will initially require a regional approach for many countries

Today, only a few African countries have productive NARES. At least 20 countries have historically allocated so few public resources to their NARES that they essentially lack a viable national agricultural R&D program, or a university system capable of producing a steady supply of qualified national professionals to effectively operate a NARES (Stads et al., 2021). For these and other reasons, about one-third of the KIs felt that delivering sustainable and productive technologies to farmers and analytical guidance to policy makers will require starting with a regional approach to agricultural R&D. A regional approach could be organized by agro-ecological zones, and could serve the immediate needs of African farmers while simultaneously building the capacities of NARES in countries where they are particularly weak.

An illustrative KI comment was that "tropical areas of Ghana, Togo, Benin, Côte d'Ivoire, and Nigeria could be served by one regional system. The Sahel region could be served by another." But those favoring a regional approach still stressed the need for large countries, like Nigeria and Ethiopia, to have their own strong NAREs, which could potentially serve as foundations for the regional R&D systems.

The scale benefits accruing from organizing R&D activities for specific agro-ecologies tailored to large farmer populations is reinforced by analysis in Goyal and Nash (2017), which found that the rate of return to expenditures on NARES tend to be higher in large countries because innovations can be scaled out for broader impact compared to countries with relatively small farmer populations.

Stads et al. (2021) propose organizing agricultural R&D investment by agro-ecological zones rather than political boundaries, at least for relatively small African countries. Integration of agricultural R&D at the subregional and regional level, through joint research programs and regional centers of excellence, may be the most effective way to allow countries with lagging agricultural research systems to benefit from the gains made in countries with similar agro-ecological conditions that have more advanced systems. Better coordination and a clear articulation of mandates and responsibilities among national, subregional, regional, and global R&D players are essential to ensuring that scarce financial, human, and infrastructure resources are optimized, duplications minimized, and synergies and complementarities enhanced.

A minority of KIs felt that regional research efforts to date have not proven very effective and hence continue to support nationally led processes. These KIs tended to have a more favorable view of NARES performance in at least some African countries.

(ii) Sustained commitment and funding from African governments is a precondition for building strong NARES and regional and continental agricultural R&D&E systems

Through their Maputo and Malabo Declaration commitments, African leaders have pledged that agriculture is a critical engine for economic development, job creation, and poverty reduction (African Union Development Agency, 2014). Yet by most metrics, SSA governments continue to spend relatively little on agricultural R&D (Table 1). A large majority of KIs felt that African leaders must become convinced that greater commitment to their NARES organizations will help them achieve many crucial national policy objectives. Of the seven themes identified in this study, this theme had the strongest consensus among the KIs.

Eighteen (18) KIs indicated that *African NARES are the weak link in the technical innovation system in most African countries*. Eleven (11) KIs stated that inadequate government commitment was a major factor explaining the generally weak performance of NARES. Respondents made such points as *"African leaders need to 'wake up' and realize how Africa's future depends on sustainable agricultural productivity growth."* This view is consistent with Goyal and Nash (2017), who found that agricultural R&D generally accounts for only between 4% to 10% of African governments' budget allocations to agriculture. Stads et al. (2021) also note that while African governments' budgets to agriculture increased somewhat in the 2000-2017 period (but did not reach levels committed to under the CAADP Maputo Declaration commitments), the share of expenditures to NARS generally declined. Several KIs stressed a point similar to one reported in Stads et al. (2021) that governments often do not fully disburse the amount of funds budgeted to agricultural R&D&E, meaning that actual allocations may be even less than the low proportions reported in Goyal and Nash (2017). Of course, there is no "optimal" level of expenditure or share of agricultural budgets that should go to agricultural R&D to guide policy makers. But most KIs expressed the view that increased funding for NARES by their national governments is necessary but not sufficient to increase the effectiveness of the NARES.

KIs highlighted several points consistent with Stads et al. (2021), who analyzed differences between "high performing" vs. "low performing" NARS in SSA. For example, most KIs felt that the size of the R&D system influences performance and impact. It is truly challenging for R&D organizations, extension systems, and agricultural universities to generate impact with a $10 million annual budget, a situation that applies to at least 15 African countries. Stads et al. (2021) found that average spending by the countries in the high performing group was $158 million (in 2011 PPP prices), compared with just $14 million in the group of low performers. To put these figures in perspective, the Gates Foundation spends over $450 million annually on agricultural development activities in Africa. Other points raised by KIs include the following (i) high volatility in R&D funding is associated with poor overall performance of the research system; and (ii) gross enrollment in tertiary education is correlated with the performance of national R&D&E systems.

Many KIs stressed that the performance of African national agricultural research institutes is determined by much more than just funding levels, although increased funding was usually expressed as necessary. Fourteen (14) KIs stressed that improved performance of NARES depends on one or more of the following coordination issues: (i) improving the internal management of the organizations within the NARES, (ii) improving coordination between the organizations in the NARES (namely the national research institutes, national agricultural universities, and the public extension system), and (iii) improving coordination between the organizations in the NARES and organizations in the international and private sector agricultural research system. This latter view is reinforced by the analysis of Goyal and Nash (2016), who estimate that the rates of return to expenditures on both NARS and the CGIAR are higher when both of their activities are accounted for.

Nine KIs stressed the need for better performing national extension systems to improve the performance of national agricultural research institutes. Most of these respondents mentioned under-staffing of the public extension system as the biggest problem, leading to low extension worker-to-farmer ratios. Notwithstanding the importance of this point, reported extension worker-to-farm ratios are not very different, on average, than for selected Asian countries or even Brazil. But as shown in Table 3, there is great variation across African countries. Rwanda's relatively favorable ratio suggests that Rwandese farmers have better access to extension services, closely followed by Ethiopia, Zimbabwe, and Burkina Faso when compared to their counterparts in other African countries. Nigeria has the worst score, where there is only one extension agent per 7,500 farmers, suggesting that most Nigerian farmers lack access to public extension services.

Table 3. A few countries in Sub-Saharan Africa stand out in the ratio of government extension workers to farmers

Illustrative countries	Number of Government Extension Workers	Ratio of Government Extension Workers to Farmers
AFRICA (2020)		
Rwanda	466	1:136
Ethiopia	71,400	1:237
Burkina Faso	3,993	1:424
Ghana	4,286	1:594
Mali	2,014	1:598
Tanzania	6,704	1:820
Kenya	5,000	1:1078
Malawi	1,604	1:2007
Nigeria	6,000	1:7500
ASIA (2012)		
China	617,706	1:416
Bangladesh	14,035	1:1854
Vietnam	13,185	1:1884
India	90,000	1:2290
Pakistan	9,749	1:2649
LATIN AMERICA (2012)		
Brazil	24,000	1:433

Source: 2020 data for African countries is from The Africa Seed Access Index (TASAI, 2020); 2012 data for Asian and Latin American countries is from Davis, Babu, and Ragasa (2020) with corrections by Dr. Keith Fuglie.

