Taking Stock of National Agricultural R&D Capacity in Africa South of the Sahara

ASTI Synthesis Report

Nienke Beintema
Gert-Jan Stads

NOVEMBER 2014

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Led by IFPRI

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About ASTI

Extensive empirical evidence demonstrates that agricultural research and development (R&D) investments have greatly contributed to economic growth, agricultural development, and poverty reduction in developing regions. Numerous regional and subregional initiatives emphasize the importance of agricultural R&D to achieving the productivity growth urgently needed to feed expanding populations; reduce poverty levels; and address new challenges, such as those imposed by climate change. Agricultural Science and Technology Indicators (ASTI), led by the International Food Policy Research Institute (IFPRI) and operating within the portfolio of the CGIAR Research Program on Policies, Institutions, and Markets, contributes to this agenda by collecting, analyzing, and publishing quantitative and qualitative information and trends on funding sources, spending levels and allocations, human resource capacities, and institutional developments in agricultural research in low- and middle-income countries. Working with a large network of country-level collaborators, ASTI conducts primary surveys to collect data from government, higher education, nonprofit, and private agricultural R&D agencies in around 80 developing countries worldwide.

About IFPRI

The International Food Policy Research Institute (IFPRI), established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. The Institute conducts research, communicates results, optimizes partnerships, and builds capacity to ensure sustainable food production, promote healthy food systems, improve markets and trade, transform agriculture, build resilience, and strengthen institutions and governance. Gender is considered in all of the Institute's work. IFPRI collaborates with partners around the world, including development implementers, public institutions, the private sector, and farmers' organizations. IFPRI is a member of the CGIAR Consortium.

Related ASTI Outputs

- ASTI country factsheets, which contain a visual, highly accessible presentation of recent institutional, financial, and human resource trends in national agricultural R&D. The factsheets also feature a more in-depth analysis of some of the key challenges that individual agricultural R&D systems are currently facing, and policy options to address these challenges.
- Interactive country pages, available at www.asti.cgiar.org, featuring national agricultural R&D capacity, investment, and institutional indicators and trends.
- ASTI's country benchmarking tool, available at www.asti.cgiar.org, which enables cross-country comparisons and rankings of key ASTI indicators.
- ASTI's data download and mapping tool, available at www.asti.cgiar.org, containing all of ASTI's regional and country-level data.

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1| Introduction

THIS REPORT IS A TIMELY INPUT into the ongoing development agenda for Africa South of the Sahara (SSA). The 2013 report on agriculture and food systems by the United Nations' Sustainable Development Solutions Network released a set of post–2015 development goals, including recommendations that low- and middle-income countries increase their spending on agricultural research and development (R&D) by a minimum of 5 percent per year during 2015–2025, and that they allocate at least 1 percent of their agricultural gross domestic product (GDP) to public agricultural R&D.[1] More recently, the Science Agenda for Agriculture in Africa was adopted at the African Heads of State Summit, necessitating the development of a continent-wide implementation plan. This report, which summarizes SSA's recent progress in developing its national agricultural R&D systems, is intended to serve as an important input into, and potential benchmark for, the implementation of the science agenda in SSA and the broader development agenda for the region. The analysis is based on comprehensive primary datasets by Agricultural Science and Technology Indicators (ASTI), the most recent of which was compiled during 2012–2013.

2| Regional Overview

Although Africa's agricultural R&D spending and number of agricultural researchers increased significantly during 2000–2011, growth was uneven over time and across countries.

HIGH POPULATION GROWTH, DETERIORATING SOILS, CLIMATE CHANGE, AND VOLATILE FOOD PRICES are major factors affecting food security in SSA. To respond effectively to these challenges, agricultural productivity in the region needs to be accelerated without delay. To succeed in generating the targeted research outputs needed to accelerate this agricultural growth, the countries of SSA need sufficient, sustainable funding of strategic agricultural research programs in alignment with national and subregional priorities, combined with talented, well-trained researchers conducting activities within an innovative yet efficient environment that motivates them. A few countries are succeeding in this this regard, and many can be said to have increased their commitment and made valuable progress. Nevertheless, many countries are still struggling with inadequate systems, funding, and human resource capacity.

Averaged across countries, the region's public agricultural research capacity increased by 50 percent during 2000–2011 to an estimated 14,500 full-time equivalent (FTE) researchers (Figure 2.1).[2] Put in context, however, three countries—Nigeria (2,688 FTEs), Ethiopia (1,877 FTEs), and Kenya (1,151 FTEs)—employed more than one-third of those researchers in 2011 (Figure 2.3). Moreover, just two countries—Nigeria and Ethiopia—were responsible for most of SSA's capacity growth during this period (Figure 2.2). Of the 38 countries included in ASTI's analysis,[3] 10 employed fewer than 100 FTEs each, and growth across countries was primarily driven by the recruitment of junior, BSc-qualified researchers (Section 4). In addition, a number of Sahel countries (Burkina Faso, Mali, Mauritania, and Senegal) recorded rapid decreases in researcher numbers between 2008 and 2011. While the number of female researchers increased, women are still under-represented in many countries (Section 6). Recruitment restrictions combined with the retirement of highly qualified researchers—or their departure into more lucrative positions in the private sector or international organizations—resulted in the loss of considerable experience and expertise in many SSA countries (Section 5). Hence, despite the absolute increase in their number, the overall pool of researchers remains inadequate in terms of their qualifications, experience, and skills mix. A further significant constraint to the effectiveness of agricultural research in SSA is inadequate, run down, and in some case dilapidated research infrastructure.

After a decade of stagnation in the 1990s, public agricultural R&D spending in SSA increased by more than one-third in real terms, from $1.2 billion in 2000 to $1.7 billion in 2011, measured in constant 2005 PPP dollars (Figure 2.1). Once again, however, about half of these investments were made in just three countries—Nigeria ($394 million), South Africa ($237 million), and Kenya

FIGURE 2.1 | Regional trends in public spending levels and researcher numbers, 2000–2011

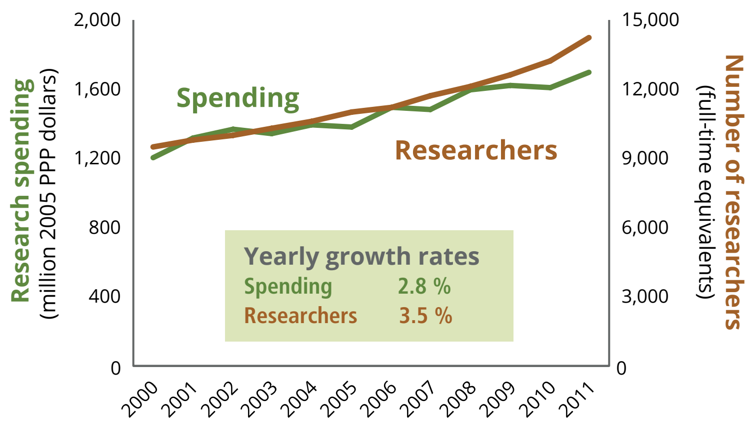


FIGURE 2.2 | Main drivers of growth in regional public spending and researcher numbers, 2000–2011

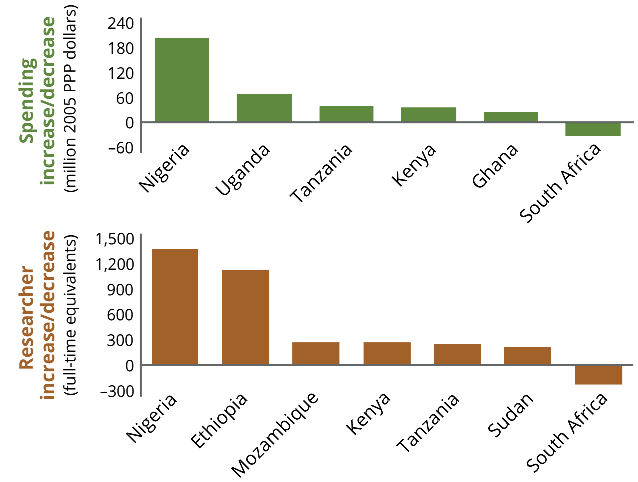


FIGURE 2.3 | Total number of public researchers by country, 2011

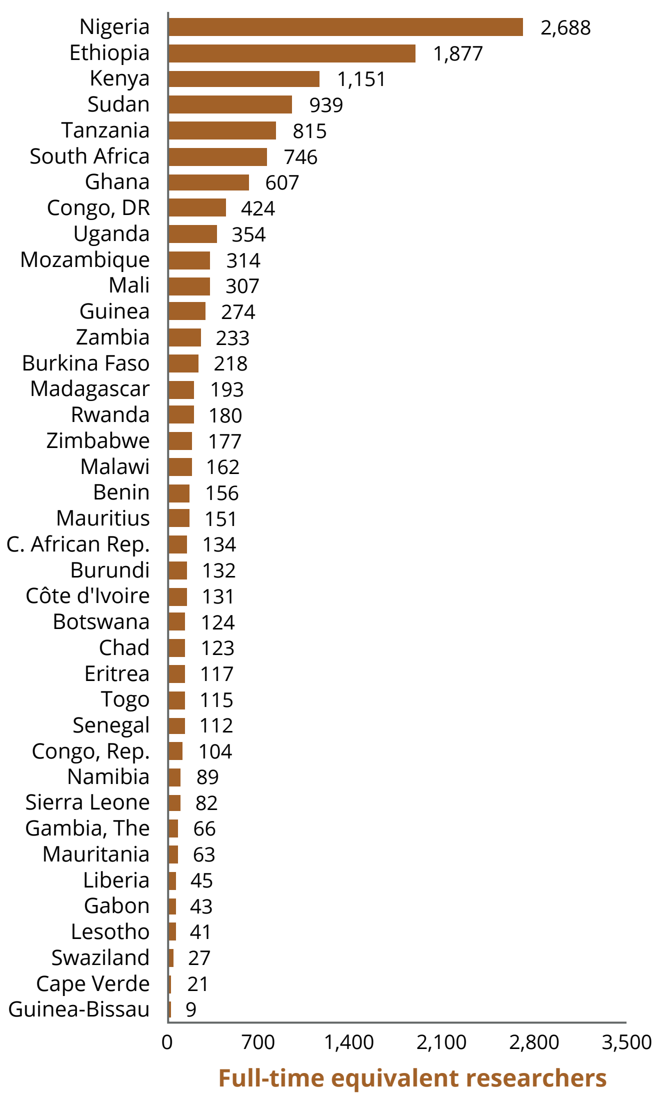
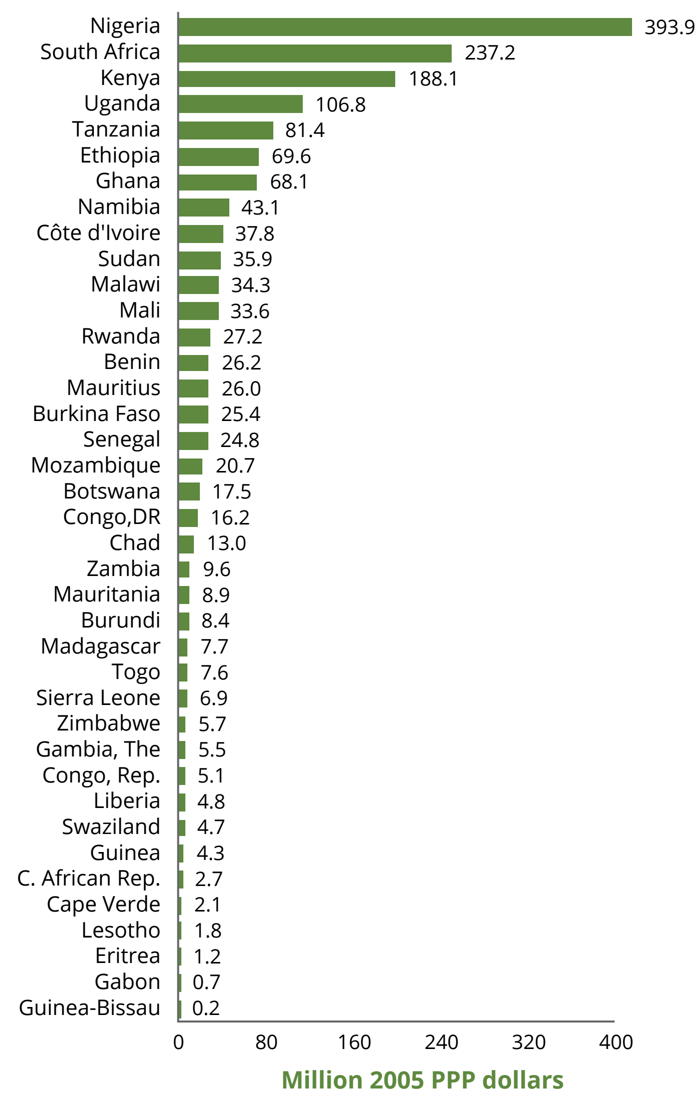


FIGURE 2.4 | Public research spending by country, 2011



Sources: Constructed by authors from ASTI data.

