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ASTI Synthesis Report

A Comprehensive Overview of Investments and Human Resource Capacity in African Agricultural Research

Nienke Beintema and Gert-Jan Stads

APRIL 2017

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CGIAR RESEARCH PROGRAM ON Policies, Institutions, and Markets Led by IFPRI

About ASTI

Extensive empirical evidence demonstrates that agricultural research 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 research 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 (PIM), 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 (when possible) private agricultural research 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.

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Related ASTI Outputs

- ASTI country factsheets, which contain a visual, highly accessible presentation of recent institutional, financial, and human resource trends in national agricultural research. The factsheets also feature a more in-depth analysis of some of the key challenges that individual agricultural research systems are currently facing, and policy options to address these challenges.
- Interactive country pages, available at https://www.asti.cgiar.org/countries, allow users to access detailed investment and human resource trends in agricultural research, and download factsheets and other information.
- ASTI's country benchmarking tool for Africa south of the Sahara, available at https://www.asti.cgiar.org/benchmarking/ssa, enables cross-country comparisons and rankings of key ASTI indicators.
- ASTI's data download tool, available at https://www.asti.cgiar.org/data, allows users to explore in-depth datasets, to filter the data by country and indicator, and to view the data graphically.
- ASTI's agency directory, available at https://www.asti.cgiar.org/directory, allows users to search and filter agencies by a number of criteria, including by country, and to locate agencies on a map.

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List of Acronyms

AgGDP	agricultural gross domestic product
APPSA	Agricultural Productivity Program for Southern Africa
ARC	Agricultural Research Council (South Africa)
ARCN	Agricultural Research Council of Nigeria
ASTI	Agricultural Science and Technology Indicators
CAADP	Comprehensive Africa Agriculture Development Programme
CAAPP	Central Africa Agricultural Productivity Program
CARBAB	African Research Center for Bananas and Plantains (Cameroon)
CIAT	International Center for Tropical Agriculture
CIFOR	Center for International Forestry Research
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CNRA	National Center for Agronomic Research (Côte d'Ivoire)
CRO	Center for Oceanographic Research (Côte d'Ivoire)
CSIR	Council for Scientific and Industrial Research (Ghana)
DAR	Department of Agricultural Research (Botswana)
DAR	Department of Agricultural Research (Lesotho)
DARD	Directorate of Agricultural Research and Development (Namibia)
DARS	Department of Agricultural Research Services (Malawi)
DARSS	Department of Agricultural Research and Specialist Services (Swaziland)
DGRST	General Delegation of Scientific and Technical Research (Republic of Congo)
DRSS	Department of Research and Specialist Services (Zimbabwe)
DAR	Department of Agricultural Research (Botswana)
EAAPP	East Africa Agricultural Productivity Program
EIAR	Ethiopian Institute of Agricultural Research (Ethiopia)
FARA	Forum for Agricultural Research in Africa
FAREI	Food and Agricultural Research Extension Institute (Mauritius)
FOFIFA	National Center for Applied Research in Rural Development (Madagascar)
FTE(s)	full-time equivalent (researchers)
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institute of Rural Economy (Mali)
IFPRI	International Food Policy Research Institute
IIAM	Mozambique Institute of Agricultural Research
IIP	National Institute of Fisheries Research (Mozambique)
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INERA	Institute of Environmental and Agricultural Research (Burkina Faso)
INERA	National Agricultural Study and Research Institute (DR Congo)

List of Acronyms *continued*

INIDA	National Institute of Agricultural Research and Development (Cabo Verde)
INRAB	National Institute of Agricultural Research of Benin
INRAN	National Institute of Agronomic Research of Niger
IRAD	Agricultural Research Institute for Development (Cameroon)
IRAF	Institute of Agronomic and Forestry Research (Gabon)
IRAG	Agronomic Research Institute of Guinea
IRRI	International Rice Research Institute
IRSAT	Institute of Applied Science and Technology Research (Burkina Faso)
ISABU	Agronomic Science Institute of Burundi
ISRA	Senegalese Institute of Agricultural Research
ITRA	Togolese Institute of Agronomic Research
ITRAD	Chadian Institute of Agricultural Research for Development
IWMI	International Water Management Institute
KALRO	Kenya Agricultural and Livestock Research Organization
MAK–CAES	Makerere University–College of Agricultural and Environmental Sciences (Uganda)
MAK–COVAB	Makerere University–College of Veterinary Medicine, Animal Resources, and Biosecurity (Uganda)
MSIRI	Mauritius Sugarcane Industry Research Institute
NARI	National Agricultural Research Institute (The Gambia)
NARI(s)	national agricultural research institute(s)
NARO	National Agricultural Research Organisation (Uganda)
NARS(s)	national agricultural research system(s)
PIM	CGIAR Research Program on Policies, Institutions, and Markets
PPP	purchasing power parity (exchange rates)
RAB	Rwanda Agriculture Board
RARI(s)	regional agricultural research institute(s) (Ethiopia)
SLARI	Sierra Leone Agricultural Research Institute
SRO(s)	subregional organization(s)
SSA	Africa south of the Sahara
TRB	Tobacco Research Board (Zimbabwe)
UNAM–FANR	University of Namibia–Faculty of Agriculture and Natural Resources
UNICV–ECAA	University of Cabo Verde–College of Agricultural and Environmental Sciences
UOM	University of Mauritius
UR–CAVM	University of Rwanda–College of Agriculture, Animal Sciences, and Veterinary Medicine
UZ–FA	University of Zimbabwe–Faculty of Agriculture
WACCI	West Africa Centre for Crop Improvement
WAAPP	West Africa Agricultural Productivity Program
ZARI	Zambia Agricultural Research Institute

Introduction

Although the proportion of people living in extreme poverty has trended downward since the mid-1990s, Africa south of the Sahara (SSA) is the only developing region of the world where the absolute number of people living below $1.25 per day continues to rise. Given the forecasted acceleration of population growth in the coming decades, poverty numbers and food imports are set to increase without matching growth in agricultural production (van Ittersum et al. 2016).

Over the past 50 years, around the world, both wealth creation and competitiveness—and thus long-term growth and poverty reduction—have been driven by increases in productivity, which in turn are determined by the pace of technical change (Badiane and Collins 2016). SSA has considerably lagged behind other regions in this regard. Increased use of (relatively abundant) land, rather than improved technical efficiency, has been the main driver of agricultural production growth in SSA. However, rapid population growth and the adverse effects of climate change are increasingly putting pressure on land availability, land fertility, and water access. Given the well-documented positive impact of agricultural research investment on agricultural productivity growth and the higher returns on investment of agricultural research compared with many other types of agricultural and nonagricultural public spending (Fuglie and Rada 2016), it is critical that countries step up their investment in agricultural research and instate sound policies to promote technological and institutional innovations in the agricultural sector.

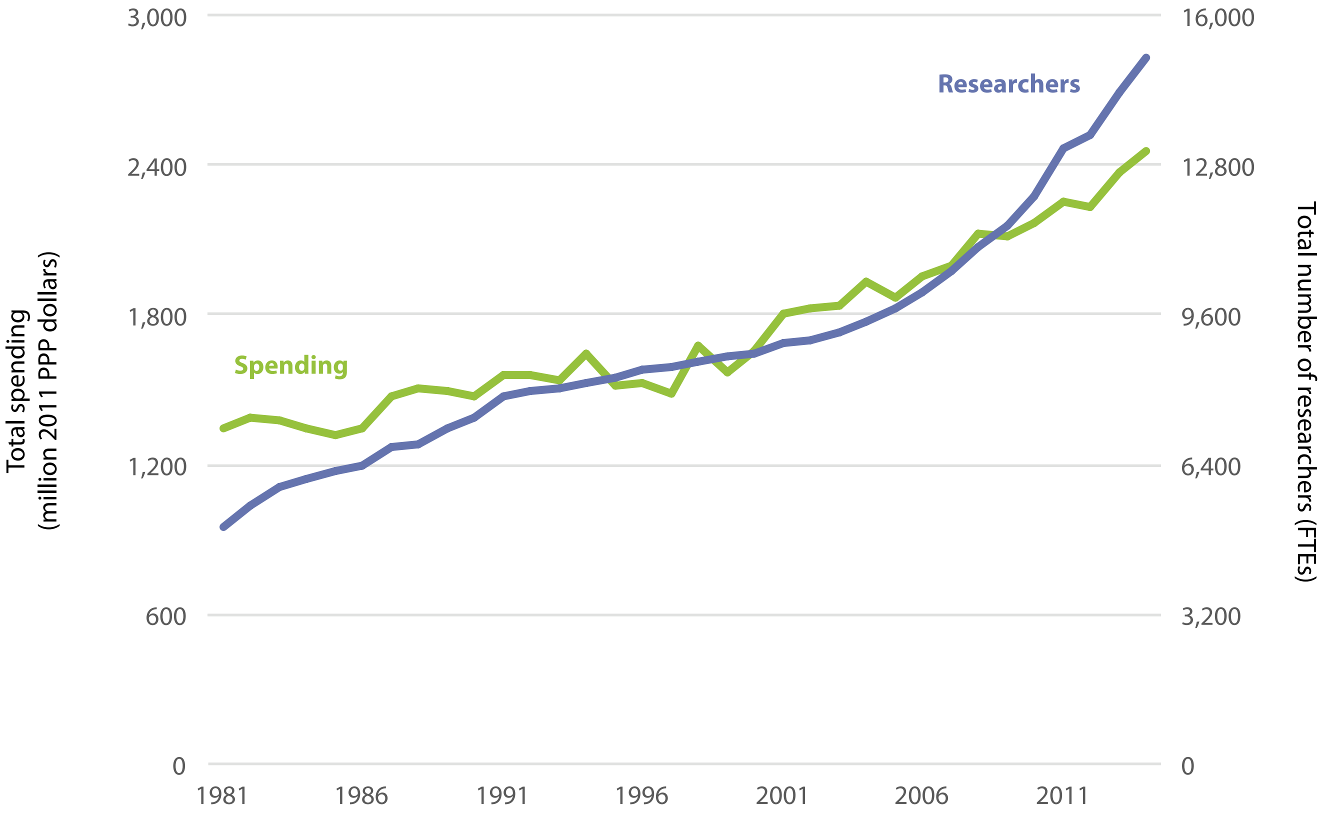
This report assesses trends in investments, human resource capacity, and outputs in agricultural research in SSA, excluding the private (for-profit) sector. The analysis uses information collected by Agricultural Science and Technology Indicators (ASTI)—led by the International Food Policy Research Institute (IFPRI) within the portfolio of the CGIAR Research Program on Policies, Institutions, and Markets (PIM). The comprehensive datasets were derived from primary surveys, collected through a series of consecutive data collection rounds; a small number of secondary sources, where survey data were missing or of poor quality; and ASTI's older investment and human resource datasets. This report highlights the cross-cutting trends and challenges that emerged from the country-level data, structuring it within four broad areas: funding capacity, human resource capacity, research outputs, and institutional conditions—all in terms of whether they support or impede the effective and efficient conduct of agricultural research. This report concludes with a set of policy recommendations for regional and national-level decision makers, and other stakeholders.

Long-Term Spending and Capacity Trends

After stagnating during the 1990s, SSA's agricultural research spending—excluding the private for-profit sector—increased considerably during 2000–2014, from $1.7 to $2.5 billion in 2011 PPP prices (Figure 1).[1] Notably, three countries accounted for nearly half of the investments made in 2014: Nigeria ($434 million), South Africa ($417 million), and Kenya ($274 million). Ethiopia, Ghana, Tanzania, and Uganda each also spent more than $100 million in 2014. In contrast, 12 of the 40 countries for which data were available spent less than $10 million on agricultural research, and most of these are in West and Central Africa (Figure 2). Ethiopia, Ghana, Nigeria, South Africa, and Uganda drove about three-quarters of the $800 million growth in agricultural research spending during 2000–2014.

SSA employed close to 15,100 full-time equivalent (FTE) researchers in agricultural and related sciences in 2014 (Box 1), representing an increase of about 70 percent over 2000 levels. Nigeria (2,975 FTEs), Ethiopia (2,768 FTEs), and Kenya (1,179 FTEs) accounted for 46 percent of SSA's agricultural researchers in 2014, and for approximately 63 percent of growth in the total number of researchers employed in SSA during 2000–2014. DR Congo, Ghana, South Africa, and Tanzania all employed between 500 and 1,000 FTE researchers in 2014. Nevertheless, many of the region's countries have considerably smaller national research systems, both in terms of size and strength: 8 of the 40 countries for which data were available employed fewer than 100 agricultural researchers in 2014 (in FTEs).

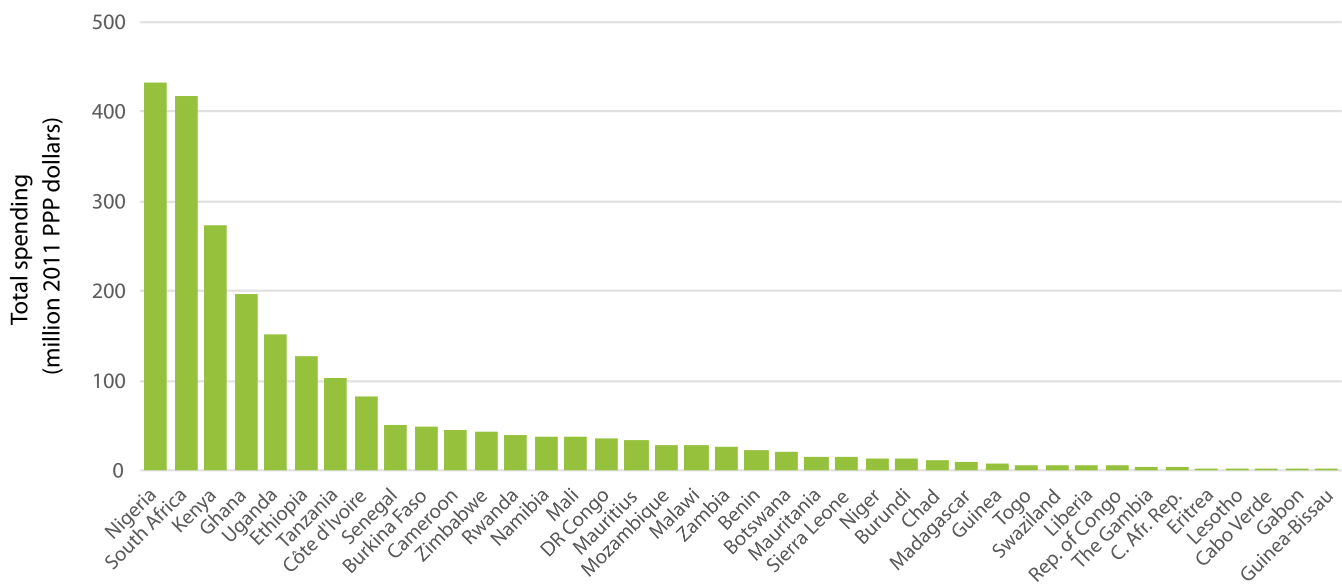
FIGURE 1 | Absolute levels of agricultural research spending and agricultural researchers, 1981–2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: Data exclude South Sudan, and were estimated for subperiods for some countries. Data on spending and researcher numbers for Angola, Comoros, Equatorial Guinea, São Tomé and Príncipe, and Seychelles were estimated for the entire period by multiplying population data for these countries with average research intensity ratios for SSA (that is, spending per capita and researcher per capita) over time.

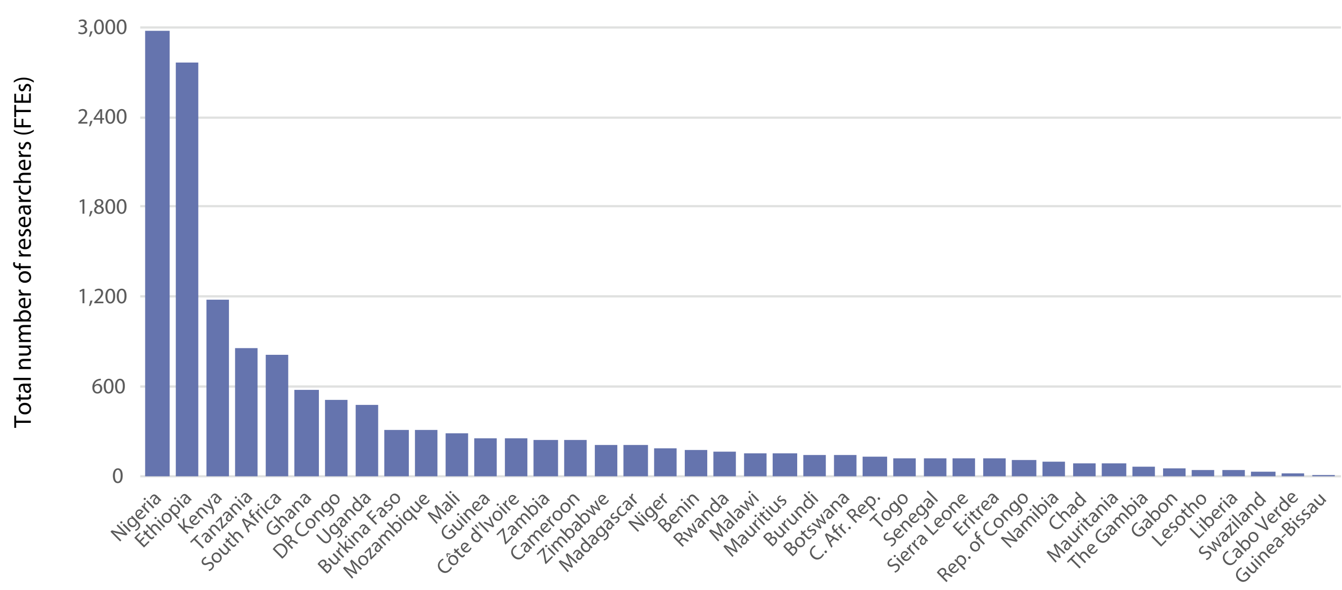
FIGURE 2 | Absolute levels of agricultural research spending by country, 2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: Values for the Central African Republic, Eritrea, Guinea-Bissau, and Liberia are based on 2011 data; the values for Nigeria and Sierra Leone include estimates for the higher education sector based on 2008 and 2011 data, respectively.