Four KIs stressed the need for better agronomy and extension to roll out improved technologies. Chronically limited operational resources, like lack of fuel for vehicles, prevent extension workers from visiting farmers. In many cases, public budgets cover little more than salaries. Interviews with staff in Malawi´s extension service indicate that an agent´s budget should include the following: motorcycle, fuel and maintenance, laptop computer, smart phone (totaling US$8600 for 5 years); annual costs for agent training, internet connectivity, and demonstration land costs (totaling US$3000 per year).

Six KIs indicated that private extension systems may more effectively deliver advisory services for some types of farmers, but that public R&D&E systems may still be required to meet the needs of less-favored farming communities with low commercial potential or willingness to pay for extension services.

Illustrative KI responses:

- *"Village-based advisory services have proven to be the optimal form of extension — must be done at village-level. Then set up a logistical plan to operationalize the village-based system. FIPS is the model."* One KI stated that FIPS-Africa (Farm Input Promotions Africa), an NGO, has been successful in Kenya, Tanzania, and Uganda assisting farmers to gain access to advisory services and local access to inputs.
- *"Extension is the real constraint and the success of the NARS and the CGIAR both depend on effective extension systems."*
- *"Extension must be accompanied by a coordinated push by the private sector, those for-profit firms that offer extension as part of their efforts to raise their own profits."*
- *"Extension system needs to recognize two types of farmers: those with effective demand for extension services — willingness to pay; and those without ability to pay for extension services but who nevertheless need access to good extension services. The public extension system is necessary for the latter group."*

Two KIs highlighted the "diluted mission" of some national extension systems, as extension agents are often tasked with distributing subsidized inputs thereby diverting their time from working with farmers. Seven KIs referred to the relative strength of the public extension systems in Ethiopia and Rwanda and felt these countries provided an example for potential replication in other African countries.

(iii) Organizations within the IARS often profess to be strengthening the capacities of the NARES, but their overall contribution has been limited

The fact that the CGIAR continues to dominate the agricultural research landscape in many African countries after decades of capacity building efforts can be interpreted as a failure of international partners to have strengthened the capacities of their national partners to assume the lead in agricultural R&D and policy guidance activities.

The continued weaknesses of African NARES contrasts sharply with rapid progress in much of Asia and Latin America. One KI indicated that most of the NARES in Asia have successfully built their capacity over the past several decades to now be comparable to the capacities of CGIAR International Agricultural Research Centers (IARCs) working in Asia, but the capacities of African NARES remain far behind that of the CGIAR.

There is a crucial distinction between individual and institutional capacity building. Most KIs stressed that the CGIAR and international universities have succeeded admirably in building the capacity of individuals, including through attachments, short- and long-term training, scholarships, and research collaboration. After receiving such support, many African researchers are hired into positions within the IARS, building the institutional capacities of the IARS and potentially widening the capacity gap between organizations in the IARS and the NARES. Several KIs specifically highlighted the "brain drain" from the NARES to the IARS, consistent with Seck's (2005) observation that expenditures to African NARES often indirectly strengthen the IARS at the expense of the NARES. Other KIs indicated that the CGIAR is moving too far into the territory that national research and extension systems should be covering, with the appropriate division of labor being that the IARS should do crop breeding and germplasm development, while NARES should lead selection, adaptation, and extension. One KI expressed the majority view as follows: *"CGIAR and NARES should have a more clear division of labor, but because NARES have been weak, the international system has naturally encroached."*

The majority of KIs in international and national organizations stated that organizations in the IARS often claim that capacity building is among their primary mandates and use that mandate to seek donor funding, but often do little after receiving grant funds to build institutional capacity within the NARES. Some KIs believe that the overall impact of the CGIAR has been to attenuate the development of the NARES. Most KIs in the African organizations pointed to variable treatment by international partners, with some being sincerely supportive while others take a more patronizing attitude, inviting African organizations to engage in proposal development at late stages of the grant development process, allocating to them a small fraction of total grant budgets, and hiring away their most talented staff. Illustrative KI comments were:

- *"Currently the CGIAR and private sector are overly dominant over NARS. CGIAR sets the goals and gets NARS to go along with CGIAR priorities — but it should be the reverse."*
- *"Some IARCs [CGIAR International Agricultural Research Centers] have patronized the NARS."* A KI from one of the NARES organizations stated, *"We are not seen as co-equals. We tend to face biases, and impromptu or late invitations to the table."*
- *"The CGIAR has still not developed a compelling vision for how to work with the NARES, though there are some notable exceptions, like [two specific CGIAR organizations], but in general, the CGIAR is not really helping build capacity of the NARES."*

Several KIs referred to a vicious cycle whereby weak NARES provide the rationale for organizations in the IARS to continue being the prime grantees of donor funding. Then, because they prepare the budgets and determine how funds are allocated, organizations in the IARS use those resources to strengthen their own capacities while doing relatively little to build the capacity of the NARES, thereby reinforcing the need for organizations in the IARS to continue to lead donor-funded projects in the future.

These views are consistent with the findings of several evaluations of CGIAR capacity development efforts. For example, Stern et al. (2006) state, *"When CGIAR centers experienced cuts in core funding, the primary cuts were often made in resources for training, primarily meant to strengthen the NARS"* and *"the Centers focus their training efforts globally and regionally depending on the mandate and focus of their research. Centers also emphasise the aim to train within their specific area of competence and often the near-term purpose is to improve capacity in that particular area of research and activity. However, the formal commitments of Center managements were not always so clearcut such that research relevance may not necessarily have led to institutional strengthening. Furthermore, where under-resourced NARS were dependent on Center support there might be a risk of distorting NARS research priorities and associated priorities for training in order to access resources"* (p. 2).

In opposition to this dominant view, about a quarter of the 26 KIs felt that the CGIAR has faithfully worked with NARES to strengthen their capacity and feel that CGIAR is adequately focused on capacity development. They suggested that counterproductive engagements between organizations in the NARES and IARS are at least partly due to inadequate African government commitments to strengthen their own NARES, which in many cases cannot fulfill their own mandates and hence the CGIAR naturally seeks to fill those gaps. These KIs state that the brain drain could be largely avoided if governments provided sufficient resources to provide salaries closer to international levels and to enable NARES researchers to conduct meaningful programs themselves. Six KIs could point to specific examples of success in improving the capacity of NARES. One KI from an African R&D organization stated, *"In my own experience, I think individual scientists from the NARES really enjoy working with*

the CG; it really gives them exposure to new tools, methods." But even here, KIs observed that individuals from the NARES were often pulled away from their own organizational priorities to engage in CGIAR-led research activities.