Many smaller countries remain seriously challenged by underinvestment, inadequate human resource capacity, and poor research infrastructure.

($188 million)—and close to half the regional growth in public agricultural R&D expenditures was attributable to increased spending in just two countries—Nigeria and Uganda (Figure 2.2). Ethiopia, Ghana, Kenya, and Tanzania also recorded relatively high increases in total spending, each accounting for between 5 and 9 percent of the total growth (Section 6). In contrast, 18 of the 38 countries included in the analysis spent less than $10 million on agricultural R&D (Figure 2.4). Many smaller countries, especially those in francophone West Africa, recorded negative growth between 2000 and 2011, although early indications signal the reversal of these trends since 2011 in a number of these countries, partly as a result of increased funding through World Bank loans.

Despite recent increases, overall investment levels in most countries are still well below those required to sustain countries' needs (Section 7). Agricultural R&D funding in many countries is highly dependent on donors and development banks (Section 8) and has been far from stable over time (Section 9). Governments and research agencies have numerous options available to them to address the prevailing human, financial, and institutional resource challenges. Notwithstanding these challenges, many SSA countries have made positive progress in recent years and can provide valuable lessons moving forward (Section 10).

BOX 2.1 | ASTI'S DEFINITIONS OF KEY CONCEPTS

ASTI collects and processes its datasets using standard procedures and definitions developed by the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO). These are described in the *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development.*

Purchasing power parities (PPPs). Unless otherwise specified, all dollar values are based on 2005 PPP exchange rates. PPPs reflect the purchasing power of currencies more effectively than do standard exchange rates because they compare the prices of a broader range of local—as opposed to internationally traded—goods and services.

Full-time equivalents (FTEs). Human resource and financial data take into account the proportion of time researchers spend on R&D versus other activities; hence, three scientists who each spend half of their time on agricultural research would be counted as 1.5 FTEs.

Agricultural research. ASTI defines agricultural research to include activities related to crops, livestock, forestry, fisheries, natural resources, and the socioeconomic aspects of primary agricultural production. On-farm storage and processing of agricultural products are also included, but research relating to off-farm postharvest or food processing activities is excluded.

Research and development (R&D). Research is the creative work and original investigation undertaken on a systematic basis to gain knowledge; development is the application of research findings or other scientific knowledge for the creation of new or significantly improved products, applications, or processes. ASTI measures financial and human resources on a "performer" basis, meaning the entity undertaking the research, not the entity or entities funding it.

Public agricultural R&D. ASTI defines public agricultural R&D to include activities conducted by government, higher education, and nonprofit agencies.

3| Institutional Fragmentation

NATIONAL AGRICULTURAL RESEARCH SYSTEMS (NARSs) IN SSA are predominantly small and quite fragmented in terms of the number of individual agencies. Given the region's diversity, it is difficult to generalize about trends in the composition of NARSs over time. In a number of countries—for example, Mozambique and, more recently, Kenya and Republic of Congo—government-based agricultural research agencies were consolidated into a single entity, whereas in others, such as Ethiopia and Tanzania, government agencies were split or decentralized. Overall, the number of higher education agencies in many countries grew during this period through the creation of new universities or new departments and faculties within existing universities. Small countries generally pursue adaptive research, but they tend to focus on as many topics as do large countries, so their limited capacity is spread extremely thin. Moreover, because many small countries are clustered together, they have little opportunity to benefit from the crossborder spillover of relevant technologies from neighboring countries with similar agroecologies but larger agricultural research systems.

National agricultural research institutes (NARIs) most commonly anchor African NARSs, typically complemented by smaller government and higher education agencies, and in some cases nonprofit and private institutions. NARIs across SSA are structured in one of four ways:

1| as a research department within a ministry of agriculture or equivalent, such as Botswana's Department of Agricultural Research (DAR);

Agricultural R&D in SSA is predominantly performed by government agencies, but the higher education sector has expanded over time. Nonprofit and private organizations still only play a minor role, but offer future growth potential.

2| as a semiautonomous government institute with the flexibility to determine key internal policies, such as the Kenya Agricultural Research Institute (KARI);

3| as multiple agencies focusing on specific agricultural subsectors, such as the combination of Sudan's Agricultural Research Corporation (ARC), which focuses on crops, and its Animal Resources Research Corporation (ARRC), which focuses on livestock; and

4| as numerous institutes organized under a council, such as Ghana's Council for Scientific and Industrial Research (CSIR).

Lack of sufficient, stable funding and coherent, supportive policy environments continues to constrain the overall quantity and quality of research outputs in many countries.

Although the NARIs' share of national agricultural R&D capacity has declined over time—from a regional average of 61 percent in 2000 to 52 percent in 2011—they continue to play a central role (Figures 3.1 and 3.2). In some of SSA's smallest countries, for example, Cape Verde or Guinea Bissau, the NARI is the only agency conducting agricultural research. In other small countries, such as Eritrea, Lesotho, and Swaziland, the NARI conducts the vast majority of research, but the higher education sector also plays a limited role (Table 3.1).

The higher education sector's share of agricultural researchers has grown substantially over time, from 15 percent in 1991, to 20 percent in 2000, and 25 percent in 2011. This was the result of the aforementioned expansion of the sector. This trend has provided many benefits, key among them an increase in the number of PhD-qualified researchers in the higher education sector and increased training opportunities. The downside of the increase in university-based research capacity, however, is a further fragmentation of NARSs, such as in Kenya and Sudan, and a potential shift away from the applied research needs of farmers to more specialized basic research.

In general, both for-profit and nonprofit private research remain limited in most SSA countries. Nonprofit research institutions are often funded through levies on production or exports. Although the sector only accounted for 2 percent of the region's public agricultural research in 2011 (that is, excluding the private sector), it fulfills an important role in a few countries, and offers a potential area for growth in many others. Private for-profit agricultural research is extremely limited in SSA, with the exception of South Africa. Private companies mostly outsource their R&D to the public sector rather than perform research themselves, but this too is a potential growth area through which NARIs can generate revenue.

Many NARIs and other agencies face numerous challenges in terms of the scope and quality of their infrastructure. This can involve the most basic needs—such as office space and supplies and access to computers, software, the Internet, research publications, and even water and electricity—but it extends across the gamut to include laboratory space and equipment, farm equipment and vehicles, and so on. Many research facilities are outdated, ill-equipped, or simply nonfunctional.

FIGURE 3.1 | Regional distribution of public researchers by institutional category, 1991–2011

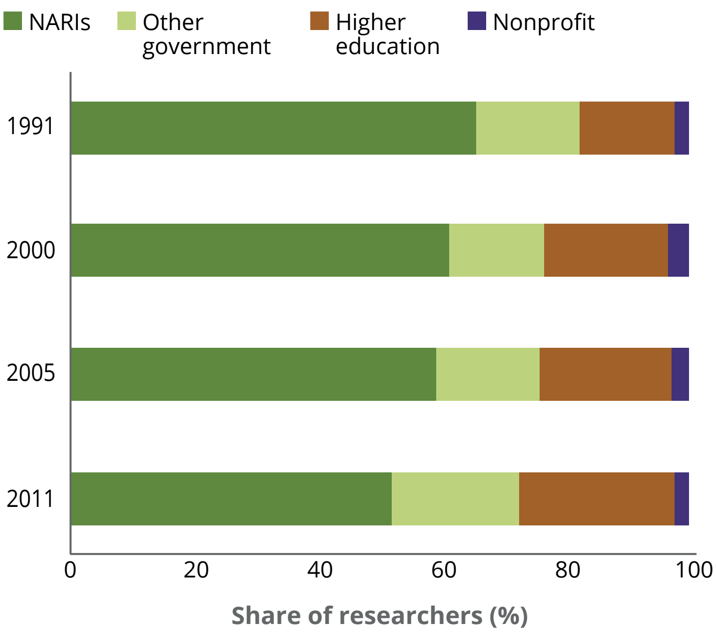


FIGURE 3.2 | Distribution of public researchers by institutional category and country, 2011

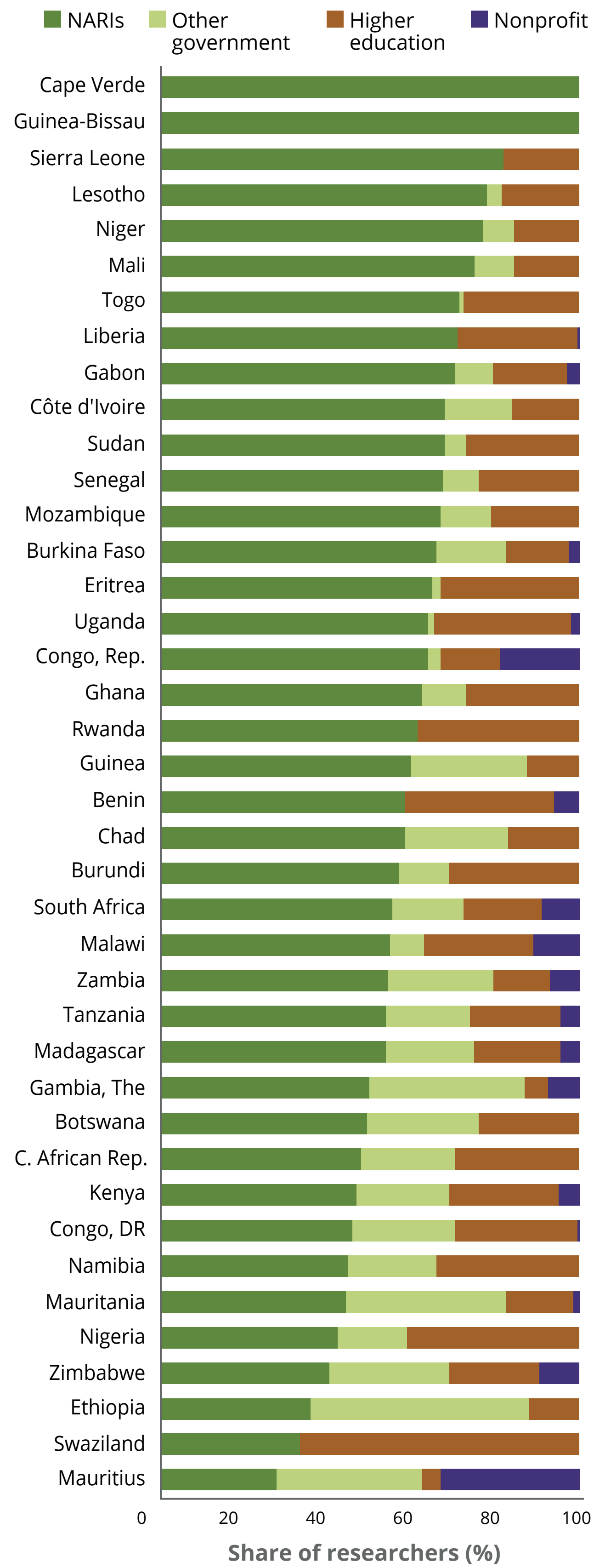


TABLE 3.1 | Number of agencies conducting agricultural research in selected countries, 2011

Category/ country	Government	Higher education	Nonprofit	TOTAL
Small NARSs				
Guinea-Bissau	1	–	–	1
Liberia	1	2	1	4
Mauritania	4	3	1	8
Swaziland	1	1	–	2
Medium-sized NARSs				
Congo, Republic	12	2	2	16
Mali	2	2	–	4
Mauritius	10	2	1	13
Rwanda	1	6	–	7
Large NARSs				
Ethiopia	8	8	–	16
Kenya	6	29	2	37
Sudan	4	28	–	32
Tanzania	6	5	3	14

Sources: Constructed by authors from ASTI data.