FIGURE 3 | Absolute levels of agricultural researchers by country, 2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: Values for the Central African Republic, Eritrea, Guinea-Bissau, and Liberia are based on 2011 data; the values for Nigeria and Sierra Leone include estimates for the higher education sector based on 2008 and 2011 data, respectively.

BOX 1 | QUANTIFYING AGRICULTURAL RESEARCHER NUMBERS AND RESEARCH SPENDING

Purchasing power parities as the preferred measure of research investments

Comparing research data is a highly complex process due to important differences in price levels across countries. The largest components of a country's agricultural research expenditures are staff salaries and local operating costs, rather than internationally traded capital investments. For example, the wages of a field laborer or a laboratory assistant at a research facility are much lower in Mozambique than they are in any European country; similarly, locally made office furniture in Senegal will cost a fraction of a similar set of furniture bought in the United States.

Standard market exchange rates are the logical choice for conversions when measuring financial flows across countries; however, they are far from perfect currency converters for comparing economic data. At present, the preferred conversion method for calculating the relative size of economies, or other economic data such as agricultural research spending, is the purchasing power parity (PPP) index. PPPs measure the relative purchasing power of currencies across countries by eliminating national differences in pricing levels for a wide range of goods and services. They are also used to convert current GDP prices in individual countries to a common currency. In addition, PPPs are relatively stable over time, whereas exchange rates fluctuate considerably (for example, the fluctuations in the U.S. dollar–euro rates of recent years).

The concept of full-time equivalent researchers

ASTI bases its calculations of human resource and financial data on full-time equivalents (FTEs), which take into account the proportion of time that researchers spend on research activities. University staff members, for example, spend the bulk of their time on nonresearch-related activities, such as teaching, administration, and student supervision, which need to be excluded from research-related resource calculations. As a result, four faculty members estimated to spend 25 percent of their time on research would individually represent 0.25 FTEs and collectively be counted as 1 FTE.

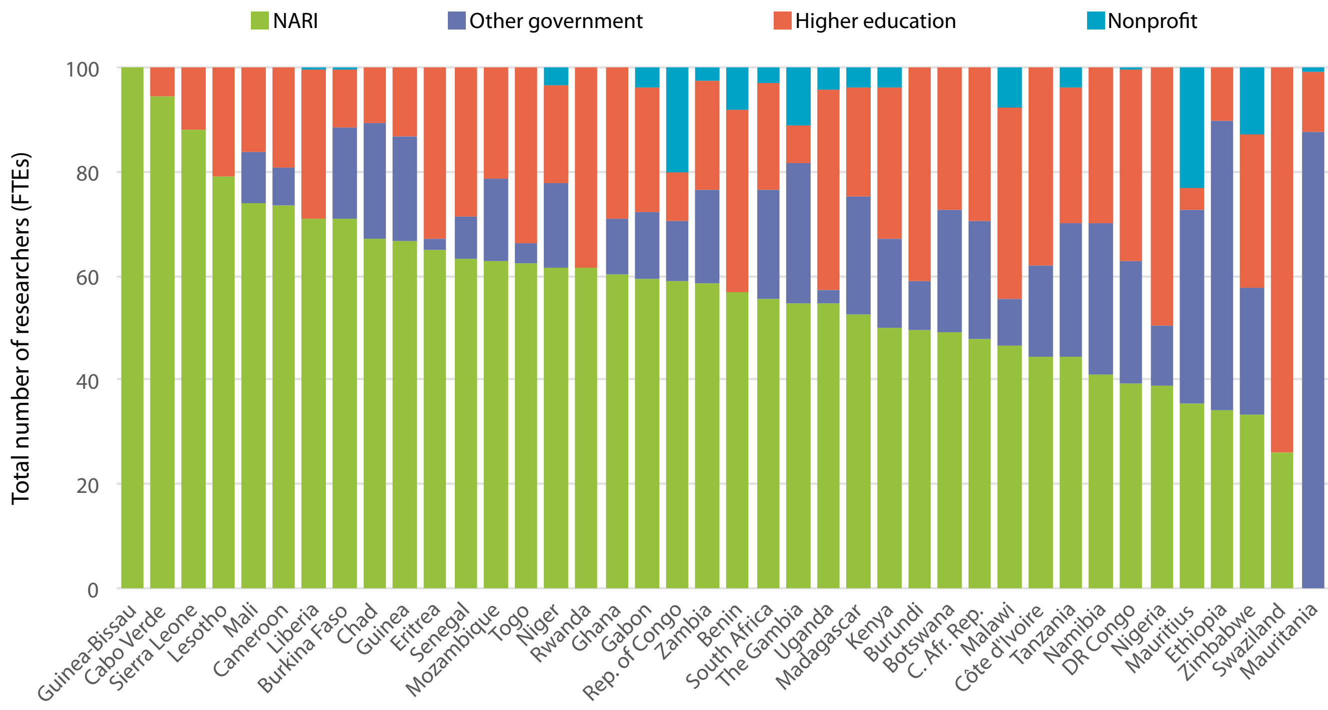
Source: ASTI (2016).

Institutional Fragmentation and Limited Collaboration

Most national agricultural research systems (NARSs) in SSA are small, but they tend to focus on the same range of issues as their large neighbors, thereby often exceeding the limits of their capacity. As a result, these smaller systems mostly conduct research to adapt technologies developed elsewhere to meet their local needs. Spillovers of relevant technologies from larger neighboring countries tend to be limited because many of the small countries are clustered together. Most NARSs in SSA also remain highly fragmented in terms of the number of individual agencies, and this has hindered the effective use of the available resources. Given the region's diversity, it is difficult to generalize about the composition of NARSs, but systems often comprise a national agricultural research institute (NARI); a number of smaller government and higher education agencies; and in some cases one or more nonprofit research entities, such as nongovernmental or producer organizations. The role of the private sector in agricultural research in SSA remains limited. NARIs across SSA are structured in a variety of ways: (1) as a research department within a ministry of agriculture or equivalent; (2) as a semiautonomous government institute with the flexibility to determine key internal policies; (3) as multiple agencies focusing on specific agricultural subsectors, such as agriculture, livestock, and forestry; and (4) as numerous institutes organized under a council. The number of higher education agencies has grown over time in many countries through the creation of new universities or new departments and faculties within existing universities. Nevertheless, NARIs still anchor the majority of NARSs (Figure 4).

Linkages across research agencies—and also between research agencies and extension providers, policymakers, and farmers' organizations—are often problematic due to the fragmentation within NARSs and lack of coordination mechanisms. Collaboration across NARSs is facilitated through three subregional organizations (SROs), the Forum for Agricultural Research in Africa (FARA), CGIAR centers, and various other organizations and initiatives. The SROs and FARA—all of which are highly dependent on unstable donor funding—do not conduct research themselves, but instead promote the conduct of regionally beneficial research by their NARS members. In addition, collaboration is promoted through three regional agricultural productivity programs funded through World Bank loans, national government contributions, and grants from the Japanese government. These programs focus on the development of national centers of excellence for a specific commodity or topic of regional relevance. The underlying idea is to create incentives for countries to share both the costs and results of mutually beneficial research, thereby maximizing scarce resources and reducing the duplication of research effort. It is too soon to determine whether this approach will achieve its desired impact (Roseboom and Flaherty 2016).

FIGURE 4 | Distribution of agricultural researchers by country and institutional category, 2014



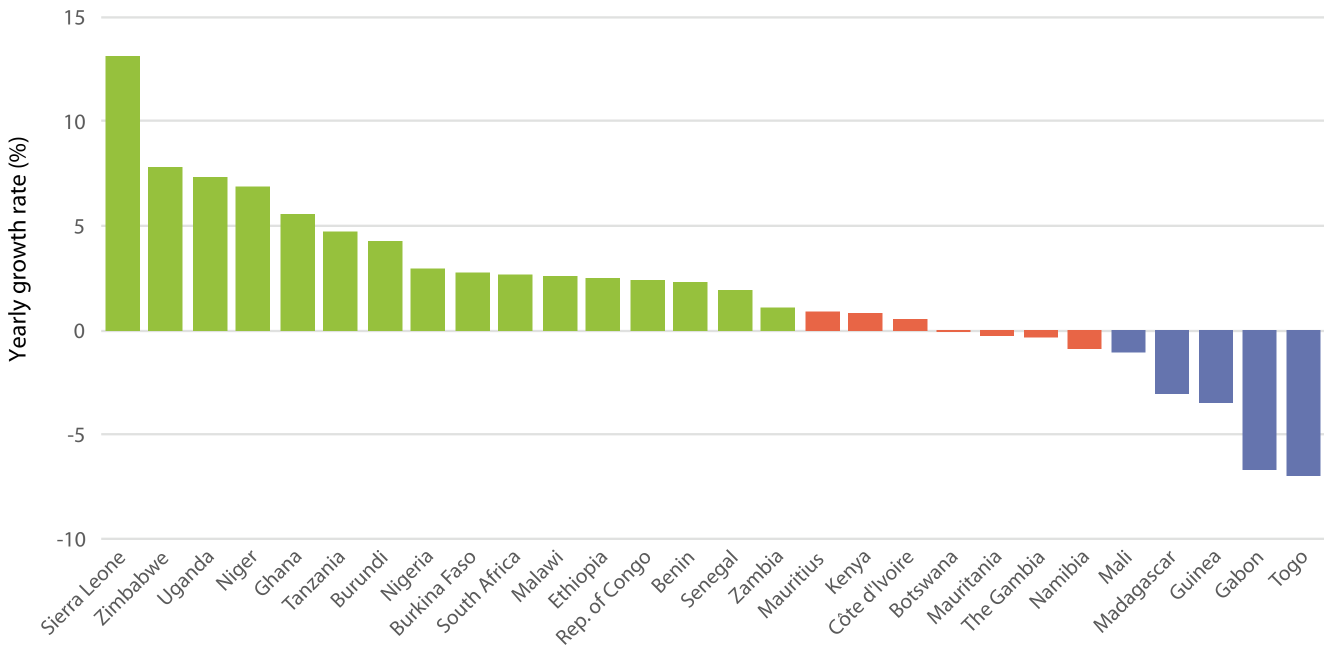
Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: Values for the Central African Republic, Eritrea, Guinea-Bissau, and Liberia are based on 2011 data; the value for Nigeria includes estimates for the higher education sector based on 2008 data.

Two-Speed Growth in Agricultural Research Spending

Despite the aforementioned growth in total agricultural research spending, the underlying national results vary considerably, with countries roughly falling into one of three categories. Sixteen of the 28 SSA countries for which a full set of time-series data was available experienced growth in public agricultural research spending in excess of 1.0 percent per year during 2000–2014; 7 countries experienced near-zero growth (at rates of between –1.0 and +1.0 percent per year); and 5 countries recorded yearly growth in excess of –1.0 percent per year (Figure 5). The large number of countries experiencing stagnant or negative yearly growth highlights a divergence in the spending levels of the region's countries, whereby numerous (generally larger) countries recorded substantial spending growth during 2000–2014, but numerous (usually smaller) countries reported the opposite. The extremely low (and often declining) long-term investment levels and human resource capacity of some of the region's smallest, often francophone, countries call into question the effectiveness of their agricultural research programs, and whether they would be better served by focusing on maximizing technological spillovers from their larger neighbors.

FIGURE 5 | Yearly growth rates in agricultural research spending by country, 2000–2014



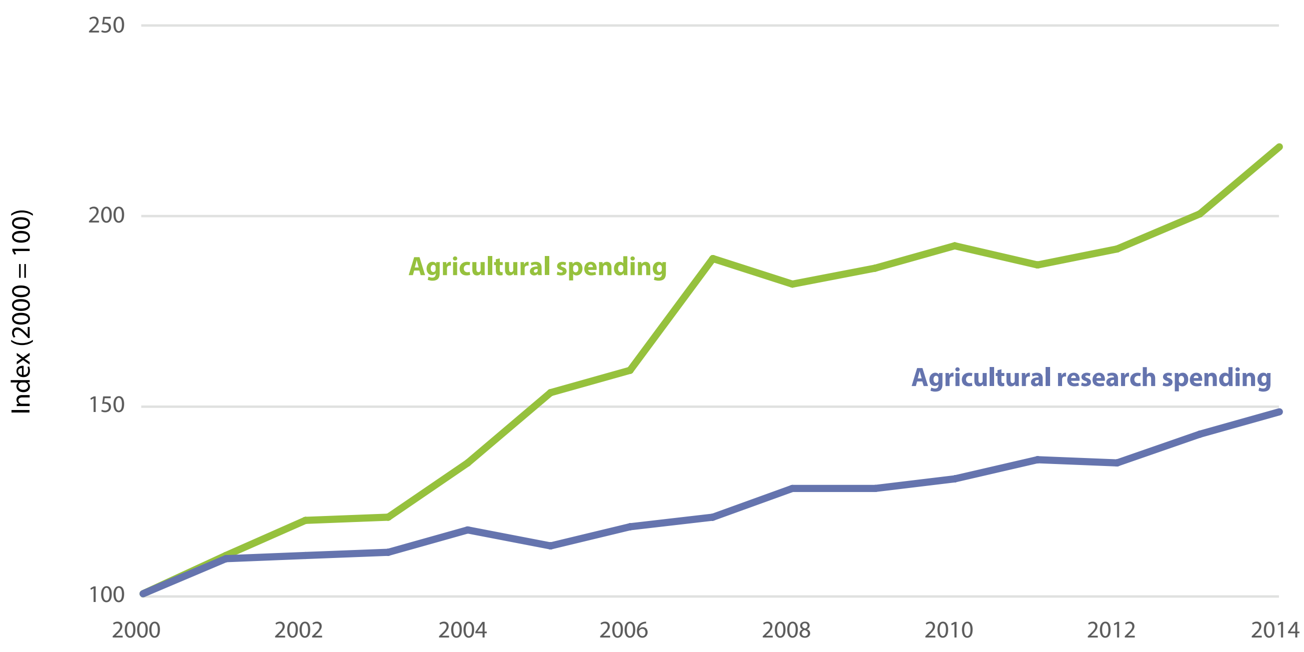
Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Growth in Research Spending Lower than for Other Kinds of Agricultural Investment

The 2003 launch of the Comprehensive Africa Agriculture Development Programme (CAADP) in Maputo elevated agriculture within Africa's political agenda. CAADP established a number of ambitious goals, including countries' commitment to spending at least 10 percent of their national budgets on agriculture in order to ensure 6 percent sectoral growth per year. Heads of State reaffirmed their support for the CAADP agenda in Malabo in 2014, at which time it was determined that, to reach the stipulated targets, additional investments were needed in areas beyond those under the mandate of agricultural ministries. Although a large number of SSA countries have yet to attain CAADP's ambitious targets, substantial progress has been made. On average, SSA governments more than doubled their investments in agriculture during 2000–2014 after long periods of neglect in prior decades (Figure 6). Agricultural research spending also grew during this timeframe, albeit at a considerably slower rate. Data indicate that, although many SSA countries have increased their investments in areas such as farm support and subsidies, training, irrigation, and extension, levels of investment in agricultural research have seriously lagged behind.

A closer look at the budgets of the national agricultural investment plans for the 2010–2015 period reveals that a large number of SSA countries allocated less than 5 percent of their agricultural budget specifically to research (Benin, McBride, and Mogues 2016). This is striking, given the well-documented evidence of the high returns to such investments in SSA, especially compared with investments in other agricultural inputs, such as fertilizer, machinery, labor, and land quality (Evenson and Gollin 2003; Thirtle, Lin, and Piesse 2003; World Bank 2007; IAASTD 2008). Similarly, investment in agricultural research has been shown to play a substantial role in reducing poverty compared with other types of public spending, such as education, health, and rural roads (Fan and Zhang 2008). One of the major contributors to underinvestment

FIGURE 6 | Spending on agriculture and agricultural research, 2000–2014



Sources: Data on agricultural spending are from ReSAKSS (2017); data on agricultural research spending are from ASTI (2017) and various secondary sources.

Note: Agricultural spending only includes funds derived from national governments; agricultural research spending includes funds derived from governments, donors, development banks, producer organizations, and revenues generated internally by research agencies.