Slightly less than half the KIs based in the NARES viewed CGIAR impacts on the NARES as generally favorable. By contrast, 82% of the KIs based in international organizations viewed CGIAR impacts on the NARES as either inadequate or adverse. Overall, roughly two-thirds of respondents felt that the CGIAR was insufficiently focused on institutional capacity strengthening of the NARES.

(iv) The effectiveness of donor funding to the IARS depends on strengthening the NARES

Since the CGIAR was formed a half-century ago, one of its mandates has been to develop agricultural technologies and transfer them to the NARES and private firms, which adapt them to local conditions and — in the case of improved genetic materials — conduct testing, certification, multiplication, and commercial production.

However, a disconnect has arisen. In many countries, the NARES and companies have not succeeded in making many of CGIAR's improved seed varieties widely accessible to farmers. As a result, many African farmers have relied on the same seed genetics for over 20 years. By contrast, farmers in the United States and other developed areas typically transition to new seed types every 3-4 years (Byerlee and Lynam, 2020).

This has limited CGIAR's effectiveness in increasing farmer adoption of new varieties and raising crop yields. Among the open-ended questions posed to KIs was whether the CGIAR's activities are affected in any way by the strengths or weaknesses of the NARES. Nineteen of the 23 KIs responding to this question indicated that the CGIAR's effectiveness is indeed limited by the capacity constraints of its NARES partners. One KI stated, *"When the local partner is weak, then the CGIAR system is limited in what it can achieve on its own."* Another KI referred to von Liebig's barrel (Law of the Minimum), stating *"it is critical that you have a partner who can carry the heavy-duty adaptation work for the various micro-climates in the country."* A third KI remarked that *"the international systems are good at some things but they work best when they're partnering with strong national programs."* One KI affiliated with the CGIAR indicated that the new *One CGIAR* strategy recognizes *"partnerships with national programs as absolutely key to attaining One CG objectives."* But at the same time, the same KI indicated that *"the CG itself does not have the resources to significantly improve the capacity of national programs in either research or extension."*

International partners — donors, the CGIAR, and international universities — must develop a greater appreciation of how their own effectiveness depends on the performance of NARES. By extension, efforts to build the capacities of these partner institutions should be prioritized more seriously.

Two KIs stated specifically that the greatest potential for success would come through private sector R&D&E programs. These two respondents, both coming from donor/private sector backgrounds, highlighted how private R&D is so far ahead of both the CGIAR and African R&D systems that the most effective approach would be to first *"modernize the CGIAR system to get up to private sector standards,"* then task the CGIAR with building the capacities of the NARES over time so they can fulfill their role of adaptation of genetics and other technologies in each country.

Roughly half of the KIs acknowledged the private sector's effectiveness in generating new technologies and extending them to specific farm populations but still stressed the need for well-functioning NARES and/or regional R&D systems under the premise that private and public R&D systems are complementary and not substitutes. Several KIs stated that crops with strong commercialization potential and export crops would naturally attract strong private sector investment in R&D that expands the production base, reduces costs of raw product procurement, and promotes sustainable and resilient forms of production. There was moderate consensus that less productive and/or commercialized areas would continue to depend on public sector approaches for scaling.

(v) Donors should confront the issue of creating organizations that duplicate activities of the NARES

Some donor organizations are reluctant to directly partner with public sector entities and tend to create new organizations that at least partly duplicate activities carried out by organizations in the NARES. These donor-created organizations are accountable to the donors that fund them rather than African governments. The impacts of these donor-created organizations on the capacity development of organizations in the NARES may well be detrimental, as the hiring practices of donor-created organizations often draw upon the best talent within the NARES, thereby weakening, demoralizing, and marginalizing organizations in the NARES that African governments continue to rely upon to carry out agricultural R&D&E in their countries. Many KIs spoke of resentment, lack of cooperation, and adverse impacts on the development of organizations in the NARES that occur after donors create and fund new organizations to carry out tasks that overlap with their mandates. One KI referred to the NARES as de facto training centers for international organizations to draw upon for hiring African researchers after they gain skills and experience in the NARES, training which thereby comes at public expense.

These concerns raise issues about the meaning of donor commitments to support "locally led development" when the organizations being developed are created by and accountable to donors and their priorities rather than African governments, and where the net impact of the activity might be a relatively greater capacity gap between the donor-funded entities and the public sector organizations in the NARES.

(vi) It is important to integrate nutritional objectives into NARES priorities

Most KIs felt that nutritional criteria needed to be more effectively integrated into agricultural R&D&E programs. Supporting more diverse diets and consumption of nutrient-dense foods was viewed by most KIs as a priority that has received inadequate attention in the past (see de Schutter, 2015, for detailed arguments along these lines). An illustrative comment from one of the KIs was that *"Nutrition RDE requires a long-term holistic integrated and transdisciplinary approach. Transdisciplinary bottom-up approaches including researchers, extension agents and education specialists from agriculture, health, and nutrition are needed to tackle the nutrition issue"*.

However, two KIs warned that increased focus on nutrition should not take away funding or attention from raising agricultural productivity of the major cereals and oilseeds. One KI stressed the need to focus on high-value crops that increase farmer incomes and enable households to diversify diets rather than meeting dietary needs by diversifying their own farm production. Because cereals and oilseeds account for over 50% of the area under cultivation by African smallholders, yield improvements in these crops are estimated to have the greatest improvements to smallholder incomes and purchasing power (Tschirley et al., 2015; McIntire and Dobermann, 2023), which greatly influences households' ability to achieve adequate and diverse diets. Moreover, Stads et al. (2021) report that cereals receive only 24% of research expenditure by the African NARS, while oilseed, horticulture and other non-cereals receive 26%, and livestock products receive 15%, suggesting that the conventional perception that cereals dominate the attention of the NARS may be inaccurate.

(vii) There is a need to recognize and strengthen the performance of tertiary education systems

The quality of a country's national education system determines the level of human capacity in that country's workforce. National universities are the main source of people recruited to work in government ministries, national agricultural R&D organizations, and extension systems. Workers graduating from national universities also influence the quality of the rest of their countries' workforces through the training that they provide to others — in primary and secondary schools, agricultural training colleges, technical and vocational education training schools (TVETs), public sector jobs,

civil society, the private sector, and households. So, even though most people in developing countries do not personally attend their national universities, their skill sets are indirectly influenced by those who do. A recent World Bank study found that a one-year increase in average tertiary education levels would raise annual GDP growth in Africa by an estimated 0.39 percentage points and eventually generate up to a 12% increase in GDP (Darvas et al., 2017).

