AN ASSESSMENT OF THE CRITICAL FINANCIAL, HUMAN, AND INSTITUTIONAL CAPACITY ISSUES AFFECTING AGRICULTURAL RESEARCH IN WEST AFRICA:

SYNTHESIS AND POLICY CONSIDERATIONS

Background document prepared for the World Bank[1]

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INTRODUCTION

High population growth, deteriorating soils, climate change, and volatile food prices are major factors affecting food security in West Africa. To respond effectively to these challenges, agricultural productivity in the subregion needs to be accelerated without delay. Given widespread evidence that investments in agricultural research have tremendously enhanced agricultural productivity around the world over the past five decades, West African governments have a critical responsibility when it comes to providing sufficient and sustained funding for agricultural research and creating a more enabling environment for agricultural innovation to flourish.

This report assesses long-term investment, human capacity, research output, and institutional trends in agricultural research in West Africa, particularly focusing on developments during 2000–2014. The analysis uses information collected by Agricultural Science and Technology Indicators (ASTI)—led by the International Food Policy Research Institute (IFPRI) and within the portfolio of the CGIAR Research Program on Policies, Institutions, and Markets (PIM)—using comprehensive datasets derived from primary surveys collected through a series of consecutive data collection rounds and a small number of secondary resources where survey data were missing or of poor quality. In addition, the collection of detailed data on the allocation of West Africa Agricultural Productivity Program (WAAPP) funding and WAAPP-funded staff training was initiated by the World Bank and shared with ASTI. All these datasets have been linked with older investment and human resource datasets, as well as with ASTI's global datasets, to provide a wider context for agricultural research investment trends in West Africa over time and in contrast to other sub-regions. The analysis in this report concludes with suggested future directions needed to address the financial and human capacity challenges that many countries currently face.

[1] This publication has not been peer reviewed. The views expressed are those of the authors and do not necessarily reflect the official position of the International Food Policy Research Institute or the World Bank.

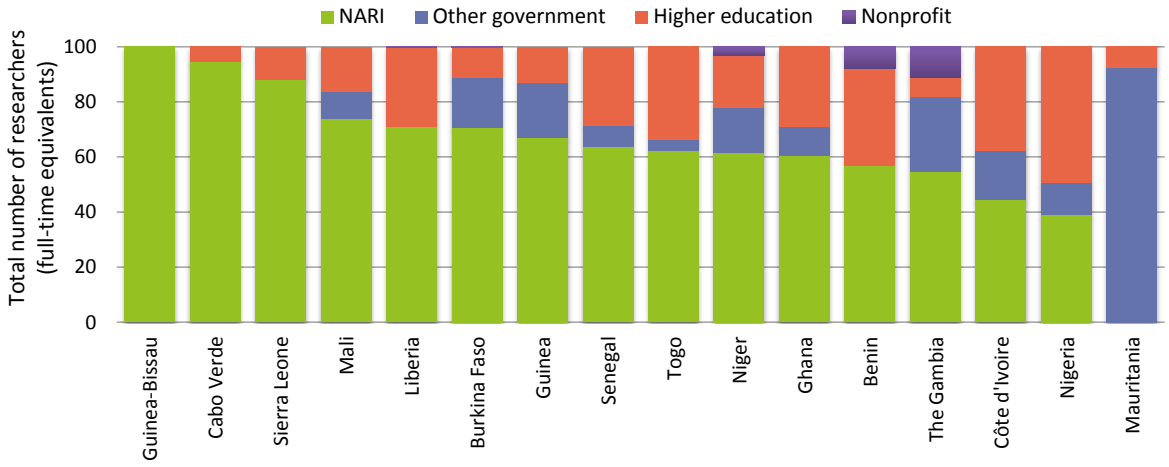
INSTITUTIONAL SETUP OF WEST AFRICAN AGRICULTURAL RESEARCH

Most West African national agricultural research systems (NARS) comprise a national agricultural research institute (NARI), a number of smaller government and higher education agencies, and in some cases a handful of nonprofit research entities, such as nongovernmental or producer organizations. The role of the private sector in agricultural research in most West African countries remains limited.

NARIs across West Africa are structured in a variety of ways: (1) as a research department within a ministry of agriculture or equivalent; (2) as a semi-autonomous government institute with the flexibility to determine key internal policies; (3) as multiple agencies focusing on specific agricultural subsectors, such as crops, livestock, and fisheries; 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 West African NARSs (Figure 1).

Most NARS in West Africa 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 NARS in West Africa also remain highly fragmented in terms of the number of individual agencies, and this has hindered the effective use of the available resources.

Figure 1—Distribution of agricultural researchers by country and institutional category in West Africa, 2014



Source: Calculated by authors based on ASTI data and various secondary sources.
Notes: Shares for Guinea-Bissau and Liberia are based on 2011 data; the value for Nigeria includes estimates for the higher education sector based on 2008 data.

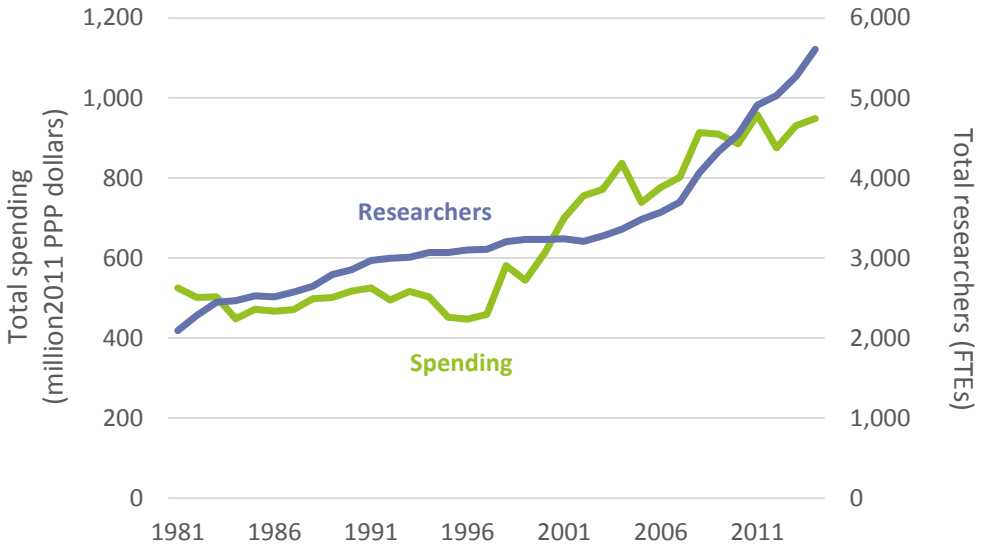
Linkages across research agencies—and also between research agencies and extension providers, policymakers, and farmers' organizations—are often weak due to the fragmentation within NARSs and lack of coordination mechanisms. Collaboration across NARSs is facilitated through the West and Central African Council for Agricultural Research and Development (CORAF/WECARD), the Forum for Agricultural Research in Africa (FARA), CGIAR centers, and various other organizations and initiatives. CORAF/WECARD

and FARA—both 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 NARSs members. One of the main objectives of WAAPP is to promote collaboration between NARS, creating national centers of specialization (NCoS), which focus on a number of priority commodities. CORAF/WECARD ensures that the research outputs of these NCoS are shared widely throughout the subregion.

LONG-TERM SPENDING AND HUMAN CAPACITY TRENDS

West African agricultural research spending—excluding the private for-profit sector—has rapidly increased since the turn of the millennium. In 2014, the subregion as a whole spent $948 million on agricultural research, in 2011 PPP prices (Figure 2).[2] [3] Nigeria alone accounted for nearly half of this total (Table 1). Ghana is the second largest country in terms of agricultural research expenditures ($197 million), followed by Côte d'Ivoire ($82 million) and Senegal ($51 million). In contrast, 6 of the 16 countries for which data were available spent less than $10 million each on agricultural research.

Figure 2—Long-term agricultural research capacity and investment trends in West Africa, 1981–2014



Source: Calculated by authors based on ASTI data and various secondary sources.
Notes: Data for subperiods were estimated for some countries. Data for the private for-profit sector were unavailable and have been excluded from this graph.

[2]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 are not accessible.

[3] 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.

Agricultural research expenditures in West Africa grew by more than 50 percent between the late 1990s and 2014, following a long period of stagnation during the 1980s and the first half of the 1990s. This subregional growth, however, is almost entirely driven by Nigeria and Ghana, and primarily stemmed from the urgent need to institute some degree of parity and competitiveness in researcher salary levels in both countries and—in the case of Nigeria—to rehabilitate derelict infrastructure and equipment. Investment levels in many other countries in the region have either stagnated or fallen during 2000–2014, although the data indicates an upsurge in spending levels in more recent years, largely in response of the launch of the West African Agricultural Productivity Program (WAAPP).

Table 1. Agricultural research spending and researchers in West Africa, 2000–2014

Country	Expenditures (million 2011 PPP dollars)			Researchers (full-time equivalents)		
	2000	**2008**	**2014**	**2000**	**2008**	**2014**
Benin	16.4	25.2	23.2	121.3	121.6	170.4
Burkina Faso	25.5	23.2	48.5	207.5	240.3	310.8
Cabo Verde	*2.9*	2.5	2.3	*23.6*	*22.3*	22.3
Côte d'Ivoire	91.6	76.7	82.1	184.6	195.4	253.2
The Gambia	4.0	3.7	5.1	51.4	41.7	60.4
Ghana	90.5	122.2	197.4	439.4	485.5	575.0
Guinea	13.8	4.1	7.7	222.5	215.5	258.7
Guinea-Bissau	*0.4*	*0.4*	*0.2*	*10.0*	*10.9*	*9.0*
Liberia	*4.9*	*5.4*	*6.7*	*25.1*	*19.6*	*45.1*
Mali	50.8	38.4	37.9	201.4	237.7	285.7
Mauritania	8.9	10.6	15.6	59.3	70.7	86.0
Niger	5.5	8.1	14.5	107.7	93.4	182.2
Nigeria	245.9	541.0	*433.5*	1,309.2	2,051.0	*2,975.5*
Senegal	31.0	31.0	51.3	133.3	134.3	124.4
Sierra Leone	*0.9*	8.9	15.3	*40.7*	58.6	123.7
Togo	19.9	12.1	6.9	95.5	67.6	125.1
Total West Africa	**612.8**	**913.6**	**948.2**	**3,232.2**	**4,066.0**	**5,607.3**

Source: Compiled by authors based on ASTI data and various secondary sources.
Notes: Numbers in italics have been estimated. 2014 data for Nigeria's higher education sector have been extrapolated based on available data for 2008. Data for the private for-profit sector were unavailable and have been excluded from this table. To facilitate cross-country comparisons, financial data have been converted to 2011 purchasing power parity (PPP) prices using the World Bank's World Development Indicators. 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. Full-time equivalents (FTEs) only take into account the time researchers actually spend on research, as opposed to other activities like teaching, time spent on secondment to other agencies, or unrelated administrative duties. For more information, see www.asti.cgiar.org/methodology.

In 2014, West Africa employed more than 5,600 full-time equivalent (FTE) researchers in agricultural and related sciences, up from 3,232 FTEs in 2000, representing a 73 percent increase. Once again, Nigeria (2,975 FTEs in 2014) accounted for more than half of this total and was the main driver behind subregional capacity growth. Ghana employed 575 FTEs in 2014, followed by Burkina Faso (311 FTEs), Mali (286 FTEs), Guinea (259 FTEs), and Côte d'Ivoire (253 FTEs). Many of the other countries in the

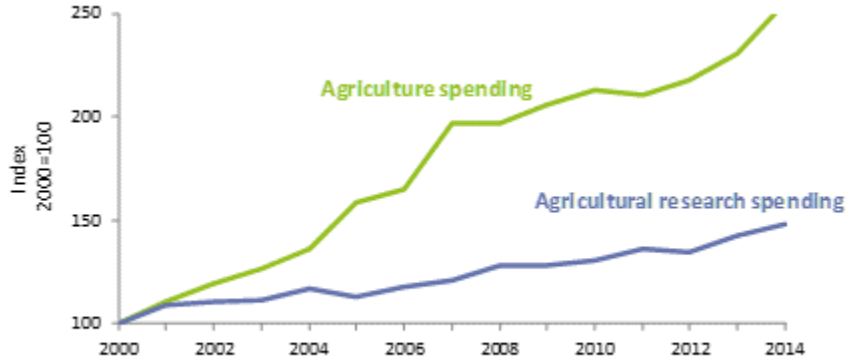
subregion have considerably smaller national research systems, both in terms of size and strength: 5 of the 16 countries for which data were available employed fewer than 100 agricultural researchers in 2014 (in FTEs).

Box 1. Growth in research spending lower than for other kinds of agricultural investment

The 2003 launch of the Comprehensive Africa Agriculture Development Programme (CAADP) elevated agriculture within Africa's political agenda. Although a large number of African countries have yet to attain CAADP's ambitious targets (i.e. spending at least 10 percent of their national budgets on agriculture in order to ensure 6 percent sectoral growth per year), substantial progress has been made. Africa south of the Sahara has more than doubled its investments in agriculture during 2000–2014 after long periods of neglect in prior decades (Figure 2). Agricultural research spending also grew during this timeframe, albeit at a considerably slower rate (48 percent during 2000–2014). Data indicate that, although many African 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.