BOX 2 | THE POLITICAL ECONOMY OF UNDERINVESTMENT IN AGRICULTURAL RESEARCH

In contrast with the aforementioned evidence of the high returns to such investments in SSA, underinvestment in agricultural research in SSA persists. According to Mogues (2015) four main factors underlie the political economy of underinvestment. First, the temporal dimension of research investments and outcomes complicates resource allocation. Political decision makers may find that the returns to long-term agricultural research investments occur too far in the future to be politically beneficial, which limits their incentive to undertake such investments. Second, smallholder farmers are severely constrained when it comes to leveraging their collective power in favor of increased public spending on agricultural research. Although smallholders constitute a significant share of the population, they are widely dispersed and lack the social, economic, and educational resources needed to effectively engage in collective action within the political arena. They are disadvantaged not only compared with urban populations, but also compared with commercial farming operations. Third, donor institutions have been a major influence on research spending since the 1990s, during which time structural adjustment reform took root across the continent. A global push to privatize public activities contributed to the funding crisis of agricultural research, despite its evident high payoffs. Finally, a country's budget process can have major impacts on the funding actually disbursed to agricultural research agencies by their governments. Rather than making a thorough assessment of a country's long-term research needs, budget allocations typically occur on a predictable, incremental schedule.

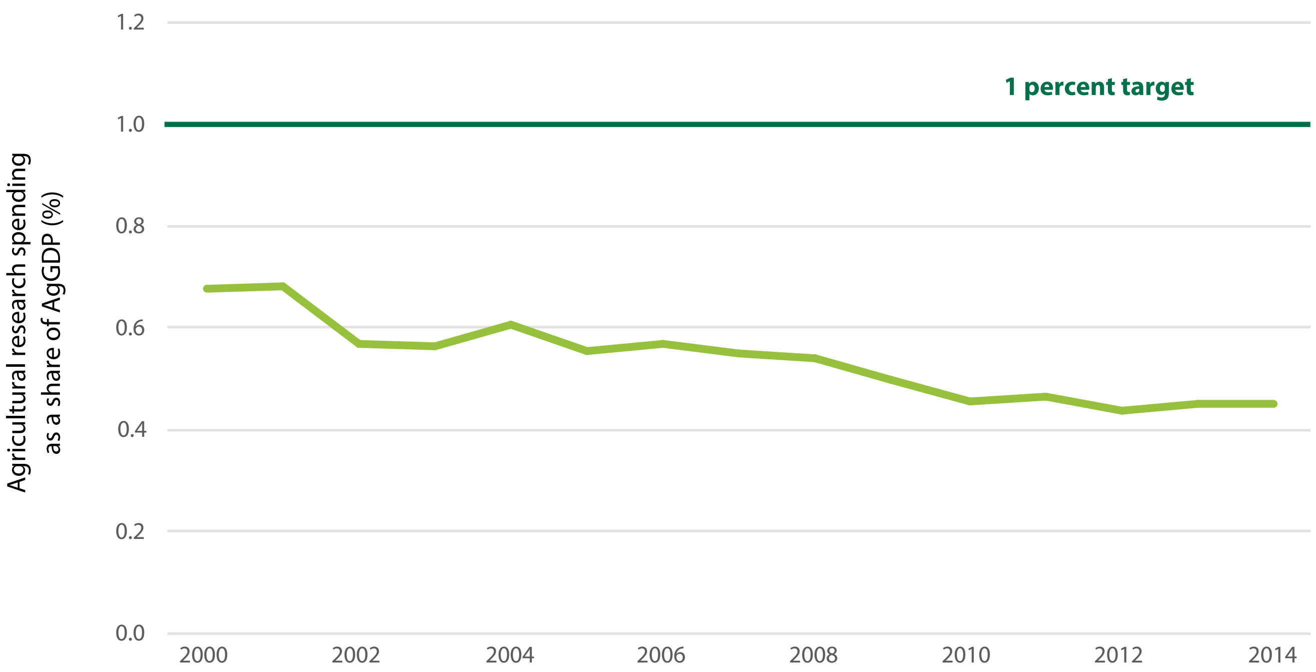
Source: Mogues (2015).

in agricultural research in SSA (as elsewhere) is the length of time required for agricultural investments to manifest results and, hence, for decision makers to reap the political benefit of prioritizing such investments (see Box 2).

Research Spending Falling Behind Agricultural Production Growth

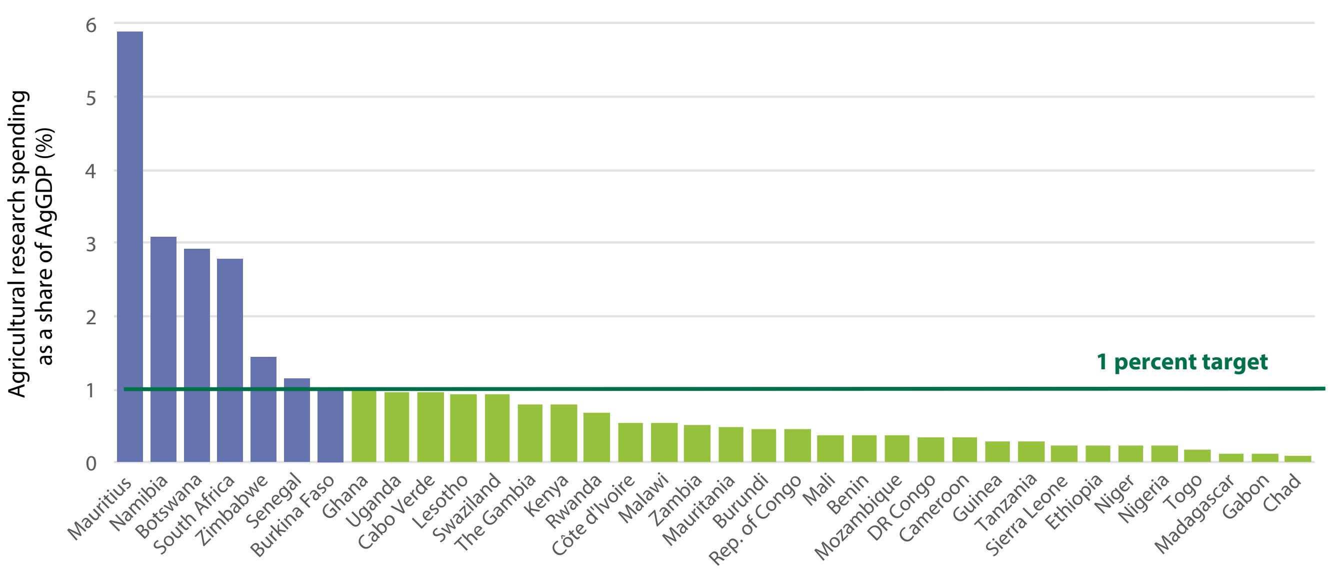
Growth in spending on agricultural research has been slower than growth in spending on agriculture, but also slower than growth in agricultural output over time. As a result, the region's agricultural research intensity ratio—that is, its agricultural research spending as a share of its agricultural gross domestic product (AgGDP)—dropped markedly, from 0.68 percent in 2000, to 0.46 percent in 2014 (Figure 7). In 2014, 29 of the 36 SSA countries for which data were available invested less than 1 percent of their AgGDP in agricultural research, thereby falling short of the minimum investment target set by the African Union and the United Nations (Figure 8).

FIGURE 7 | Agricultural research spending as a share of agricultural GDP, 2000–2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources; data on AgGDP are from World Bank (2016).

FIGURE 8 | Agricultural research intensity ratios by country, 2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources; data on AgGDP are from World Bank (2016).
Note: Values for Nigeria and Sierra Leone include estimates for the higher education sector based on 2008 and 2011 data, respectively.

In fact, 21 of these 40 countries spent less than 0.5 percent of their AgGDP on agricultural research.

Although research intensity ratios provide useful insights into relative investment levels across countries and over time, they do not 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. Small countries, for instance, can't take advantage of economies of scale, so their returns to investments in agricultural research are lower than those of large countries (all else being equal). Similarly, countries with greater agroecological diversity require higher research investments compared with countries with greater homogeneity. In addition, a higher agricultural research intensity ratio can actually reflect reduced agricultural output rather than higher investment. More detailed analysis is therefore needed to ensure a clear understanding of the implications of intensity ratios. Despite these limitations, agricultural research intensity ratios reveal that many SSA countries are underinvesting in agricultural research. For most small and medium-sized countries, even the recommended investment target of 1 percent of AgGDP is inadequate to support some form of technological autonomy, so their research will largely be limited to adapting existing technologies to meet local conditions.

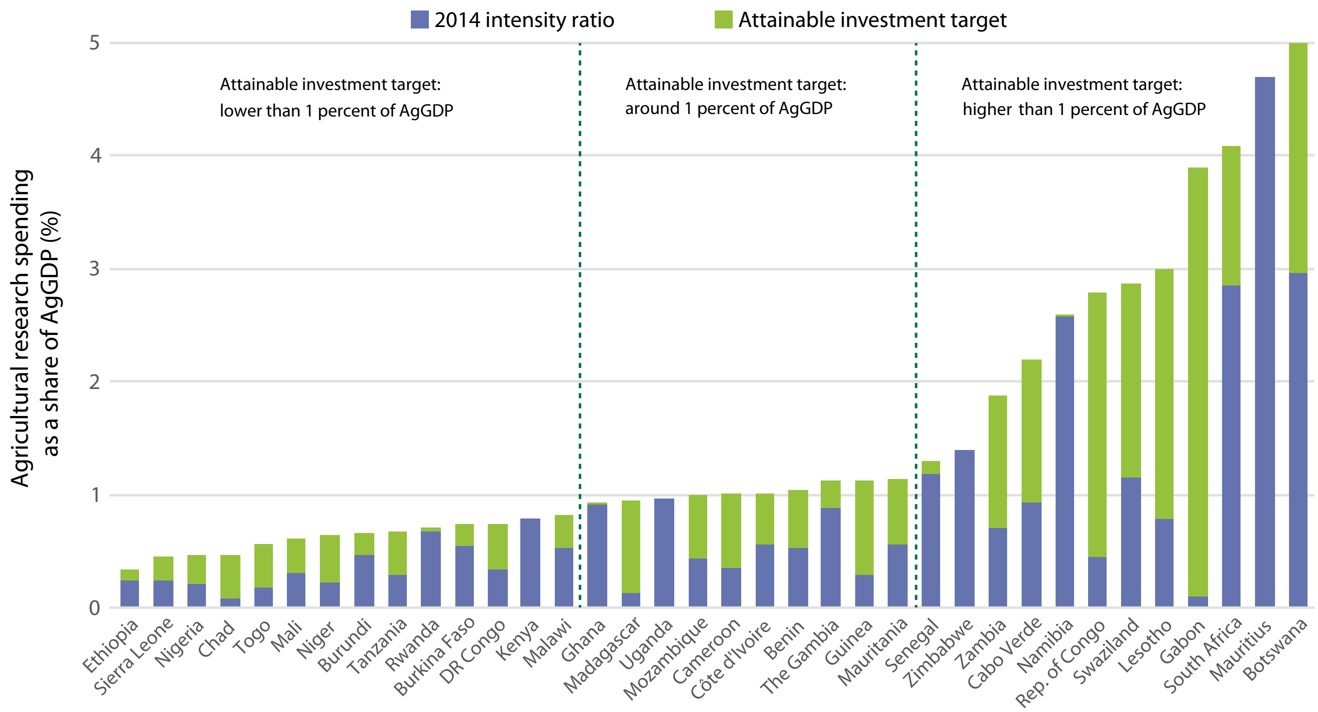
Moving Beyond One-Size-Fits-All Investment Targets

Conventional recommendations of agricultural research intensity levels, such as the 1 percent target set by the African Union and United Nations, assume that national investments should be proportional to the size of the agricultural sector in all cases. In reality, a country's capacity to invest in agricultural research depends on a range of variables, including the size of the economy, a country's income level, the level of diversification of agricultural production, and the availability of relevant technology spillovers from other countries. In efforts to address these nuances, ASTI developed a multi-factored indicator of research intensity using a "data envelopment analysis" approach, whereby the index comprises a range of weighted criteria (for further details, see Nin Pratt 2016). Under this approach, countries with the same mix of inputs are expected to require similar minimum levels of research investment, and investment below that level can be interpreted as an indicator that the country is potentially underinvesting based on its particular input mix.

This weighted indicator of research intensity demonstrates that, for a large number of SSA countries, the 1 percent investment target is simply unattainable. Based on the structural characteristic of the economies and agricultural sectors of countries like Ethiopia and Nigeria, investment targets of around 0.4–0.5 percent of AgGDP would be much more realistic. In contrast, in small countries like the Republic of Congo, Gabon, Lesotho, and Swaziland, intensity ratios of between 2.5 and 4 percent should be attainable (Figure 9). In other words, rather than a one-size-fits-all 1 percent investment target for every SSA country, investment targets need to be established in reference to the structural characteristics of each country's economy and agricultural sector.

ASTI's intensity index results in a very different picture of both the state and extent of underinvestment in the region's agricultural research compared with conventional research intensity ratios. Based on ASTI's index, investment levels in countries like Ghana, Kenya, Mauritius, Namibia, Uganda, and Zimbabwe are deemed to be very close to their optimal levels, taking into consideration each country's size, income level, specialization, and potential access to technology spillovers. Similarly, the index indicates that underinvestment in Ethiopia is less severe than conventional intensity ratios would suggest, and that a 1 percent investment target is in fact unrealistic for Ethiopia. Nonetheless—irrespective of which intensity measure is used—a

FIGURE 9 | Actual agricultural research intensity ratios versus estimated attainable investment targets by country, 2014

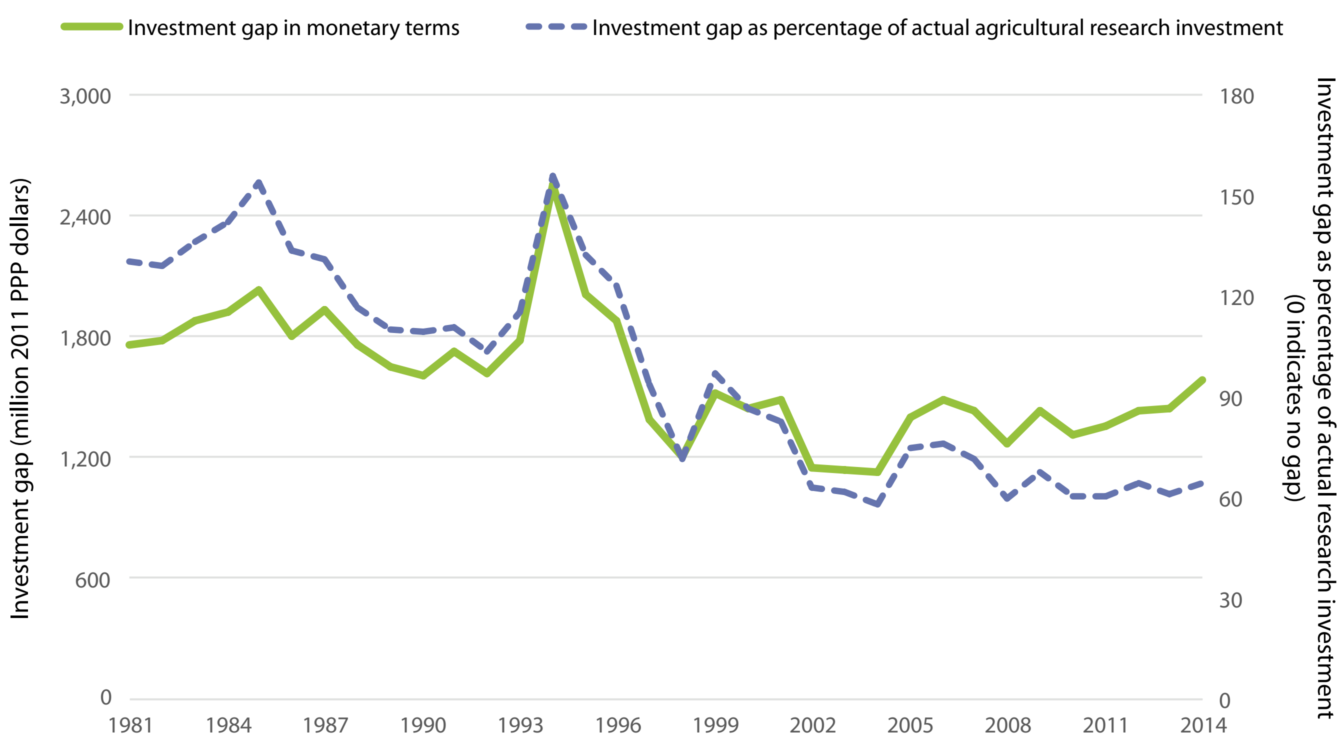


Sources: Calculated by Nin Pratt (IFPRI) based on ASTI (2017); data on AgGDP are from World Bank (2016).
Note: For details of the underlying methodology, see Nin Pratt (2016).

large number of francophone countries significantly underinvest in agricultural research. These include Chad, Gabon, Guinea, Madagascar, Niger, and Togo.

The intensity index can also be used to calculate the research investment gap—meaning, the difference between the research investment of a particular country and that of the country with the highest investment among countries with the same input mix as the analyzed country. From there, the additional investment needed to close the investment gap can also be calculated. As previously established, SSA invested $2.5 billion in agricultural research in 2014 (in 2011 PPP prices). If all SSA countries invested as much as those on the "investment frontier," regional investment levels in 2014 could have totaled $4.0 billion. In other words, the gap between actual investment in agricultural research and estimated attainable agricultural research investment was $1.5 billion. Even though the current investment gap is lower than in the 1980s and 1990s (Figure 10), it remains very high, raising questions as to what agricultural productivity in SSA could have looked like today had these investments been made in the past.