In recognition of the fact that agricultural scientists in most African countries are trained at universities in their own countries, several KIs noted the need for strong national agricultural universities to create a pipeline of qualified scientists to fill the positions in national agricultural research systems. While almost all KIs stressed the need for strengthened national agricultural universities, 12 KIs also noted that the NARES in at least several African countries (Nigeria, Ghana, and Ethiopia) are already accumulating qualified scientists and extension personnel and benefit from rapidly growing numbers of students graduating with university degrees related to agriculture who are filling the ranks of the NARES. Four KIs mentioned that policy analysis and advocacy for agriculture is an opportunity or necessity for strengthening NARs and extension systems.

The proportion of youth attending university in Sub-Saharan Africa (school enrollment, tertiary, % gross) has risen from 4.4% in 2000 to 9.6% in 2020 (World Bank, 2022). While the share of students in agricultural programs is believed to have declined over this period, the absolute number of Africans with bachelor's level university degrees in agricultural fields has risen dramatically over the past two decades.

Illustrative KI comments:

- *"It is remarkable that donors don't continue to defend capacity development in faculties of agriculture in Sub Saharan Africa."*
- *"African universities are beginning to offer good MSc degrees but less so PhD degrees. Improvement in postgraduate training in faculties of agriculture is needed. A sandwich program with a developed country university with experience in Africa is probably best at this stage."*
- *"One of the challenges we have in our universities [is that] we have to get the training programs to meet the needs of the private sector."*
- *"Some countries have what they call agricultural committees, in the parliament. Ministers of finance are often dealing with competing things. We rarely have champions for agricultural research that really puts out the evidence, or a DG [director general] that is well versed with their needs."*

PRIORITY ACTIONS: WHO MUST DO WHAT?

Based on the views expressed by KIs and the opinions of the report authors, this section considers who needs to act, and how, to improve the performance of agricultural R&D&E systems in Africa. The pivotal actors are continental African development agencies, African leaders and governments, the leadership of organizations in the NARES, the CGIAR organizations and other international research organizations, and the private sector.

African non-governmental organizations

The strategies of most African development organizations include promoting agricultural productivity, climate resilience, food security, capacity development, and knowledge management within the agricultural sector of African countries. Therefore, support for the development of African NARES and R&D&E systems should already be an important component of African development organizations' programs. We propose that the leading continental African development organizations — the African Union and the African Development Bank (AfDB) — play the catalytic role.

External reviews of earlier versions of this report have revealed some skepticism, mostly outside Africa but also to some extent within Africa, whether the continental African development organizations are up to the challenge to carry out the tasks specified below. We acknowledge these concerns but at the same time emphasize that, whether now or in the future, sustained commitment and leadership from these continental African institutions will be a decisive force in enabling a 21st-century model of agricultural R&D&E in Africa in which research is defined, prioritized, and implemented by NARES with the IARS being in service to the NARES.

Proposals for consideration:

- Seek greater accountability and commitment from African governments to build their NARES and provide the sustained funding required to do so.
- The AfDB, using its now considerably expanded capital base (African Development Bank, 2019), can create a new regional architecture for agricultural research, organized by agro-ecological zones, to serve the immediate needs of African farmers while simultaneously building the capacities of NARES in countries where they are particularly weak.

- The continental African development organizations can provide specific guidance for how international partners could support continental African-led initiatives, including guidance specifically for the CGIAR, international funding organizations, and international research universities working in Africa.
- The AfDB can leverage cooperative funding commitments from multilateral and bilateral donors to support its own investments in building the capacity of regional and national research systems.
- African continental development organizations can encourage international donors to stop funding donor-created organizations designed to duplicate the activities of the NARES and encourage them to engage directly with the organizations of the NARES.
- African continental development organizations can encourage African governments to adopt regulations requiring that grant funds provided by international donors to international primary grantees (including CGIAR organizations and international universities) to conduct research in African countries be reviewed for approval by a specified national authority. This national authority could also ensure that the activities of the CGIAR and international universities and U.N. organizations working in their countries are in support of nationally defined priorities and processes.

African governments

There is a wide consensus, both among the KIs interviewed for this study as well as in the existing literature, that the most crucial step to improving the performance of NARS is for national governments to increase their funding and commitment to supporting their own NARES, to monitor performance, and to demand greater accountability for results. Doing so would also help most African countries comply with their own commitments under the CAADP Maputo Declaration.

Proposals for consideration:

- Empower the national systems to define their own vision and priorities, consistent with broader national development strategies in a national R&D&E strategic plan.
- Increase overall public disbursements to agriculture and raise the share of public agricultural expenditures going to organizations in the NARS. Provide stable and sustainable levels of funding to secure a strategic program of effective research activities that yields increased agricultural productivity. Rather than relying too much on donor contributions and development bank loans to fund critical areas of research, governments need to determine their own

long-term national priorities and design relevant, focused, and coherent agricultural R&D programs accordingly.

- Ensure that budget lines to organizations in the NARS are fully disbursed each year.
- Consider increasing funding support for higher-value and nutrient-dense commodities, e.g., fruits, vegetables, and animal products to serve national policy objectives. Including these issues for consideration in NARS priority-setting activities would in some cases entail restructuring the organization of RD&E efforts to expand well beyond a small number of staple crops and industrial cash crops.
- Identify and support initiatives to strengthen the quality of education in agricultural universities, training colleges and Technical and Vocational Education and Training (TVET) organizations.
- Implement accountability frameworks to encourage greater impact from public funds allocated to the NARS.
- Explore opportunities to leverage the formidable R&D systems of the private sector. The private sector is currently the least developed source of sustainable financing for agricultural R&D in Africa. Cultivating private funding requires that national governments provide a favorable enabling policy environment through tax incentives, protection of intellectual property rights, and regulatory reforms to encourage the spill-in of international technology.

National agricultural research institutes and extension services in the NARES

The national research and extension services should be empowered to define their own vision and objectives, and then to develop the capacity to enact them. NARS and extension services should lead the work with assistance from CGIAR centers, universities, and other sources of knowledge. The NARES strategy must align with other nationally-defined priorities and strategies.