Relative underinvestment in agricultural research is striking, given the well-documented evidence of the high returns to such investments in Africa, 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). One of the major contributors to underinvestment in agricultural research in Africa (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.

Spending on agriculture and on agricultural research in Africa south of the Sahara, 2000–2014

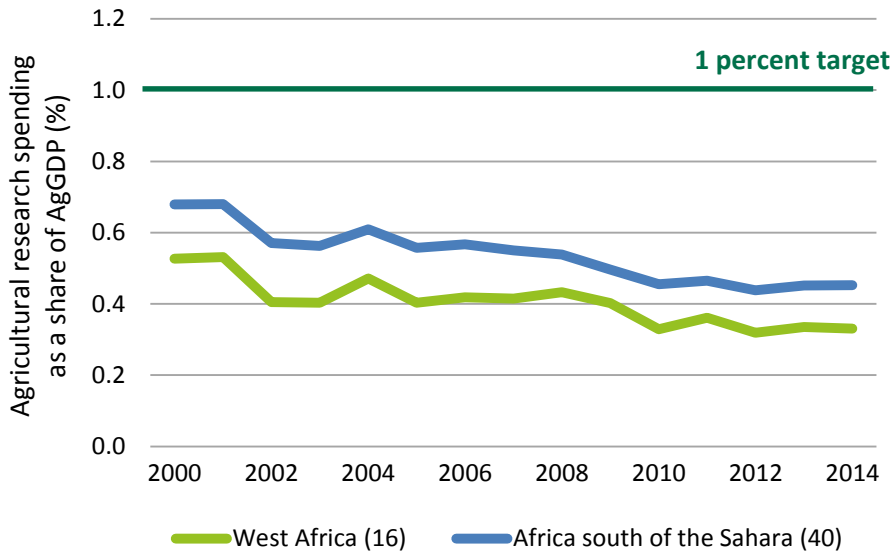


Sources: Data on agricultural spending are from ReSAKSS (2017); data on agricultural research spending are from ASTI and various secondary sources.

RESEARCH SPENDING FALLING BEHIND AGRICULTURAL PRODUCTION GROWTH

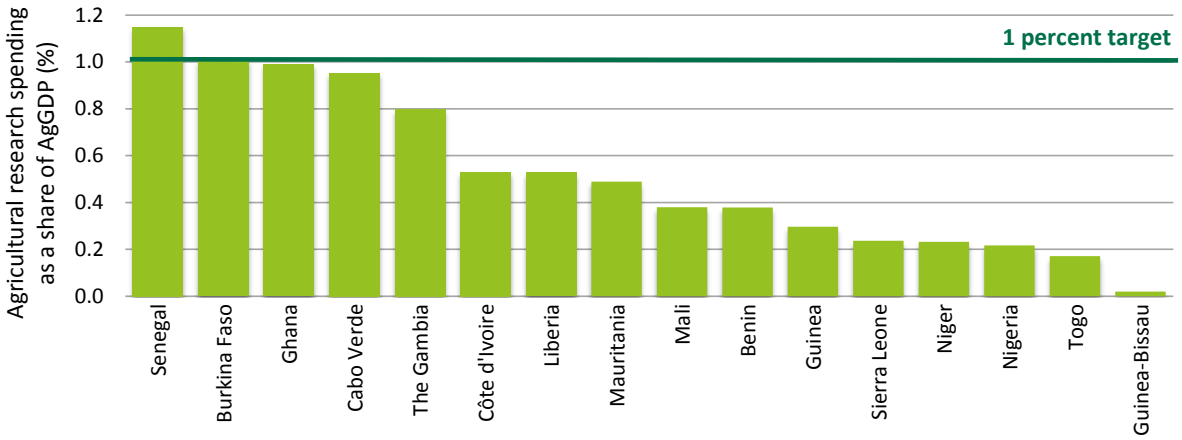
Growth in spending on agricultural research has been slower than growth in spending on agriculture (see Box 1), but also slower than growth in agricultural output over time. As a result, West Africa's agricultural research intensity ratio—that is, its agricultural research spending as a share of its agricultural gross domestic product (AgGDP)—dropped markedly, from 0.53 percent in 2000 to just 0.33 percent in 2014 (Figure 3). In comparison, the 2014 research intensity ratio for Africa south of the Sahara as a whole was 0.46 percent, indicating that West Africa invests comparatively less in agricultural research than other African subregions. In 2014, 14 of the 16 West African 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 3). In fact, 9 of these 16 countries spent less than 0.5 percent of their AgGDP on agricultural research (Figure 4). Only Senegal and Burkina Faso reached the 1 percent target in 2014 (with Ghana and Cabo Verde coming very close to target). Burkina Faso's intensity ratio is highly volatile over time, however, coinciding largely with fluctuations in donor funding.

Figure 3—Agricultural research spending as a share of agricultural GDP, 2000–2014



Sources: Calculated by authors based on ASTI data and various secondary sources; data on AgGDP are from World Bank (2016).
Note: The numbers in brackets denote the number of countries included in each sample.

Figure 4—Agricultural research intensity ratios, 2014



Sources: Calculated by authors based on ASTI data and various secondary sources; data on AgGDP are from World Bank (2016).
Notes: Values for Guinea-Bissau and Liberia are based on 2011 data; the value for Nigeria includes estimates for the higher education sector based on 2008 data.

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 West African 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

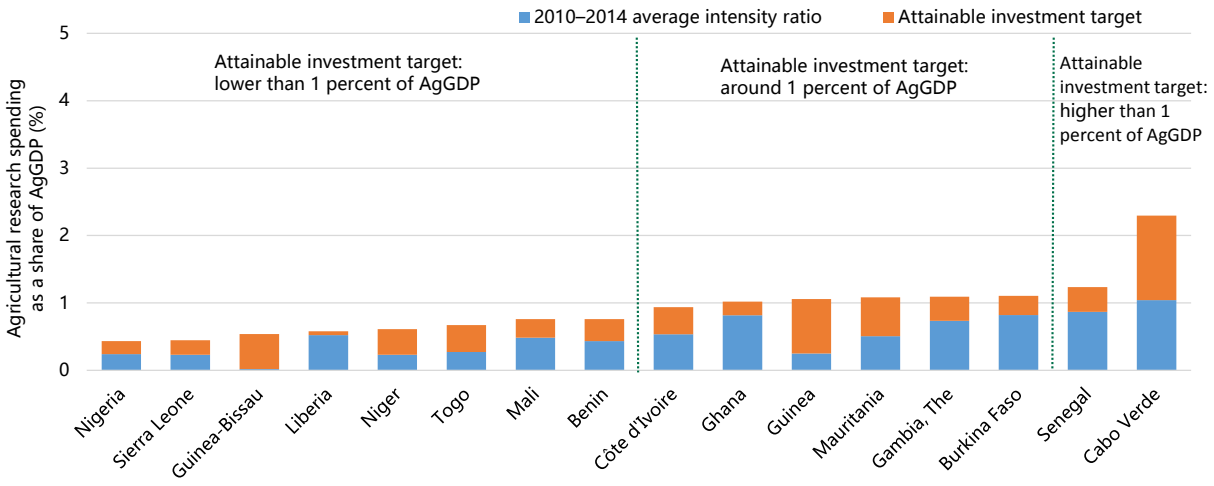
intensity using a "data envelopment analysis" approach, whereby the index comprises a range of weighted criteria (for further details, see Nin Pratt 2016). Under this approach, countries with the same mix of inputs are expected to require similar minimum levels of research investment, and investment 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 five West African countries, the 1 percent investment target is simply unattainable. Based on the structural characteristic of the economies and agricultural sectors of Mali, Niger, Nigeria, Togo, Sierra Leone, investment targets of around 0.4–0.6 percent of AgGDP would be much more realistic. In contrast, in Cabo Verde, an intensity ratio above 2.0 percent should be attainable (Figure 5). 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 The Gambia, Ghana, and Senegal 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 Nigeria or Sierra Leone is less severe than conventional intensity ratios would suggest, and that a 1 percent investment target is in fact unrealistic for these countries. Nonetheless—irrespective of which intensity measure is used—a large number of countries in West Africa significantly underinvest in agricultural research.

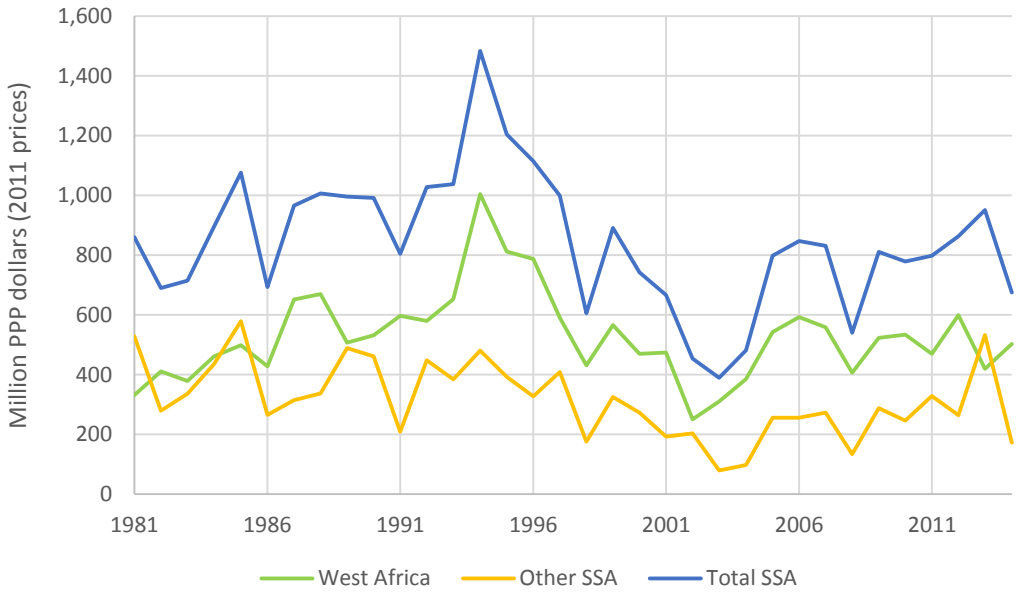
The intensity index can also be used to calculate the research investment gap—meaning, the difference between the research investment of a particular country and that of the country with the highest investment among countries with the same input mix as the analyzed country. From there, the additional investment needed to close the investment gap can also be calculated. As previously established, West Africa invested $948 million in agricultural research in 2014 (in 2011 PPP prices). If all SSA countries invested as much as those on the "investment frontier," subregional investment levels in 2014 could have totaled $1.4 billion. In other words, the gap between actual investment in agricultural research and estimated attainable agricultural research investment was about $500 million (in 2011 PPP prices) in 2014. Even though the annual investment gaps in recent years are lower than in the 1990s (Figure 6), they remain very high, raising questions as to what agricultural productivity in West Africa could have looked like today had all these additional investments been made in the past. Moreover, the investment gap in West Africa is consistently higher than in other parts of Africa, highlighting once again the severe level of underinvestment in agricultural research in West Africa compared to other parts of the region.

Figure 5—Five-year average 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). Please note that the intensity ratios in Figure 8 are for 2014 only. The intensity ratios in Figure 9 are 5-year averages.

Figure 6—Gap between actual agricultural research investment and attainable agricultural research investment, 1981–2014



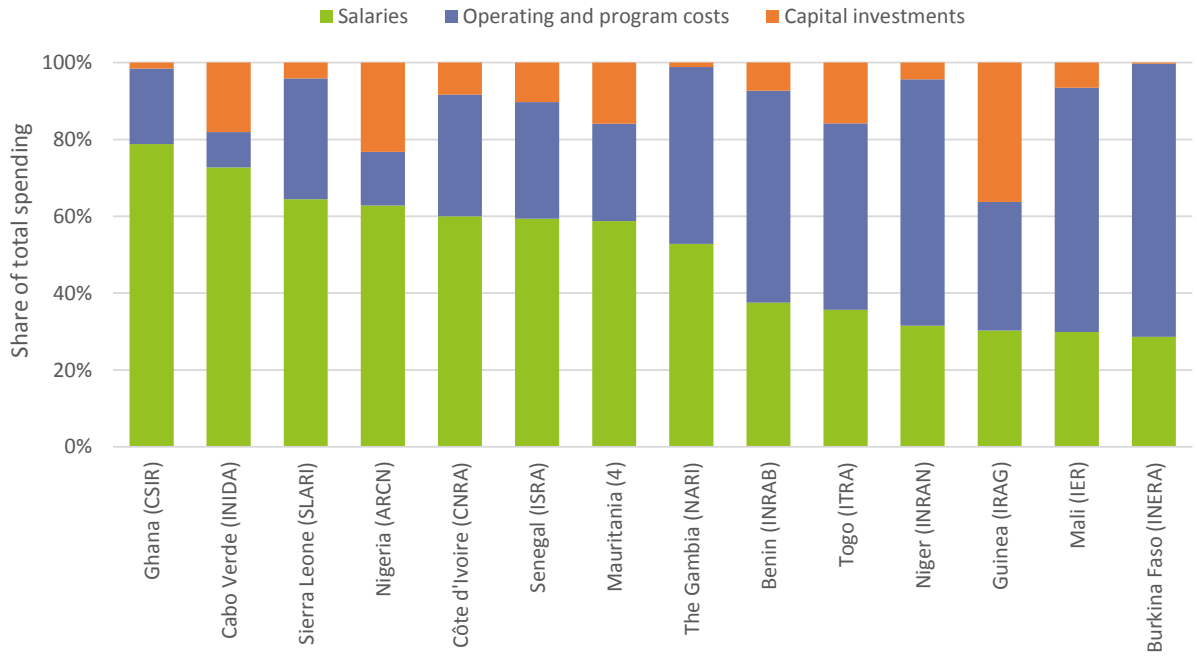
Source: Calculated by Nin Pratt (IFPRI) based on ASTI (2017).
Note: For details of the underlying methodology, see Nin Pratt (2016).