FIGURE 10 | Gap between actual agricultural research investment and attainable agricultural research investment, 1981–2014



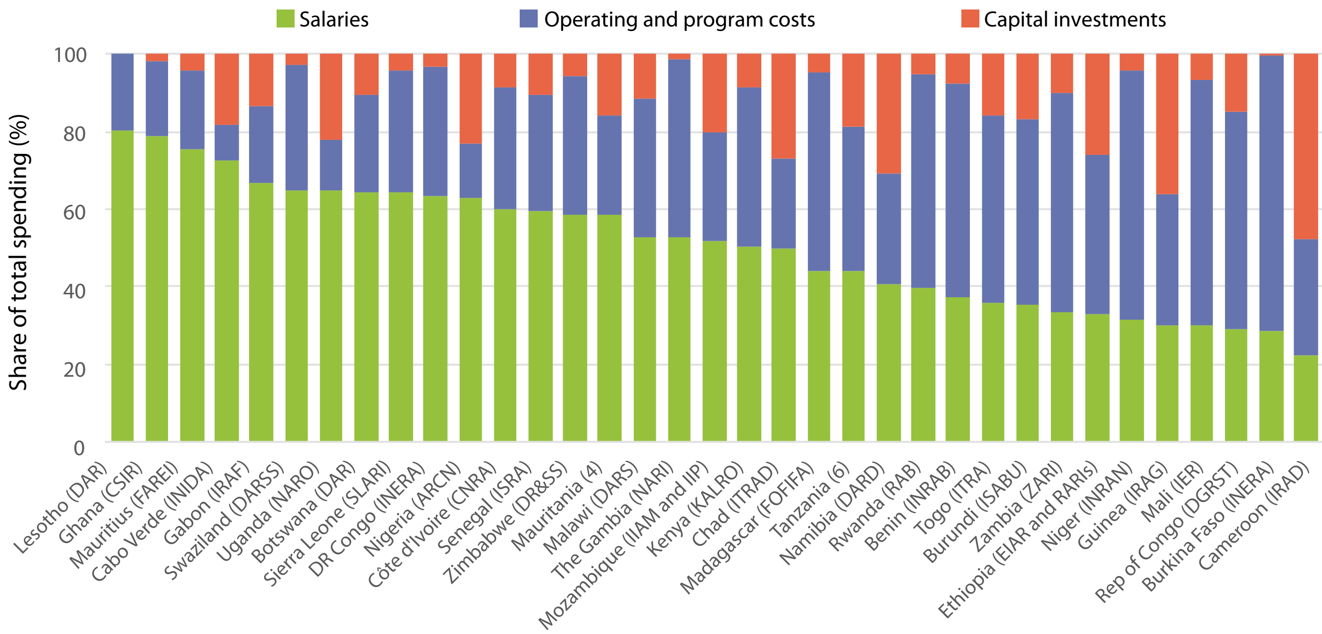
Source: Calculated by Nin Pratt (IFPRI) based on ASTI (2017).
Note: For details of the underlying methodology, see Nin Pratt (2016).

The Impact of Spending Allocation on the Effectiveness of Agricultural Research

A breakdown of spending during 2000–2014 by cost category reveals important differences across countries. Rapid growth in agricultural research spending in Ghana, for instance, was almost entirely driven by increased salary levels at the Council for Scientific and Industrial Research (CSIR), rather than by an increase in the amount of research being conducted or in investments in equipment or infrastructure. Growth in agricultural research spending in Tanzania, on the other hand, largely stemmed from higher government allocations both for the conduct of research and for investment in infrastructure and equipment. In Uganda, increased government funding had a positive impact across all three cost categories—that is, salaries, operating and program costs, and capital investments. The allocation of research budgets across these three major categories has an important impact on the effectiveness and efficiency of agricultural research. No formula can determine the optimal allocation, however. It depends on numerous factors, including country size, agroecological diversity, the research mandate, and the composition of staffing. That said, when salary-related expenses consume more than three-quarters of a research agency's total budget, a clear imbalance exists, such that too few resources remain to support the costs of operating viable research programs.

During 2009–2014, based on a 35-country sample encompassing the principal government and nonprofit agencies for which detailed cost category data were available, 54 percent of available finances was spent on staff salaries, 29 percent was spent on operating and program costs, and the remaining 17 percent was invested in capital improvements (Figure 11). These regional averages mask a significant degree of cross-country variation. The national agricultural research institutes in countries like Cabo Verde, Ghana, Lesotho, and Mauritius spent extremely high shares of their total budgets on salary-related expenses, leaving few resources for the day-to-day running of research programs or the rehabilitation of infrastructure and equipment. In contrast, a large number of francophone West African countries, as well as Ethiopia, fall at the other end of the spectrum, allocating two-thirds of agricultural research expenditures to operating and program costs and capital investments.

FIGURE 11 | Agricultural research spending by country and cost category, 2009–2014 average



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: See the acronym list for the full names of each agency. The principal agencies included for Mauritania are the Mauritanian Institute of Oceanographic and Fisheries Research, the National Agricultural Research and Development Center, the National Livestock and Veterinary Research Center, and the National Anti-Locust Center; the principal agencies included for Tanzania are the Department of Research and Development, the Tanzania Fisheries Research Institute, the Tanzania Forestry Research Institute, the Tanzanian Livestock Research Institute, the Tropical Pesticides Research Institute, and the Tse-Tse and Trypanosomiasis Research Institute. Data for Cameroon and Sierra Leone are for 2012–2014 only.

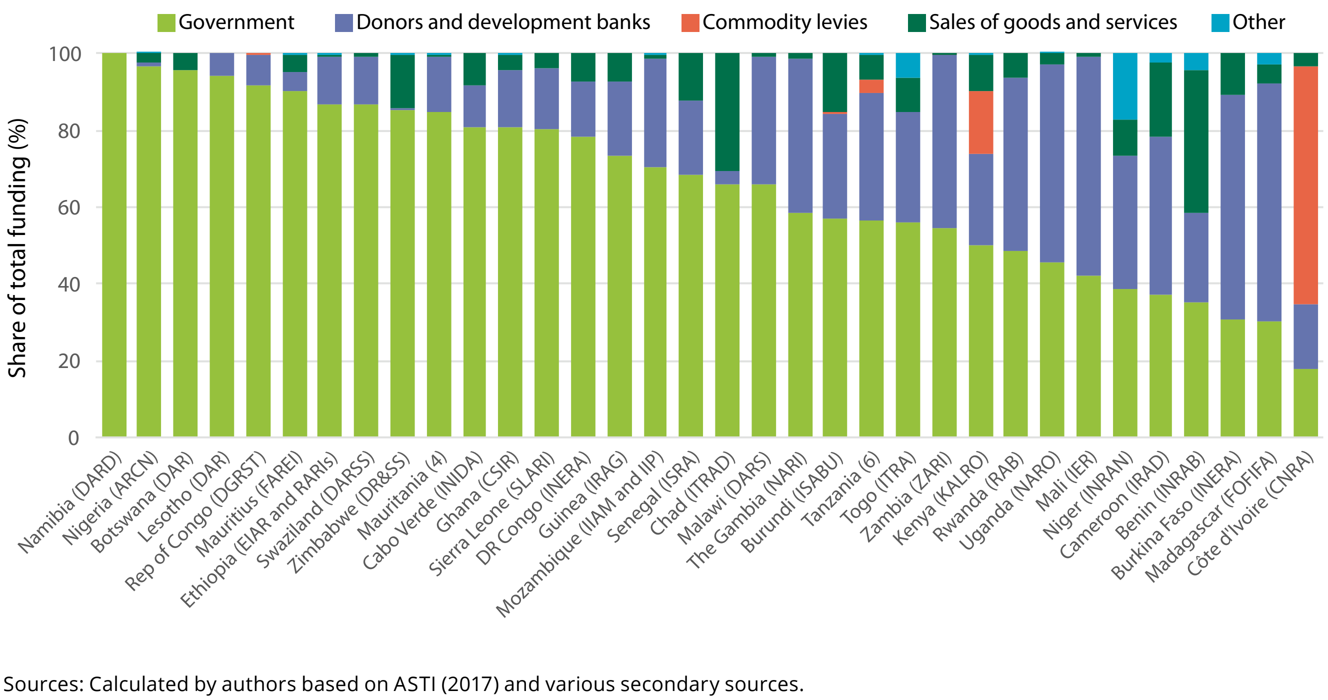
High Dependence on Donors for Agricultural Research Funding

A complete analysis of yearly agricultural research investment levels across countries also requires an examination of how agricultural research is funded (Figure 12). In some countries, the national government funds the bulk of agricultural research activities undertaken by NARIs, whereas other countries are extremely dependent on outside funding from donors, development banks, and subregional organizations. In certain countries, research agencies generate substantial amounts of funding internally by selling goods and services, while in other countries, the proceeds of such sales are channeled back to the national treasury, discouraging agencies from pursuing this revenue stream. Several countries, including Côte d'Ivoire, Ghana, and Tanzania, have established funding systems that mobilize private-sector resources, either via a tax levy or through subscription dues.

Agricultural research in SSA is far more dependent on donor and development bank funding compared with other developing regions around the world (Stads 2015; Stads 2016; Stads et al. 2016). Overall, during 2009–2014, 60 percent of the funding to the NARIs across SSA (excluding Nigeria, South Africa, and a number of the smaller countries) was provided by national governments, and funding from donors and development banks constituted 27 percent. Dependency on donor funding is particularly high among francophone West African countries. In many countries, the national government funds the salaries of researchers and support staff, but little else, leaving nonsalary-related expenses highly dependent on donor and development funding. Although many governments are committed to funding agricultural research in principle, the amounts disbursed are habitually lower than—and in many cases only a fraction of—budgeted allocations. It goes without saying that these funding discrepancies have severe repercussions on the day-to-day operations of agricultural research agencies and their planned activities.

Donor and development bank funding to agricultural research 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 SSA in the form of country-level projects financed through loans and supplemented by grants. Projects have variously

FIGURE 12 | Funding sources of principal agricultural research agencies by country, 2009–2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: See the acronym list for the full names of each agency. The principal agencies included for Mauritania are the Mauritanian Institute of Oceanographic and Fisheries Research, the National Agricultural Research and Development Center, the National Livestock and Veterinary Research Center, and the National Anti-Locust Center; the principal agencies included for Tanzania are the Department of Research and Development, the Tanzania Fisheries Research Institute, the Tanzania Forestry Research Institute, the Tanzanian Livestock Research Institute, the Tropical Pesticides Research Institute, and the Tse-Tse and Trypanosomiasis Research Institute. Data for Cameroon and Sierra Leone are for 2012–2014 only.

focused purely on agricultural research (the more common approach in the 1980s and 1990s) or on agriculture more generally, while including an agricultural research 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 research in SSA through the model of regional productivity programs—that is, the agricultural productivity programs of East Africa, West Africa, and Southern Africa (EAAPP, WAAPP, and APPSA, respectively). 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 research activities in SSA.

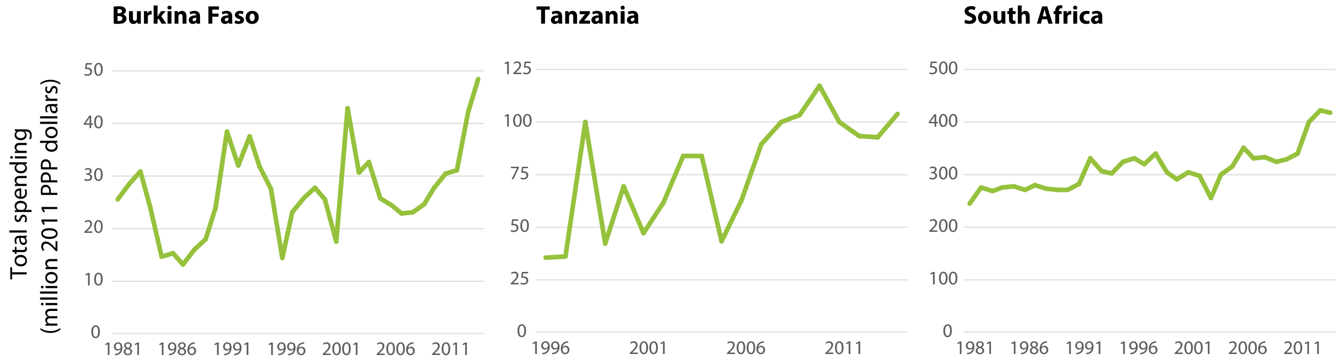
High Volatility of Agricultural Research Funding Due to Donor Dependence

Severe fluctuations in yearly agricultural research 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.

Long-term spending data reveal that agricultural research funding in many SSA countries has been far from stable over time. For example, agricultural research spending in Burkina Faso and Tanzania has fluctuated considerably from one year to the next, while expenditure levels in South Africa have been more stable (Figure 13). ASTI developed a measure to quantify funding volatility across countries by applying the standard deviation formula to average yearly logarithmic growth of agricultural research spending over time (see Stads and Beintema 2015). The SSA countries with the highest fluctuation in yearly agricultural research spending during 2000–2014 (in descending order) were Gabon, Sierra Leone, Zimbabwe, Mauritania, and Burkina Faso (Figure 14). In contrast, agricultural research spending in countries like Kenya and South Africa was very stable during this timeframe.

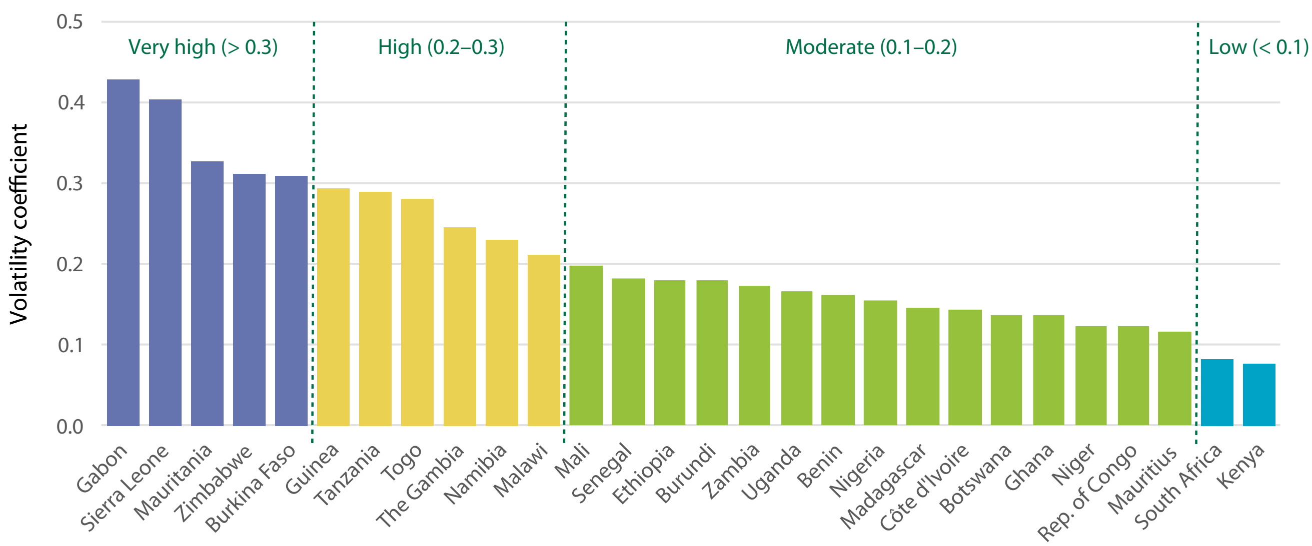
Of most concern, research spending for the region as a whole is more than twice as volatile as in other developing regions of the world (Stads and Beintema 2015). Agricultural research agencies in SSA, particularly those in the region's low-income countries, are considerably more dependent on funding from donors and

FIGURE 13 | Long-term trends in agricultural research spending for selected countries



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

FIGURE 14 | Volatility coefficients for agricultural research spending by country, 2000–2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

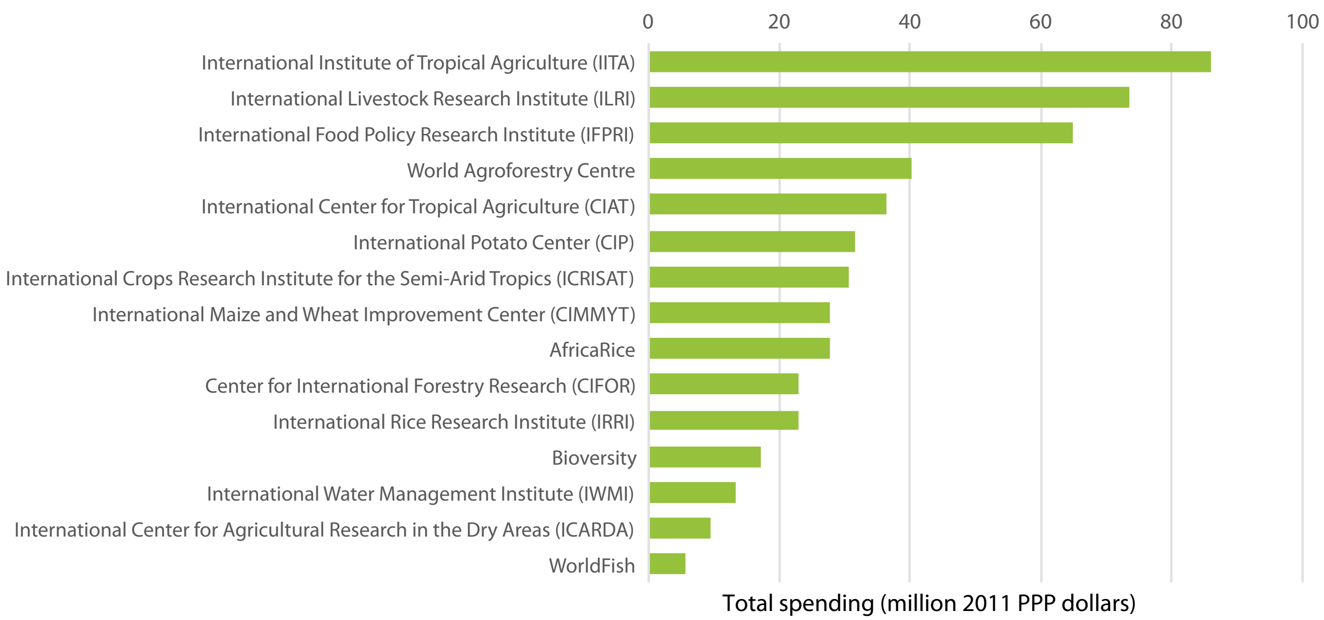
development banks than their counterparts in other developing regions, and this type of funding has shown considerably greater volatility over the past decade compared with government funding. In a large number of SSA countries, donors fund the bulk of nonsalary-related expenditures (that is, program and operating costs and capital investments), and there is extensive evidence of agencies reverting to financial crisis upon the completion of large donor-funded projects, forcing them to scale back their activities. Too much of the critical decision making about research priorities appears to be devolved to donors, with the result that the research agendas of many agricultural research agencies across SSA—particularly in smaller, low-income countries—can be skewed either toward short-term goals that are not necessarily aligned with national and (sub)regional priorities or to commodities of comparatively limited economic importance. A new framework is therefore needed whereby governments establish strategic priorities that donors contribute to.