Notes: In Table 3.1, small NARSs are defined as those employing fewer than 100 full-time equivalent (FTE) researchers; medium-sized NARSs as those employing between 100 and 500 FTEs; and large NARSs as those employing more than 500 FTEs. Higher education agencies are not necessarily defined as single universities but can include multiple faculties, departments, institutes, or other units within universities.

4| Shifts in Researcher Qualifications

Overall, the distribution of researchers by qualification level has shifted over time toward younger, mostly BSc-qualified scientists due to the departure and retirement of senior researchers and their predominant replacement, after years of recruitment restrictions, with junior researchers.

A MINIMUM NUMBER OF PHD-QUALIFIED SCIENTISTS is generally considered fundamental to the conception, execution, and management of high-quality research; to effective communication with policymakers, donors, and other stakeholders, both locally and through regional and international forums; and for increasing an institute's chances of securing competitive funding. Of 37 countries for which a complete set of degree-level data was available, five countries recorded shares of PhD researchers of more than 40 percent (Benin, Burkina Faso, Madagascar, Senegal, and Swaziland), whereas five countries reported shares of PhD researchers of 10 percent or lower (Ethiopia, The Gambia, Guinea-Bissau, Lesotho, and Mozambique) (Figure 4.1).

While the regional number of agricultural researchers increased by 50 percent to an estimated 14,500 FTEs during 2000–2011 (Section 2), most of this increase stemmed from the recruitment of junior BSc- or MSc- qualified researchers, replacing retiring or departing senior researchers after years of recruitment restrictions (Section 5). Despite an absolute increase in the number of PhD-qualified researchers during 2008–2011, the regional share of agricultural researchers with PhD degrees fell from 25 to 22 percent during this timeframe (Figure 4.2).

Building the capacity of researchers to the doctoral level is an inherently expensive, multi-decade process. Furthermore, many of the smaller countries do not offer PhD training in agricultural sciences, so researchers who want to further their careers need to secure (scarce) scholarships to undertake PhD degree training abroad. A worrisome trend is that 13 of the 30 countries for which long-term data on agricultural researchers by degree qualification were available reported a decline in the absolute number of PhD-qualified researchers (Figure 4.3). In contrast, the number of junior researchers with only BSc degrees increased substantially in a number of countries (Table 4.1), often resulting from the combination of recruitment bans being lifted and difficulties attracting PhD-qualified appointees due to agencies' lack of competitive remuneration packages and service conditions or countries' lack of postgraduate training opportunities in agricultural sciences.

Universities generally employ a much higher share of PhD-qualified scientists compared with most NARIs and other government agencies, but with high—and growing—student populations in the agricultural sciences, it is not surprising that they spend the vast majority of their time on their primary mandate, teaching, and not on research. Nonetheless, the growing core of PhD-qualified researchers within the higher education sector is a valuable resource with inherent future potential for African NARSs.

FIGURE 4.1 | Distribution of public researchers by qualification level and country, 2011

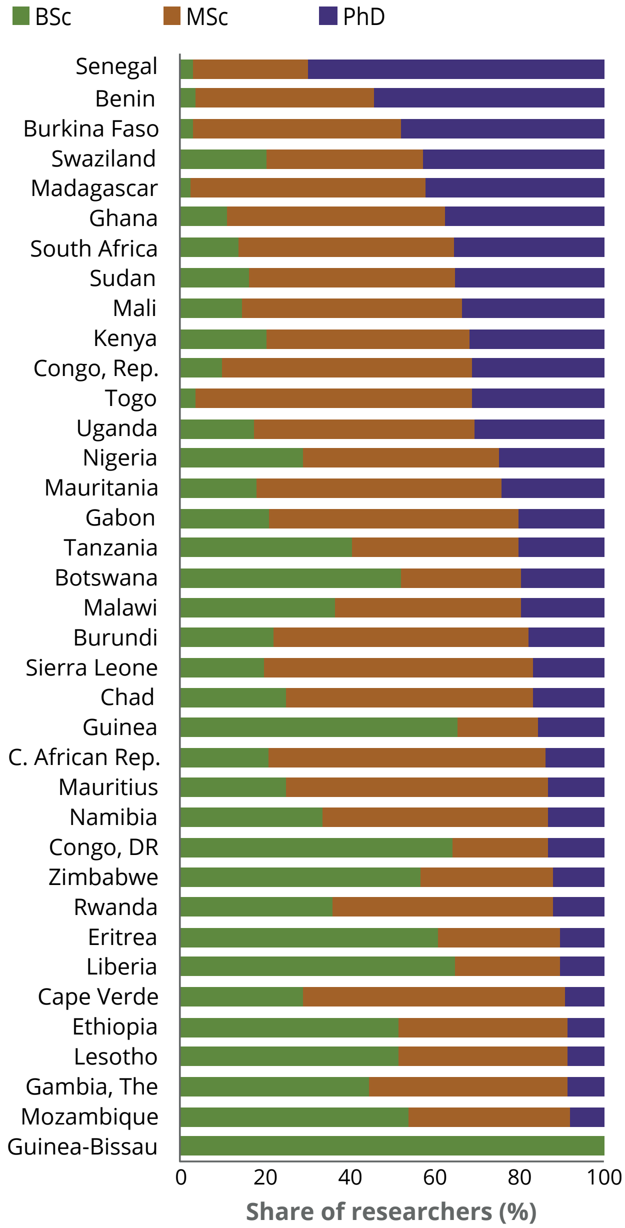


FIGURE 4.2 | Regional trends in the number of public researchers by qualification level, 2000–2011

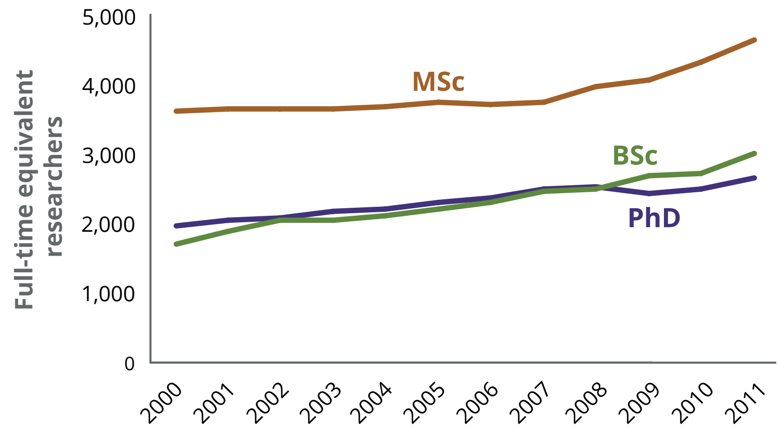


FIGURE 4.3 | Growth in the number of PhD-qualified researchers by country, 2008–2011

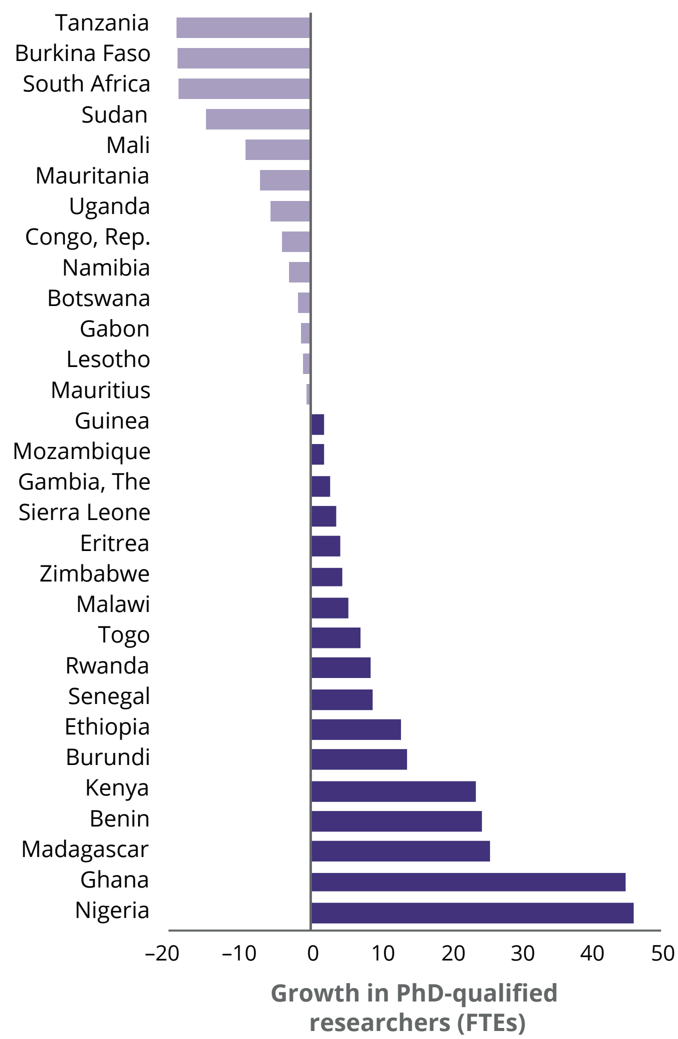


TABLE 4.1 | Countries with the largest growth in the number of BSc-qualified researchers, 2000–2011

Country	Total number of researchers (FTEs)		Number qualified to BSc level only (FTEs)		Share qualified to BSc level only (%)	
	2000	2011	2000	2011	2000	2011
Botswana	57	124	19	64	33	52
Ethiopia	734	1,876	353	960	48	51
Guinea	212	270	133	176	63	65
Kenya	859	1,151	121	229	14	20
Nigeria	616	1,138	115	330	19	29
Tanzania	553	815	121	326	22	40
Uganda	254	354	28	60	11	17

Sources: Constructed by authors from ASTI data.

Notes: Data for Nigeria and South Africa include only the institutes under the Agricultural Research Council of Nigeria (ARCN) and the Agricultural Research Council (ARC), respectively.

5| Staff Turnover and Aging

Long-term recruitment restrictions have left numerous NARIs with aging pools of agricultural researchers, many of whom are set to retire in the next 5 to 15 years.

IN A NUMBER OF COUNTRIES, LONG-TERM PUBLIC-SECTOR RECRUITMENT RESTRICTIONS have left agencies with aging pools of researchers, many of whom are approaching retirement. This trend, combined with high shares of more recently recruited junior staff in need of experience and mentoring, has left many agencies vulnerable. In addition, many NARIs are challenged in their ability to compete with universities, the private sector, and other organizations when it comes to recruiting, retaining, and motivating well-qualified researchers. While details of the exact nature and scope of staff attrition are lacking, key contributing issues are evident.

In a number of countries, researchers employed by NARIs are classified as civil servants and hence are subject to fixed salary scales that are considerably lower than those offered researchers in the higher education sector. This reality—combined with other limiting factors, such as poor benefit and retirement packages; limited promotional opportunities and work flexibility;[4] lack of infrastructure, services, and equipment; and poor management structures—is a significant barrier to attracting, retaining, and motivating researchers at NARIs. Many agencies have also lost a large number of researchers to the private sector or international organizations. Another source of staff turnover is the practice of seconding, and sometimes promoting, senior researchers to (often nonresearch-related) administrative or managerial positions within different ministerial divisions or directorates.

Although the aging of researchers, especially those with PhD degrees, has been emphasized as an increasing issue, evidence on the composition of research staff by age has been lacking. For this reason, ASTI collected detailed information on the age distribution of researchers by degree for a sample of 37 countries (Figure 5.1). As of 2011, in 19 countries for which data were available, at least half of PhD-qualified researchers were more than 50 years old (Figure 5.2). The situation is most severe in West Africa, Madagascar, and a few other countries. To address this challenge, a number of countries have increased the official retirement age from 60 to 65 years, and even from 65 to 70 years in a few cases, but without large-scale recruitment efforts this approach only offers a temporary solution (Table 5.1). The fact that the retirement age is higher at universities in some countries only acts as a further recruitment barrier to the NARIs in those countries.

Overall, the retirement and departure of many senior, well-qualified researchers from NARIs has created significant knowledge gaps and concerns about the quality of research outputs; it has also left many agencies without the critical mass of experienced, PhD-qualified researchers needed to lead research programs and mentor and train junior staff.