Proposals for consideration:

- All organizations in the NARES proactively develop practical 5- and 10-year national R&D&E strategies to guide operations and set accountability targets — linked to nationally-defined priorities and objectives — with input from a range of national stakeholders. Malawi´s Vision 2063 (National Planning Commission 2020) is a good example of a locally led national development strategy created using input from national R&D&E services, to guide their operations and those of external partners wishing to support Malawi's own strategy.

- Promote transdisciplinary-driven research, developing performance metrics for R&D systems to monitor performance. Metrics should be related to farmer adoption, repeat adoption, and measures of farm productivity, not just number of varieties released.
- Proactively initiate discussions with donors, CGIAR organizations, and international and local universities to secure funds that will contribute to the objectives set in the national R&D&E strategy, including capacity strengthening objectives. Implement guidance for engagement in external grants to require that members of the NARS participate as co-PIs.
- Develop plans for determining how the NARS will accomplish downstream activities, like adaptation of technologies to specific agroecological zones and farmer resource categories in the country, seed testing, certification, registration, multiplication, and commercial production. Explore partnerships with international, continental and regional organizations, like the CGIAR, international universities, FARA, CORAF, ASARECA, and CANARDA, for accomplishing these tasks, so that improved genetic materials developed by the CGIAR and/or private sector are more effectively translated into adoption and impact on the ground.
- Encourage incoming new CGIAR directors general to take periodic management training courses to improve their organization's effectiveness; NARES leadership could benefit from being offered similar opportunities.
- NARS directors can consider ways to increase the capacity of their scientists in food systems across the value chain. This often includes increasing linkages with the CGIAR centers and their donors.
- NARS and extension directors should create challenging and rewarding opportunities for scientists and extension specialists who are thinking creatively, and provide adequate pay to attract and retain good African scientists.
- Reinforce collaboration and exchange between scientists and networks in both the global north and south. According to several KIs, NARS scientists tend to be more productive when they join networks with international scientists.
- Consider creating regional centers of excellence in agricultural research to support clusters of NARS. Several KIs noted the advantages, at least in principle, associated with organizing R&D according to agro-ecological zones, e.g., Miombo woodlands, savannahs, Tropical Forests, Sahel, etc.
- Elevate soil health as a component of NARS programs given its importance in supporting resilience, adaptation to climate change, greater yield response from the use of inorganic fertilizers, and sustainable agricultural intensification.

- Consider African-led policy research units as part of a well-resourced NARS system and fund them accordingly. Several KIs suggested this given the importance of favorable policies and public goods investments in encouraging private agribusiness investments and R&D, and interacting with many ministries affecting agricultural performance and appropriate parliamentary committees.
- Organize agricultural R&D investment by agro-ecological zones rather than political boundaries, at least for relatively small African countries. Consider integration of agricultural R&D at the subregional and regional level (through joint research programs and regional centers of excellence) to allow countries with lagging agricultural research systems to benefit from the gains made in countries with similar agro-ecological conditions that have more advanced systems.
- Better coordinate and clearly articulate mandates and responsibilities among national, subregional, regional, and global R&D players; this is essential to ensure that scarce financial, human, and infrastructure resources are optimized, duplications minimized, and synergies and complementarities enhanced. This is not just a policy consideration for African governments but for continental and regional African development organizations as well.

Public extension systems

A key barrier to overcome is low extension-agent-to-farmer ratios. Table 3 shows considerable variation in the ratio of extension workers to farmers in Africa, with Ethiopia and Rwanda — countries enjoying quite rapid rates of farm productivity growth over the past two decades — having the most favorable extension worker-farm ratios.

While the digital revolution shows enormous potential to reduce information asymmetries and raise farm productivity, anecdotal reports indicate that some digital extension services provide farmers with advisory services that are not clearly appropriate for the specific locations of farmers or their resource levels (FAO and ITU, 2022), which can spoil farmers' trust in extension services overall.

Proposals for consideration:

- Consider successful extension models for broader replication, including the village-based extension services in Ethiopia (see Dorosh and Minten, 2020 for details) and the Farm Input Promotions (FIPS) program of advisory services and local access to inputs in Kenya, Tanzania, and Uganda.

- Consider two features that have been identified as particularly important for performance: (i) an extension system that enables bi-directional learning between research units and farmers to encourage adaptation in ways that fit farmers resources (Cook et al., 2021; Davis et al., 2020); and (ii) close integration of extension workers and researchers into an integrated R&D&E system (Antwi-Agyei and Stringer, 2021), i.e., breaking down the divisions between R&D and extension systems, to ensure that the advisory services received by farmers are founded on established research evidence (Davis et al., 2020).
- Increase integration between extension and local research institutes to strengthen advisory services' capacity to adapt digital innovations to local contexts.
- Create collaborations with content moderators on digital platforms to ensure greater oversight over the content targeted at smallholder farmers and to safeguard farmer privacy.
- Governments and development partners can also play a key role in minimizing the growing "digital divide," so as not to leave behind underprivileged members of society who may lack access to information and communication technologies.

African universities

The tertiary education system must be strengthened to create a pipeline of qualified scientists to staff the national agricultural research systems. Many African countries fall far behind Brazil and many Asian countries in the numbers of Bsc, Msc, and PhD graduates working in their NARES, and increasingly so for higher degree levels; however, countries like Nigeria, Ghana, and Ethiopia are making much progress in strengthening this pipeline.

Proposals for consideration:

- Prioritize improving post-graduate training in faculties of agriculture, including sandwich programs at qualified universities. The University of Pretoria's collaborative masters in agricultural economics and extension provides a useful model for consideration; this program allowed MSc students to take courses both at their home university and at the University of Pretoria for a year, where international faculty and UP faculty taught and mentored them, guided their thesis work, and supported their efforts to be placed in suitable organizations on the African continent after graduation. External reviews considered the program highly effective in raising the supply of well-trained MSc agricultural economists and could be considered for other disciplines.

- Update course curricula, recruit well-trained young professionals to enliven faculties of agriculture, and achieve greater engagement with the private sector to encourage mentorship and the training of skills demanded by the private sector after graduation.
- Seek to expand university budgets by proactively competing for international donor resources. Consider forming partnerships with CGIAR organizations, international universities, and/or relevant organizations in the global south to prepare proposals for funding new activities or expanding the funding for existing activities.

International funding partners

Several KIs felt strongly that donors, especially those that can afford to take a long-term time horizon for impact, should see the necessity of long-term commitments to support the NARS, extension, and agricultural universities, moving away from grants that focus on low-hanging fruit with short-term impact. Donors must engage with governments to support priorities defined by nationally led, not externally led, processes.