International Investment in Agricultural Research

The CGIAR centers have been a key source of agricultural innovation in SSA since the 1970s. Activities include conducting joint research with NARSs; training scientists; and providing access to improved germplasm, either for direct release or as parent material. A large (and increasing) share of varieties grown in SSA today can trace their ancestry to CGIAR-delivered germplasm. Investments made by CGIAR centers therefore provide critical resources to complement national agricultural research expenditures. The CGIAR's research agenda has also advanced substantially from a focus on improved crop productivity in the 1970s, to that of research addressing the many challenges of complex agroecosystems. This has resulted in an expansion of the number of CGIAR centers and partnerships at local, national, and regional levels (Roy-Macauley et al. 2016). AfricaRice, the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI), and the World Agroforestry Center are all headquartered in SSA, and most of the remaining CGIAR centers have offices in SSA, often with considerable research facilities and staffing. In 2014, the highest-contributing centers were IITA, ILRI, and IFPRI, which together accounted for 44 percent of CGIAR's overall investment in SSA (Figure 15). In addition to the CGIAR centers, several other international and regional organizations have a presence in SSA and conduct agricultural research in the region. These include the Center for International Cooperation and Agricultural Research for Development (France), the Institute for Research for Development (France), and the World Vegetable Center. Detailed expenditure data for these agencies were not available.

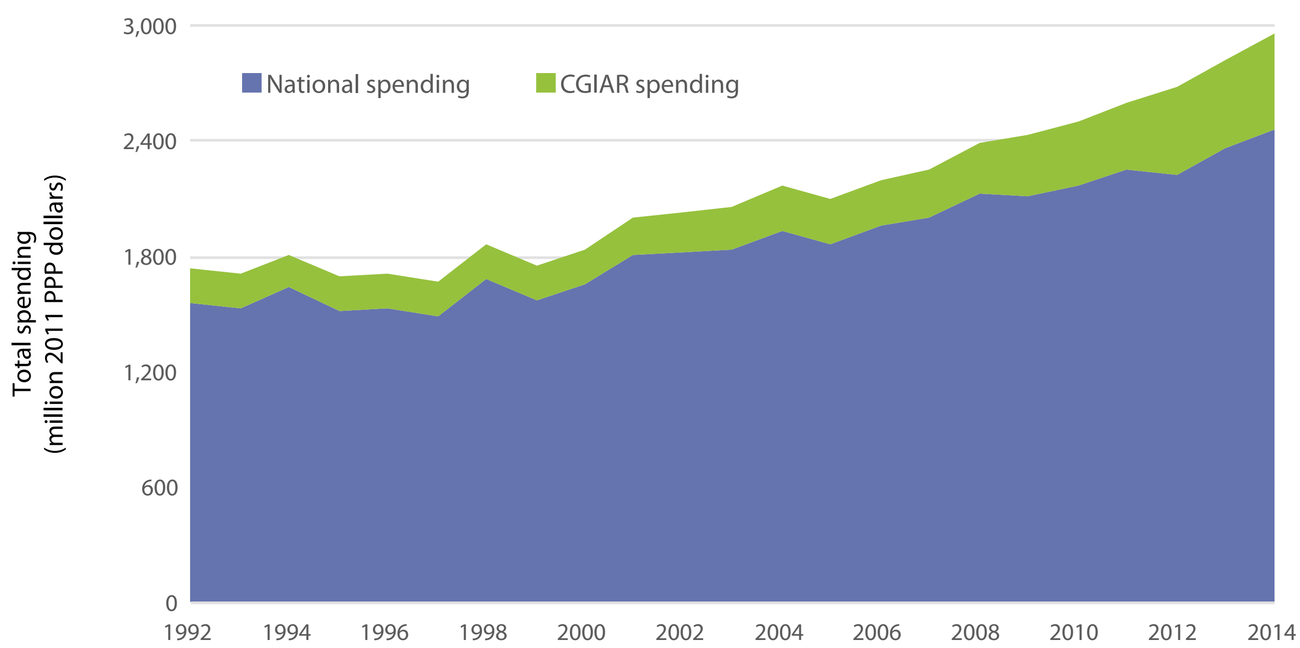
In 2014, the CGIAR centers spent a combined total of US$1.06 billion on agricultural research globally; US$550 million was spent in SSA alone. CGIAR has increased its focus on SSA over time, particularly since the 2008 food crisis. SSA was the recipient of around 40 percent of CGIAR investments during most of the 1990s, rising to 47 percent in 2008, and 52 percent in 2014. In fact, total CGIAR spending on agricultural research in SSA tripled between 1992 and 2014 whereas spending by the countries themselves only increased by one-third during the same timeframe (Figure 16).

FIGURE 15 | CGIAR spending in SSA by center, 2014



Source: Constructed by authors based on CGIAR (various years).

FIGURE 16 | National and CGIAR spending on agricultural research in SSA, 1992–2014



Sources: Constructed by authors based on ASTI (2017) and CGIAR (various years).

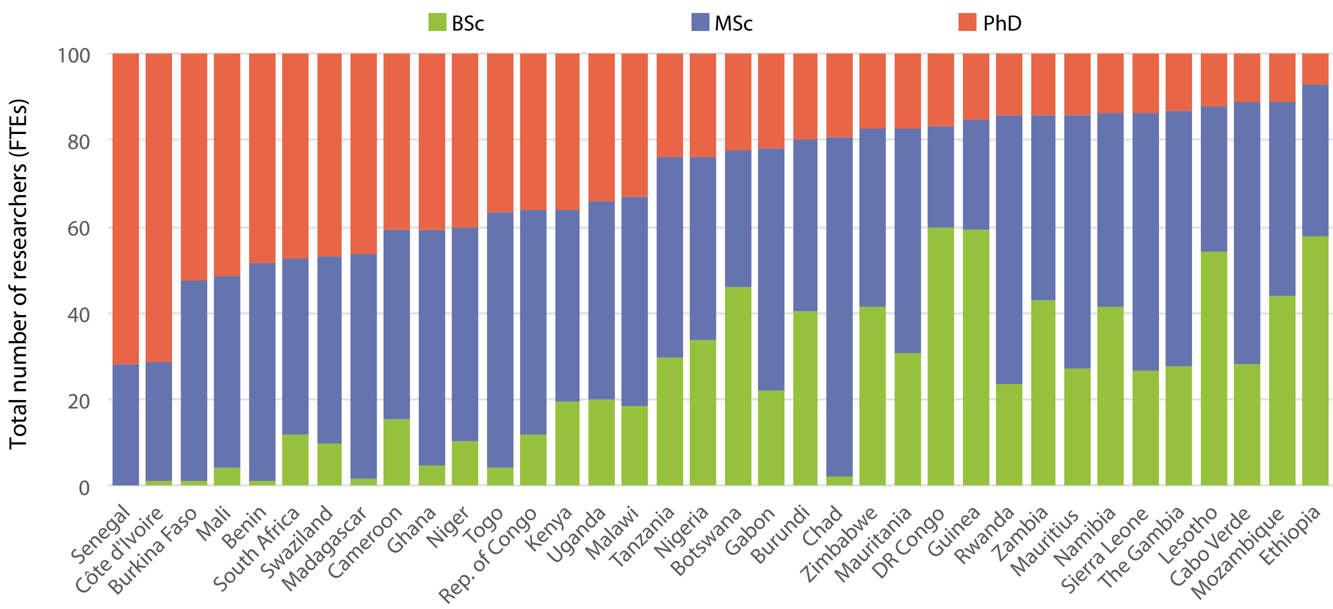
Qualification Levels of Agricultural Researchers

A minimum number of PhD-qualified scientists is generally considered necessary for the conception, execution, and management of high-quality research and for effective communication with policymakers, donors, and other stakeholders. Senegal and Côte d'Ivoire recorded the highest shares of PhD researchers—72 and 71 percent, respectively—whereas nine other countries reported shares of more than 40 percent (Figure 17). Ethiopia was the only country with a PhD share below 10 percent, mostly due to increased recruitment of junior BSc- or MSc- qualified researchers.

Building the capacity of researchers to the doctoral level is an inherently expensive, long-term process. Furthermore, many of the smaller countries do not offer PhD training in agricultural sciences, so researchers wanting to further their careers need to secure (scarce) scholarships to undertake PhD-degree training abroad. Although the share of total PhD-qualified researchers remained constant at 27 percent for the region as a whole during 2000–2014, most countries experienced an increase in absolute numbers during this period (Figure 18). Nevertheless, the number of junior researchers with only BSc degrees also grew substantially in a number of countries during this period.

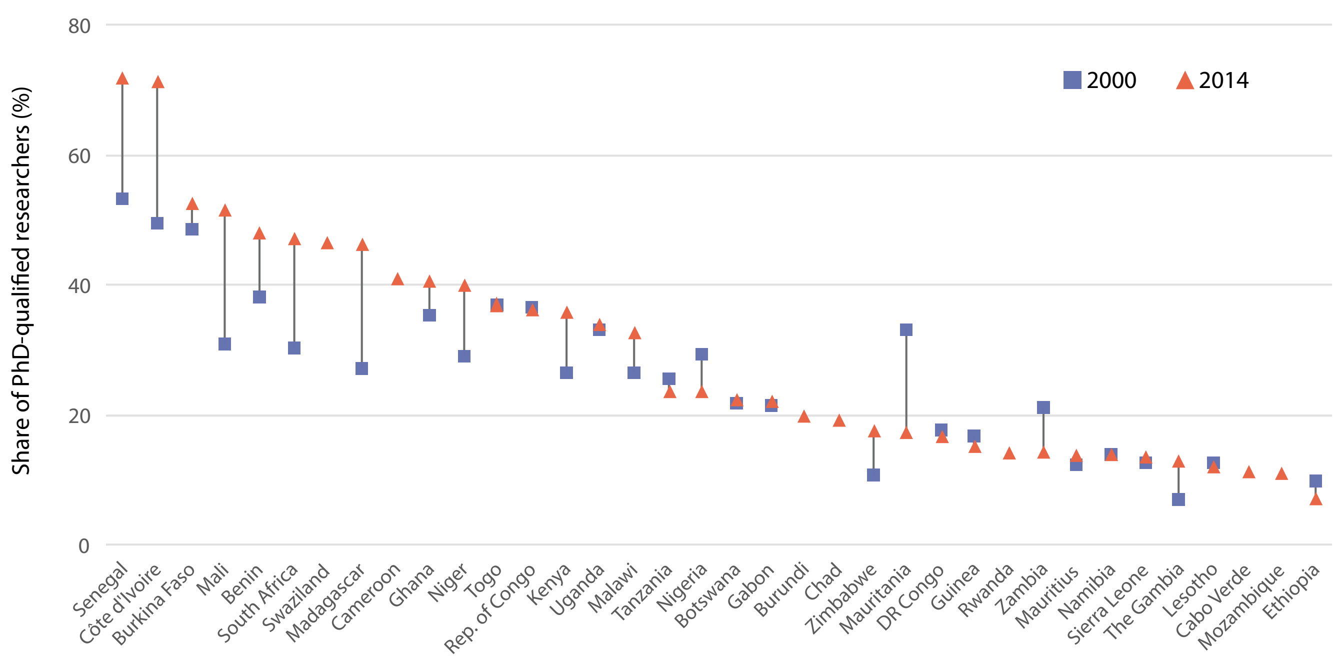
Universities generally employ a much higher share of PhD-qualified scientists compared with most NARIs and other government agencies. In 2014, more than half the researchers employed in the higher education sector held PhD degrees compared with about 20 percent in the government and nonprofit sectors. This higher share can in part be explained by the fact that many universities offer more lucrative remuneration packages and conditions of service, although faculty members also spend the vast majority of their time on their primary mandate, teaching, rather than on research.

FIGURE 17 | Distribution of agricultural researchers by country and qualification level, 2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

FIGURE 18 | Change in the share of PhD-qualified agricultural researchers by country, 2000–2014



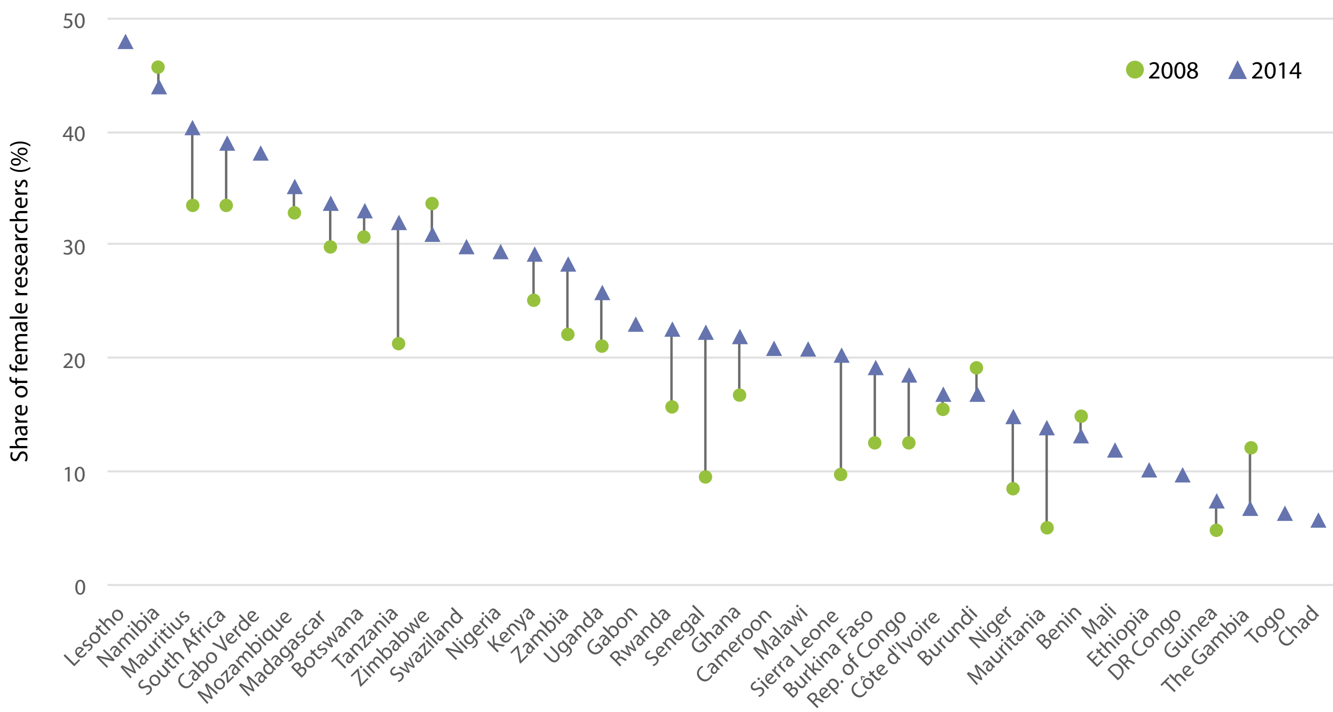
Sources: Calculated by authors based on ASTI (2017) and various secondary sources.
Note: Data for 2000 for Burundi, Cabo Verde, Cameroon, Chad, Côte d'Ivoire, Mozambique, Rwanda, and Swaziland were not available.