FIGURE 5.1 | Distribution of public researchers by age bracket and country, 2011

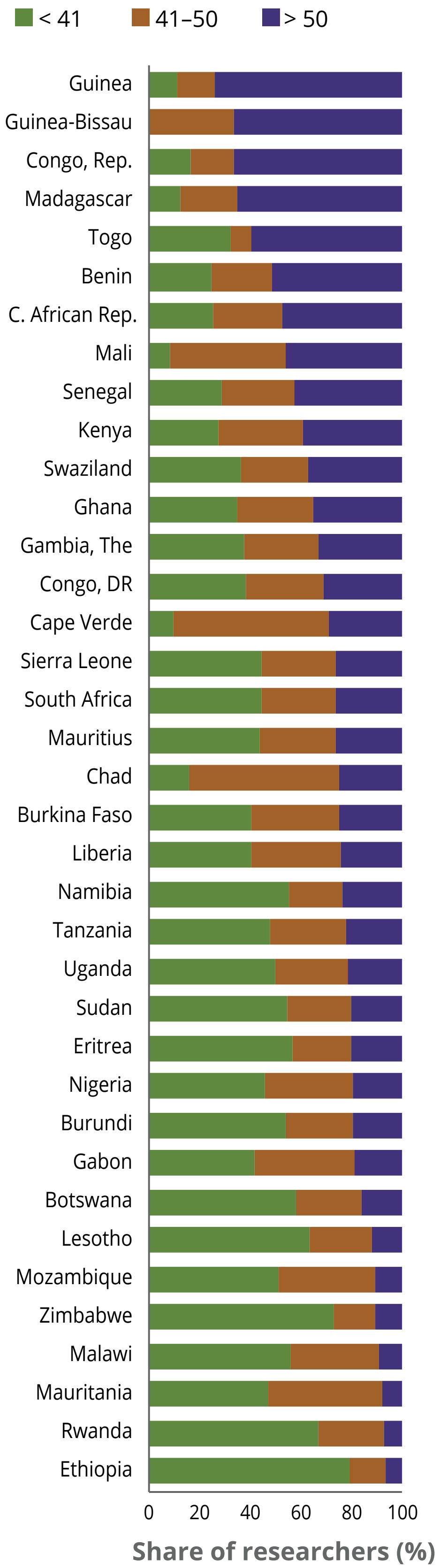


FIGURE 5.2 | Share of PhD-qualified researchers over 50 years old, 2011

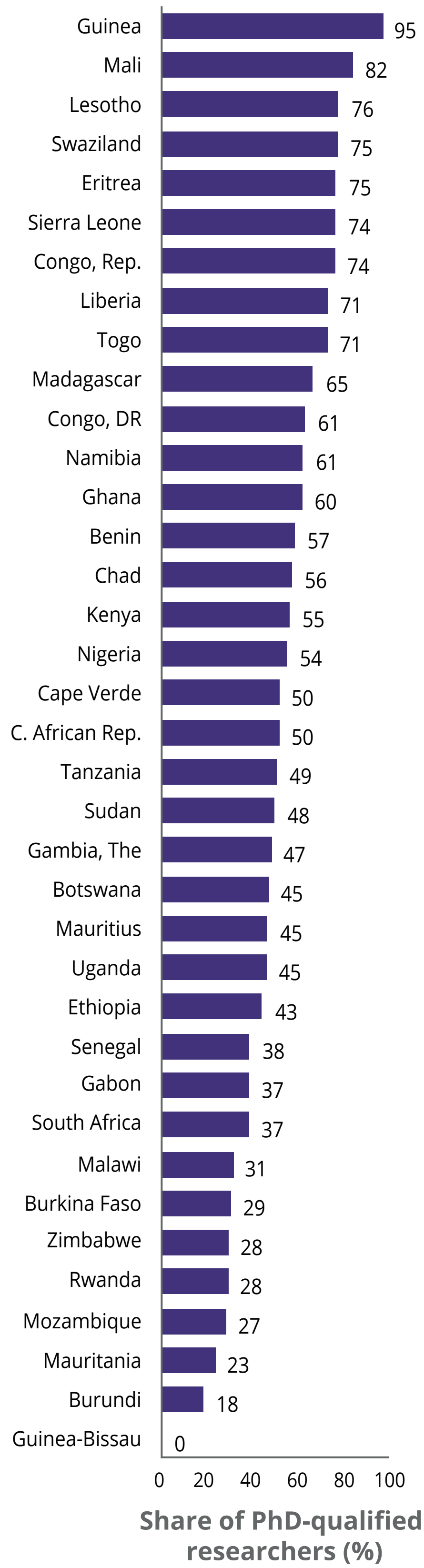


TABLE 5.1 | Official retirement age of researchers by country and sector, 2011

Country	Government	Higher education
Zambia	55	
Gabon	55	65
Chad	60	
Ethiopia	60	
Gambia, The	60	
Ghana	60	
Guinea-Bissau	60	
Lesotho	60	
Liberia	60	
Madagascar	60	
Malawi	60	
Tanzania	60	
Zimbabwe	60	
Benin	60	65
Botswana	60	65
Burundi	60	65
Congo, DR	60	65
Congo, Rep.	60	65
Namibia	60	65
Swaziland	60	65
Togo	60	65
C. African Rep.	62	64
Mozambique	60 for women/65 for men	
Burkina Faso	65	
Cape Verde	65	
Eritrea	65	
Mali	65	
Mauritania	65	
Mauritius	65	
Nigeria	65	
Rwanda	65	
Sierra Leone	65	
Sudan	65	
Guinea	65	70
Kenya	65	70
Senegal	65	70
Uganda	65	70

Sources: Constructed by authors from ASTI data.

Notes: Data for Nigeria and South Africa only include institutes under the Agricultural Research Council of Nigeria (ARCN) and the Agricultural Research Council (ARC), respectively. Data on age distribution in the higher education sector were not available for Burkina Faso, Malawi, Senegal, Sudan, and Tanzania.

6| Low Female Participation

Although the share of female agricultural researchers has grown over time, women remain grossly underrepresented in agricultural R&D, especially in francophone Africa.

PROMOTING GREATER PARTICIPATION IN AGRICULTURAL RESEARCH BY WOMEN has a number of potential benefits. First, it would ensure that a broader range of insights and perspectives were brought to bear on the unique and pressing challenges facing SSA farmers, the majority of whom are female. Second, it could be a highly effective means of filling current capacity gaps in most African countries. Female involvement in agricultural R&D in SSA has increased substantially in recent decades, both in absolute as well as relative terms; nevertheless, shares of female researchers remain low in many countries. In a sample of 37 SSA countries in 2011, 22 percent of agricultural researchers were female (Figure 6.1). In general, southern African countries employ relatively more female researchers than other subregions. In contrast, the representation of women in agricultural research in West Africa, as well as in Eritrea, Ethiopia, and DR Congo, is particularly low (10 percent or less).

In 2011 there was little difference in the shares of female researchers by qualification level; 21 percent of BSc-qualified researchers were women, as were 25 percent of MSc-qualified researchers and 20 percent of those with PhD degrees (Figure 6.2). A quarter of all researchers aged 40 years or younger were female, and only 13 percent of researchers in their 50s and 60s were female, which could indicate that agricultural R&D is becoming increasingly gender-balanced with more and more young women becoming involved. National-level discrepancies were significant, however. Ten of the 27 countries for which gender-disaggregated data were available for 2008–2011 recorded declining shares of female agricultural researchers (Figure 6.3). On a positive note, the countries with substantial increases in their shares of female researchers were predominantly located in West Africa, where shares have been historically low.

Although female involvement in agricultural R&D has increased over time, both in absolute and relative terms, most high-level research and management positions are still held by men. Consequently, women have less influence in policy- and decisionmaking processes. The ASTI–AWARD (2010) study,[5] which collected data for key NARIs and agricultural higher education agencies across SSA, found that the 2008 share of women in management positions was only 14 percent.

African women face unique challenges in pursuing careers in agricultural research, including (1) unequal access to basic education; (2) traditional belief systems that can promote the perception that women are not suited for careers in the sciences; (3) challenges in balancing work and family commitments; (4) barriers to entering formal and informal networks, which are still often managed by men; and (5) lower rates of remuneration than their male colleagues. In many countries various institutional reforms and policies have been initiated to promote gender equality, and various research agencies are taking steps to increase the recruitment of female researchers. These efforts all represent positive progress, although significant scope for further improvement remains.

FIGURE 6.1 | Share of female researchers by country, 2011

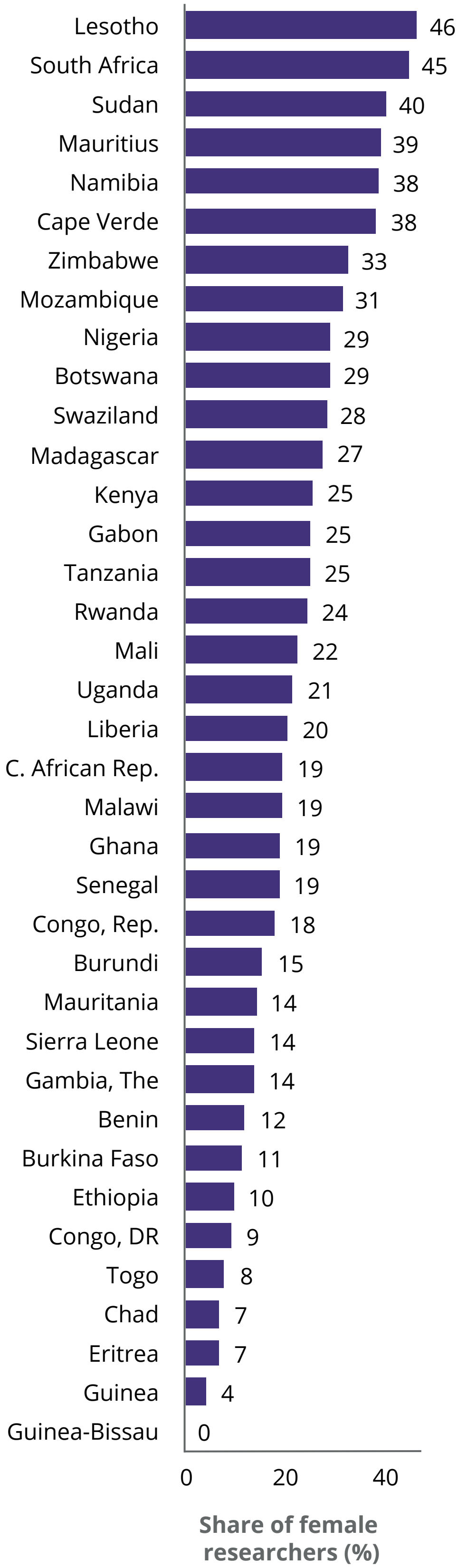
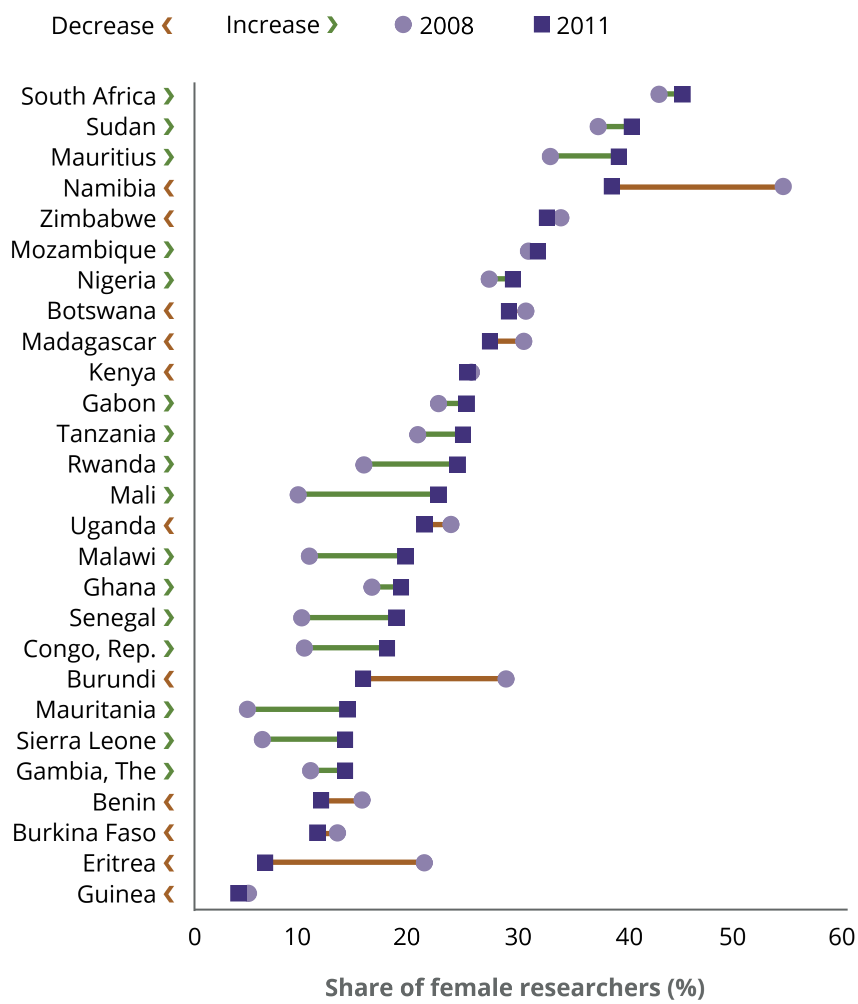


FIGURE 6.2 | Regional share of female researchers by qualification level and age bracket, 2011

FIGURE 6.3 | Change in the share of female researchers by country, 2008–2011



Sources: Constructed by authors from ASTI data.