Several KIs expressed disappointment that some donors appear reluctant to directly fund public-sector entities and are inclined to create parallel structures to the NARES that carry out activities that duplicate the mandates of the NARES. While donors may ensure greater accountability for their funding by creating their own partners working on the ground, the long-term impacts are unclear, as they may weaken or marginalize organizations in the NARES that are still mandated by African governments to carry out the public goods role of agricultural R&D&E in their countries.

Proposals for consideration:

- Encourage donor grants targeted to CGIAR or international universities to include organizations in the NARS at the design stage, ensuring that NARS interests and priorities are reflected in proposal and budget development. Encourage grants with co-directors from NARS so that their interests are equally reflected.
- Ensure that donor and development bank funding is consistent with priorities set by national governments.
- Address instability of donor funding. Other studies (e.g., Stads et al., 2021) note that abrupt changes in aid disbursement can have a deleterious effect on the development and effectiveness of NARS activities.

The private sector

Several KIs pointed out that sustainability and resilience are increasingly important objectives in large private international companies. A favorable policy and enabling environment with accountability is one of the most important factors influencing the degree of collaboration between the NARS and the private sector. Many multinational companies, mainly seed and fertilizer companies, are heavily involved in Sub-Saharan Africa where they develop and test their products under field conditions. If companies could be assured of accountability and transparency in the use of funds by NARS, there could be mutual benefit, and NARS could potentially receive much greater funding than they currently do.

Proposals for consideration:

- Make collaboration potential explicit to NARS organizations.
- Promote improved financial accounting protocols by NARS.

Organizations in the CGIAR

In 2021, the CGIAR launched a new research and innovation prospectus and a 2030 Research and Innovation Strategy to provide the science, knowledge, and tools needed to carry out a radical realignment of food systems and reach global targets for transforming food, land, and water systems by 2030. It includes three action areas to drive progress on climate adaptation and mitigation: (i) food systems transformation; (ii) resilient agrifood systems; and (iii) genetic innovation. All three themes are critically important for African NARES.

Several KIs indicated that the success of the new One CGIAR strategy rests with developing closer partnerships with NARES, which are absolutely key to attaining its objectives. Most KIs stated that the CGIAR will enhance the effectiveness of their own programs, as well as those of the NARS, by renewing and intensifying its efforts to strengthen the capacities of its regional and national partners, regional centers of excellence, African agricultural universities, and public extension systems. One KI noted that in most Asian countries, the capacities of their NARS were low several decades ago but are now comparable to those of the CGIAR organizations working in Asia. This has served both the Asian NARS and the CGIAR well because their roles are synergistic. Because the CGIAR's impact in Africa similarly depends on well-functioning local partners, the authors of this report agree with the majority of KIs who stated that the CGIAR can and should intensify its capacity strengthening efforts, focusing both on organizational as well as individual capacity development.

Donor organizations that primarily fund the CGIAR can support this proposed intensification of CGIAR capacity development activities by encouraging grants and programs that (i) involve NARS partners from the inception of grant design; (ii) have joint-directors and principal investigators from both CGIAR and NARS organizations; (iii) allocate substantial portions of grant budgets to the NARS; and (iv) have well-specified performance metrics and accountability for both CGIAR and NARS partners.

Proposals for consideration:

- Renew and intensify efforts to strengthen the capacities of regional and national partners, regional centers of excellence, African agricultural universities, and public extension systems.
- Initiate a multistakeholder commitment platform, specifying commitments to be made by international and African development organizations, CGIAR organizations, NARES, and African governments in a coordinated plan to strengthen the capacity of African-led R&D&E systems.

CONCLUSIONS

Achieving many of Africa's most important development goals, including most of the Sustainable Development Goals (SDGs), depend on agricultural productivity growth and adaptation to climate change, which in turn requires technical innovation on tens of millions of African farms. The pace of farm technical innovation and productivity growth are greatly influenced by the performance of agricultural research, development, and extension services (R&D&E), both international and national (Fuglie et al., 2020).

Each year, African governments and international development partners invest roughly US$2.5 billion (in constant 2011 PPP) on agricultural R&D activities. The perspectives given by key informants in this study suggest that the payoffs of these considerable investments are attenuated by long-standing weaknesses in African-led agricultural R&D&E systems. These weaknesses also impede the effectiveness of research funding allocated to international research partners, because the CGIAR and other international partners are not structured to, and lack the resources to, scale-out technical innovations on their own. Strong national partners on the ground are needed to adapt international germplasm, management practices, and policies to the highly varied agroecological conditions and resource constraints faced by smallholder farmers. Strong national partners are also required for effective social science work in support of farmer adoption and tasks related to seed certification, registration, and commercial distribution. For these reasons, efforts to strengthen the performance of African NARES may not only raise their own direct contributions to technical innovation but also increase the benefits accruing from programs of international research and donor organizations.

In light of changing conditions over the past several decades, and based on the foregoing, we propose that the historical 20th-century model of agricultural R&D&E in SSA needs to fundamentally change. The AUC's Agenda 2063 recognizes the need for African governments to be at the core of continental programs and an Africa that holds itself accountable for results (Africian Union Commission, 2015). Current conditions warrant a 21st-century model of agricultural research in which African continental and regional development organizations and national governments take control and accountability for how agricultural research (including research conducted by the IARS) is prioritized, implemented, and evaluated in their countries.

We contend that *institutional* capacity development should be seen as the fundamental goal of capacity development efforts and the appropriate litmus test by which international capacity-building efforts are evaluated. Building the capacities of individuals is important for achieving institutional capacity development, but it is far from sufficient. The institutions in African NARES need to be strengthened sufficiently to retain the trained individuals and effectively utilize their capacities.

Most key informants interviewed for this study felt that building the capacity of individuals without due focus on institutional capacity development has contributed to the migration of trained individuals from African NARES to international research organizations, widening rather than narrowing the capacity gap between African and international R&D organizations.

What exactly does institutional capacity development entail? Strengthening locally led agricultural R&D&E organizations requires explicit attention to both the *internal* and the *external* environment in which these units operate.

The internal environment means management: Does the organization provide incentives to attract and retain qualified professionals? Does the organization provide a favorable environment for individuals to build a research program and contribute to both scholarly- and impact-oriented objectives? Does the organization reward good performance?

The external environment means the "policy ecosystem," which determines the scope for locally led R&D&E organizations to develop and thrive. Long-standing weaknesses of the NARES have led international donor organizations to create new agencies with mandates that overlap with those of the NARES. These donor-created organizations essentially create parallel structures to "work around" the weaknesses of the NARES, but they often generate overlapping agendas and mandates with the NARES organizations, leading to resentment, competition, and dysfunctionalities that may both weaken the institutional capacities of the NARES and impede the performance of international partners.