SPENDING ALLOCATION OF WEST AFRICAN AGRICULTURAL RESEARCH

No formula can determine the optimal allocation of agricultural research expenditures across salaries, program and operating costs, and capital investments. 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 sample encompassing the principal government and nonprofit agencies of 13 West African countries for which detailed cost category data were available, 59 percent of available finances was spent on staff salaries, 27 percent was spent on operating and program costs, and the remaining 14 percent was invested in capital improvements (Figure 7). These regional averages mask a significant degree of cross-country variation. The national agricultural research institutes in Ghana and Cabo Verde spent 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 countries fall at the other end of the spectrum, allocating two-thirds of agricultural research expenditures to operating and program costs and capital investments.

Figure 7—NARI expenditures by cost category, 2009–2014 average



Sources: Calculated by authors based on ASTI data and various secondary sources.
Notes: The principal agencies included for Mauritania are IMROP, CNRADA, CNERV, and CNLA. Data for Sierra Leone are for 2012–2014 only. Data for Guinea-Bissau and Liberia were unavailable.

HIGH DEPENDENCE ON DONORS FOR AGRICULTURAL RESEARCH FUNDING

Agricultural research in Africa 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, 54 percent of the funding to the national agricultural research institutes across West Africa (excluding Guinea-Bissau, Liberia, and Nigeria) was provided by national governments, and funding from donors and development banks constituted 26 percent (Figure 8). 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. Leaving salary costs out of consideration, donor funding for West African agricultural research would in fact exceed the 50 percent mark. Following years of decline, contributions by donors and development banks to agricultural research agencies have rebounded in West Africa since 2008 with the launch of sizable projects funded through World Bank loans/grants as part of WAAPP.

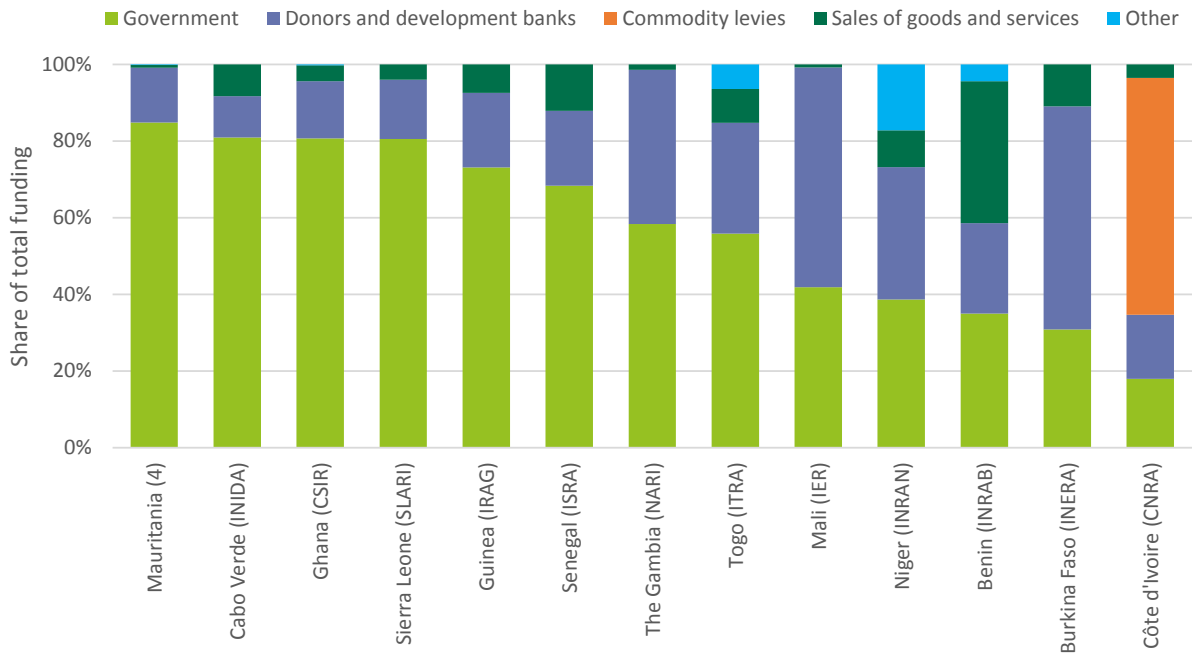
Although many governments are committed to funding agricultural research at face value, the amounts disbursed are habitually lower than—and in many cases only a fraction of—budgeted allocations. The governments of Ghana and Senegal, for example, only disbursed 15 percent of the development budget originally allocated to CSIR agencies and ISRA during 2008–2012. It goes without saying that these funding discrepancies have severe repercussions on the day-to-day operations of agricultural research institutes and their planned research activities based on anticipated funding levels.

Given low or nonexistent government funding for the operation of actual research programs, many institutes across West Africa have no choice but to seek alternative sources of funding such as through the sale of goods and services. In Benin, two-thirds of INRAB's program costs are funded through the sale of rice, maize, cowpea, and germinated palm oil seeds. In Ghana, CSIR institutes are mandated to generate a significant share of their financial resources through commercial means. Although this is a sound long-term goal, it is impeded in the short- to medium-term given the level of funding required, lack of capacity at CSIR to generate funds internally, as well as patent issues. Funding diversification through the sale of goods services is not encouraged in all West African countries, however. ITRA in Togo reverted from a semiautonomous agency to a public agency in 2008, and with that change ceased to benefit from any revenues it generates internally. Similarly, INERA in Burkina Faso and INIDA in Cabo Verde must transfer any funding they generate internally back to the Treasury. ARCN in Nigeria is only allowed to keep 30 percent of its internally generated income. The disincentive effect of such policies in these countries is a missed funding opportunity.

The funding structure of CNRA in Côte d'Ivoire is unique and exemplary in West Africa. The second National Agricultural Services Support Project (PNASA II), which was launched in 1998 and administered by the World Bank, stipulated that CNRA would be structured as a public–private entity, with 40 percent of its funding being contributed by the government and 60 percent derived from the private sector. To this end, the Inter-Professional Fund for Agricultural Research and Extension (FIRCA) was established in 2002. FIRCA relies on financial contributions not only from the government but also from the country's producers, who pay membership subscription dues through commodity-specific producer organizations. At least 75 percent of the subscription fees raised through agricultural production in a given subsector are allocated to programs serving the needs of that subsector. The remaining funds are allocated to a solidarity fund, and a marginal share underwrites FIRCA's operating costs. The purpose of the solidarity

fund is to finance programs designed to serve production sectors (mostly food crops) unable to raise sufficient funding through their own subscription fees or that have difficulty doing so because of the way they are structured. The amounts raised and contributed by the coffee, cocoa, rubber, and oil palm producer organizations represent the bulk of total subscription dues raised by all the producer organizations combined.

Figure 8—Funding sources of principal agricultural research agencies in West Africa, 2009–2014



Source: Calculated by authors based on ASTI data and various secondary sources.
Notes: The principal agencies included for Mauritania are IMROP, CNRADA, CNERV, and CNLA. Data for Sierra Leone are for 2012–2014 only. Data for Guinea-Bissau, Liberia, and Nigeria were unavailable.

THE WEST AFRICA AGRICULTURAL PRODUCTIVITY PROGRAM (WAAP)

Donor and development bank funding to West African 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 West Africa in the form of country-level projects financed through loans and supplemented by grants. Projects have variously 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 early 2000s). Some projects aimed to reshape the entire national agricultural research system, whereas others focused on specific crops, agencies, or general research management and coordination. Since 2008, the World Bank has shifted from a country-level to a regional approach to financing agricultural research in Africa through the model of regional productivity programs—that is, the East African, West African, and Southern African agricultural

productivity programs (EAAPP, WAAPP, and APPSA, respectively). The goal of these programs was 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.

WAAPP was designed to respond to the challenges of increasing agricultural productivity, which is an important area of the agricultural policies of the Regional Economic Communities (RECs) for the implementation of Pillar IV of CAADP. The program commenced in 2008 under the auspices of the Economic Community of West African States (ECOWAS) and is coordinated at the subregional level by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD). WAAPP was initially designed as a ten-year program implemented in two phases of 5 years each. During the first phase, the objective is to generate and disseminate improved agricultural technologies. Based on lessons learnt during the first phase, the second phase focused on the intensification of the dissemination and adoption of improved technologies in the priority agricultural sectors of the countries benefiting from the program.

WAAPP is organized around four main components that form a framework to position the agricultural sector as an engine of growth in West Africa. The first component focuses on enabling conditions for regional cooperation in improved technologies generation and dissemination; the second aims at building the capacities of agricultural research institutions and particularly infrastructural and human training; the third focuses on funding of demand-driven technology generation and adoption; and the fourth component aims at building the capacities of institutions involved in the implementation of the project at the administrative and financial level, the monitoring, evaluation, learning and information as well as communication management.

WAAPP's financial arrangement truly reflects its regional scope. It is funded under the Adaptable Programmatic Loan (APL) formula at the regional desk of the International Development Association (IDA) of the World Bank. One-third of the program's resources come from the World Bank envelope allocated to each beneficiary country, while the other two-thirds are derived from the Bank's funds for the financing of regional programs. Besides, beneficiary countries pay one-fifteenth of their funding to CORAF/WECARD to ensure the regional coordination. In addition to IDA funding, the Policy and Human Resources Development (PHRD) and the Global Food Response Program (GFRP) trust funds also contribute to WAAPP funding. PHRD is provided by the Government of Japan to the Mano River countries (Côte d'Ivoire, Guinea, Liberia, and Sierra Leone) for the development of the rice value chain. GFRP is provided by the Government of Spain in response to the 2010 global food price crisis. It supports the accelerated adoption of released technologies.

In March 2007, the first phase of WAAPP was approved. This phase, with a total cost of US$45 million, known as WAAPP-1A, included three countries: Ghana, Senegal, and Mali (Table 2). These countries are working on the high-priority value chains identified in ECOWAS' mobilizing programs, namely roots and tubers in Ghana, dry land cereals in Senegal, and rice in Mali. The second phase, known as WAAPP-1B, brought in Burkina Faso (horticulture), Côte d'Ivoire (bananas and plantains), and Nigeria (catfish and tilapia). It was approved in September 2010, for a total cost of $116 million. The third set, WAAPP-1C, was approved in March 2011 and covers seven countries: Benin, The Gambia, Guinea, Liberia, Niger, Sierra Leone, and Togo. The countries of WAAPP A ended their first phase and are currently in their second phase. Moreover, additional financing was granted to 4 countries (Benin, Togo, Niger, and Guinea)

to extend the first phase of WAAPP for three years. The World Bank has decided to close the WAAPP series and to prepare a follow up Program, which will be more transformative and which builds on WAAPP achievements.

Table 2—Total WAAPP financing by country and phase, 2008–2018

		Funding (in million US dollars)				
	Country	**IDA**	**IDA (add.)**	**GFRP**	**PHRD**	**Total**
WAAPP 1A	Ghana	15	—	—	—	15
	Mali	15	—	—	—	15
	Senegal	15	—	—	—	15
WAAPP 1B	Burkina Faso	15	—	6	—	21
	Côte d'Ivoire	30	—	6	8	44
	Nigeria	45	—	6	—	51
WAAPP 1C	Benin	16.8	20	—	—	16.8
	The Gambia	7	—	5	—	12
	Guinea	—	23	—	9	9
	Liberia	6	—	—	8	14
	Niger	30	15	—	—	30
	Sierra Leone	12	—	—	10	22
	Togo	12	10	—	—	12
WAAPP 2A	Ghana	60	—	—	—	60
	Mali	60	—	—	—	60
	Senegal	60	20	—	—	80
Total		**398.8**	**88**	**23**	**35**	**544.8**

Source: World Bank.

Note: This table includes WAAPP funding to research and non-research activities. It excludes country counterpart funding.

WAAPP FUNDING ALLOCATION TO NATIONAL AGRICULTURAL RESEARCH

In order to achieve its ambitious goals, WAAPP works with scientists, researchers, extension workers, and farmers to generate, disseminate and adopt improved technologies; create enabling conditions for regional cooperation; build human and institutional capacity across the sub-region; and create youth employment, engage women, and adapt to climate change. As such, a relatively large number of agencies are recipients of WAAPP funding, both at the country and regional level. Recipients include research agencies, extension agencies, universities, private-sector companies, research coordinating bodies, NGOs, farmer organizations, international research institutes, and many more.