Notes: Data for Nigeria and South Africa only include institutes under the Agricultural Research Council of Nigeria (ARCN) and the Agricultural Research Council (ARC), respectively. Data on gender for the higher education sector were not available for Malawi and Senegal. Data on age by gender for the higher education sector were not available for Burkina Faso, Malawi, Senegal, Sudan, and Tanzania.

7| Widespread Underinvestment

In 2011, Africa invested 0.51 percent of agricultural output in agricultural research, far below the African Union's target of 1 percent or more.

TOTAL AGRICULTURAL R&D SPENDING IN SSA INCREASED RAPIDLY BETWEEN 2000 AND 2011, mostly driven by a handful of larger countries that recognized the urgent need to increase researcher salary levels and to rehabilitate derelict infrastructure and equipment. Hence these spending increases consolidated and strengthened the NARIs involved, without necessarily increasing the amount of research being conducted.

During 2000–2011, only 13 of the 27 SSA countries for which a full set of time-series data was available recorded growth in public agricultural R&D spending in excess of 1 percent per year, and just 5 countries succeeded in attaining the more ambitious target of 5 percent per year recommended in 2013 by the United Nations' Sustainable Development Solutions Network. The remaining countries experienced negative or near-zero growth, highlighting the challenge of "two-speed" growth in agricultural R&D in SSA: overall spending has grown substantially since 2000, but it has been extremely uneven and has bypassed many countries. The extremely low (and often declining) long-term investment levels and human resource capacity of some of the region's smallest, often francophone, countries calls into question the effectiveness of their national agricultural R&D outputs, and whether they would not be better served by narrowing their focus to technological spillovers from their larger neighbors.

Relative investment levels may be a more suitable measure than absolute levels or growth rates to examine the severity of regional underinvestment in agricultural R&D spending. Agricultural R&D intensity ratios express a country's total public agricultural R&D spending as a share of its agricultural output (AgGDP), and are a useful tool for comparing spending levels over time and across countries. Despite tremendous growth in agricultural R&D spending in recent years, SSA's agricultural R&D intensity ratio has steadily declined, from 0.59 percent in 2006 to 0.51 percent in 2011. This indicates that—notwithstanding the injection of significant funds through regional initiatives such as the West Africa Agricultural Productivity Program (WAAPP) and East Africa Agricultural Productivity Program (EAAPP)—regional agricultural R&D spending has not kept pace with growth in agricultural output.

In fact, 28 of the 38 SSA countries for which data were available still fall short of the minimum investment target of 1 percent of AgGDP set by the African Union and United Nations. Moreover, 18 countries recorded 2011 intensity ratios of less than 0.5 percent. Mobilizing domestic political support

FIGURE 7.1 | Yearly rates of public spending growth, 2000–2011

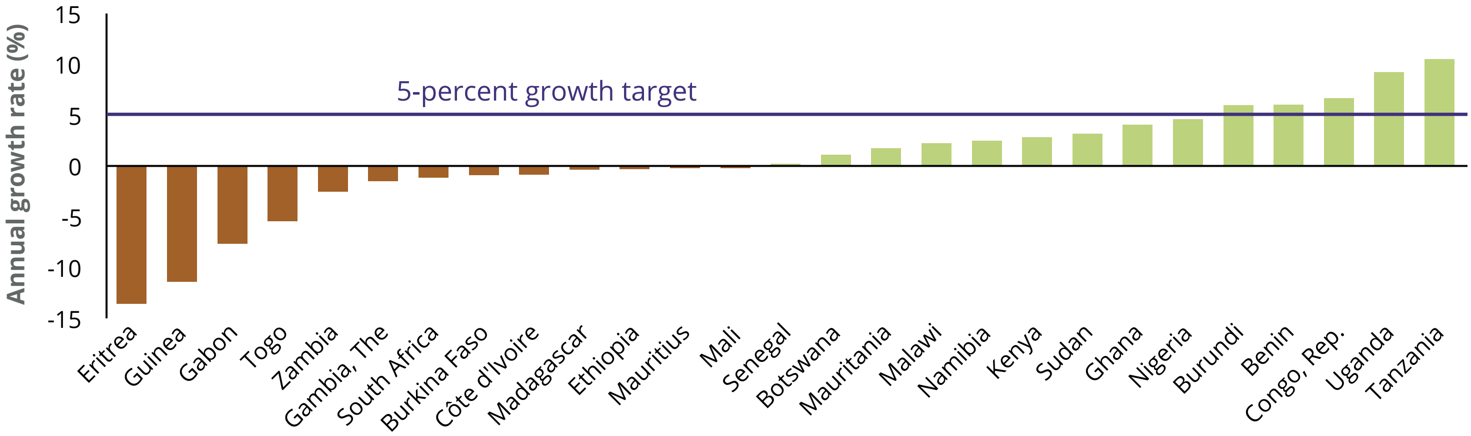


FIGURE 7.2 | Public research intensity ratios by country, 2011

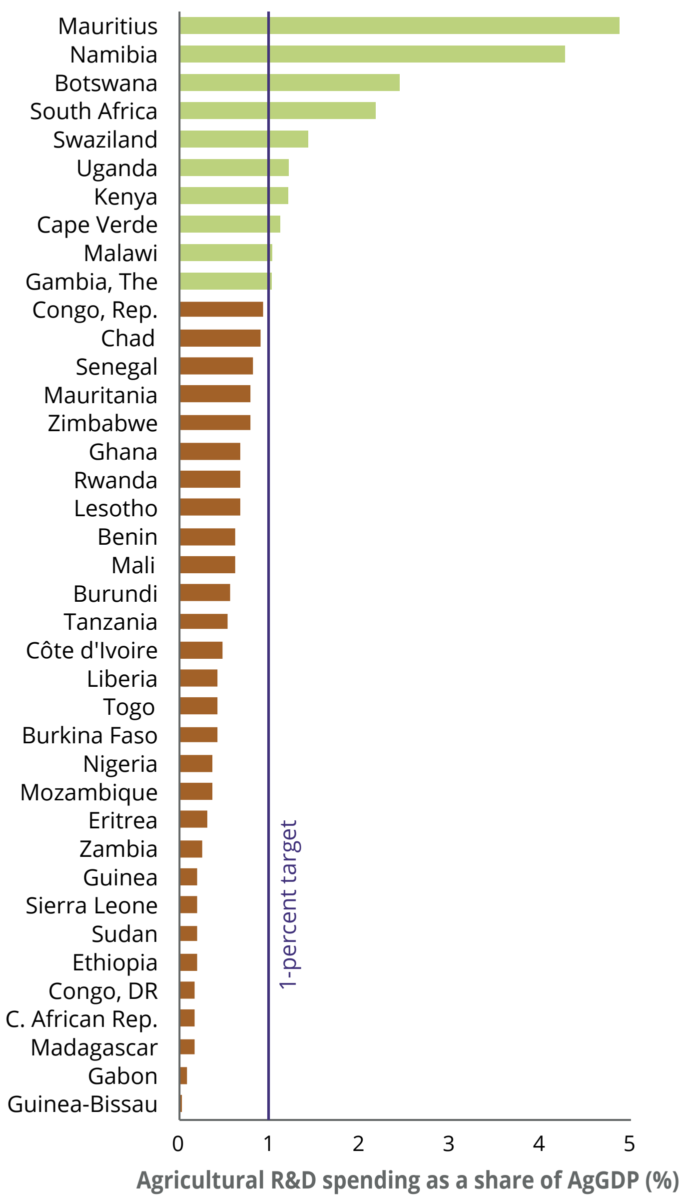
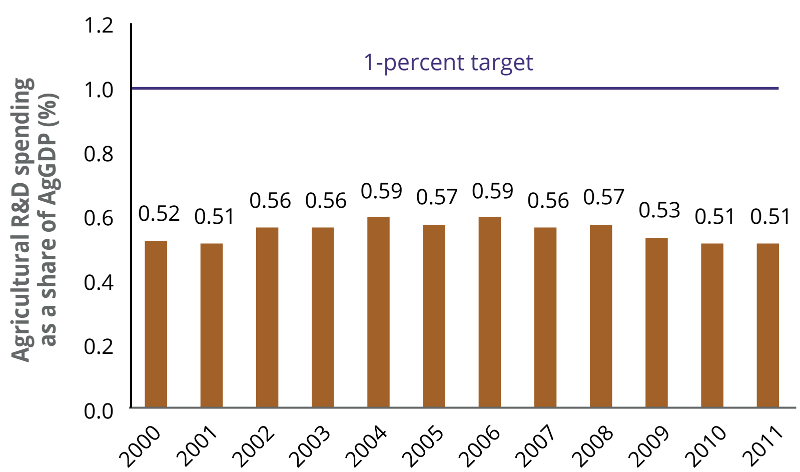


FIGURE 7.3 | Regional public research intensity ratios, 2000–2011



Sources: Constructed by authors from ASTI data.

Yearly growth in African agricultural R&D spending during 2000–2011 averaged 2.7 percent, nearly half the minimum 5-percent target proposed by the United Nations for 2015–2025.

for agriculture, and especially for agricultural R&D, has been difficult. One reason for this is the inherently long gap between the time investments in research are made and the attainment of tangible benefits. The inability to extract short-term political credit acts as a disincentive on the part of policymakers to commit to such investments.

Examples from DR Congo and Ethiopia—SSA's second- and third-most populous countries—clearly highlight the underinvestment challenge that many countries are facing. In 2011, DR Congo invested just $16 million or 0.17 percent of AgGDP in agricultural R&D, and Ethiopia invested $78 million or 0.22 percent of AgGDP. Spending would need to increase sixfold in DR Congo and fivefold in Ethiopia to reach the 1-percent target. For most small and medium-sized countries, even the 1-percent investment target is inadequate to support their agricultural R&D needs, which limits them to adapting technologies developed elsewhere.

Although intensity ratios provide useful insights into relative investment levels across countries and over time, they fail to take into account the policy and institutional environment within which agricultural research occurs, the broader size and structure of a country's agricultural sector and economy, or qualitative differences in research performance across countries; hence, they should be interpreted with care. Despite these limitations, intensity ratios do show that public support for agricultural R&D in most SSA countries is still far too low to sustain viable agricultural R&D programs capable of addressing current and future priorities. In a large number of the region's countries, a significant majority of government funding is allocated to staff salaries, leaving comparatively small shares to support the actual day-to-day costs of running research programs (see Section 8).