Despite the creation of donor-funded parallel structures, most African governments continue to rely primarily on their own national agricultural organizations for agricultural technical innovation, extension services, and policy guidance. Donors may create more favorable external environments for local policy and R&D&E units to thrive by carefully re-evaluating how their funding decisions may unintentionally affect the viability of other actors and functions in the system.

The dominant view expressed by KIs in this study is that the natural partner that should be leading and mobilizing local support for agricultural R&D&E systems are the organizations within the NARES: national agricultural research institutes, agricultural universities, extension systems, and policy analysis units. Countries that have built strong NARES, e.g., Brazil and many Asian countries, have been able to mobilize greater and more sustained political support for increased expenditures to agricultural R&D&E and for favorable policies that together create "virtuous cycle" synergies between private-sector investment, improved farmer access to new technologies and management practices, agricultural productivity growth, and broader agrifood systems transformation.

Today in 2023, there are many more professionally trained agricultural scientists and researchers than several decades ago (Jayne et al., 2021). For example, the Association of African Agricultural Economists (AAAE) had 46 members in 2004, rising to more than 470 members in 2019 (AAAE Management Office, 2019). However, many of these African agricultural economists choose not to join African universities or policy analysis units due to differences in workplace conditions compared to those of international organizations. Investments in individual capacity development do not necessarily improve the performance of organizations within the NARES unless organizational- and system-level issues are also addressed. Capacity development models that emphasize policy systems also recognize that investing in the capacity of individuals alone risks creating enclaves of better-educated nationals working, even in their own countries, for well-funded international organizations or new entities designed to respond to donor priorities that do not necessarily flow from African continental or regional development or research organizations (e.g., AU, AfDB, Forum for Agricultural Research in Africa) or national governments.

Who needs to act to strengthen the performance of the NARES? This study identifies three key planks.

First, the African Union and the AfDB must play the catalytic role in continental leadership and coordination, including seeking greater accountability and commitment from African governments themselves to build their NARES, and allocating sustained funding required to do so. The African Union and AfDB must also work with international funding partners to ensure a reallocation of donor funding to prioritize institutional capacity development of African continental, regional, and national R&D&E organizations.

Second, international partners, including the CGIAR and international universities, must develop a greater appreciation of how their own effectiveness (e.g., impact generated per dollar of donor funds allocated) is dependent on the performance of local partners working on the ground, and prioritize efforts to collaborate with and build the capacities of these partners.

Third, donors themselves must consider modifications to their priorities and/or procedures. After African development organizations and governments, international donors hold the key to strengthening African R&D&E systems by the grants that they make. Donors must ensure that grants related to African agricultural technical innovation (i) require including organizations in the NARES at the design stage, (ii) support nationally led priority-setting agendas, and (iii) ensure that the priorities of national governments are reflected in proposal and budget development. Mandating that grants have co-directors from NARES organizations would encourage greater ownership and commitment of African organizations to achieving the objectives of the grant.

The authors of this report acknowledge the considerable heterogeneity in national capacities across African countries. Strategies may differ, especially according to the size and effectiveness of existing NARES programs. Roughly 20 Sub-Saharan African countries spend very little on NARES organizations. For such countries, a regional approach to African-led agricultural R&D may be the most practical and cost-effective approach. For relatively large countries, direct support for NARES may be the most constructive route.

African countries can also capitalize on the considerable power of the private sector to provide yield-enhancing technologies to farmers. Longstanding mistrust of the private sector has led to a situation where most African governments and citizens are uncomfortable with entrusting agricultural R&D&E activities and associated influence over national food security to outside private interests. For this reason alone, strong national agricultural R&D&E systems are necessary. However, African farmers and economies stand to greatly benefit if governments can craft *win-win* partnerships with private agribusiness firms (international and national, large and small) and create a policy environment that encourages greater private investment in their food systems. This challenge, among other reasons, underscores why agricultural policy research institutes are important components of an effective NARES.

This formula for success has already been demonstrated by several African countries. For example, Ethiopia tripled its real expenditure on public agricultural research between 2000 and 2015 and expanded its agricultural extension service to such an extent that in 2018 it possessed half of SSA's agricultural extension workers (Fuglie et al., 2020; Dorosh and Minten, 2020). Not surprisingly, Ethiopia has achieved the highest rate of agricultural growth of any country in SSA since 2000 (FAOSTAT). Each additional $1 of agricultural value-added in the Ethiopian economy generated an additional $0.29 in non-farm GDP and hence contributed powerfully to the country's rapid economic transformation (Dorosh and Minten, 2020). Ethiopia's successes provide a powerful example that by committing greater investment to national and international agricultural R&D&E and improving the operational performance of these organizations, SSA governments will be taking one of the single most important steps to sustain their countries' economic transformation.

The essential issue is aligning incentives with objectives. If the funders of agriculture-related grants value institutional capacity development of African NARES, they will elevate institutional capacity building to a major objective of their grants and insist on grant outcomes that achieve those objectives. International research partners will then have the incentives to prepare grant proposals and budgets that achieve those outcomes. New grantees are also likely to emerge, including the NARES themselves, which can select international partners committed to helping them achieve their institutional capacity development objectives.

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AUTHOR CONTRIBUTIONS

TSJ and SS conceptualized the project. TSJ, SS, CP, AIN, SZ, and PS conducted the KI interviews. SS and EK conducted data analysis and visualization. SS, EK, and TSJ coordinated the team. TSJ wrote the manuscript. All authors commented on the draft for revision.

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APPENDIX 1: KEY INFORMANT PROFILE

Appendix 1 lists individuals interviewed for the project (name, country/region represented, and institutional affiliation). No remarks cited in the report are attributed to individuals, and all information from interviews with individuals is cited as from the KIs as a whole. Neither participation in interviews nor inclusion in the list of participants in Appendix 3 implies endorsement of any of the contents of the report.