In an effort to filter out funding received by research agencies from non-research recipients of WAAPP funding, ASTI requested detailed annual financial data broken down by WAAPP funding recipient and a set of predefined cost categories from the World Bank. In small countries like Liberia and Sierra Leone, the NARIs turned out to be the only recipients of research-related WAAPP funding, whereas in a large country like Nigeria, 140 separate agencies received research-related WAAPP funding. The NARIs that received the largest amount of WAAPP funding are ISRA (Senegal), CSIR (Ghana), and IER (Mali) (Table 3). This is not surprising, given that WAAPP started much earlier in these countries and the fact that WAAPP 2A funding to these countries is four times higher than WAAPP 1A funding. The fact that IER

received a considerably lower mount of funding than ISRA and CSIR can be explained by the fact that the 2012 military coup and conflict in the north caused a suspension of all World Bank aid to Mali. The NARIs that are part of WAAPP 1B received a total of around $12–$14 million (in 2011 PPP prices) of WAAPP funding each during 2012–2016. Most NARIs that are part of WAAPP 1C received around $6–$7 million each over this timeframe with the exception of INRAB in Benin (which received close to $17 million) and INRAN in Niger (which received just $2.3 million). The latter can be explained by the fact that most of the WAAPP funds in Niger are allocated to the National Agricultural Research Council (CNRA), which coordinates agricultural research in the country, rather than the National Agricultural Research Institute of Niger (INRAN), which carries out agricultural research.

Table 3—WAAPP funding allocation to NARIs, 2008–2016

Country (institute)	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
					million 2011 PPP dollars					
Benin (INRAB)	—	—	—	—	—	2.017	4.959	5.627	4.168	16.770
Burkina Faso (INERA)	—	—	—	—	—	0.969	4.028	2.122	4.831	11.950
Côte d'Ivoire (CNRA)	—	—	—	—	1.506	3.527	6.201	0.663	0.338	12.235
Gambia, The (NARI)	—	—	—	—	5.257	0.366	1.234	0.072	1.152	7.083
Ghana (CSIR institutes)	0.414	1.807	2.876	5.004	2.042	4.077	8.785	14.398	3.683	43.086
Guinea (IRAG)	—	—	—	—	0.939	1.578	2.379	1.600	0.433	6.929
Liberia (CARI)	—	—	—	—	0.013	2.532	2.311	0.832	0.098	5.786
Mali (IER)	6.706	4.639	5.191	3.907	2.349	0.114	1.462	4.032	4.176	32.575
Niger (INRAN)	—	—	—	—	0.045	0.060	0.147	0.222	1.900	2.374
Nigeria (ARCN institutes)	—	—	—	—	2.405	3.146	4.637	4.245	na	14.433
Senegal (ISRA)	0.190	1.546	2.396	4.441	3.337	6.801	6.381	11.862	8.211	45.165
Sierra Leone (SLARI)	—	—	—	—	0.011	1.966	3.281	1.373	0.424	7.056
Togo (ITRA)	—	—	—	—	0.426	0.861	3.749	1.501	0.499	7.035
Total	**7.310**	**7.992**	**10.463**	**13.352**	**18.330**	**28.014**	**49.554**	**48.550**	**28.911**	**212.477**

Source: Compiled by authors from World Bank (2017).
Notes: "na" denotes that data are unavailable. WAAPP funding includes all IDA, GFRP, and PHRP allocations. The 2016 total excludes Nigeria.

As previously mentioned, WAAPP funding does not only target NARIs, but a large number of additional agencies involved in agricultural research at the national level as well. These non-NARI recipients of research-related WAAPP funding include research coordinating bodies (such as CNRA in Niger and Mali or CNRST in Burkina Faso); specialized government research institutes involved in livestock, soil, fisheries, or food technology research; universities and colleges; NGOs; producer organizations; and private sector companies. In Nigeria, in particular, a large number of private fisheries companies received WAAPP funding for research on catfish and tilapia. These companies and the large number of higher education agencies combined received considerably more WAAPP funding that the ARCN institutes. This situation is similar in Côte d'Ivoire, The Gambia, and Niger. In all these countries, non-NARI entities as a group were larger recipients of WAAPP funding than the NARIs (Table 4). In addition to in-country recipients, a very small proportion of WAAPP funding is disbursed to international research centers (e.g. CGIAR centers) or universities outside West Africa. On average, during 2008–2016, 53 percent of research-

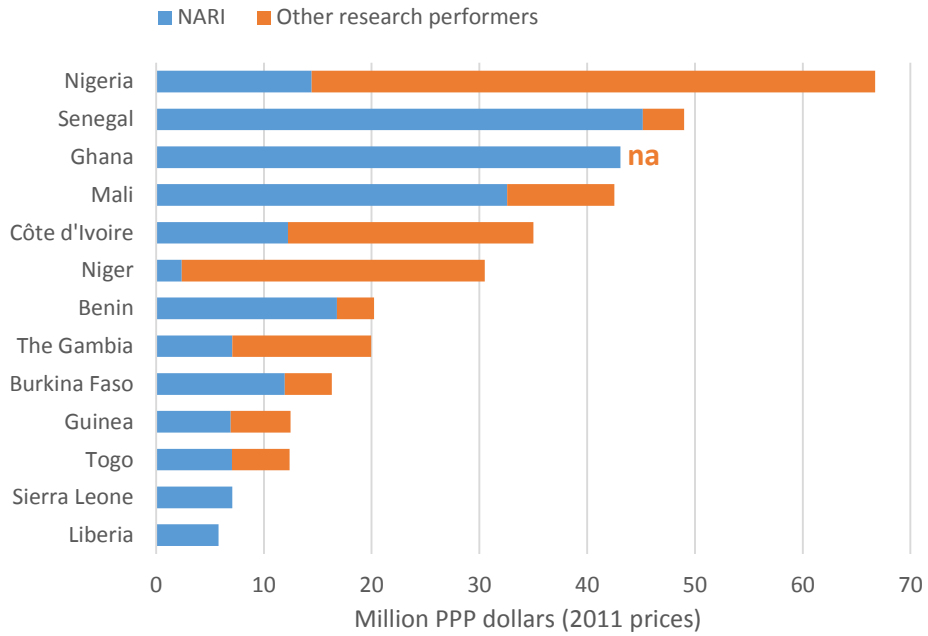
related WAAPP funding was disbursed to NARIs and 47 percent to non-NARI research performers. This subregional average, however, masks a considerable degree of cross-country variation (Figure 9).

Table 4—WAAPP funding allocation to non-NARI research performers, 2008–2016

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
					million 2011 PPP dollars					
Benin	—	—	—	—	—	0.274	1.863	1.321	—	3.457
Burkina Faso	—	—	—	—	—	0.457	0.546	0.936	2.412	4.351
Côte d'Ivoire	—	—	—	—	1.986	7.747	7.608	4.097	1.351	22.789
Gambia, The	—	—	—	—	2.464	0.932	2.648	3.958	2.859	12.862
Ghana	na	na	na	na	na	na	na	na	na	na
Guinea	—	—	—	—	1.171	2.370	1.724	0.234	0.038	5.538
Liberia	—	—	—	—	—	—	—	—	—	—
Mali	—	—	—	—	—	—	0.113	6.848	2.990	9.951
Niger	—	—	—	—	1.697	2.399	7.126	8.375	8.535	28.133
Nigeria	—	—	—	—	2.788	7.979	23.350	17.512	na	52.290
Senegal	—	0.315	0.305	0.247	0.083	1.208	0.706	0.786	0.176	3.826
Sierra Leone	—	—	—	—	—	—	—	—	—	—
Togo	—	—	—	—	0.042	2.727	2.170	0.399	—	5.337
Total	**—**	**0.315**	**0.305**	**0.247**	**10.232**	**26.093**	**47.853**	**44.466**	**19.023**	**148.534**

Source: Compiled by authors from World Bank (2017).
Notes: "na" denotes that data are unavailable. WAAPP funding includes all IDA, GFRP, and PHRP allocations. The 2016 total excludes Nigeria.

Figure 9—Total research-related WAAPP funding to NARIs and other in-country research performers, 2008–2016



Source: Compiled by authors from World Bank (2017).
Notes: na denotes that data were unavailable. WAAPP funding includes all IDA, GFRP, and PHRP allocations. The Nigeria data cover the period 2012–2015.

WAAPP funding has been a very important source of funding to West African NARIs. In 2014, an average of 10 percent of funding to the NARIs came from WAAPP (Table 5). An important point to take into consideration is that the bulk of NARI expenditures is allocated to staff salaries, which are typically funded by national governments. WAAPP funding, on the other hand, is mostly targeted towards research programs, infrastructure upgrades, and capacity building. If salary costs are taken out of the equation, the 2014 share of WAAPP funding in total funding to the NARIs would increase to 24 percent.

These regional averages mask a considerable amount of variation across NARIs. WAAPP funding as a percentage of total funding was extremely high in certain years at NARI (The Gambia) and ITRA (Togo). Both institutes received very large amounts of WAAPP funding for the onstruction/rehabilitation of research stations and laboratories in certain years, which they spent over multiple years. ISRA in Senegal is also highly dependent on WAAPP funding. In 2014, 83 percent of the institute's non-salary costs were funded through WAAPP. Dependency on WAAPP to fund non-salary costs is also relatively high (between 40 and 60 percent) at INRAB (Benin), CSIR (Ghana), and IRAG (Guinea). In contrast, WAAPP funding accounts for only a small share of total funding received by Nigeria's ARCN institutes. As previously mentioned, universities and the private sector are the main beneficiaries of WAAPP funding in Nigeria.

Table 5—WAAPP funding as a share of total funding to NARIs, 2008–2014

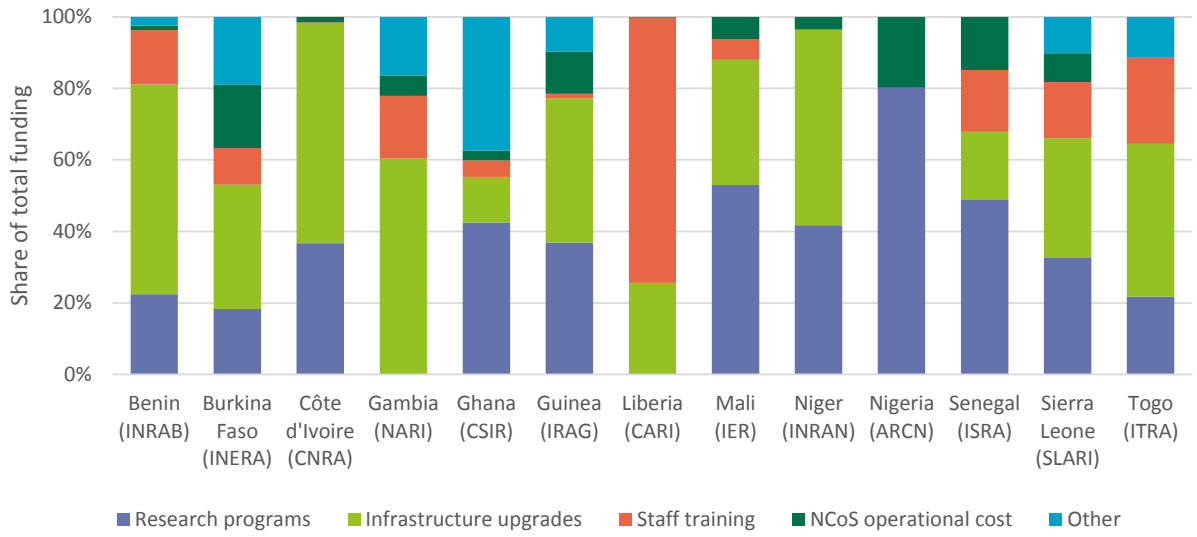
Country (institute)	2008	2009	2010	2011	2012	2013	2014	Total
Benin (INRAB)	—	—	—	—	—	14.9%	35.2%	25.3%
Burkina Faso (INERA)	—	—	—	—	—	3.3%	10.8%	7.5%
Côte d'Ivoire (CNRA)	—	—	—	—	2.9%	6.4%	10.3%	6.7%
Gambia, The (NARI)	—	—	—	—	174.8%*	15.7%	53.9%	89.9%
Ghana (CSIR institutes)	0.8%	2.8%	4.8%	8.5%	2.7%	4.0%	9.5%	5.0%
Guinea (IRAG)	—	—	—	—	11.3%	23.8%	35.2%	22.6%
Mali (IER)	20.9%	12.9%	13.5%	10.6%	8.1%	0.4%	5.1%	10.6%
Niger (INRAN)	—	—	—	—	0.6%	0.7%	1.6%	1.0%
Nigeria (ARCN institutes)	—	—	—	—	1.3%	2.8%	2.7%	1.9%
Senegal (ISRA)	0.8%	6.6%	9.6%	18.7%	19.8%	27.4%	16.1%	14.2%
Sierra Leone (SLARI)	—	—	—	—	0.1%	14.7%	25.3%	15.2%
Togo (ITRA)	—	—	—	—	10.5%	23.4%	85.4%*	41.5%
Total	**6.9%**	**6.4%**	**8.4%**	**11.2%**	**4.6%**	**5.5%**	**9.9%**	

Source: Compiled by authors from World Bank (2017).

Notes: Total funding to NARIs includes all research-related expenditures, including salaries, operating and program costs, and capital investments. * The extremely high shares of WAAPP funding in The Gambia (2012) and Togo (2014) are due to the disbursement of large amounts of WAAPP funding for construction and large infrastructure upgrades during those years. Data for Liberia are unavailable.