8| High Donor Dependency

FUNDING FOR AFRICAN AGRICULTURAL R&D IS DERIVED FROM A VARIETY OF SOURCES, including support from national governments, contributions from donors, loans from development banks, taxes on producer organizations, initiatives by the private sector, and revenues generated through the sale of goods and services (Figure 8.1). A significant degree of cross-agency and cross-country variation exists in the funding of agricultural R&D. In some countries, national government funding dominates, whereas in other countries agencies are extremely dependent on donors and development banks. In certain countries R&D agencies generate revenues to support their activities internally, whereas in other countries such revenues are returned to the national Treasury, which discourages agencies from pursuing this income stream. Numerous countries have established funding systems that mobilize private resources, either through subscription dues or a tax on production or exports.

African agricultural R&D is much more dependent on donor and development funding compared with other developing regions around the world (even though this type of funding is negligible in many middle-income countries in southern Africa or in countries afflicted by political unrest). Overall, in 2011 roughly 60 percent of the funding to NARIs across SSA (excluding Nigeria, South Africa, and a number of smaller countries) was provided by national governments; funding from donors and development banks constituted close to 30 percent. These regionwide averages mask considerable cross-country variation. The principal agricultural R&D institutes in Burkina Faso, Madagascar, and Mali,

Compared with other developing regions, SSA is highly dependent on donor and development bank funding for agricultural R&D.

In an attempt to maximize economies of scale and reduce duplication of effort across neighboring countries, the World Bank has adopted a regional approach to financing African agricultural R&D in recent years.

for instance, derived between 60 and 75 percent of their total funding from donors and development banks in 2011. Although overall shares were lower in other countries, donors are still an important source of funding for agencies in many countries.

It is important to stress that in most countries, the bulk of government funding is allocated to salaries, so the costs of operating actual research programs and of developing and maintaining R&D infrastructure and equipment are highly dependent on donor contributions (Figure 8.2). This being the case, donors and development banks can have a disproportionate influence on critical decisionmaking processes, potentially skewing the research agenda toward short-term goals that may not necessarily be aligned with national and (sub)regional priorities.

Donor and development bank funding to African agricultural R&D has been on the rise in recent years after prior contractions. The World Bank has been a major contributor to the institutional development of agricultural research in Africa in the form of country projects financed through loans and supplemented by grants. Projects have variously focused purely on agricultural R&D (the more common approach in the 1980s and 1990s) or on agriculture more generally, while including an agricultural R&D component (the more common approach in the 2000s). Some projects aimed to reshape the entire NARS, whereas others focused on specific crops, agencies, or general research management and coordination. As of the mid-2000s, the World Bank shifted from a country-level to a regional approach to financing agricultural R&D in Africa through the model of regional productivity programs (WAAPP in West Africa, EAAPP in East Africa, and APPSA in Southern Africa). The goal was to facilitate regional cooperation in generating and disseminating agricultural technologies, and to establish a more differentiated research agenda through national centers of specialization or excellence that serve regional research priorities. This is an interesting attempt to maximize economies of scale and reduce duplication of effort across neighboring countries. Administratively, these programs are highly complex because World Bank loans are structured nationally, not regionally. Aside from the World Bank, a large number of other bilateral and multilateral donors, development banks, and private foundations fund agricultural R&D activities in SSA.

FIGURE 8.1 | Relative shares of public research funding by source, selected institutes 2011

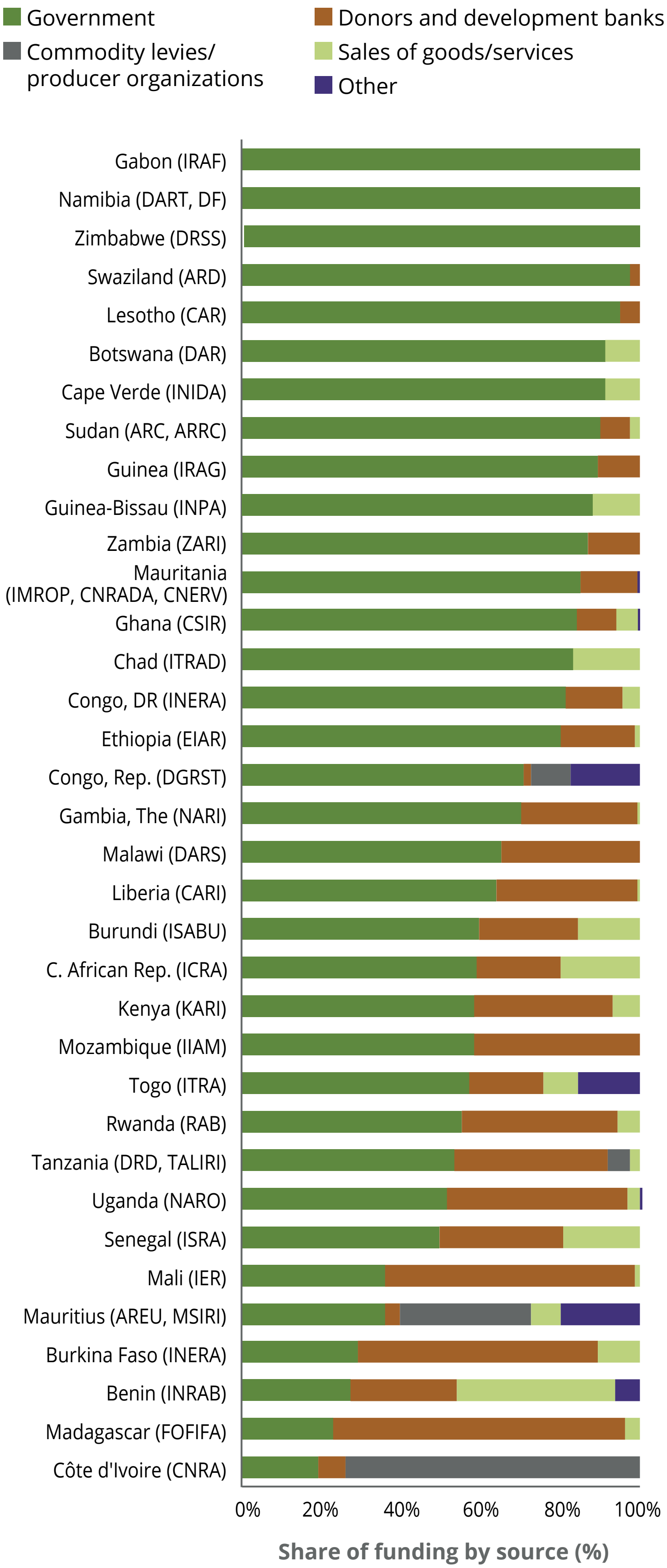
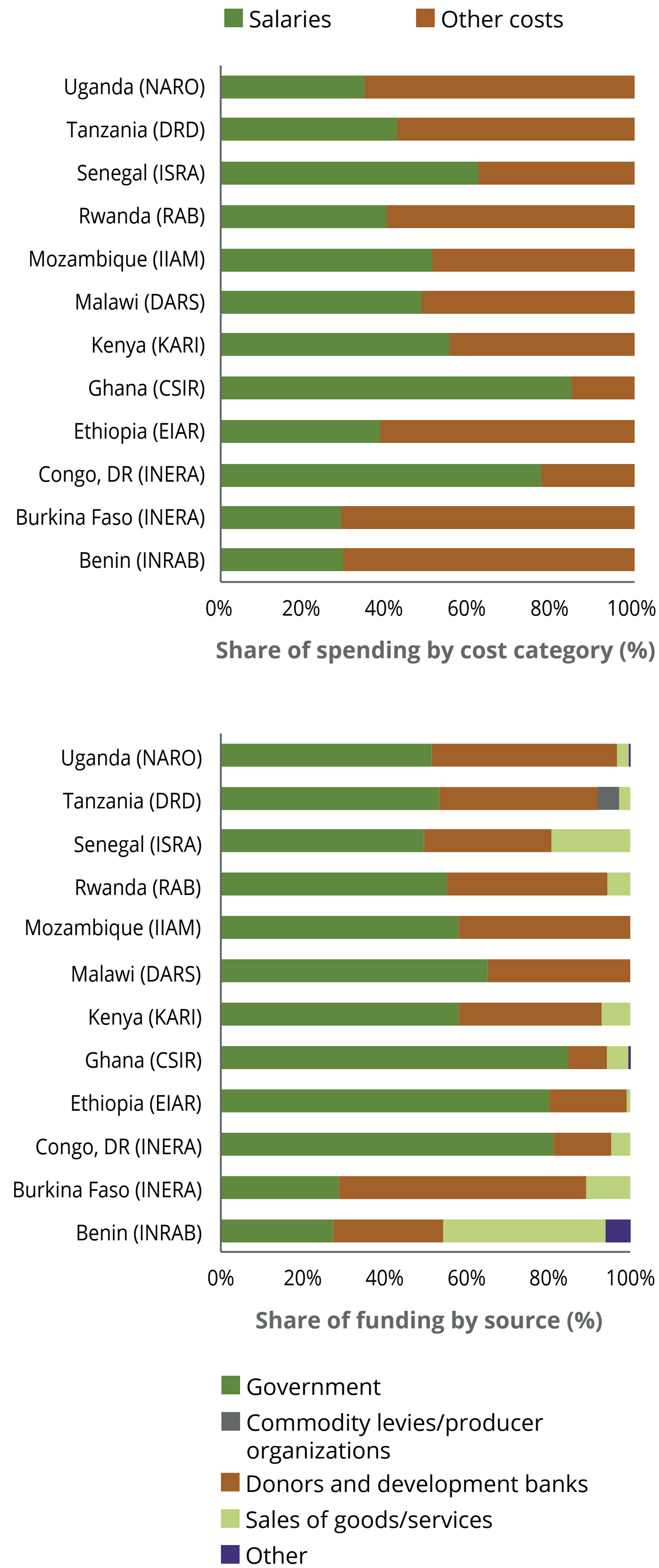


FIGURE 8.2 | Comparison of public research spending allocations and funding sources, selected institutes 2011



Sources: Constructed by authors from ASTI data.

9| High Funding Volatility

Agricultural R&D funding in SSA is more than twice as volatile as funding in Latin America or the Asia–Pacific region. African research agencies that are highly dependent on funding from donors and development banks are more vulnerable to funding shocks than those that depend mostly on government funding.

AGRICULTURAL R&D INVESTMENT IS POSITIVELY ASSOCIATED WITH HIGH RETURNS, but these returns take time—commonly decades—to develop.[6] Consequently, the inherent time lag between the inception of research and the adoption of a new technologies calls for sustained and stable R&D funding. However, long-term spending data reveal that agricultural R&D funding in many SSA countries has been far from stable over time and that R&D spending for the region as a whole shows higher volatility compared with spending in other developing regions of the world. Severe fluctuations in yearly agricultural R&D funding significantly complicate and compromise long-term budget, staffing, and planning decisions, all of which affect the continuity and outcomes of research. Large fluctuations in yearly investment levels thus hinder the advancement of technical change and the release of new varieties and technologies in the long run, in turn negatively affecting agricultural productivity growth and poverty reduction.

Understandably, a large degree of variation was recorded across SSA countries. Those with the highest degree of fluctuation in yearly agricultural R&D spending were Burkina Faso, Gabon, Mauritania, Sierra Leone, Sudan, and Tanzania (Figures 9.1 and 9.3). In contrast, yearly agricultural R&D spending in countries like the Republic of Congo, Rwanda, and South Africa was found to be more stable. It is important to note that volatility in spending at the agency level is typically higher than at the country level because aggregate fluctuations tend to hide idiosyncratic spending shocks. Similarly, spending in SSA as a whole is less volatile than spending in individual countries, which again is not surprising.

Agricultural R&D agencies in different SSA countries derive their funding from a variety of sources (Section 8). Shifts in yearly allocations from one or more funding sources can therefore have a large positive or negative impact on overall agricultural R&D spending levels. Governments, for example, are often forced to adjust previously approved funding levels downward during the budgetary year in response to revenues that are ultimately lower than anticipated or due to shifts in government funding priorities. Donor and development bank funding can also be a major cause of volatile agricultural R&D spending over time. This type of funding is typically short-term and ad hoc, and in many instances the completion of large donor-funded projects can cause abrupt drops in national agricultural R&D spending. Rising or falling world market prices for cash crops can also have a significant impact on funding levels, especially those derived through a direct tax on production or exports of a certain crop.