Female Participation In Agricultural Research

Female researchers, professors, and senior managers offer different insights from their male counterparts, and their input provides an important perspective in addressing the unique and pressing challenges of farmers. Consequently, it is important that agricultural research agencies employ a balance of male and female researchers. Due to the large influx of agricultural researchers in SSA during 2000–2014, the number of women participating in agricultural research rose, both in absolute and in relative terms. In a 2014 sample of 36 SSA countries, on average, 24 percent of the total number of agricultural researchers (in FTEs) was female (Figure 19). National shares varied widely, but in general the countries of Southern Africa employ comparatively higher shares of female researcher. As of 2014, Lesotho, Mauritius, Namibia, and South Africa were all close to reaching gender parity in agricultural research, recording female researcher shares of over 40 percent. In contrast, other countries still employ very low shares of female agricultural researchers. Chad, DR Congo, Ethiopia, The Gambia, Guinea, and Togo all recorded shares of between 6 and 10 percent.

Despite an increase in female participation in agricultural research in recent years, women remain less likely to hold management positions than their male colleagues in most SSA countries (Figure 20). In Ethiopia, just 4 percent of research management positions were held by women. Similarly, in countries like Nigeria, South Africa, and Tanzania, the share of women in agricultural research management positions is considerably lower than the overall share of female agricultural researchers. The fact that the share of women in management positions is low overall, means that women have less influence in policy- and decision making processes, potentially creating a bias in decision making and priority-setting (Huyer and Westholm 2007).

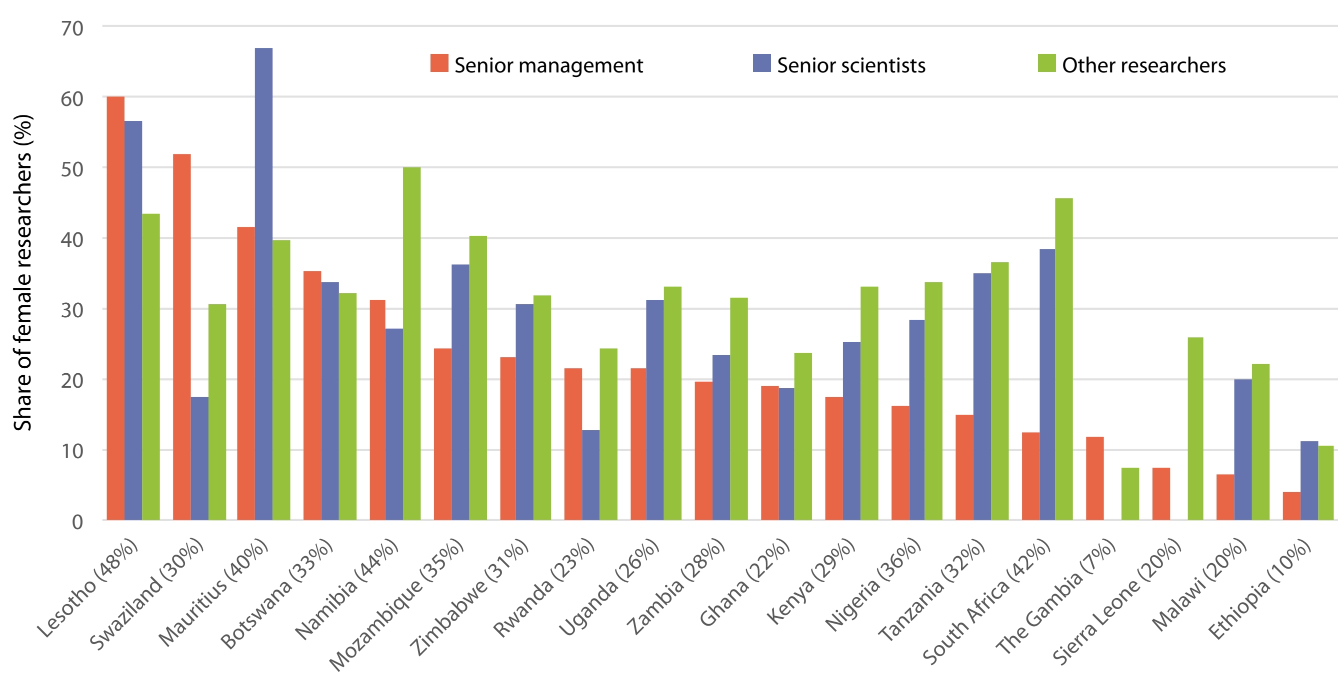
FIGURE 19 | Change in share of female agricultural researchers by country, 2008–2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Note: Data for 2008 were not available for Chad, DR Congo, Ethiopia, Gabon, Lesotho, Malawi, Mali, Swaziland, and Togo.

FIGURE 20 | Share of female agricultural researchers by country and level of seniority, 2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.

Notes: Data in parentheses indicate the country's average share of female agricultural researchers. Data for Nigeria, Sierra Leone, and Uganda exclude the government sector. Senior management includes university deans, senior scientists include university professors, and other researchers include other university teaching staff.

Predominant Disciplines of Agricultural Researchers

In order to fulfill research mandates effectively, it is important for agricultural research systems to have a well-balanced pool of researchers not only in terms of qualification levels, age distribution, and gender, but also in terms of research disciplines. Data on the educational disciplines of agricultural researchers had been largely unavailable. To fill this gap, ASTI collected detailed data for 2014, broken down by degree qualification and 25 disciplines. On average, 10 percent of the MSc- and PhD-qualified researchers in a sample of 32 countries were plant breeders or geneticists (Table 1). Other well-represented disciplines included socioeconomists (9 percent), soil scientists (6 percent), and veterinary scientists (6 percent).

Despite the fact that plant breeding/genetics constitutes the largest discipline, SSA lacks crop breeders. For example, Ghana employed 56 MSc- and PhD-qualified crop breeders in 2014 (in FTEs), which on average is fewer than an average of ten breeders for each of its six agroecological zones. This is insufficient for the large number of crops the country is growing. The West Africa Centre for Crop Improvement (WACCI) indicates that plant breeders are especially scarce for many of the region's indigenous crops because they have been neglected by research in high-income countries. Crops such as cassava, cocoyams, cowpeas, groundnuts, millet, plantains, sorghum, taro, teff, and yams are regionally important but not traded around the world. They receive no attention by research networks and are therefore described as "orphan crops" (WACCI 2017).

Large NARSs, such as those in Ghana, Kenya, and Tanzania, employ staff in all disciplinary fields, although various individual government and higher education agencies indicated that they lacked researchers in certain key disciplines. Severe gaps in disciplines are common in smaller NARSs. For example, Botswana and The Gambia have no animal breeders/geneticists; or researchers in animal husbandry.

TABLE 1 | MSc- and PhD-qualified agricultural researchers by discipline, 2014

Discipline	32-country sample		Examples of large NARSs (FTEs)			Examples of small NARSs (FTEs)		
	Share (%)	FTEs	Ghana	Kenya	Tanzania	Botswana	The Gambia	Lesotho
Plant breeding and genetics (incl. biotechnology)	10.4	853.2	55.9	78.7	64.3	5.2	3.1	1.6
Plant pathology	5.0	408.1	20.0	48.9	10.0	4.2	—	—
Plant physiology	2.3	189.1	12.2	13.4	2.2	—	1.5	—
Botany	2.0	165.8	9.2	6.0	24.4	—	—	—
Seed science and technology	1.4	118.2	8.9	12.2	—	1.0	1.5	—
Other crop sciences	8.2	669.7	41.0	132.8	15.6	—	4.6	5.9
Animal breeding and genetics	2.0	161.8	6.0	14.4	17.2	—	—	0.6
Animal husbandry	2.0	167.0	3.2	18.6	15.7	—	—	0.3
Animal nutrition	3.1	250.8	17.2	32.2	32.4	—	4.1	1.3
Dairy science	0.6	48.5	0.6	6.5	8.5	—	—	—
Poultry	0.5	44.1	6.8	1.1	2.6	—	—	—
Veterinary medicine	5.6	459.4	4.3	101.4	16.6	3.4	—	0.6
Zoology/entomology	4.6	375.5	32.3	30.5	9.8	3.4	3.1	1.0
Other animal and livestock	2.5	202.3	6.6	0.7	8.2	—	—	—
Forestry and agroforestry	3.4	278.6	13.7	12.3	34.7	2.0	1.5	—
Fisheries and aquatic resources	4.7	388.4	11.2	84.4	30.1	1.0	1.5	—
Soil sciences	6.5	533.3	50.1	75.8	43.9	2.0	4.1	1.9
Natural resources management	2.9	235.0	12.6	28.1	24.3	1.0	—	0.6
Water and irrigation management	1.5	119.8	7.7	4.1	—	1.0	—	—
Ecology	1.7	137.1	10.6	22.9	3.3	3.0	—	0.3
Biodiversity conservation	1.0	82.8	8.4	3.9	2.3	1.0	—	2.0
Food sciences and nutrition	3.7	300.3	21.7	18.2	36.3	—	3.1	0.9
Socioeconomics (incl. agricultural economics)	8.6	709.5	62.1	124.3	73.3	2.0	3.1	1.2
Extension and education	2.8	231.2	12.3	14.5	25.3	—	—	1.6
Other sciences	13.2	1,080.6	114.2	61.0	80.1	2.8	6.5	1.2

Source: Calculated by authors based on ASTI (2017).

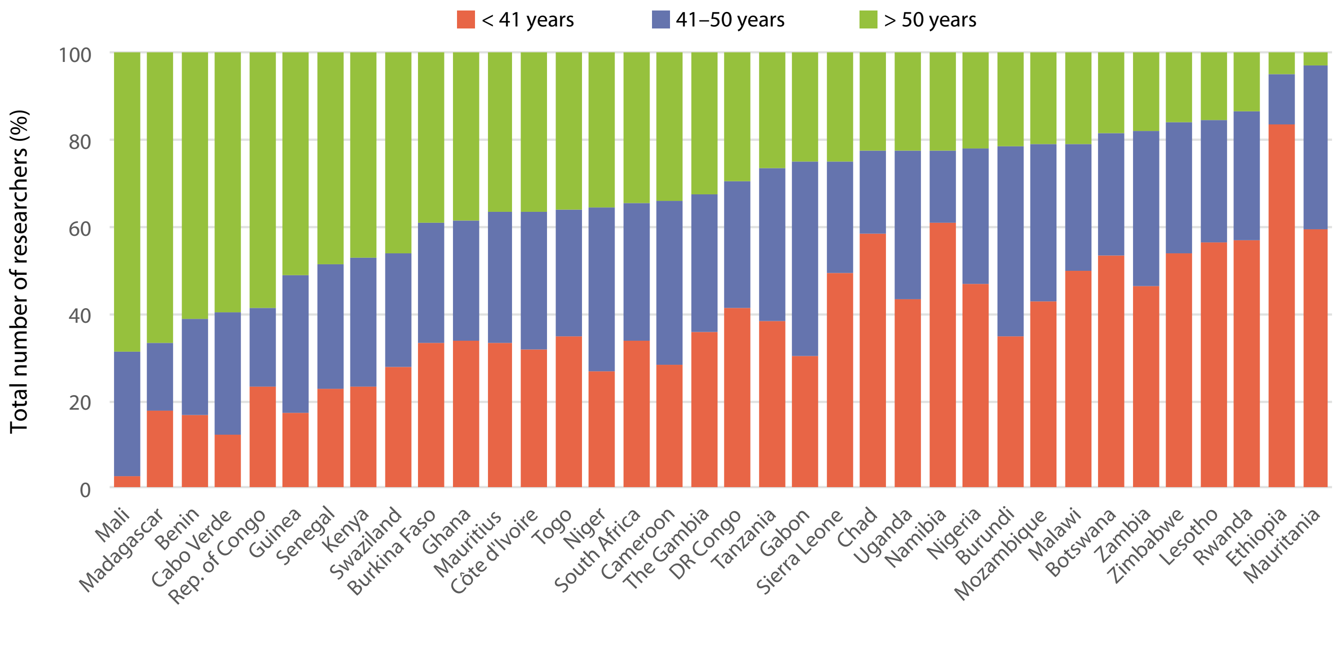
Notes: For a number of countries data were lacking for some institutional groups. More information on the composition of researchers by discipline for other countries is available in ASTI's country factsheets.

Aging Pool of Agricultural Researchers

Long-term public-sector recruitment restrictions in many SSA countries (particularly in francophone Africa) have skewed the average age of researchers to the higher end of the spectrum, such that many are approaching retirement age. In contrast, in Ethiopia, the majority of researchers are very young, causing potential issues with management and mentorship (Figure 21). Overall, as of 2014, more than half the region's PhD-qualified agricultural researchers were in their 50s or 60s (Figure 22). The situation appears particularly grave in Chad, Republic of Congo, Guinea, Mali, Namibia, Sierra Leone, and Swaziland, where more than 70 percent of PhD-qualified agricultural researchers were over 50 years old in 2014. A growing number of agricultural research agencies across SSA will be left without the critical mass of senior researchers needed to lead research programs and mentor and train junior staff. Without adequate succession strategies and training, significant knowledge gaps will emerge, raising concerns about the quality of future research outputs.

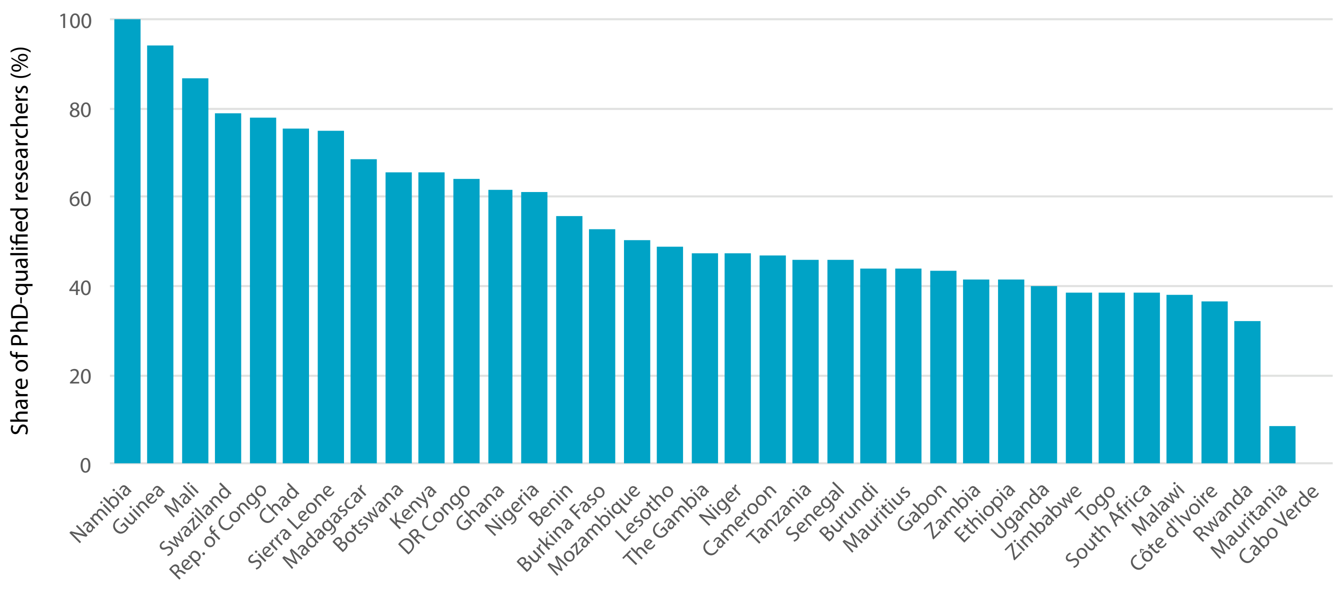
In a number of countries, researchers employed by NARIs are classified as civil servants and as such they are subject to fixed salary scales that are considerably lower than those offered by the higher education sector. This reality—combined with other limiting factors, such as poor benefit and retirement packages; limited promotional opportunities and work flexibility; lack of infrastructure, services, and equipment; and poor management structures—is a significant barrier to attracting, retaining, and motivating researchers within 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.

FIGURE 21 | Distribution of agricultural researchers by country and age bracket, 2014



Source: Calculated by authors based on ASTI (2017).

FIGURE 22 | Share of PhD-qualified agricultural researchers over age 50 by country, 2014



Source: Calculated by authors based on ASTI (2017).
Note: Cabo Verde employed no PhD-qualified agricultural researchers over the age of 50.

Addressing Capacity Challenges Through Regional Agricultural Productivity Programs

Since 2008, the World Bank has shifted from a national to a regional approach to financing agricultural research in SSA through the model of regional productivity programs—the aforementioned APPSA, EAAPP, and WAAPP. In addition, discussions are underway to launch a Central African Agricultural Productivity Program (CAAPP) to include Chad, Cameroon, and the Republic of Congo. As previously discussed, the goal of these programs is to facilitate regional cooperation in the generation and dissemination of agricultural technologies, and to establish a more differentiated, yet regionally relevant, research agenda through the establishment of national centers of excellence. The programs commenced in 2008 under the auspices of SSA's regional economic communities, coordinated by the SROs (Table 2).

The programs provide ample funding to strengthen the infrastructure and human resource capacity of agricultural research institutions. WAAPP's training component, for example, is addressing the most acute staff shortages, especially in smaller countries where the gaps are the largest. Overall, WAAPP funding supports MSc- and PhD-level training of more than 1,000 young professionals at research institutes, extension agencies, universities, and nongovernmental and farmer organizations (WAAPP 2015). Similarly, EAAPP is providing funding for MSc- and PhD-level training of 77 and 36 researchers and other professionals, respectively (Wellard et al. 2015). As of December 2015, 37 scientists and other professional staff were undertaking MSc-degree training, and 18 were undertaking PhD-degree training funded through APPSA (CCARDESA 2015). About 30 percent of recipients of training funded through these regional programs are female.