A closer look at the composition of WAAPP funding that NARIs received reveals some interesting cross-country variation. At INRAB (Benin), INERA (Burkina Faso), CNRA (Côte d'Ivoire), NARI (The Gambia), IRAG (Guinea), INRAN (Niger), and ITRA (Togo), the bulk of WAAPP funding was allocated to infrastructure upgrades, which includes renovation/construction of research laboratories and investment in research equipment (Figure 10). In contrast, at all three NARIs in WAAPP 1A countries, as well as ARCN (Nigeria), investment in research programs constituted the lion's share of WAAPP funding. At SLARI (Sierra Leone), equal proportions were allocated to research programs and infrastructure upgrades, while at CARI (Liberia), the bulk of WAAPP funding was spent on staff training.

Figure 10—Composition of WAAPP funding to NARIs, 2008–2016 averages



Source: Compiled by authors from World Bank (2017).
Notes: WAAPP funding includes all IDA, GFRP, and PHRP allocations.

WAAPP-FUNDED COMPETITIVE AGRICULTURAL RESEARCH GRANTS

In addition to direct World Bank support to the countries, a portion of WAAPP funding is channeled through the CORAF/WECARD-operated Multi Donor Trust Fund (MDTF). This fund consists of three main components: 1) Research; 2) CORAF/WECARD governance and administration; and 3) Management, Administration, and Supervision of the MDTF. Funding for research is channeled through a Competitive Agricultural Research Grant Scheme (CARGS), which consists of 7 regional competitive and/or commissioned projects financed within the WAAPP framework; four ILWAC Trust Fund sub-grant projects that are implemented under WAAPP; and 17 MDTF-financed projects outside of WAAPP (covering both WAAPP and non-WAAPP member countries of CORAF/WECARD). Although the latter do not benefit directly from WAAPP funding, there are a lot of complementarities and synergies between WAAPP and MDTF projects, both at the country and the CORAF coordination levels.

Between 2013 and 2017, a total of US$7.2 million of WAAPP 1B, 1C, and 2A funding was channeled to the MDTF and allocated to the countries on a competitive or commissioned basis (Table 7). These seven projects cover a wide variety of research topics and themes. Benin and Senegal have been most successful in securing CARGS funding: 6 of the 7 projects cover these two countries. In contrast, Guinea, Liberia, Sierra Leone, and Togo only received funding through 2 CARGS projects. Exact funding allocation amounts per country per year are unavailable.

In addition to the seven regional projects that are funded within the WAAPP framework, the government of Denmark has funded a series of integrated land and water management projects that were implemented under WAAPP. These projects, with a total cost of US$4.8 million, covered the 13 WAAPP countries as well as Cameroon and Chad. The main objective of these projects was to improve the ability of African users of agricultural land and water resources to plan and manage climate change adaptation measures. These projects came to a close in 2015.

Table 7—Projects financed within the WAAPP framework under the regional CARGS

Project Title	Objectives	Source of financing	Implementing Countries	Total Amount (USD)	Period (start/end dates)
Capacity Development of Cashew Value Chain Actors in West Africa (Anacarde)	To improve the generation of jobs and income of actors in the cashew value chain in five participating countries and beyond. Specifically, the project aims to improve the productivity and value of cashew	WAAPP-2A	Benin, Burkina Faso, Côte d'Ivoire, Ghana, and Senegal	1,400,000	Jan 2015-Dec 2017
Upscaling the Nigerian flash drying experience for sustainable regional trade and income generation in West Africa (UDESWA)	To improve access and usage of efficient drying technologies by SMEs in project locations in West Africa.	WAAPP-1B	Benin, Ghana, Nigeria, and Sierra Leone	1,200,000	Apr 2013-Mar 2016
Fruit fly control technologies dissemination and capacity building of West African fruit value chain stakeholders	To promote the mango value chain by increasing productivity and improving quality and trade through the effective management of fruit flies in West Africa.	WAAPP-1C	Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Mali, Niger, Nigeria, Senegal, The Gambia, and Togo	1,300,000	Mar 2014 – Jun 2016
Identification d'options politiques et stratégiques pour une meilleure adoption des résultats de la recherche par les exploitations agricoles familiales en Afrique de l'Ouest (AGRIFAM)	To propose policy and strategic options for supporting innovation adoption and up scaling within small-scale farmers	WAAPP-1B	Benin, Burkina Faso, Mali, Niger, Senegal, and Togo	1,500,000	Sept 2013-Aug 2016
Amélioration et diffusion de système de riziculture intensif (SRI) *en Afrique de l'Ouest*	To improve the productivity and competitiveness of rice across the region.	WAAPP-1C	WAAPP 13 countries	1,036,000	July 2013-June 2016
Development of a Seed Program (ASPRODEB/ ROPPA)	Sustainable increase of the production of certified seeds in Benin, Gambia, Liberia and Niger	WAAPP-1C	Benin, The Gambia, Burkina Faso, Liberia, Mali, Niger, and Senegal	200,000	Mar 2014-Feb 2016
Organic Fertilizers project – (FERTORAO)	Determine the technical and economic performance of the use of organic fertilizers in order to make recommendations	WAAAPP-2A	Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria, and Senegal	600,000	2017-2018

Source: Compiled by authors from World Bank (2017).

CONTRIBUTION OF WAAPP TO OVERALL WEST AFRICAN AGRICULTURAL RESARCH INVESTMENT

A comprehensive analysis of the contribution of WAAPP in total (i.e. NARI and non-NARI) agricultural research funding in West Africa is challenging, due to certain fundamental methodological and data coverage differences between ASTI datasets and WAAPP research funding datasets. Any results derived from a comparison between these two datasets should therefore be interpreted with care. For example, the ASTI database has detailed information on agricultural research spending and funding by research performer. Research coordinating bodies, such as CNRA in Mali and Niger or CNRST in Burkina Faso, do not perform research themselves, and are therefore excluded from the ASTI database. Nevertheless, these centers are very important recipients of WAAPP research funding. In addition, ASTI makes FTE adjustments to its financial datasets to truly reflect the amount of time/funding an agency spends on research versus non-research activities. Many of the recipients of WAAPP funding (other than the NARIs) are agencies that do not have a full research mandate and spend a lot of their time on non-research activities. Finally, ASTI's coverage of private-sector agricultural research in West Africa is weak. Yet, private entities are important recipients of WAAPP funding, particularly in Nigeria. Keeping these methodological and data coverage challenges in mind, Table 6 provides an overview on total West African agricultural research investment and WAAPP funding during 2008–2015.

Table 6—West Africa's total agricultural research expenditures and WAAPP funding compared, 2008–2016

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016
					million 2011 PPP dollars				
Total agricultural research spending	913.6	909.4	885.2	957.9	875.5	930.6	948.2	na	na
WAAPP research funding									
- directly to countries	7.3	8.3	10.8	13.6	28.6	54.1	97.4	93.0	na
- through regional CARGS	—	—	—	—	—	*1.4*	*4.4*	*7.0*	*3.9*

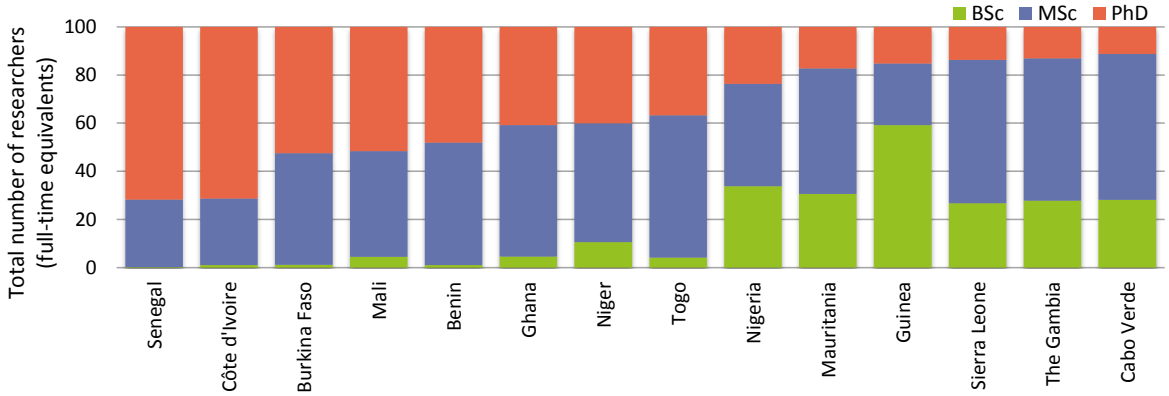
Sources: Total agricultural research spending from ASTI database; total WAAPP funding from World Bank (2017).
Notes: Total agricultural research spending includes salary expenditures, operating and program costs, and capital investments from government, higher education, and nonprofit agencies involved in agricultural research (and excludes the private for-profit sector). All data in this dataset have been FTE adjusted. Total WAAPP funding includes all public and private recipients of research funds, regardless of whether they have a research mandate. WAAPP funding data have not been FTE adjusted. WAAPP country funding data exclude non-CSIR recipients in Ghana. Data on WAAPP research funding through regional CARGS have been estimated assuming that the funds presented in Table 7 were spread equally over time.

QUALIFICATION LEVELS OF WEST AFRICAN AGRICULTURAL RESEARCHERS

A minimal number of PhD-qualified researchers is generally considered fundamental to the conception, execution, and management of high-quality research and to communicating its results to policymakers, donors, and other stakeholders at national and regional levels. Average qualification levels of agricultural researchers in West Africa tend to be higher than in other parts of Africa. Senegal and Côte d'Ivoire recorded the highest shares of PhD researchers on the continent—72 and 71 percent, respectively—whereas five other countries reported shares of more than 40 percent (Figure 11). Cabo Verde, The Gambia, and Sierra Leone were the only countries with PhD shares below 15 percent.

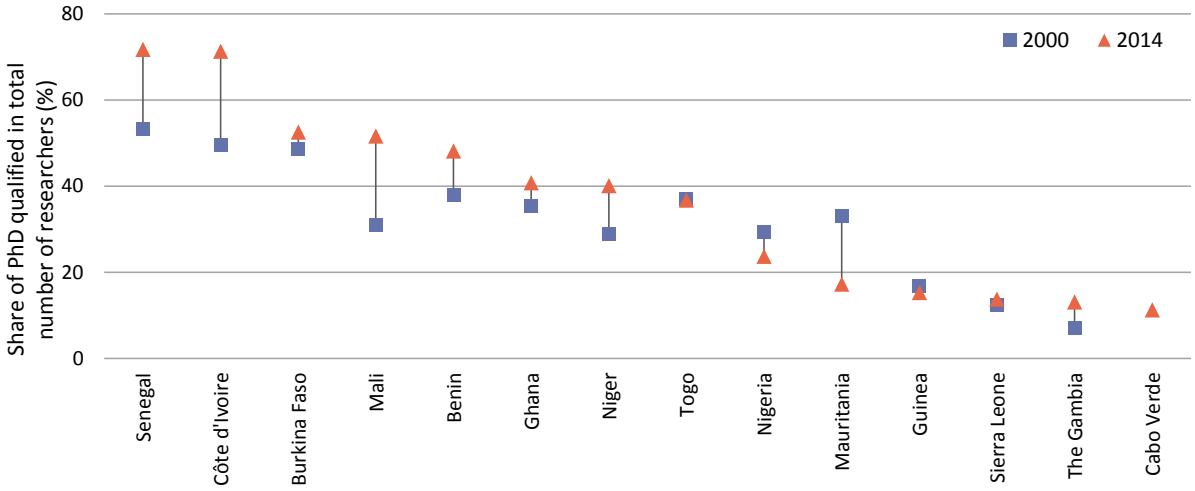
Building the capacity of researchers to the doctoral level is an inherently expensive, long-term process. Furthermore, many of the smaller countries do not offer PhD training in agricultural sciences, so researchers wanting to further their careers need to secure (scarce and highly competitive) scholarships to undertake PhD degree training abroad. Nonetheless, West Africa expanded its capacity of PhD-qualified researchers considerably during 2000–2014, thanks to WAAPP. In 2000, the subregion employed 1,830 FTE agricultural researchers with PhD degrees, compared to 2,539 FTEs in 2014, an increase of nearly 40 percent. The overall share of PhD-qualified researchers has also risen markedly over time, from 46 percent of total research staff in 2000 to 54 percent in 2014 (Figure 12). Within countries, universities generally employ a higher share of PhD-qualified scientists compared with NARIs and other government agencies. 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 11—Distribution of agricultural researchers by qualification level, 2014



Source: Calculated by authors based on ASTI data and various secondary sources.
Note: Data for Guinea-Bissau and Liberia were unavailable.