Key Informant Name	Country or region represented	Institutional affiliation (as of report writing)
Agnes Mwangwela	Africa, Malawi	LUANAR University
Bashir Jama Adan	Africa, International	Islamic Development Bank
Christian Witt	International	Gates Foundation
Frank Place	International (CG system)	IFPRI
Gert-Jan Stads	International	IFPRI
Jessica Masira	Africa, Ethiopia	National Ministries of Agriculture
Jim Borel	International	Independent (formerly DuPont Pioneer)
Joe DeVries	Africa, international	AGRA
John Lynam	International (CG system)	CIAT
Keith Fuglie	International	USDA
Pamela Anderson	International (CG system)	Independent (formerly CIAT and international foundation)
Sadiq Sunisi	Africa, Nigeria	Federal University Dutse
Sam Gameda	International (CG system)	CIMMYT
Sara Boettinger	International	Bayer
Tom Kehoe	International	Gates Foundation
Wilkson Makumba	Africa, Malawi/Kenya	Senior Research director, Ministry of Agriculture
Oluwole Fatunbi	Africa	FARA
Anonymous	Africa	
Anonymous	Africa	
Anonymous	Africa, Kenya	
Anonymous	Africa, Nigeria	
Anonymous	Africa, Malawi	
Anonymous	International	
Anonymous	International, CGIAR	
Anonymous	World Bank	
Anonymous	International	
Anonymous	African university	
Anonymous	Africa, Nigeria	
Anonymous	International	

APPENDIX 2: METHODS OF ANALYSIS AND DATA

Findings and conclusions are drawn from two main sources. First, we review existing literature related to agricultural R&D&E systems in Sub-Saharan Africa and examine trends in, and composition of, R&D expenditures and staffing in 11 African and comparison countries in Asia and South America, utilizing data compiled by Agricultural Science and Technology Indicators (ASTI), FAOSTAT, and CGIAR annual reports.

The second source of the study's findings were from key informant (KI) interviews and descriptive analysis thereof. The KIs were mainly senior or midlevel representatives of national, regional, and international agricultural research institutions. We also selected three representatives of foundations and bilateral organizations funding agricultural research in or for Africa. Selection of KIs was necessarily purposive as it was not possible to compile lists of relevant representatives from all national and international organizations involved in agricultural R&D&E in Africa. We selected roughly equal numbers of representatives from African-led agricultural research systems and international research organizations. A full list of KI titles and affiliations is provided in Appendix Table 1.

Analysis of KI interviews were considered appropriate for this study for several reasons. The study's objectives require obtaining detailed information about the functioning, priorities, management, and coordination of national and international R&D institutions responsible for generating farm technical innovation. A deep understanding of these issues can be obtained by drawing upon the extensive experience of individuals directly involved in the system. The in-depth KI interview technique is especially suitable in contexts where data is unavailable or where issues are too complex to yield insights from quantitative data based on pre-coded responses. The average interview time was 1 hour 9 minutes.

KI interviews followed three steps. First, the team interviewed 29 KIs based on nine open-ended questions shared in advance with each KI. The nine questions explored with experts were designed to shed light on the strengths, weaknesses, opportunities and threats facing NARES in SSA, reasons for varying performance across countries, synergies and coordination challenges between the NARES and international research systems, impacts on each other's performance, and proposed actions for improving the performance and positive impacts of agricultural R&D&E systems. The 9 questions are presented in Appendix 2. Interviews were conducted individually rather than in groups to avoid the influence of dominant individual(s). Interviews were conducted over Zoom by one main interviewer and at least two other team members. Written and video transcripts were recorded for each KI using Otter.AI software. Second, transcripts were reviewed by at least two of the author team and

summarized for each of the nine questions. Third, after all interviews were conducted, the author team counted the proportion of respondents providing similar responses and identified key recurrent themes for each of the nine questions. We adopted Chatham House Rule for these interviews to ensure that respondents felt free to express views without attribution. The seven key themes highlighted from this process are summarized in the section titled "Themes From Informant Interviews."

Because of variations in the organization and performance of NARES in Africa, we selected relatively equal numbers of African-based representatives from the four systems: (i) Ethiopia/Rwanda, which feature relatively centralized R&D systems and strong national extension systems; (ii) Malawi/Kenya/Tanzania, which share similar R&D&E systems stemming from their former British colonial settler history; (iii) the francophone system of Senegal, Mali, and Burkina Faso; and (iv) Nigeria.

The budget for the study necessitated that the KI sample be quite small (n=29 total). We selected individual managers and directors of both international (n=14) and national (n=12) R&D&E organizations and three international donor organizations. Hence our methodological approach has drawbacks. For example, the study cannot be regarded as statistically representative of either international or all African national R&D&E organizations; it is possible that alternative KI samples would have put a different ranking on the issues highlighted by this KI sample. We can confirm, however, that the issues highlighted by the KIs were largely recurrent and toward the end of the interview process we detected few if any new themes that were not identified in earlier interviews. We also examined whether responses varied according to the KI's affiliation and background (e.g., whether their work history was in the NARES or an international organization) and note in the section titled "Themes From Informant Interviews" where differences in viewpoints emerged.

Open-ended questions posed to key informants

1. How does the importance of nutritional security affect how agricultural R&D&E and agricultural policy research should be organized and instituted?
2. What is the required policy and programmatic agenda (re your response to Q1)?
3. To what extent is progress in improving livelihoods, nutrition and food security in Africa dependent on improving the performance of African national agricultural R&D&E systems? On a scale of 1 to 10?
4. What is the agricultural research and extension "capacity gap" between Africa and other developing countries?
    - How would you define and/or measure the capacity gap?

5. What is the current state of national agricultural R&D&E systems in sub-Saharan Africa? Strengths, weaknesses, opportunities, threats.
    - Feel free to identify both relatively successful and less successful examples.
6. How is the CGIAR system affecting the development and capacities of the NARES?
7. Is the contribution of international public and private agricultural R&D (and the CGIAR system in particular) limited by weaknesses in national-level adaptive agricultural R&D&E systems?
8. Is strengthening African R&D&E systems necessary to raise the effectiveness of the CGIAR system in achieving its goals? Scale of 1-10?
9. What is the priority agenda for action? How can African agricultural R&D&E systems be restructured and supported (e.g., funding, capacity strengthening, coordinated with regional and continental and international research institutions) to promote the achievement of resilient, sustainable, and productive food systems transformation?

APPENDIX 3: ADDITIONAL DATA COLLECTED

We collected additional data from Nigeria and Senegal, beyond what was available via aggregated online sources. These data were collected by contractors in each country, using various sources (as listed in each linked spreadsheet).

The collected data are not included in the body of the report, but are available in the following two linked documents: Summary of Data Collected - Senegal and Summary of Data Collected - Nigeria. Data for Senegal were collected for individual institutions, but are presented as totals across categories of institution types, with the names of individual institutions that are included listed in aggregate. Data for Senegal were collected by survey to individual institutions; all the surveys were similar to this sample, but each contained only the categories of data relevant to each type of institution. Data for Nigeria were collected from various published sources.

THE BREAKTHROUGH INSTITUTE

BERKELEY, CA 94704

WWW.THEBREAKTHROUGH.ORG

TWITTER:@TheBTI