The rehabilitation of research infrastructure—including research stations, laboratories, offices, and field infrastructure—is one of WAAPP's key objectives. The first phase of WAAPP funding predominantly targeted upgrades of centers and stations focusing on preselected priority commodities. WAAPP's second phase, however, is targeting other centers and stations in urgent need of rehabilitation as well. APPSA and EAAPP funding also focuses on upgrading research infrastructure and staff residences, and on research facilities of relevance to preselected priority commodities.

TABLE 2 | Funding and commodity focus of agricultural productivity programs by country and phase

Program/phase/approval date	Country	Funding (million US$)	Commodity focus of national center of excellence
West Africa Agricultural Productivity Program, Phase 1A (2008)	Ghana	15	Roots and tubers
	Mali	15	Rice
	Senegal	15	Drought-resistant cereals
East Africa Agricultural Productivity Program, Phase 1 (2009)	Ethiopia	30	Wheat
	Kenya	30	Dairy
	Tanzania	30	Rice
	Uganda	30	Cassava
West Africa Agricultural Productivity Program, Phase 1B (2010)	Burkina Faso	21	Mangoes, onions
	Côte d'Ivoire	44	Bananas, plantains
	Nigeria	51	Fisheries (catfish, tilapia)
West Africa Agricultural Productivity Program, Phase 1C (2011)	Benin	17	Maize
	The Gambia	12	—
	Guinea	9	Rice
	Liberia	14	—
	Niger	30	Livestock
	Sierra Leone	22	Mangrove rice
	Togo	12	—
Agricultural Productivity Program for Southern Africa, Phase 1 (2013)	Malawi	30	Maize
	Mozambique	30	Rice
	Zambia	30	Food legumes
West Africa Agricultural Productivity Program, Phase 2A (2013)	Ghana	60	Roots and tubers, cereals, legumes, livestock
	Mali	60	Rice, other cereals, livestock
	Senegal	60	Dryland cereals, horticulture, livestock

Sources: CCARDESA 2015; Stads and Beintema 2017; Wellard et al. 2015.

Note: Although the programs were established to focus on priority crops, WAAPP 1B, 1C, and 2A appear to have expanded to include other commodities.

Predominant Focus of Agricultural Research

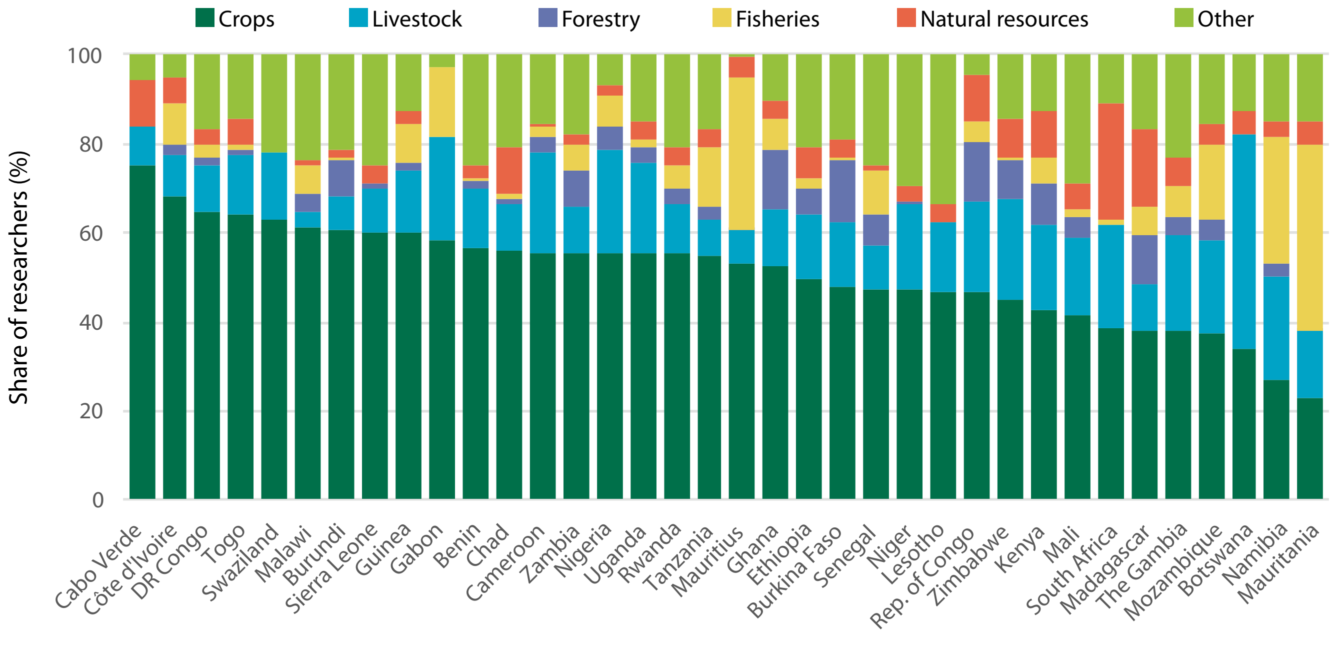
Governments and agricultural research agencies across SSA—especially the many small countries—are limited in their choice of options of how to allocate scare resources. It is important, however, that they allocate sufficient resources to the types of research and commodities that are highly relevant to their country's agricultural sector in order to ensure that the results have lasting impacts in increasing productivity and reducing poverty.

Crop research remained the dominant commodity group for most countries as of 2014. That year, 44 percent of all agricultural researchers in a sample of 36 SSA countries conducted crop research; 20 percent of researchers were working on livestock issues, and 18 percent on research related to natural resources. The remaining researchers focused their attention on forestry, fisheries, or other areas (Figure 23). Botswana is unique among SSA countries in that it focuses a higher proportion of its agricultural research effort on livestock than on crops (48 percent compared with 33 percent, respectively). Similarly in Mauritania, fisheries research receives more attention than crop research (42 percent of agricultural researchers compared with 23 percent, respectively). Fisheries research was also comparatively important in Mauritius (34 percent), Namibia (28 percent), Mozambique (17 percent), and Gabon (16 percent), whereas natural resources research was prominent in South Africa (27 percent) and Madagascar (17 percent).

On average, the most researched crops in SSA include horticultural crops (34 percent) and cereal crops (30 percent). But there were some fundamental differences in the focus of crop research across countries (Figure 24). Cereals were the focus of 40 percent or more of all crop researchers in 13 of the 36 countries for which data were available. Horticultural crops were also the focus of a third or more of all crop researchers in Cabo Verde, Gabon, Mauritius, South Africa, and Swaziland. Export crops are important research areas for several countries, which is reflected in the relatively high shares of other crops in 2014. Examples include tobacco in Zimbabwe, cotton and cocoa in Côte d'Ivoire, and sugar in Mauritius.

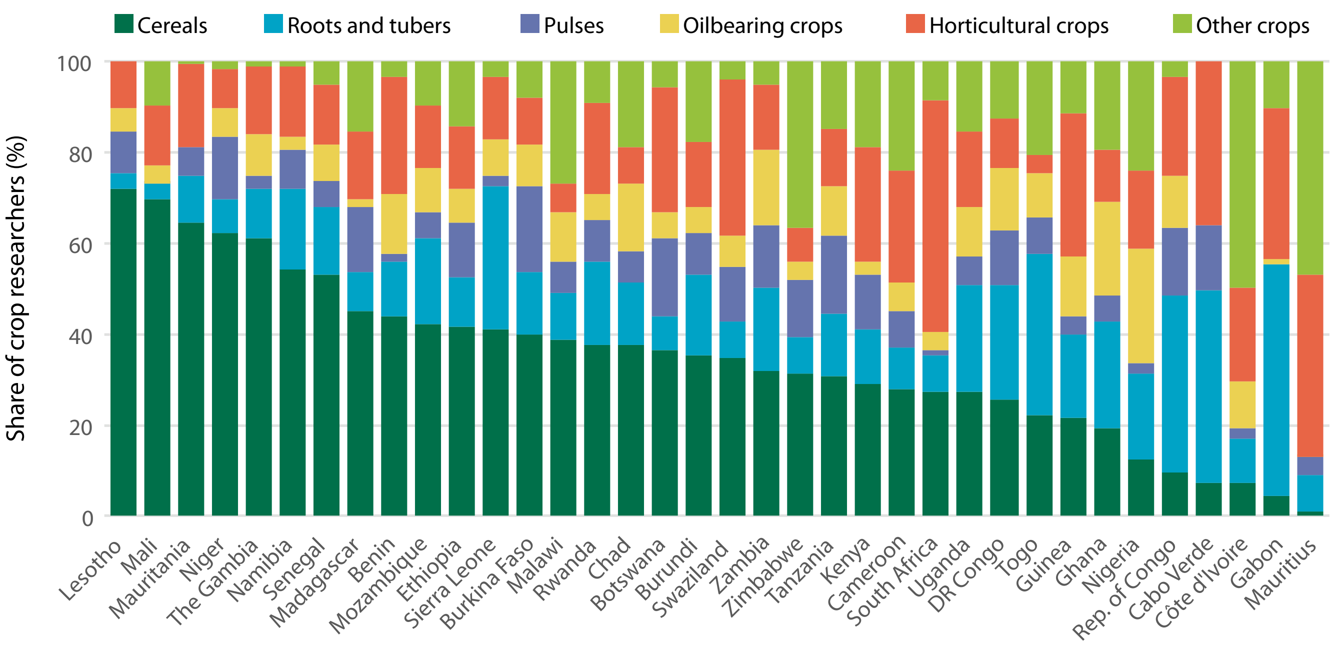
The congruency or parity model is a commonly used method of assessing the allocation of research resources. This usually involves allocating funds (or, in this instance, research personnel) among research areas in proportion to their corresponding contribution to the value of agricultural production. For example, if the value of rice output were twice that of maize, then congruence would be achieved if research on rice were to receive twice as much funding (or, say, employ twice as many scientists) as research on maize. If research spending or scientist shares are congruent with the corresponding value of output for a particular commodity—measuring the share of researchers per commodity to the

FIGURE 23 | Focus of agricultural research by country, 2014



Source: Calculated by authors based on ASTI (2017).

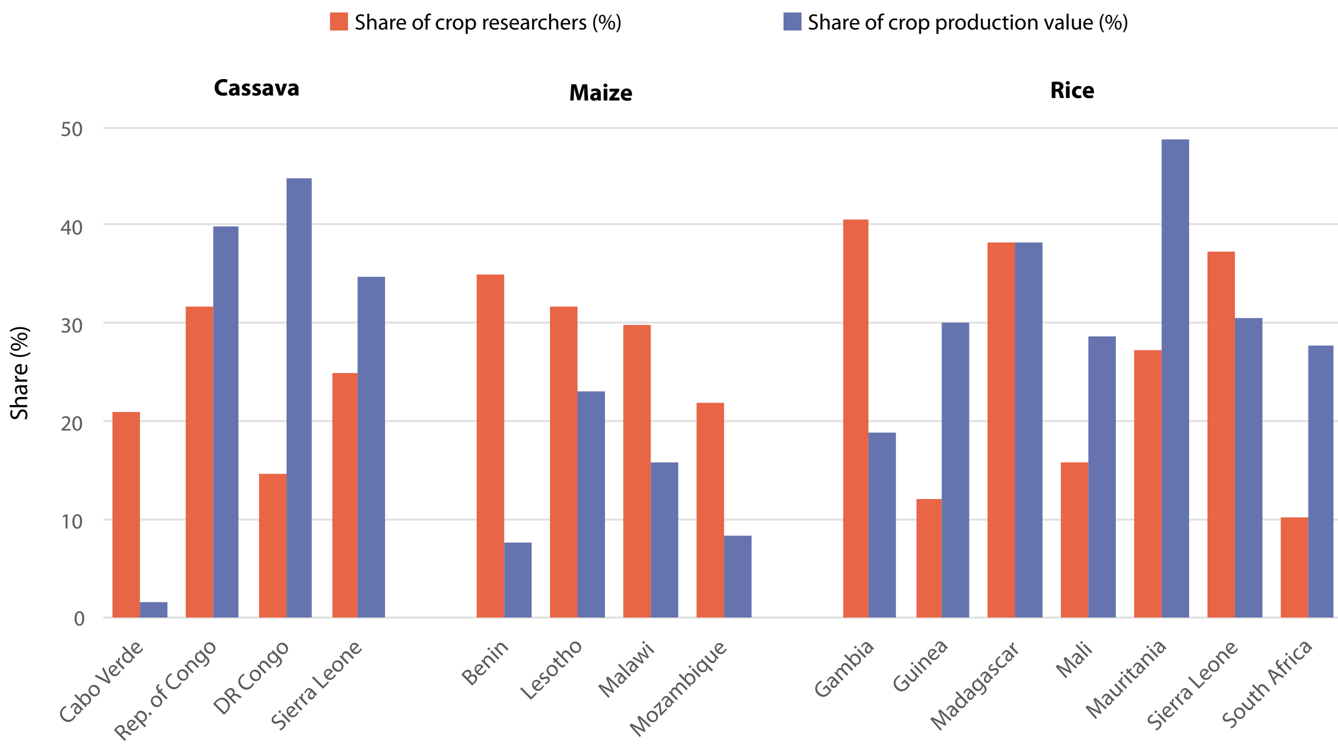
FIGURE 24 | Focus of crop research by country, 2014



Source: Calculated by authors based on ASTI (2017).

corresponding share of output—then the congruency ratio for that commodity would be 1.0. In the Republic of Congo, DR Congo, and Sierra Leone, cassava's 2014 share of the total value of crop production was higher than its corresponding share of crop researchers, implying that cassava is comparatively underresearched in these countries (Figure 25). For maize, this situation was reversed: more researcher time was allocated to this crop relative to its crop production value in all four sample countries. For rice, the results were mixed, with some countries recording shares of crop researchers higher than shares of crop production value, and other countries recording shares of researchers lower than shares of crop production value. Madagascar's rice research was congruent with the value of the country's rice production.

FIGURE 25 | Share of crop researchers and crop production value for selected countries and crops, 2014



Sources: Calculated by authors based on ASTI (2017) and various secondary sources.
Note: Data for 2008 were not available for Chad, DR Congo, Ethiopia, Gabon, Lesotho, Malawi, Mali, Swaziland, and Togo.

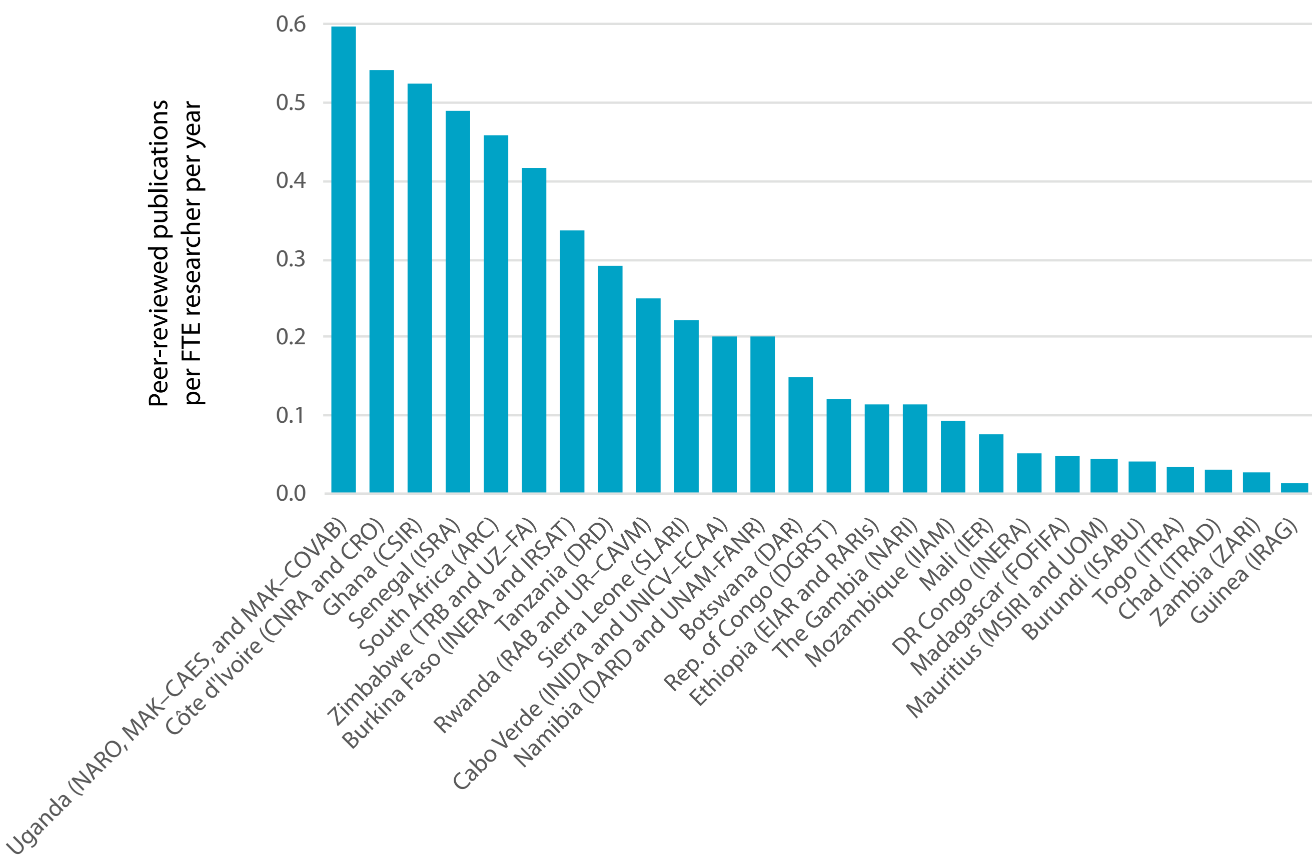
Low Research Outputs In Many Countries

As of 2014, just 1.4 percent of all global scientific publications were produced by the countries of SSA. Excluding South Africa, this share would be just 0.7 percent (UNESCO 2015). Although national totals of peer-reviewed agricultural publications were not available, detailed data from a number of NARIs and some of the larger agricultural faculties indicate that scientific output in terms of peer-reviewed journal articles, books, and book chapters is very low. A considerable degree of cross-country variation exists, but most NARSs recorded ratios of publications per researcher of between 0.1 and 0.6 per year (Figure 26), representing only a fraction of comparable ratios of high-income countries. This is a major cause for concern given that research institutes with a poor track record of publications are less likely to have impact, to collaborate with international partners, and to generate competitively sourced funding. Most NARIs provide insufficient incentives for their scientists to publish their results, and very few link the publication of results with performance appraisals. Moreover, given the lack of prioritization of publishing research results, many scientists actually lack the required expertise to have their work accepted for publication in academic outlets and other forums.