Figure 12—Change in the share of PhD-qualified researchers by country, 2000–2014



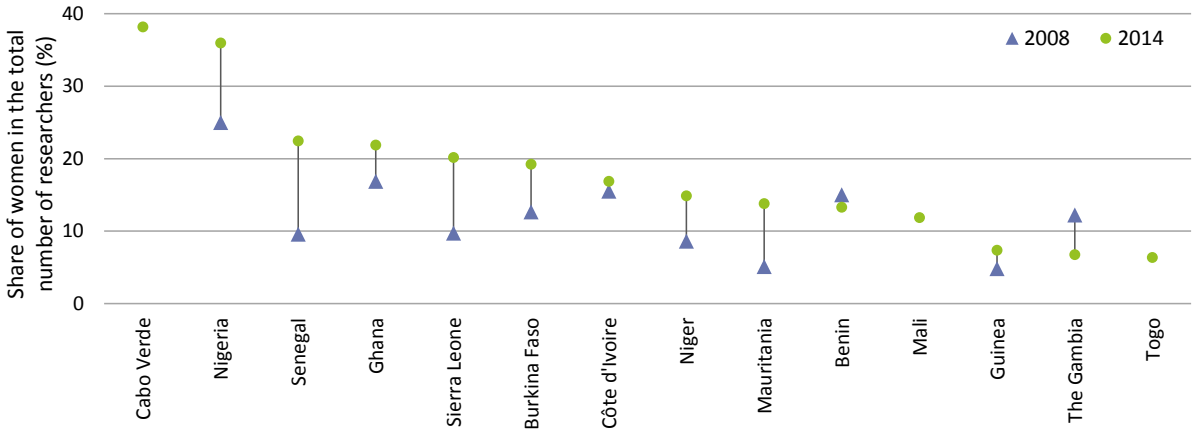
Source: Calculated by authors based on ASTI data and various secondary sources.
Note: Guinea-Bissau and Liberia data were unavailable, as were data for 2000 for Cabo Verde.

FEMALE PARTICIPATION IN WEST AFRICAN 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. A survey conducted in 13 West African countries in 2014 indicated that, on average, 21 percent of the total number of agricultural researchers (in FTEs) was female (Figure 13). Without the inclusion of Nigeria, this share would drop to just 16 percent. Most countries in the subregion employ very low numbers of female agricultural researchers. In The Gambia, Guinea, and Togo, women represented a mere 6 or 7 percent of agricultural researchers. Due to the large influx of agricultural researchers in West Africa since the turn of the millennium, the number of women participating in agricultural research also rose, both in absolute and in relative terms. Nonetheless, female participation in West Africa is considerably lagging behind female participation in other parts of Africa.

Female scientists are also far less likely to hold PhD degrees than their male colleagues, so West Africa still has a long way to increase female participation in agricultural research and hence integrating gender perspectives into the formulation of related policies. Moreover, the fact that the share of women in research and research management positions is generally low means that women have less influence in policy- and decision-making processes, potentially creating a bias in decision-making and priority-setting.

Figure 13—Change in share of female agricultural researchers by country, 2008–2014

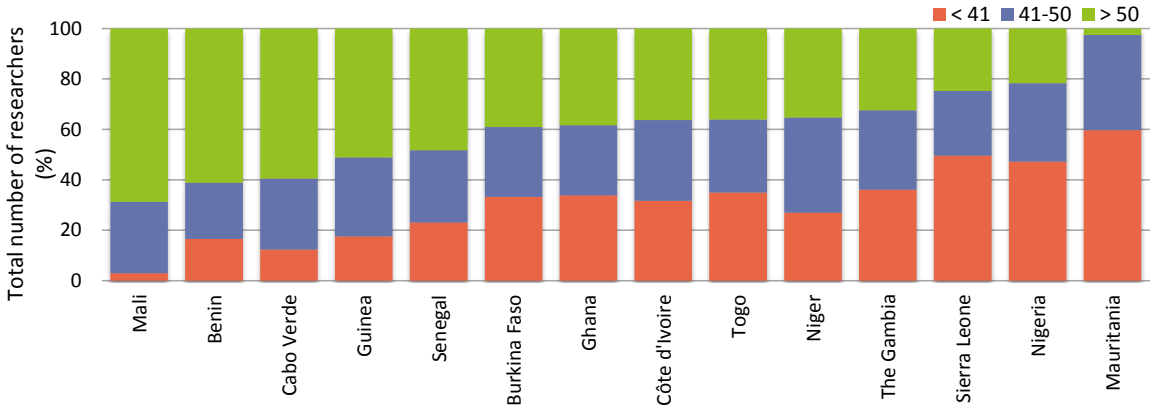


Source: Calculated by authors based on ASTI data and various secondary sources.
Note: Guinea-Bissau and Liberia data were unavailable, as were 2008 data for Cabo Verde, Mali, and Togo.

WEST AFRICA'S AGING POOL OF AGRICULTURAL RESEARCHERS

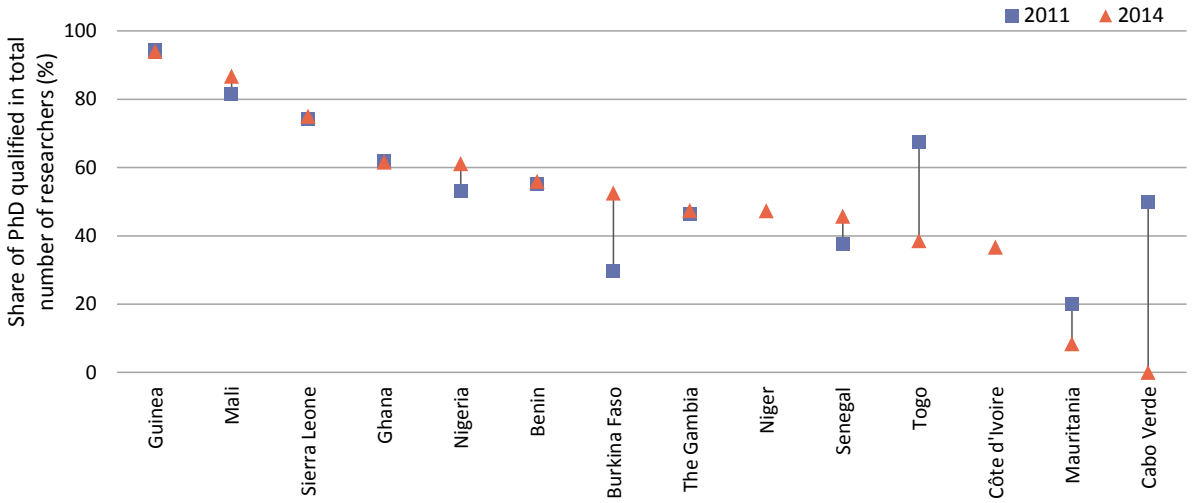
Long-term public-sector recruitment restrictions have left institutes in many countries with an aging pool of agricultural researchers, many of whom are set to retire within the next decade (Figure 14). In 2014, on average, more than half the agricultural scientists in West Africa with PhD degrees were older than 50 (Figure 15). In Guinea, Liberia, Mali, Sierra Leone, and Togo, the situation is even more alarming, with more than 70 percent of PhD-qualified researchers being over the age of 50. An official retirement age of either 60 or 65 years only puts further pressure on already inadequate researcher capacities in most countries (Table 8).

Figure 14—Distribution of researchers (including BSc, MSc, and PhD holders) by country and age bracket, 2014



Source: Calculated by authors based on ASTI data.

Figure 15—Change in the share of PhD-qualified researchers over the age of 50, 2011– 2014



Source: Calculated by authors based on ASTI data.

Table 8—Official retirement age of agricultural researchers, 2014

Country	Official retirement age (years)
Benin	60 for government / 65 for higher education
Burkina Faso	65
Cabo Verde	65
Côte d'Ivoire	62 / 65 depending on rank
The Gambia	60
Ghana	60
Guinea	60 for women / 65 for men
Guinea-Bissau	60
Liberia	60
Mali	65
Niger	60 for government / 65–70 for higher education depending on rank
Nigeria	65
Senegal	65
Sierra Leone	65
Togo	60 for government / 65 for higher education

Source: Information compiled by ASTI.

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. Key issues include low salaries and poor benefit and retirement packages; limited promotional opportunities and work flexibility (for example, in terms of working hours or opportunities to collaborate with other

agencies); lack of infrastructure, services, and equipment; and poor management structures. Another source of staff turnover is the practice of seconding, and sometimes promoting, senior researchers to (often non research-related) administrative or managerial positions within different ministerial divisions or directorates.

To halt the high rates of staff attrition, various NARIs increase salary levels with government support to improve incentives. For example, the Senegalese government more than doubled the salary levels of ISRA's researchers and improved their promotional opportunities. The government of Ghana instituted the "Single Spine Pay Policy," which introduced parity between the salaries of CSIR scientists and those of university-based scientists. Staff morale has improved considerably at both institutes, the supply of candidates for vacant positions has increased, and staff turnover appears to have declined.

Box 2. Motivation of NARI-based researchers

As part of an ASTI/IFPRI–CORAF project, a staff motivation survey was conducted during 2013/2014 in Benin, Burkina Faso, Ghana, Senegal, Sierra Leone, and Togo for the purpose of eliciting a better understanding of the factors that both positively or negatively affect staff motivation at NARIs. Unsurprisingly, staff members are motivated by a variety of factors. Although financial rewards are generally paramount, numerous other factors come into play, including conditions of service, job satisfaction, institutional culture, and job security—to name a few.

Overall, researchers and managerial staff in Ghana, Senegal, and Sierra Leone reported being more motivated and feeling more appreciated by their institute than their colleagues in Benin, Burkina Faso, and Togo. The same country divide is apparent in respondents' ratings of the conduciveness of civil service policies to their work. This dichotomy can largely be explained by differences in the official status of researchers across countries, as well as differences in salaries and benefits. Researchers in Ghana, Senegal, and Sierra Leone have received substantial salary increases in recent years. In the other three countries, salary disparities between the national agricultural research institutes and the university sector remain significant, and hence act as a strong detractor of motivation. A large percentage of researchers in all six countries indicated that their level of motivation was negatively affected by a lack of research funding and inadequate research infrastructure and equipment. Limited promotional opportunities and a lack of attractive benefit packages remain areas of concern in all six countries.

It should be noted that factors motivating staff followed a logical distribution, as indicated by the focus on salary levels in the three countries where inequities exist. Similarly, younger researchers were understandably more concerned with training and promotional opportunities than older, more qualified researchers approaching retirement age; and researchers employed in areas lacking facilities and equipment were more focused on these issues. Hence, motivating factors have an inherent hierarchy depending on the institutional context.

WAAPP IS ADDRESSING WEST AFRICA'S MOST ACUTE RESEARCH CAPACITY CHALLENGES

Growing concern exists regarding the lack of human resource capacity in agricultural research to respond effectively to the challenges that agriculture in West Africa is facing. In nearly all countries in West Africa, the majority of PhD-qualified researchers will retire by 2025, which means that a growing number of agricultural research institutes 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 hence deeming the future of agricultural research in the region.

WAAPP's training component aims to address the most acute staff shortages, especially in the smaller countries where the gaps are the largest. WAAPP funding supports postgraduate studies (MSc- and PhD-level) of more than 1,000 young scientists, 30 percent of whom are women, in various priority areas. It is important to note that not all of the people who are being trained are researchers. WAAPP also supports postgraduate training for staff at extension agencies, universities, NGOs, and farmer organizations.

ASTI obtained detailed data on the number of staff at NARIs and other agencies receiving degree-level training. The data reveal that West Africa's challenge of an aging research capacity is being tackled at a large scale. A considerable number of NARI staff members have undergone or are currently undergoing PhD- or MSc-level training as part of WAAPP (Table 9). The vast majority of those being trained are trained at a university in their own country. In countries where in-country postgraduate training is limited (such as The Gambia, Liberia, Sierra Leone, and Togo), most researchers are trained in another country in the subregion. Senegal stands out in that a large number of ISRA and ITA researchers are pursuing PhD training outside Africa, mostly at universities in France and Belgium. Postgraduate training of research staff was not a component of WAAPP 1C in Guinea. Many Guinean researchers, however, have received short-term training, both locally and abroad.

The data clearly indicate that, in the coming years, extensive capacity losses due to retirement will to a large extent be offset by an important influx of younger scientists who received WAAPP-funded postgraduate training. It will be crucial, however, that these younger (and relatively inexperienced) MSc- and PhD-qualified researchers receive sufficient training and mentoring rom their older, more experienced colleagues before they retire.

Table 9—Number of staff receiving WAAPP-funded postgraduate training, by gender and location, 2008–2016

Country (institute)		Female	Male	Total	In-country	In Africa	Elsewhere
			(head counts)				
Benin (INRAB)	MSc	10	16	26	26	—	—
	PhD	18	18	36	36	—	—
Burkina Faso (INERA)	MSc	2	5	7	7	—	—
	PhD	4	12	16	16	—	—
Burkina Faso (IRSAT)	MSc	3	3	6	6	—	—
	PhD	1	0	1	1	—	—
Côte d'Ivoire (CNRA)	MSc	7	18	25	25	—	—
	PhD	3	19	22	20	1	1
Ghana (CSIR institutes)	MSc	16	12	28	27	—	1
	PhD	6	19	25	23	1	1
The Gambia (NARI)	MSc	—	6	6	—	6	—
	PhD	—	2	2	—	2	—
Guinea (IRAG)	MSc	—	—	—	—	—	—
	PhD	—	—	—	—	—	—
Liberia (CARI)	MSc	2	—	2	—	2	—
	PhD	—	2	2	—	2	—
Mali (IER)	MSc	2	1	3	2	1	—
	PhD	12	24	36	36	—	—
Mali (LCV)	MSc	—	—	—	—	—	—
	PhD	—	6	6	6	—	—
Niger (INRAN)	MSc	5	4	9	7	2	—
	PhD	3	14	17	9	7	1
Nigeria (ARCN institutes)	MSc	4	11	15	2	5	8
	PhD	6	7	13	2	9	2
Senegal (ISRA)	MSc	2	7	9	6	1	2
	PhD	9	18	27	5	5	17
Senegal (ITA)	MSc	6	6	12	11	—	1
	PhD	7	7	14	8	1	5
Sierra Leone (SLARI)	MSc	3	25	28	5	23	—
	PhD	5	4	9	2	7	—
Togo (ITRA)	MSc	2	18	20	1	18	1
	PhD	4	16	20	8	9	3

Source: Compiled by authors from World Bank (2017).