FIGURE 9.1 | Long-term fluctuations in yearly public research spending, selected countries

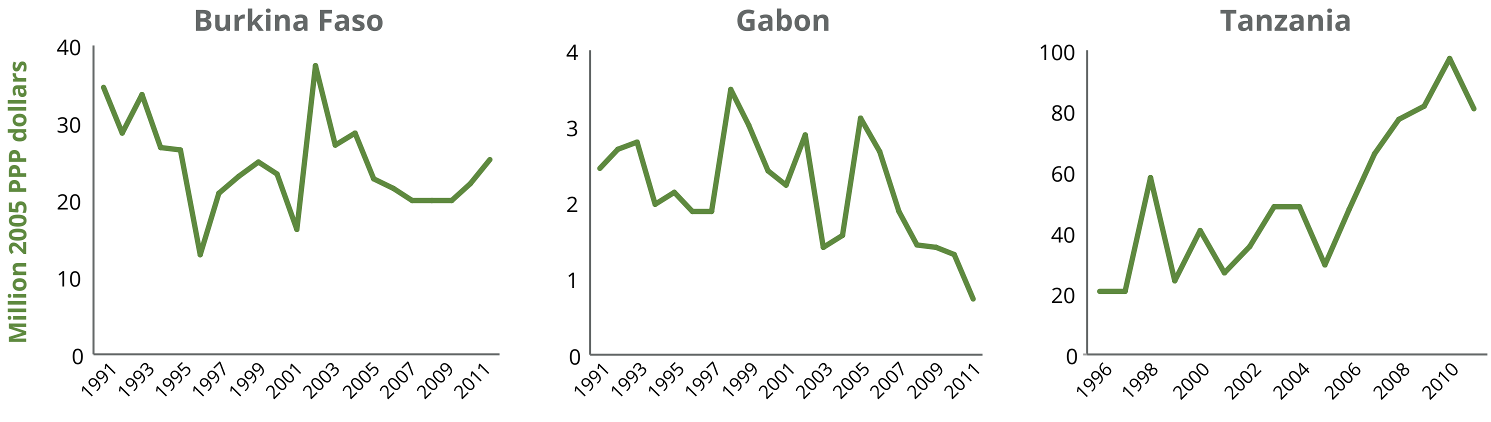
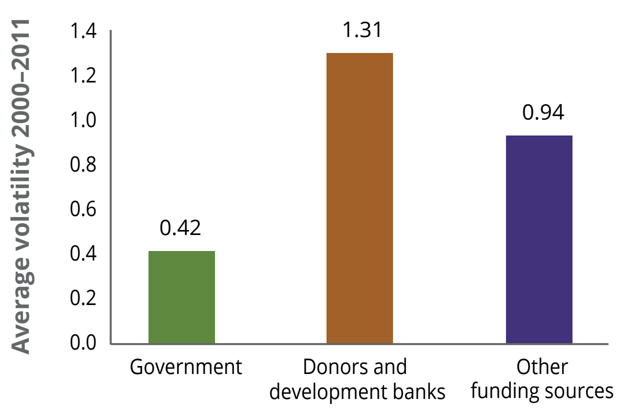


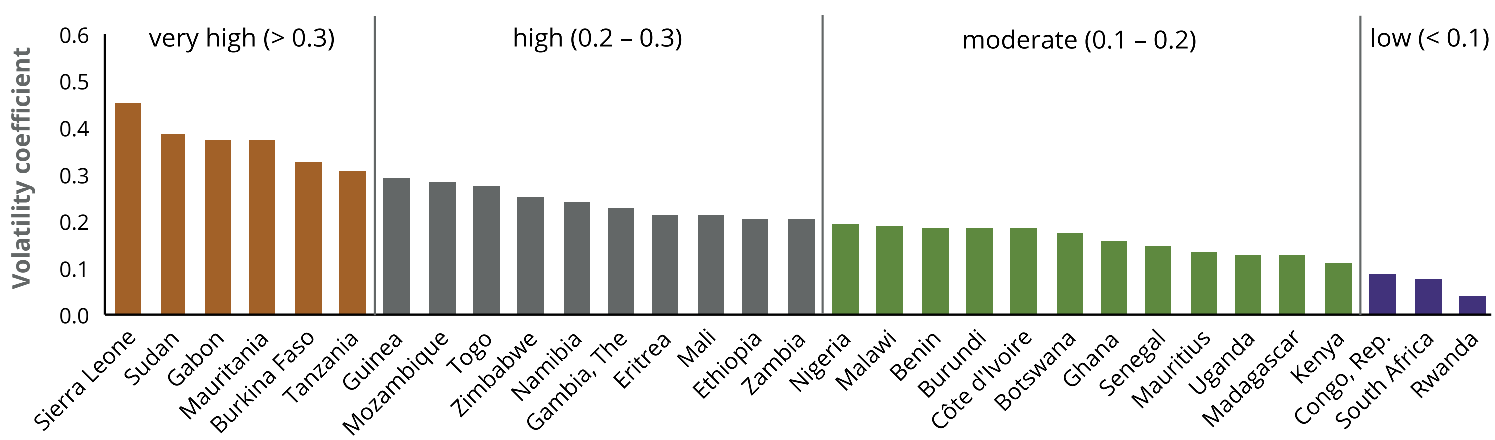
FIGURE 9.2 | Regional average volatility coefficients by funding source, 2001–2011



Quantifying volatility in public research spending

The so-called volatility coefficient quantifies volatility in agricultural research spending by applying the standard deviation formula to average one-year logarithmic growth of agricultural R&D spending over a certain period. Volatility coefficients were calculated based on complete time-series data on public R&D spending for the 2001–2011 period. A value of 0 indicates "no volatility," countries with values between 0 and 0.1 were classified as having "low volatility," countries with values between 0.1 and 0.2 were considered to have "moderate volatility," and countries with values above 0.2 fell into the "high volatility" category. The mean 2001–2011 volatility coefficient for the 31 SSA countries totaled 0.22.

FIGURE 9.3 | Volatility coefficients for public research spending by country, 2001–2011



Sources: Constructed by authors from ASTI data.

A breakdown of volatility by funding source reveals that overall funding from donors and development banks to African agricultural R&D was more than three times more volatile over the 2001–2011 period than government funding, which itself was far from stable (Figure 9.2). Funding from producer organizations and commodity boards, internally generated resources through the sale of goods and services, and other funding sources also showed relatively large fluctuations from year to year. Interestingly, average institute-level volatility is lower than the volatility within individual funding sources, indicating that in many cases shocks in one funding source are to some extent absorbed by reverse shocks in others.

BOX 9.1 | MORE R&D INVESTMENT NEEDED TO FUEL PRODUCTIVITY GROWTH

Much evidence shows that investments in agricultural R&D have tremendously enhanced agricultural productivity in recent decades, representing significant progress in the region. From the mid-1990s, regional agricultural output in SSA grew at an average rate of 3.5 percent per year, compared with only 1.1 percent per year during 1971–1985 (less than the average 2.8 percent population growth for the period). It is important to understand what drives improved agricultural performance. Total factor productivity (TFP) measures the rate of total agricultural output growth relative to production inputs—that is, land, labor, capital, and materials—used. TFP is a comprehensive measure of how improvements in technology, efficiency, and scale allow greater agricultural supply from the same or fewer resources. Positive TFP growth implies that more output can be produced with the same amount of inputs (or that the same amount of output can be produced with fewer inputs). These questions are also important in the context of sustainable future productivity growth in light of natural resource constraints, growing population pressure, and emerging issues like climate change, all of which will require more efficient use of inputs and new technologies that increase productivity.

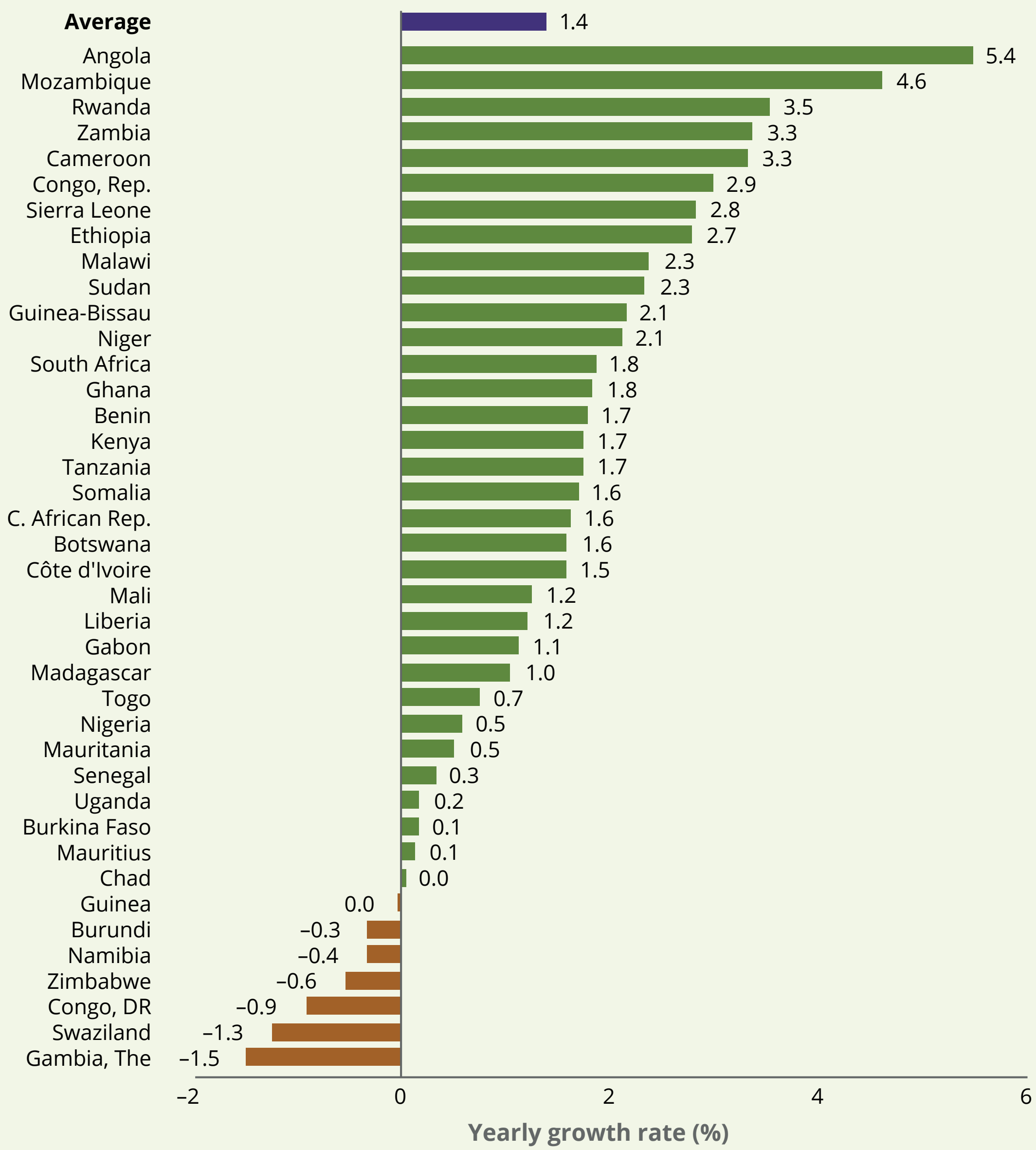
Based on a sample of 40 SSA countries for the period 1971–2011, yearly growth in output per worker averaged 0.5 percent, differentiated across two time periods. A first period of poor performance and decline stretched from the early 1970s to the mid-1990s, during which time TFP growth was –0.3 percent. This was followed by a period of recovery and improved performance from the mid-1990s until 2011 (the end of political unrest in some countries, major policy changes in Ghana and Nigeria, and the 1994 devaluation of the CFA Franc), wherein growth in output per worker averaged 1.6 percent per year. TFP was the main driver of growth in output per worker from the mid-1990s until 2011, growing at an average rate of 1.4 percent. As a result, 80 percent of growth in output per worker can be attributed to TFP growth, whereas increased inputs explain the remaining 20 percent.