Publications are only one type of research output. More relevant to the livelihoods of millions of farmers is the release of new varieties and technologies by research agencies. Data on the release of new crop varieties by SSA agencies is incomplete, but the data that are available indicate significant cross-country variation in terms of new releases. Results for the 2012–2014 period were low or nonexistent for many of the smaller NARSs. These results are an indicator of low innovative capacity, raising the question as to whether these countries should purely focus on—and potentially contribute to—spillovers of relevant technologies from their larger neighbors. In contrast, numerous NARSs released a steady stream of new crop varieties of crops such as beans, maize, rice, sorghum, vegetables, and wheat (Table 3). Unfortunately, available data were insufficient to enable a determination of which new varieties were developed locally by the NARI and which were developed by CGIAR centers and tested to local conditions by the NARI. As a result, the data presented do not reflect the comparative innovative capacity of the countries, and hence should be interpreted with care.

Weak intellectual property rights legislation remains a key challenge across SSA countries and can also be seen as a factor impeding innovation. Many countries struggle with how to reconcile intellectual property rights with farmers' rights and other local interests, which is a valid concern. Few NARIs succeed in protecting improved varieties under the African Organization of Intellectual Property or the African Regional Intellectual Property Organization. Moreover, increased regionalization of agricultural research in SSA—for example, through APPSA, EAAPP, and WAAPP—further complicates the issue of how to resolve intellectual property rights.

FIGURE 26 | Number of peer-reviewed publications per agricultural researcher per year by country for selected agencies, 2012–2014 average



Source: Calculated by authors based on ASTI (2017).
Note: See the acronym list for the full names of each agency.

TABLE 3 | Crop varieties released by country, principal agency, and type of crop, 2012–2014

Country (agency)	Beans	Maize	Vegetables	Rice	Sorghum	Wheat	Cowpeas	Groundnuts	Flowers	Sweet potatoes and potatoes	Millet	Sugarcane	Barley	Bananas and plantains	Cotton	Cassava	Other	Total
Benin (INRAB)		11	2												3		1	17
Botswana (DAR)		1			3		1											5
Burkina Faso (INERA)			2	4	2		6				2				1			17
Cameroon (IRAD, CARBAP)	7				1		1							6				15
Côte d'Ivoire (CNRA)		1	3	2													3	9
DR Congo (INERA)	1	2								1						3		7
Ethiopia (EIAR, RARIs)	12	7	11		6	14			14				7				45	116
Kenya (KALRO)	3	3			1	3				1	2	8	2				3	26
Madagascar (FOFIFA)	2			4														6
Malawi (DARS)	2	3	2	1												1		9
Mali (IER)		3		3	3	2					3							14
Mauritius (MSIRI)												1						1
Mozambique (IIAM)			10	3				1										14
Niger (INRAN)			4	2			4			2							4	16
Rwanda (RAB)	12									4							4	20
Senegal (ISRA)		1			5		7	10			3							26
Swaziland (DARSS)	3	4																7
Tanzania (DRD)	1	2	3			1		2		2		1			1	1	3	17
Togo (ITRA)		2		2				2										6
Uganda (NARO)	9	3		11										1			1	25
Zambia (ZARI)	3	10			1					3								17
Zimbabwe (DR&SS, TRB)	2	3		3		1											5	14

Source: Calculated by authors based on ASTI (2017).

Notes: See the acronym list for the full names of each agency. Data for some of the larger countries, including Nigeria, South Africa, and Ghana, were not available. Many smaller countries released no new varieties during 2012–2014 and hence are not included. The data presented are not necessarily exhaustive and do not distinguish between varieties developed locally and those derived or adapted from a CGIAR center or other source.

Conclusion and Policy Implications

Some encouraging signs indicate that, in recent years, SSA countries have become increasingly focused on investing in agriculture for economic growth, evidenced by a number of influential initiatives and regional and subregional processes that have put agriculture back on political and donor agendas. Many countries have developed solid agricultural development and financing plans to strengthen agricultural production and food security as part of CAADP. But attaining agricultural development, food security, and poverty reduction will also require well-developed NARSs and adequate levels of investment and human resources. Agricultural research spending and human resource capacity both grew in SSA as a whole during 2000–2014, but results were uneven, with a number of countries experiencing stagnating or declining investment growth. Underinvestment in agricultural research continues. The region's agricultural research intensity ratio fell during 2000–2015 because growth in agricultural research spending was slower than growth in agricultural output over time. Furthermore, agricultural research spending became more dependent on volatile donor funding. Many SSA countries face serious human resource capacity and infrastructure challenges. As of 2014, a large number of agricultural researchers, especially those qualified to the PhD-level, were approaching retirement age, representing a significant risk that the affected agencies could be left without the critical mass of senior, well-experienced researchers needed to lead research programs. This trend, combined with high shares of more recently recruited junior staff in need of experience and mentoring, has left many countries vulnerable. Without adequate succession strategies and training, significant knowledge gaps will emerge, raising concerns about the quality of future research outputs. Outdated research facilities and equipment are also impeding the conduct of productive research, which compromises the number and quality of research outputs and ultimately translates into reduced impact.

In recent years, APPSA, EAAPP, and WAAPP have made considerable progress in addressing SSA's most acute agricultural research capacity challenges, in rehabilitating research infrastructure, and in funding priority research areas. However, much more is needed if SSA is to reach the ambitious agricultural growth targets set by CAADP and the United Nations. Governments will need to institute a number of policy directives if the many challenges facing agricultural research systems are to be addressed. Taking into account the various challenges related to agricultural research funding, human capacity, outputs, infrastructure, and institutional structure presented in this report, policy implications for SSA governments are indicated in the key areas outlined below.

Governments must address underinvestment in agricultural research and take the necessary policy steps to diversify funding sources.

Despite increased allocations of funding to agricultural research by a number of governments in recent years, agricultural research spending in most SSA countries is still far below the levels required to sustain their agricultural sectors' needs. Countries that have increased their expenditures substantially, such as Ethiopia, Ghana, and Nigeria, have directed most of the funds toward (much-needed) salary increases or staff recruitment, rather than actual research programs. National governments urgently need to address underinvestment in agricultural research and ensure the full disbursement of approved budgets. They must 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 research programs accordingly. Donor and development bank funding needs to be closely aligned with national priorities, and donor programs should synergistically complement these priorities. 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. Funding potential from the private sector remains largely untapped in most countries. Cultivating private funding requires that national governments provide a more enabling policy environment through tax incentives, protection of intellectual property rights, and regulatory reforms to encourage the spill-in of international technology.

Governments must invest in training and capacity building and remove status and salary discrepancies between NARI researchers and university-based researchers.

Growing concern exists regarding the lack of human resource capacity in agricultural research to respond effectively to the agricultural challenges facing the countries of SSA. In many countries, the majority of PhD-qualified researchers will retire by 2025. NARIs therefore need to develop systematic human resource strategies without delay, incorporating existing and anticipated skills gaps and training needs. The successful implementation of such strategies will require both political and financial support. National governments must expand their investments in agricultural higher education to allow universities to increase the number and size of their MSc and PhD programs—or establish such programs in countries were MSc and PhD programs are still lacking—and to improve the curricula of existing programs. This includes the expansion of various regional capacity-building initiatives initiated in recent years. The large-scale MSc- and PhD-level training of young researchers through APSSA, EAAPP, and WAAPP will remedy the most acute capacity challenges in the coming years. It is important, however, that NARIs involve present (and past) tenured researchers in mentoring their young, inexperienced colleagues. In some countries, this may involve increasing the official retirement age of researchers or instituting some form of flexible working arrangements for retired researchers. Developing incentives to create a more conducive work environment for agricultural researchers is crucial. In a large number of countries, significant discrepancies exist in the remuneration, working conditions, and incentives offered to NARI researchers compared with their university-based colleagues. These inequities need to be removed or overcome to enable the NARIs to attract, retain, and motivate well-qualified researchers.

Governments must develop long-term national agricultural research policy agendas and provide stronger institutional, financial, and infrastructural support to NARIs.

Although many NARIs in SSA have (semi)autonomous status, funding and capacity constraints often prevent them from exercising this autonomy. Most NARIs are bound by ministerial directives and regulations, and therefore have little or no flexibility in recruiting staff, setting competitive salary levels, or determining what laboratories need renovation—all of which are needed to strengthen NARIs institutionally and ensure the continuity of their research. A critical area needing urgent attention is the development of strong, national agricultural research policy agendas, together with the necessary expertise to support these agendas long term. It is also essential that governments strengthen the institutional, financial, and infrastructural foundations of NARIs so they can more effectively address farm productivity challenges and poverty issues. Strengthening planning capacity at the research-program level is crucial to the overall effectiveness of NARIs. Many NARIs currently lack efficient administration systems and practices needed to more effectively monitor progress and inform strategic decision making.

Governments will also need to provide the necessary policy environment to stimulate cooperation among the country's agricultural research agencies in order to maximize synergies and efficiencies in the use of the scarce resources available to universities and government agencies. In addition, governments must take action to ensure that improved varieties and technologies released by the NARIs are disseminated to and adopted by farmers. This involves strengthening extension agencies and more clearly delineating the roles of NARIs and extension agencies to actively promote cooperation. Gender considerations also need to be taken into account in terms of identifying gender-specific research needs, designing training programs, and determining criteria for technology development and adaptation.

Note

1| Agricultural research investment and human resource data in this report include government, higher education, and nonprofit agencies involved in the performance of agricultural research. The private for-profit sector is excluded because data for the majority of private firms were not accessible.

References

ASTI (Agricultural Science and Technology Indicators). 2017. ASTI database. Washington, DC: International Food Policy Research Institute. www.asti.cgiar.org.

________. 2016. "Practitioner's Guide for National and Regional Focal Points: ASTI Methodology and Data Collection Standards." Accessed January 2017. www.asti.cgiar.org/sites/default/files/Guide_Methodology_Procedures.pdf.

Badiane, O., and J. Collins. 2016. "Agricultural Sector Growth and Productivity in Africa: Recent Trends and Future Outlook." Chapter 1 in *Agricultural Research in Africa: Investing in Future Harvests*, edited by J. Lynam, N. Beintema, J. Roseboom, and O. Badiane. Washington, DC: International Food Policy Research Institute.

Benin, S., L. McBride, and T. Mogues. 2016. "Why Do African Countries Underinvest in Agricultural R&D?" Chapter 5 in *Agricultural Research in Africa: Investing in Future Harvests*, edited by J. Lynam, N. Beintema, J. Roseboom, and O. Badiane. Washington, DC: International Food Policy Research Institute.

CCARDESA (Centre for Coordination of Agricultural Research and Development in Southern Africa). 2015. *Agricultural Productivity Programme for Southern Africa (APPSA) Annual Report: January–December 2015*. Gabarone, Botswana.

CGIAR. Various years. "CGIAR Financial Reports." Accessed February 2017. www.cgiar.org/resources/cgiarfinancial-reports.

Evenson, R., and D. Gollin, eds. 2003. *Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research*. Wallingford, UK: CABI Publishing.

Fan, S., and X. Zhang. 2008. "Public Expenditure, Growth and Poverty Reduction in Rural Uganda." *African Development Review* 20 (3): 466–496.

FAO (Food and Agriculture Organization of the United Nations). 2017. FAOSTAT database. Accessed March 2017. www.fao.org/faostat/en/#home.

Fuglie, K., and N. Rada. 2016. "Economies of Size in National Agricultural Research Systems." Chapter 3 in *Agricultural Research in Africa: Investing in Future Harvests*, edited by J. Lynam, N. Beintema, J. Roseboom, and O. Badiane. Washington, DC: International Food Policy Research Institute.

Huyer, S. and G. Westholm. 2007. Gender Indicators in Science, Engineering, and Technology: An information Toolkit. Science and Technology for Development Series. Paris: United Nations Educational, Scientific and Cultural Organization.

IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development). 2008. *Synthesis Report*. Washington, DC: Island Press.

Ittersum, M. van, L. van Bussel, J. Wolf, P. Grassini, J. van Wart, N. Guilpart, L. Claessens, et.al. 2016. Can Sub-Saharan Africa Feed Itself? *Proceedings of the National Academy of Sciences of the United States of America* 113 (52): 14964–14969.

Mogues, T. 2015. "Political Economy Determinants of Public Spending Allocations: A Review of Theories, and Implications for Agricultural Public Investment." *European Journal of Development Research* 27 (3): 452–473.

Nin Pratt, A. 2016. *Comparing Apples to Apples: A New Indicator of Research and Development Intensity in Agriculture*. IFPRI Discussion Paper 1559. Washington, DC: International Food Policy Research Institute.

ReSAKSS (Regional Strategic Analysis and Knowledge Support System). 2017. ReSAKSS Map Tool. Accessed February 2017. www.resakss.org/map.

Roseboom, J., and K. Flaherty. 2016. "The Evolution of Agricultural Research in Africa: Key Trends and Institutional Developments." Chapter 2 in *Agricultural Research in Africa: Investing in Future Harvests*, edited by J. Lynam, N. Beintema, J. Roseboom, and O. Badiane. Washington, DC: International Food Policy Research Institute.

Roy-Macauley, H., A. Izac, and F. Rijsberman. 2016. "The Role of the CGIAR in Agricultural Research for Development in Africa South of the Sahara." Chapter 15 in *Agricultural Research in Africa: Investing in Future Harvests*, edited by J. Lynam, N. Beintema, J. Roseboom, and O. Badiane. Washington, DC: International Food Policy Research Institute.

Stads, G. 2015. *Agricultural R&D in West Asia and North Africa*. ASTI Synthesis Report. Washington, DC: International Food Policy Research Institute.

________. 2016. "A Snapshot of Agricultural R&D Investment and Capacity in Asia." Chapter 2 in *High Level Policy Dialogue on Investment in Agricultural Research for Sustainable Development in Asia and the Pacific: Papers Presented*, edited by J. Karihaloo, B. Mal, and R. Ghodake. Bangkok: Asia Pacific Association of Agricultural Research Institutions.

Stads, G., and N. Beintema. 2015. "Agricultural R&D Expenditure in Africa: An Analysis of Growth and Volatility." *European Journal of Development Research* 27 (3): 391–406.

________. 2017. "An Assessment of the Critical Financial, Human, and Institutional Capacity Issues Affecting Agricultural Research in West Africa: Synthesis and Policy Considerations." Background document for The World Bank. International Food Policy Research Institute, Washington, DC (in preparation).

Stads, G., N. Beintema, S. Perez, K. Flaherty, and C. Falconi. 2016. *Agricultural Research in Latin America and the Caribbean: A Cross-Country Analysis of Institutions, Investment, and Capacities*. ASTI Synthesis Report. Washington, DC: International Food Policy Research Institute and Inter-American Development Bank.

Thirtle, C., L. Lin, and J. Piesse. 2003. "The Impact of Research-Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia, and Latin America." *World Development* 31 (12): 1959–1975.

UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2015. *UNESCO Science Report: Towards 2030*. Paris.

WAAPP (West Africa Agricultural Productivity Program). 2015. "Young Scientists Training." Accessed March 2017. www.waapp-ppaao.org/en/content/young-scientists-training.

WACCI (West African Centre for Crop Improvement). 2014. "About WACCI." Accessed March 28, 2017. http://wacci.edu.gh/background.

Wellard, K., T. Chancellor, G. Okecho, S. Ndagire, and S. Mugarura. 2014. *End of Phase I Evaluation of the Eastern Africa Agricultural Productivity Programme – EAAPP*. Entebbe, Uganda: Association for Strengthening Agricultural Research in Eastern and Central Africa.

World Bank. 2007. *World Development Report 2008: Agriculture for Development*. Washington, DC.

________. 2016. World Development Indicators. Accessed March 2016. http://data.worldbank.org/data-catalog/world-development-indicators.

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