Notes: This table focuses on the main agricultural research institutes. A large number of additional scientists at smaller government research agencies or universities have also received WAAPP-funded MSc- and PhD-training.

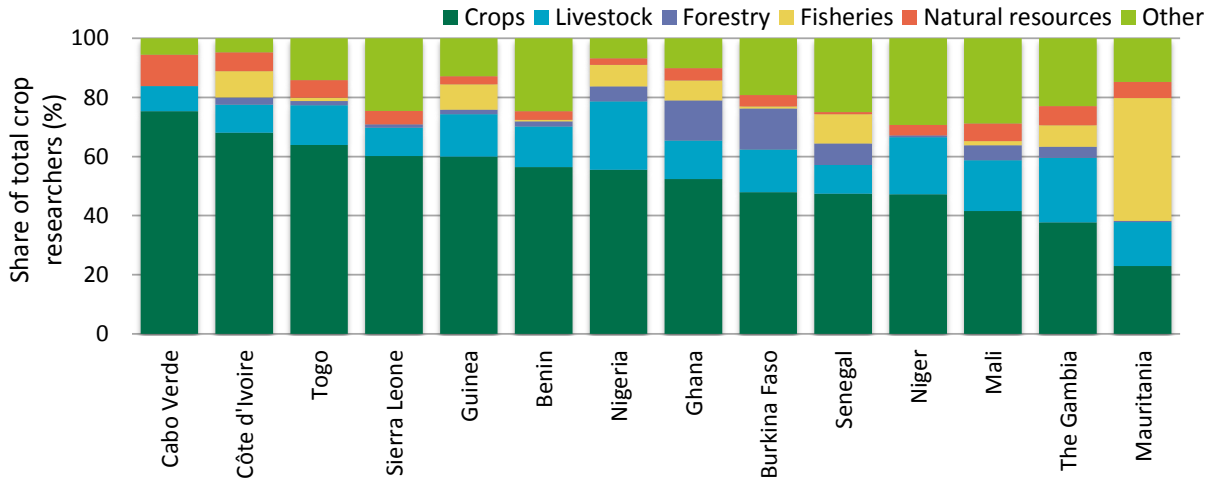
AGRICULTURAL RESEARCH FOCUS

Governments and agricultural research agencies across West Africa are limited in their choice of options of how to allocate their scare resources. It is important, however, that they allocate sufficient resources to the types of research and commodities that are of critical importance and high relevance in their countries to have lasting effects on productivity growth, poverty reduction, and nutrition.

Crop research remains the dominant type of research conducted throughout West Africa (Figure 16). Livestock research also plays a relatively important, particularly in Nigeria, The Gambia, and Niger. Limited forestry research is conducted in West Africa, although Burkina Faso and Ghana are important exceptions. Mauritania stands out from most other countries in that it carries out limited crop research (given its arid climate). Instead, fisheries research is the country's dominant type of research.

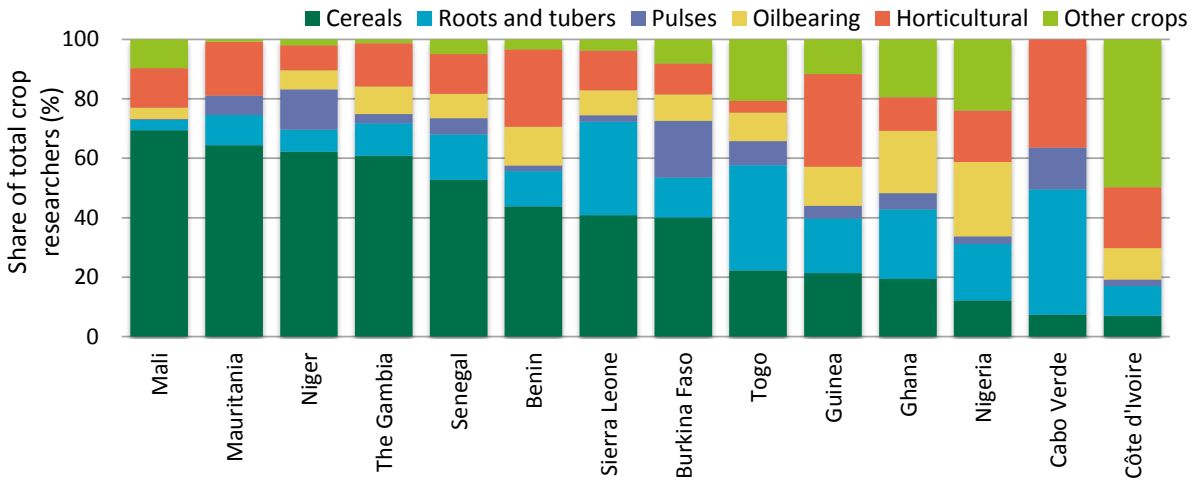
West Africa's agro-climatic diversity is clearly reflected in the type of crop research conducted across countries. The Sahel countries focus their research efforts predominantly on cereal crops, while roots and tuber research plays a relatively more important role in West Africa's tropical zones (Figure 17). Horticultural research is conducted throughout the subregion. Research on pulses (mostly cowpea) is particularly prominent in Burkina Faso and Niger.

Figure 16—Agricultural research focus by components by country in West Africa, 2014



Source: Calculated by authors based on ASTI data.
Note: The category "Other" comprises socioeconomic research, on-farm postharvest research, agricultural engineering research, etc.

Figure 17—Crop research focus by category by country, 2014



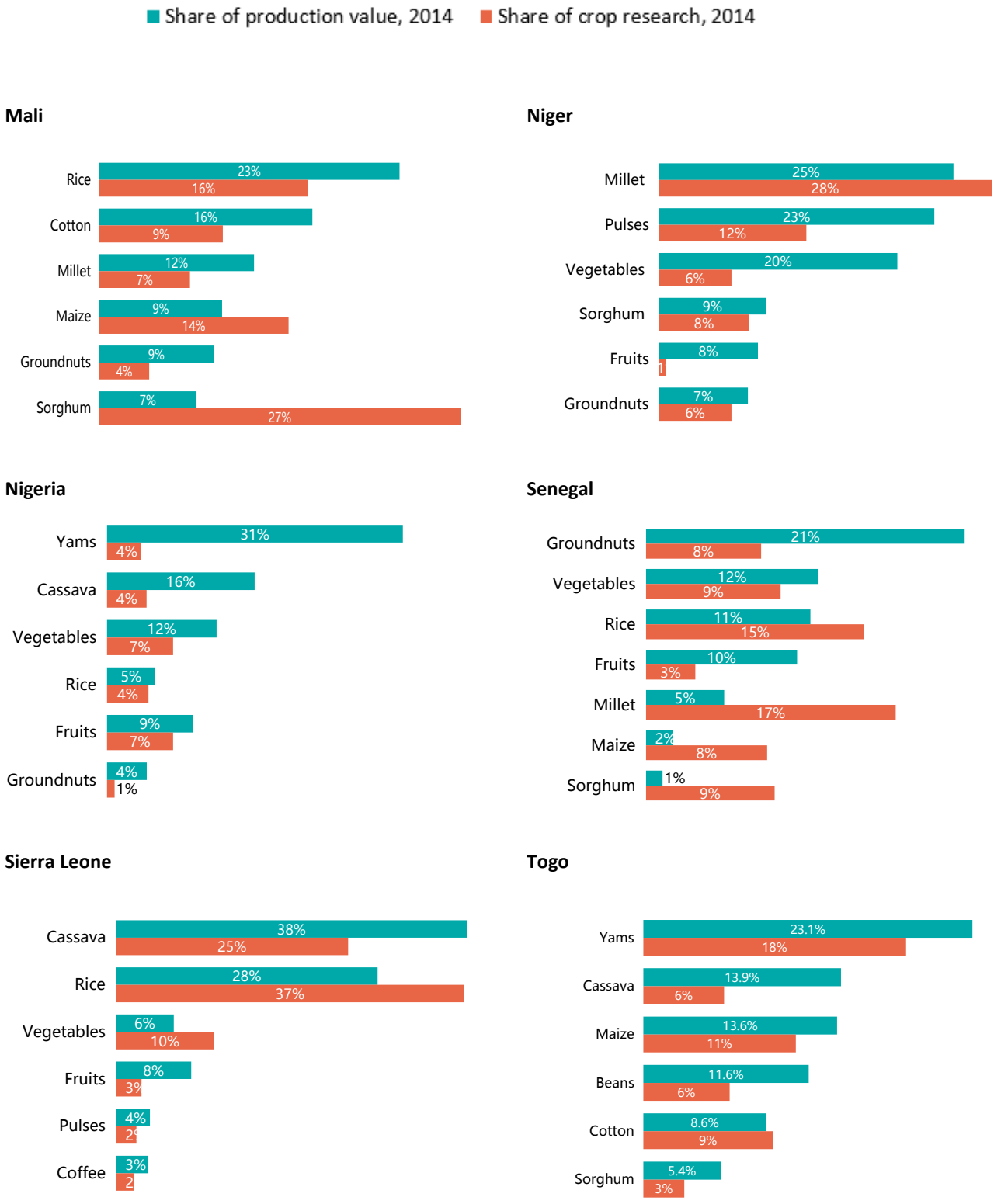
Source: Calculated by authors based on ASTI data.
Note: The category "Other crops" comprises nuts, cotton, sugar, coffee, cocoa, rubber, etc.

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 corresponding share of output—then the congruency ratio for that commodity would be 1.0.

Yams are the most important crop in terms of production value in Benin, Ghana, Nigeria, and Togo, and the second most important crop in Côte d'Ivoire. Yet, in all these five countries, the share of yams in the total value of crop production was considerably higher than the corresponding share of crop researchers, implying that yams are comparatively underresearched. This situation is particularly severe in Benin, Ghana, and Nigeria (Figure 18). For maize, this situation was reversed: more researcher time was allocated to this crop relative to its crop production value in five of the seven countries where maize is an important crop in terms of production value. 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.

The data highlight the importance of viewing research support in a regional context and strengthening regional linkages. Countries show differing commodities of emphasis which, if seen only at the national level, can imply suboptimal allocation. Alternatively, if viewed at the regional level in a setting with good regional interlinkage, national specialization can be a regional asset. For example, maize is the principal crop being researched in Benin, rice research is dominant in Sierra Leone, and both sorghum and millet research are important in Senegal. The NCoS approach of WAAPP in the absence of strong regional flows of knowledge and results would imply incongruences between crop production value and research focus at the country level. Congruency in a regional context would require

Figure 18—Comparison of research allocation and production value for selected crops, 2014



Sources: Commodity focus shares are calculated by authors based on ASTI data. Production values are from FAO (2017).
Note: Data for Liberia are unavailable.

assessment of the combined investment in specific crops and livestock products across countries compared to the regional value of production. Meaningful interpretation of congruency would further require that the barriers to moving new technologies across national boundaries are low.

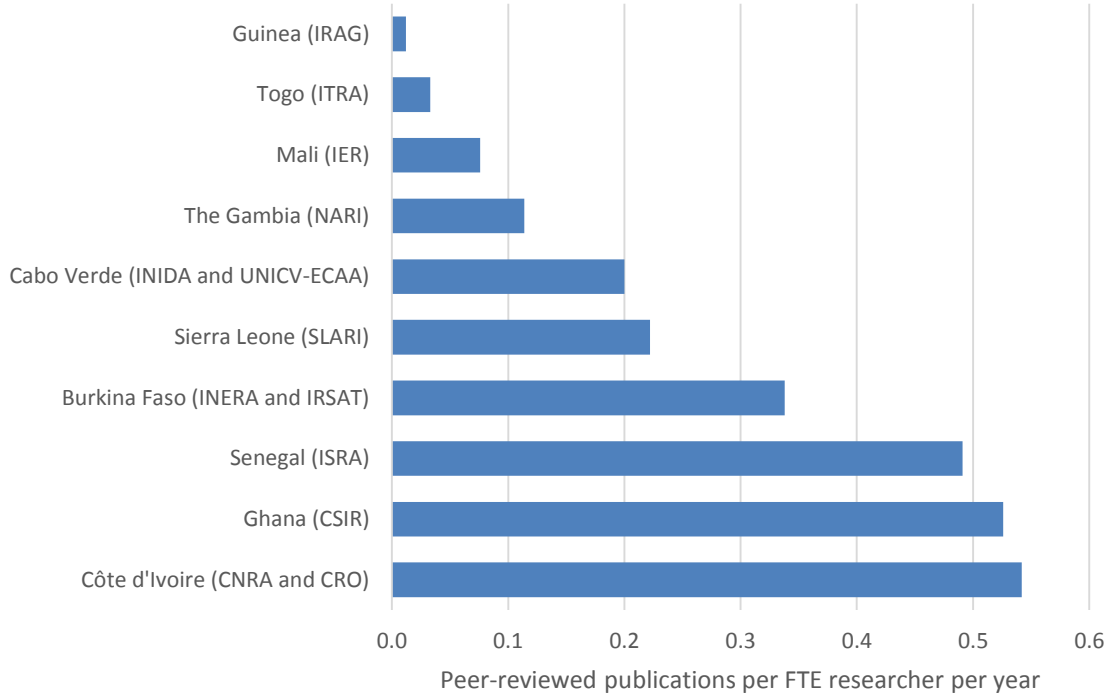
The concept of congruency can be useful in assessing the distribution of research effort across commodities, but it is not an allocative rule. Research effort might be appropriately disproportionately allocated to a product with modest current value, but projected high growth in demand. In addition, multiple objectives for agricultural development might channel research effort toward a product with lesser weight in sectoral value added, but particular relevance for, for example, nutrition or job creation. Congruence analysis therefore is not in itself a sufficient tool for allocation of research funds, but it offers important insight into the current distribution of capacity, highlights where regional alliances should be strengthened, and can be combined with analysis of foresight and general equilibrium models, such as RIAPA, to inform decision making.