Naturally, TFP growth varied widely across SSA countries. Growth rates of over 2.0 percent were recorded in a group of 11 countries, including Angola, Ethiopia, Malawi, Mozambique, Sudan, and Zambia. A further group of eight countries averaged growth rates of between 1.0 and 2.0 percent, including Côte d'Ivoire, Ghana, Kenya, and Tanzania (Figure 1). Weighting TFP growth rates by each country's share of the regional agricultural labor force reveals that just five countries were responsible for two-thirds of SSA's total growth in output per worker between 1995 and 2011 (Angola, Ethiopia, Malawi, Sudan, and Tanzania), and seven countries were responsible for 75 percent of total TFP growth for the same period (the previously mentioned five countries, plus Mozambique and Nigeria).

The increased agricultural productivity in the region was brought about by more efficient use of inputs following policy reforms in the 1980s and 1990s, whereas gains from improved technologies were only modest. With policy reforms that have now run their course, future agricultural growth will increasingly depend on technological change, which will require greater investment in agricultural R&D.

Agricultural R&D agencies in SSA, particularly in the region's low-income countries, are more dependent on funding from donors and development banks than their counterparts in other developing regions, and this type of funding has shown considerably greater volatility over the past decade compared with government funding. In a large number of SSA countries, donors fund the bulk of nonsalary-related expenditures (Section 8), and there is extensive anecdotal evidence of agencies reverting into financial crisis upon the completion of large donor-funded projects.

FIGURE 1 | Average rates of TFP growth, 1995–2011



10| Policy Implications

GOVERNMENTS AND RESEARCH AGENCIES are limited in their choice of options to address the many challenges they face in developing their NARSs because of funding constraints. Nevertheless, areas exist where increased strategic planning and coordination could make a significant difference—especially in the area of human resource management. Moreover, successful policy changes already adopted in certain countries offer valuable lessons for other countries. ASTI's recent work with its national partners in SSA reveal the following implications for national policy.

Human Resources

Fundamental to building strong human resource capacity in agricultural research is the development of comprehensive recruitment, training, and succession plans to fill existing and anticipated staffing gaps medium- to long-term. Such plans should include assessments of gaps in specific skills and disciplines, the distribution of staffing by age and gender, and degree-level and short-term training needs. Skills assessments should also include fundamental skills (such as proposal writing) and targeted training requirements (such as program management and research design). An implementation plan is required for the management and provision of training and mentoring, especially given that many countries now have high shares of junior scientists, often only trained to the BSc degree level. In some countries the establishment and expansion of postgraduate training programs would be a viable solution to providing the needed supply of qualified agricultural scientists. Training opportunities should also be sought through bilateral cooperation with countries that already have strong agricultural research systems and higher education networks.

Obviously countries and institutions with uncompetitive salary and benefits packages need to take steps to redress these barriers. In a large number of countries, significant discrepancies exist in the salary and benefits packages offered to government researchers compared with their university-based colleagues. Furthermore, advocating an increase in the retirement age to 65 years for those agencies with lower mandatory retirement ages would ameliorate the impending loss of senior researchers to retirement in the short- to medium-term, and establish parity in retirement ages between the government and higher education sectors in countries where it is lacking. The ability to employ recently retired researchers as consultants on a contract basis is another valuable approach to training and mentoring junior scientists during a transition period and maintaining continuity in the stock of institutional knowledge.

Equally important is establishing and more strictly enforcing policies requiring scientists to return to their sponsoring organizations for a minimum term of employment upon completing their postgraduate training. Improving service conditions and incentives is another key factor in building a strong core of motivated research professionals and inspiring their long-term commitment. Integral to this process is the provision of a supportive working environment that allows researchers to develop; to achieve and advance in their careers; and to collaborate with national, regional, and international partners. Institutional reforms and policies that promote gender equality and provide an attractive working environment for women are also needed.

Finally, all this depends on the allocation of a stable and continuous stream of sufficient financial resources, which is discussed next.

EXAMPLES OF RECENT POLICY RESPONSES TO HUMAN RESOURCE CHALLENGES

Burkina Faso, Ghana, Kenya, Senegal, Sierra Leone, and Nigeria. In efforts to curb high turnover of NARI-based researchers, the governments of these countries have increased salary levels, often to introduce parity with researchers employed in the higher education sector. This measure has significantly improved staff morale and motivation, as well as the attrition rate. Related incentive measures instituted include scholarships, paid study leave, and the ability to engage in consultancies and even accept part-time teaching positions at nearby universities (Kenya), as well as greater opportunities for merit-based career advancement (Kenya and Senegal).

Burkina Faso, Senegal, Sudan, and Togo. The governments in several countries provided funding for and approved the recruitment of large numbers of researchers often after long periods of public-sector recruitment freezes.

Burundi. A 2009 law improving faculty salary levels prompted most of the Burundian nationals who had sought better paying positions in Rwanda to return to the National University of Burundi.

Eritrea and Uganda. Eritrea has one of the youngest and least-qualified pools of agricultural researchers in Africa, so the National Agricultural Research Institute (NARI) and Hamelmalo Agricultural College are collaborating to develop a PhD program at HAC, and the government has increased its support to make this possible. In Uganda, collaboration between the National Agricultural Research Organisation (NARO) and Makerere University is even more extensive; the two organizations are working together to strengthen human resource capacity, develop and implement research projects, and share and build on their knowledge bases.

Guinea, Madagascar, and Sudan. The governments in several countries have raised the official retirement age for public agricultural researchers, which gives the institutes extra time for senior staff to train and mentor their junior colleagues, and acts as an incentive for researchers to pursue higher training (because they can gain financial and career benefit from it over a longer timespan).

Rwanda. To capitalize on recent progress and ensure a sufficient pool of well-qualified researchers, the government has supported the development of a number of MSc and PhD programs in agricultural sciences at the University of Rwanda, which was recently established through the merger of the countries public universities.

EAAPP/WAAPP/APPSA. Capacity building plays a major role in the World Bank loan–funded agricultural productivity programs in East, West, and Southern Africa (EAAPP, WAAPP, and APPSA). Many researchers and technicians are already benefiting from postgraduate and short-term training, and many more are expected to take advantage of this opportunity in the coming years.

Financial Resources

Sufficient, stable, and sustainable levels of government funding are key to establishing and maintaining viable agricultural research programs that achieve tangible results. While many governments have increased their commitment to agricultural research, funding is still often insufficient for the day-to-day operation of research programs. Government funding is necessary not just for competitive researcher salaries, but also to support the fundamental nonsalary-related expenses required to conduct research. This includes fundamentals like office space and equipment, computer hardware and software, water and electricity, telecommunications infrastructure, as well as appropriate laboratory and field infrastructure and equipment. Rather than relying too much on donors and development banks to fund critical research areas, governments need to more clearly identify their own long-term national priorities and design relevant, focused, and coherent agricultural R&D programs accordingly. Donor and development bank funding needs to be closely aligned with these national priorities, and consistency and complementarities among donor programs need to be assured. Mitigating the effects of any single donor's abrupt change in aid disbursement is crucial, highlighting the need for greater funding diversification, for example, through the sale of goods and services, or by attracting complementary investment from the private sector.

EXAMPLES OF RECENT POLICY RESPONSES TO FUNDING CHALLENGES

Benin. With a decline in donor funding, the National Agricultural Research Institute of Benin (INRAB) has had to develop alternative sources of financing. As of 2011, two-thirds of the institute's program costs were funded internally, predominantly through the sale of germinated palm oil seeds and the sale of rice, maize, and cowpea seed.

Côte d'Ivoire. The National Center for Agricultural Research (CNRA) is unique to the region in that it was established as a public–private entity that derives 40 percent of its funding from the government and 60 percent from the private sector. Private funding is raised through membership subscription dues from commodity-specific producer organizations, and at least 75 percent of funding raised in a given subsector is allocated to programs serving the needs of that subsector.

Ghana. The Ghanaian government has set a goal that institutes generate a significant share of their financial resources through commercial means. While this is a sound long-term goal, it is impeded in the short- to medium-term given the levels of funding required, lack of CSIR's capacity to generate funds internally, and patent issues.

Sudan. The Sudanese government not only began to increase its funding for national agricultural research in 2013 after severe declines in previous years, but also became an official CGIAR member, which is expected to attract new research projects and funding.

EAAPP/WAAPP/APPSA. The World Bank–led agricultural productivity programs support the NARIs involved by rehabilitating research laboratories and equipment for the priority crops identified. The programs are also addressing fundamental needs through investments in broadband Internet service, electrical generators, and vehicles. One side effect of the increased regionalization of agricultural research arising from these programs is a set of complex intellectual properties rights issues that urgently need to be resolved.

The private sector is currently the least developed source of sustainable financing for agricultural R&D in SSA, and its funding potential remains largely untapped in most countries. Cultivating private funding involves providing a more enabling policy environment by national governments in terms of tax incentives, protection of intellectual property rights, and regulatory reforms to encourage the spill-in of international technologies. Collective action by farmers and related agribusinesses (through formal producer organizations) also has the potential to generate additional resources for agricultural research in a number of countries in the region. An added benefit of this funding mechanism is that decisionmaking on the use of the resulting funds would generally rest with producers and other stakeholders in the relevant value chain.

Institutional and Policy Environment

Given the tremendous constraints that many countries are facing in terms of funding, human resource capacity, and infrastructure, scarce resources need to be used more effectively. For this to be possible, governments need to provide the necessary policy environment to eliminate competition and stimulate cooperation among agricultural research agencies at national, subregional, regional, and international levels. Another fundamental step is the establishment of long-range agricultural research policy agendas accompanied by necessary implementation, operating, and monitoring and assessment plans, and the development of the necessary expertise to enact these plans.

At the national level, it is extremely important for NARIs to have a sufficient level of autonomy to build human resource capacity; attract and generate

EXAMPLES OF RECENT POLICY RESPONSES TO INSTITUTIONAL AND POLICY CHALLENGES

Kenya. The government is restructuring public agricultural research by merging various government and nonprofit agencies under the Kenya Agricultural and Livestock Research Organization (KALRO) to streamline and coordinate the country's agricultural research system. This will eventually lead to greater efficiency and effectiveness in addressing diverse national development goals within the context of limited human, financial, and physical resources.

Namibia, Republic of Congo, and Tanzania. Following a prevalent trend in the region since the 1980s, several countries have restructured or committed to restructuring their government agricultural research agencies into semiautonomous bodies to enable the institutional flexibility needed to operate efficiently, competitively, and synergistically.

Senegal. The Senegalese Agricultural Research Institute (ISRA) was recently brought back under the administrative responsibility of the Ministry of Agriculture for the purpose of integrating research more closely with its end users. Regardless, collaboration between ISRA and Senegal's agricultural extension system remains weak, and the two functions can even compete for scarce resources rather than cooperating within the context of the broader agricultural innovation system.

funding; interact locally with the higher education sector, extension providers, and farmer organizations; and collaborate within the broader spectrum of innovation. In a few countries, government agencies have been given semi-autonomous status to decouple them from some of the restrictive administrative constraints of the public sector and allow them to set their own human resource, financing, and institutional procedures. For example, agencies in many countries are restricted in offering competitive salary levels due to civil service staffing classifications; with semiautonomous status institutes can set their own pay scales outside the public service system.

Ensuring the dissemination and uptake of new technologies is another key area requiring attention. Governments must take action to see that newly released varieties and technologies reach farmers. This involves strengthening extension agencies, more clearly delineating the roles of research agencies and extension services, and promoting active cooperation between the two functions.

Notes

1| United Nations Sustainable Development Solutions Network (UNSDSN), *Solutions for Sustainable Agriculture and Food Systems: Technical Report for the Post-2015 Development Agenda* (New York: United Nations, 2013).

2| Due to lack of available data, private for-profit research is excluded from the analysis in this report. See Box 2.1 for definitions of key concepts, such as PPPs and FTEs.

3| The countries not included in ASTI's analysis are Angola, Cameroon, Comoros, Djibouti, Equatorial Guinea, São Tomé and Príncipe, Seychelles, Somalia, and South Sudan.

4| For example, in terms of working hours and opportunities to collaborate with other agencies, take sabbaticals, or accept paid consultancies.

5| Beintema, N., and F. Di Marcantonio, *Female Participation in African Agricultural Research and Higher Education: New Insights, Synthesis of the ASTI–Award Benchmarking Survey on Gender-Disaggregated Capacity Indicators*, IFPRI Discussion Paper 957 (Washington, DC: International Food Policy Research Institute and African Women in Agricultural Research and Development, 2010).

6| See Box 9.1 for a discussion of regional productivity trends.

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