AGRICULTURAL RESEARCH OUTPUTS IN WEST AFRICA

As of 2014, just 1.4 percent of all global scientific publications were produced by African countries. 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 West African NARIs recorded ratios of publications per researcher of between 0.1 and 0.6 per year (Figure 19), 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 African agencies is incomplete, but the data that are available indicate significant cross-country variation in terms of new releases. West Africa's smaller NARS have a 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, the larger NARS released a steady stream of new crop varieties of crops such as maize, vegetables, rice, sorghum, wheat, and cowpea over time.

Figure 19—Number of peer-reviewed publications per agricultural researcher per year, 2012–2014 average



Source: Calculated by authors based on ASTI data.
Note: Data for Benin, Liberia, Niger, and Nigeria are unavailable.

As part of this study, detailed information was collected on variety release by NARS under WAAPP. It was difficult to make a distinction between varieties that were fully funded through WAAPP and those that were partially funded through WAAPP. In some cases, WAAPP funded the release or diffusion of new crop varieties, while the development of these varieties was funded through different sources (e.g. the release of 12 new NERICA rice varieties in Sierra Leone). The three WAAPP 1A countries have been the most productive in terms of variety release, which is not surprising given the earlier start date of WAAPP in these countries. WAAPP 1A funded research on dryland cereals in Senegal, which has led to the release of a series of new millet (2011), sorghum (2011 and 2015), cowpea (2015), and groundnut (2016) varieties (all based on local germplasm) (Table 10). WAAPP 1A support for roots and tuber research in Ghana has resulted in the release of a number of cassava (2010 and 2015), cocoyam (2012), sweet potato (2012), and yam (2017) varieties, based on a combination of both CGIAR and local germplasm. Mali was set to specialize on rice under WAAPP. WAAPP 1A and 2A funding has directly contributed to the development and release of five new rice varieties in Mali in 2012 and 2016, and the dissemination of many more new varieties developed through different funding sources. Similarly, the development of five new tomato varieties in Burkina Faso was not directly financed by WAAPP, but WAAPP funding has been instrumental in the dissemination of these new varieties. Given that WAAPP supports the livestock sector in Niger and the fisheries sector in Nigeria, no new WAAPP-supported crop varieties were released in these two countries.

Table 10—Crop varieties that were registered and released, or adapted and diffused, with WAAPP (co-) funding, 2010–2017

Country	Crop	Number of new varieties	Germplasm source
Benin	Maize	3	CGIAR
Burkina Faso	Tomato	5	Local
Côte d'Ivoire	Maize	8	CGIAR
	Cassava	4	CGIAR
	Potato	2	CGIAR
	Plantain	2	CGIAR/local
Ghana	Cassava	10	CGIAR/local
	Cocoyam	3	Local
	Sweet potato	4	CGIAR
	Yam	4	CGIAR
Mali	Rice	5	CGIAR/local
Senegal	Groundnut	7	Local
	Cowpea	5	Local
	Sorghum	6	Local
	Millet	3	Local
Sierra Leone	Rice	12	CGIAR

Source: Compiled by authors from World Bank (2017).

Weak intellectual property rights legislation remains a key challenge across African 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 West Africa—for example, through WAAPP—further complicates the issue of how to resolve intellectual property rights.

INFRASTRUCTURE CHALLENGES

One of the principal reasons for the relatively limited scientific output of West African agricultural research institutes is the lack of adequate research infrastructure and equipment. For example, ITRA in Togo has numerous laboratories that are not operational because of the dilapidated state of their equipment and infrastructure. This is also true for INRAB in neighboring Benin also, which has two defunct laboratories. Although its center serving the north of the country is still operational, it lacks access to electricity, raising questions about the effectiveness of its research. NARIs across West Africa all reported similar challenges to their research efforts due to outdated research infrastructure; equipment that has gone into disrepair; insufficient access to vehicles to conduct field research; frequent power cuts that disrupt trials; unreliable Internet access; and a lack of up-to-date hardware, software, and servers. Without any doubt, outdated agricultural research infrastructure has a significant detrimental impact on the quantity and quality of research outputs in West Africa.

The rehabilitation of research infrastructure is one of the key objectives of WAAPP. Currently, research stations and laboratories, offices, field infrastructure, and staff residences are being upgraded across West Africa with WAAPP support. Throughout the region, research centers and laboratories are being equipped with state-of-the-art facilities, reducing the need to get certain analyses performed abroad. WAAPP is also addressing electricity, Internet access, and staff mobility challenges by investing in broadband Internet, generators, and vehicles. Despite these much-needed investments, more is still needed. WAAPP funding is predominantly targeted to upgrade centers and stations focusing on selected priority commodities, and largely overlooks many other centers and stations that are in urgent need of rehabilitation as well.

CONCLUSIONS AND POLICY IMPLICATIONS

Well-developed national agricultural research systems and adequate levels of investment and human resource capacities are prerequisites in the attainment of agricultural development, food security, and poverty reduction. Some encouraging signs indicate that West African countries have become increasingly focused on investing in agriculture for economic growth in recent years. Many countries have developed solid agricultural development and financing plans to strengthen agricultural production and food security as part of the CAADP implementation framework. Despite this increased political support to agricultural research, West Africa is still severely lagging behind other parts of Africa in the area of agricultural research capacity and investment. Underinvestment in agricultural research in West Africa is considerably greater than in other parts of Africa, the subregion is more dependent on volatile donor funding, and it employs both a much older pool of scientists (many of whom are approaching retirement age) and fewer female agricultural scientists. Furthermore, West Africa is severely challenged in terms of research infrastructure. Outdated research equipment and facilities are impeding the performance of productive research, which compromises the number and quality of research outputs and ultimately translates into reduced impact.

Since 2008, WAAPP has injected a significant amount of funding into West African NARS. The program has made substantial progress in addressing the subregion's most acute agricultural research challenges. It has invested extensively in the construction and rehabilitation of research infrastructure for predefined priority commodity areas and in providing adequate laboratory equipment. Another major achievement of WAAPP has been the investment in postgraduate training of more than 1,000 young scientists across West Africa—30 percent of whom are female. As such, looming large-scale human capacity losses due to the retirement of senior researchers are being offset. This extensive WAAPP investment in infrastructure and staff training has considerably strengthened the position of West African countries to perform high-quality priority research over the coming years.

Another important accomplishment of WAAPP is the foundation for a truly subregional approach to agricultural research. Most NARS in West Africa are small and fragmented. They have traditionally focused on the same range of research issues as their large neighbors, often exceeding the limits of their capacity. Through the establishment of NCoS and subregional research coordination and funding mechanisms, cross-country research collaboration has been encouraged under WAAPP, duplication of research efforts minimized, and the flow of relevant technologies enhanced.

Despite these important achievements of WAAPP, a few critical challenges remain. WAAPP funding is predominantly targeted to upgrades of centers and stations focusing on preselected priority commodities, and training of staff in these priority areas. A number of important research priority areas are overlooked by WAAPP. Yams, for instance, are of critical economic importance in West Africa's tropical zones (see Figure 18), but WAAPP has not focused on establishing a regional center of excellence in yam research, or on rehabilitating national yams research centers and stations. The same can be said for cowpea in the Sahel. Farmers growing these crops need varieties that are resilient to drought, flooding, or extreme temperatures; high in productivity; and less vulnerable to pests and disease. It is therefore essential that research on these orphan crops (that are researched less extensively by CGIAR centers than rice, maize, and wheat, for example) is not ignored.

In addition, notwithstanding the important strides made by WAAPP in stimulating technology transfer by bringing researchers, extension services, cooperatives, and other civil society organizations to work together, more needs to be done to scale up the adoption of improved technologies and meeting the food and nutritional needs of the population, and ensuring economic development and poverty reduction throughout West Africa. The proposed West Africa Agricultural Transformation Program (WAATP) is set to address these challenges by scaling up the adoption of climate-smart technologies to sustainably enhance productivity; reducing post-harvest losses, increasing value addition, and enhancing nutrition; and promoting an enabling policy environment, strengthening the regional market, and creating employment for youth.

In addition to large-scale support through donor-led initiatives such as WAAPP (and WAATP), strong country commitment to support processes towards the attainment of CAADP growth targets is needed as well. 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 West African governments are indicated in the key areas outlined below.

- ***Governments must address underinvestment in agricultural research***

Evidence does not indicate significant improvement in the relative intensity of agricultural research investment (agricultural research spending as a share of AgGDP) in West Africa over time. Despite CAADP's efforts to promote stronger investment in agriculture (including agricultural research) across the region, as well as increased allocations of national budgets to agricultural research by a number of West African governments in recent years, agricultural research spending in most West African countries is still far below the levels required to sustain the needs of their agricultural sectors. It is also worrying that agricultural research investment has considerably lagged behind other types of agricultural investment since the turn of the millennium (see Box 1), despite the widespread evidence of the important returns on investment of agricultural research. This calls for an urgent need by country governments 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.

- ***Governments must take the necessary policy steps to diversify funding sources***

Dependency on donor funding for agricultural research in West Africa is much higher than in other parts of Africa (or the developing world). Rather than relying too much on donor contributions 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. The private sector is currently the least developed source of sustainable financing for agricultural research in West Africa (its funding potential remains largely untapped in most countries with the exception of Côte d'Ivoire). Securing 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 consider bringing agricultural research of regional relevance under the control of a regional body***

Given the many challenges faced by agricultural value chains at the national level and the limited resources of NARS to address this wide variety of challenges, agricultural research coordination (and funding) on a regional scale is necessary, not only to share the results of research, but also in order for each West African country to focus on the commodities in which it has a comparative advantage. WAAPP has already paved the way for the institutionalization of a regional research approach. To make this regionalization a long-term reality, a number of research areas of regional importance should be identified and placed under the coordination of a regional organization (such as ECOWAS). This regional body, in turn, needs to decide which country (or countries) are best suited to carry out research on these regional priorities based on calls for proposals, and award funding accordingly. National governments must decide what share of research funding they wish to allocate to national priority areas and to regional priority areas. Under this scenario, intellectual property rights issues related to the regional use of research outputs produced by national research systems will need to be resolved first, so that all countries can equally benefit from regional research outputs.

- ***Governments must enable NARIs to develop autonomous human resource strategies.***

Few NARIs have autonomous status in setting their own human resource policies, which limits their ability to offer competitive salaries and working conditions. In addition, civil servant recruitment restrictions often affect the recruitment potential of NARIs. In order not to jeopardize long-standing research programs, NARIs in West Africa will need to be offered the autonomy to develop systematic human resource strategies, incorporating existing and anticipated skills gaps and training needs. Large-scale WAAPP-funded MSc- and PhD-level training of young researchers has remedied the most acute agricultural research capacity challenges, and will be adequate to offset the very large number of experienced PhD-qualified scientists that will retire in the coming years. However, it will be crucial for the

NARIs to develop incentives to attract, retain, and motivate well-qualified researchers over time. This includes the removal of the large discrepancies that exist in the remuneration, working conditions, and incentives offered to NARI researchers compared with their university-based colleagues. Finally, national governments must expand their investments in higher education in agriculture to allow universities to increase the number and size of their MSc and PhD programs and to improve the curricula of existing programs.

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

Although many NARIs in West Africa have (semi)autonomous status, funding and capacity constraints often prevent them from exercising this autonomy. A critical area, which needs 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 the planning capacity at the research program level is crucial to the overall effectiveness of NARIs. 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, including fostering partnerships between public and private sector. 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.

REFERENCES

ASTI (Agricultural Science and Technology Indicators). ASTI website. http://www.asti.cgiar.org.

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.

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

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

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. http://www.resakss.org/map.

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.

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

Stads, G. 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 Karihaloo, J, B Mal, and R Ghodake. Bangkok: Asia Pacific Association of Agricultural Research Institutions.

Stads, G.; Beintema, N.; Perez, S.; Flaherty, K.; and Falconi, C. 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: UNESCO.

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

World Bank. 2017. Unpublished surveys.